Towards a Workable and Effective Climate Regime

Edited by Scott Barrett, Carlo Carraro and Jaime de Melo

CEPR Press

A VoxEU.org Book

Towards a Workable and Effective Climate Regime

A VoxEU.org eBook

CEPR Press

Centre for Economic Policy Research
2nd Floor
33 Great Sutton Street
London, EC1V 0DX
UK

Tel: +44 (0)20 7183 8801
Email: cepr@cepr.org
Web: www.cepr.org

Ferdi

Fondation pour les études et recherches sur le développement international (Ferdi)
63, boulevard François-Mitterrand
63000 Clermont-Ferrand
France

ISBN: 978-1-907142-95-6

Towards a Workable and Effective Climate Regime

A VoxEU.org eBook

Edited by Scott Barrett, Carlo Carraro and Jaime de Melo

CEPR Press

Centre for Economic Policy Research (CEPR)

The Centre for Economic Policy Research (CEPR) is a network of over 900 research economists based mostly in European universities. The Centre's goal is twofold: to promote world-class research, and to get the policy-relevant results into the hands of key decision-makers. CEPR's guiding principle is 'Research excellence with policy relevance'. A registered charity since it was founded in 1983, CEPR is independent of all public and private interest groups. It takes no institutional stand on economic policy matters and its core funding comes from its Institutional Members and sales of publications. Because it draws on such a large network of researchers, its output reflects a broad spectrum of individual viewpoints as well as perspectives drawn from civil society.

CEPR research may include views on policy, but the Trustees of the Centre do not give prior review to its publications. The opinions expressed in this report are those of the authors and not those of CEPR.

Fondation pour les études et recherches sur le développement international

The Fondation pour les études et recherches sur le développement international (FERDI) was created in 2003 at the initiative of CERDI (Centre d'études et de recherches sur le développement international, University of Auvergne and CNRS). Its mission is to promote a fuller understanding of international economic development and the factors that influence it.

With its network of over 150 experts, FERDI supports research activities that use the most directly relevant instruments and methods to study development and seeks to strengthen the potential of the French-speaking world in this area. FERDI endeavours to promote the contribution of French and European work to the international debate on major development issues, in particular on how Southern and Northern economic policies can best assist development by broadening the capacity for individual choice and by developing equality of opportunity among nations. FERDI wishes to contribute to improving these policies and providing information for companies whose business depends on world markets and their outlook.

Contents

PART III: Architecture and Governance

PART IV: Policy Options

PART V: Technology Options

List of Abbreviations

3E+S	economy, energy security, environment, and safety
A&R	assessment and review
AB	Appellate Body
AfDB	African Development Bank
AGN	African Group of Negotiators
AIIB	Asian Infrastructure Investment Bank
APP	Asian Pacific Partnership
AR5	IPCC Fifth Assessment Report
BAU	business as usual
BCA	border carbon adjustment
BNEF	Bloomberg New Energy Finance
C2ES	Center for Climate and Energy Solutions
CAT	cap and trade
CBDR	common but differentiated responsibilities
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CEA	Council of Economic Advisors
CIFs	Climate Investment Funds
CO_2	carbon dioxide
COP	Conference of the Parties
DRC	Democratic Republic of Congo
EIA	US Energy Information Administration
EITE	energy-intensive, trade-exposed
EPA	Environmental Protection Agency
ERC	emission reduction credits
ETPC	Emission Tax Payment Credits
ETS	emissions trading system
EU ETS	European Union Emission Trading Scheme
FCCC	Framework Convention on Climate Change
FDRE	Federal Democratic Republic of Ethiopia
FiT	feed-in tariff
GCF	Green Climate Fund
GDP	gross domestic product
GEF	global environmental facility
GGKP	Global Green Growth Knowledge Platform
GHG	greenhouse gas
GIEC	*Groupe d'experts intergouvernemental sur l'évolution du climat*
GNI	gross national income
GRICCE	Grantham Research Institute on Climate Change and the Environment
GSEP	Global Superior Energy Performance Partnership
IAMs	integrated assessment models
ICAO	International Civil Aviation Organization

ICDPs	Integrated Conservation and Development Programmes
ICEF	Innovation for Cool Earth Forum
ICLEI	Local Governments for Sustainability (founded in 1990 as the International Council for Local Environmental Initiatives)
IGCC	integrated coal gasification combined cycle
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ITO	International Trade Organization
KP	Kyoto Protocol
LDCs	Least Developed Countries
MFN	Most Favoured Nation
MRV	monitoring, reporting and verification
NCBs	non-carbon benefits
NDC	Nationally Determined Contribution
NGO	non-governmental organisation
non-CCS	non-carbon capture and storage
OBR	output-based rebating
OECD	Organisation for Economic Co-operation and Development
PES	payment for environmental services
PPM	process and production method
PV	photovoltaic
R&D	research and development
RD&D	research, development and demonstration
REDD	Reducing Emissions from Deforestation and Forest Degradation
RGGI	Regional Greenhouse Gas Initiative
RITE	Research Institute of Innovative Technology for the Earth
RoR	Republic of Rwanda
SCC	social cost of carbon
SCM	Subsidies and Countervailing Measures (Agreement on)
SIDS	Small Island Developing States
SRM	solar radiation management
TBT	technical barriers to trade
tCO_2e	tonne CO_2 equivalent
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra supercritical
VCLT	Vienna Convention on the Law
WTO	World Trade Organization
XG	experimental governance

Acknowledgements

The work on this book is part of Ferdi's Environment, Climate and Development programme. It has relied on the participation of authors from all parts of the world, whose contributions are gratefully acknowledged. The views expressed in this volume reflect the personal views of the authors and are not necessarily those of their affiliated organisations, Ferdi or CEPR

During the preparation of the book, the editors benefitted from the support of the entire Ferdi staff. The help and organisational skills of Kelly Labart and Fabienne Rouanet were particularly appreciated. A special thanks goes to Vincent Nossek for his substantive inputs, his tireless support and diligence in keeping the authors on track as the project moved along. At Feem, Martina Gambaro helped with the production of the artwork and the glossary. As usual, our thanks go to Anil Shamdasani for lending his editorial talents to the project.

As part of a Ferdi work programme, this work benefitted from the financial support of the French government's 'Investissement d'Avenir' programme (ANDR-10-LABX-14-01).

Foreword

Climate change is an extreme global challenge and is high on the agenda of the Sustainable Development Goals (SDGs) recently adopted by the United Nations General Assembly. Although this is not the first significant episode of climate change in modern history (see the *Histoire du climat depuis l'an mil* by Le Roy Ladurie, published in 1967), it is now a major threat to ecosystems, glaciers, coastal zones, agricultural yields and, above all, to our economic systems and our societies. It is not only a threat to future generations, but also a problem for the present ones. Sustaining and improving the standard of living of all peoples, and especially the poor, will require slowing down climate change and adapting to its effects.

Widespread apprehension is shared by both business and political leaders as well as by the general public in most countries. If too little is done, the impacts of unabated climate change could prove disastrous to all, above all in the most vulnerable regions of the world that are usually the poorest. Cities, business organisations, and major companies are taking steps to reduce their greenhouse gas emissions, but in order to succeed, governments will have to push beyond the pledges submitted for the COP21 meeting in Paris.

The essays in this book provide an extensive panorama of the dimensions of this challenge: How will we get countries to act beyond their self-interest for the sake of their collective interest? Perceptions about past responsibilities for climate change and future obligations vary greatly across regions. These perceptions have to be taken into account. Institutions have to go beyond the UNFCC/Paris process to promote experimentation and learning and include increasingly ambitious provisions for monitoring, reporting and verification that progressively extend beyond emission levels. Policies have to be carried out simultaneously on several fronts, ranging from investment in low-carbon technology and R&D, to adaptation, to financing. To be effective, simultaneous cooperation in multiple areas will be necessary. Several contributions to the book concur that the necessary societal transformation path will require that this cooperation be driven – at least in market economies – by a change in relative prices revolving around agreement on a reference carbon price to be implemented progressively, starting from a unilateral basis.

Financial burden sharing is a hard challenge to meet because of the magnitude of the estimated transfers. Typically located in the hottest regions, poor countries will probably be the hardest hit by rising temperatures. They are also the least resilient, have contributed the least to emissions so far, and have limited bargaining power. Funding is needed for adaptation as well as for mitigation. This requires massive investment, technological transfer and financial support from the more developed countries. Ferdi has a mandate to promote ideas for improving the equality of opportunity across nations, and the essays in this book are a contribution to this objective. It is our hope that they will stimulate thinking, new ideas and new initiatives for developing a workable and effective global climate regime, which is essential to our common future.

CEPR and Ferdi thank Scott Barrett, Carlo Carraro and Jaime de Melo for their tireless efforts in putting this volume together. CEPR, which takes no institutional positions on economic policy matters, is delighted to provide a platform for an exchange of views on this critical topic.

Patrick Guillaumont,	Tessa Ogden
President, Ferdi	Deputy Director, CEPR

2 November 2015

1 Introduction

Scott Barrett, Carlo Carraro and Jaime de Melo[1]
Columbia University; University of Venice and Feem; Ferdi

For the first time ever, in Paris at COP21, almost all of the world's countries will commit to reducing or controlling their own greenhouse gas emissions. At the same time, cities, business organisations and major companies will also commit to reducing their own emissions. This will represent an important success of diplomatic efforts to address the climate change problem. However, preliminary assessment of the Intended Nationally Determined Contributions (INDCs) submitted so far shows that the agreement being prepared for adoption in Paris in late 2015 will need to create incentives for parties to pledge to do more in the immediate future. Incentives will also be needed for parties to *actually do more*. These incentives may come not only from within the United Nations Framework Convention on Climate Change (UNFCCC) process, but also from other sources, such as the effort currently underway to amend the Montreal Protocol to limit hydrofluorocarbons (HFCs). The emerging regime for limiting climate change will therefore consist of multiple agreements, policies, and actions adopted at the local, regional, and global levels.

In Paris, but also beyond, attention will probably focus on whether similar countries are making similar pledges to limit their emissions. It will also focus on whether the sum total of all pledges will put the world on track towards meeting its common goal. The current goal is to prevent mean global temperature from rising by more than 2°C relative to the pre-industrial level. Attainment of this goal may already be beyond our reach, but the bigger point is that limiting temperature change to any level will require reducing carbon dioxide (CO_2) emissions to zero, or removing CO_2 directly from the atmosphere. This is an unprecedented global challenge.

1 Thanks to Arild Angelsen, Ottmar Edenhofer, Brian Flannery, Patrick Guillaumont, Thomas Stocker, David Victor and Mitsutsune Yamaguchi for helpful comments.

From a top-down perspective, the approach needed to meet this challenge is straightforward. To limit concentrations, cumulative future emissions must stay within a fixed 'carbon budget'. This perspective reduces negotiations to a zero-sum emission game, one in which a smaller emission reduction for one player necessarily implies a larger reduction for another. In other words, the top-down perspective puts the spotlight on equity and fairness, assuming away the problems of efficiency and effectiveness. However, the top-down approach cannot be implemented directly in a world in which states are sovereign. In contrast, the bottom-up approach takes as its starting point that states are likely to act so as to advance their self-interests, unless they are given incentives to limit their emissions further for the sake of their collective interests. The challenge in this case is to provide these incentives. The process of assessment and review negotiated for Paris is one way to provide such incentives – by creating opportunities for 'naming and shaming'. The Paris approach is thus a blend of the top-down and bottom-up approaches, simultaneously pushing countries away from the non-cooperative outcome and pulling them towards the full cooperative outcome.

However, the gap between these two outcomes is vast and will be difficult to close. The non-cooperative outcome, being grounded in self-interest, holds a strong attraction. By contrast, the ideal outcome requires deep cooperation and may be beyond the reach of our existing institutions. What we need is a regime for limiting climate change that is workable and effective, rather than workable and insufficiently effective (as might be the case with Paris) or effective if implemented but politically unacceptable (as would be true of an 'ideal', top-down climate agreement). This volume presents a number of analyses, ideas, and proposals for how to design, build, and sustain such a workable and effective regime. The contributions look to – but also beyond – Paris, identifying the paths that the evolving climate regime can and should take.

This book's main goal is to provide hints, guidelines, and policy recommendations for a workable and effective climate agreement. Most chapters focus on effectiveness. However, one of the merits of the book is that it also provides sound analyses of fairness (and therefore workability) of a climate agreement. The concern with distributional issues cannot be neglected. Countries will agree on reducing their own greenhouse gas (GHG) emissions only if they believe that the burden of this emission reduction effort is fairly shared among all the world's regions.

The book is organised into seven sections. Aimed at a non-specialist audience, each chapter is short, pragmatic, and can be read independently. Part I identifies the challenge, focusing on the science of climate change, the 2°C goal, and the state of the climate negotiations. Part II provides a perspective on how some of the key players see this issue – from Africa to China, from Europe to India, and from Japan to the United States. Part III describes how the self-interests of players like these can be leveraged by the design of international institutions to provide meaningful and effective collective action. Part IV moves from a focus on institutions to the design and implementation of policies. Part V is concerned with technology options, discussing not only how policies can stimulate the development and diffusion of key technologies, but also how some technologies (such as geoengineering) present their own challenges for the design of policies and institutions. Part VI addresses the distributional issues around burden-sharing and the need for the poorest countries to develop even as the world moves towards a new energy future. Finally, Part VII is concerned with how to address these issues with international finance.

Part I: The challenge

Climate change is a monumental challenge for policy (Arrow 2009). As we approach the Paris Conference (COP21), many participants and observers are filled with hope but are also concerned that the new agreement will fall short of the 'ambition' needed to stabilise greenhouse gas concentrations at a 'safe' level.

This apprehension about the future is shared not only by the scientific community, but also by business and political leaders, and by the general public in most countries. If too little is done to limit emissions, the impacts of unabated climate change could prove disastrous in many regions of the planet. Part I thus leads off with a state-of-the-art assessment of the scientific, economic, and policy aspects of climate change.[2] The

2 In their chapters, several contributors refer to IPCC reports, occasionally the same ones. To save space, end-of-chapter references only cite the co-lead authors for each publication. Readers wishing to refer to the full documents will find the full citation in the references to this Introduction.

purpose is to explain what is at stake in Paris. Part I ends with a summary of where the negotiations stand now, as we head into Paris.

As President Barack Obama recently said, "*[s]cience, accumulated and reviewed over decades, tells us that our planet is changing in ways that will have profound impacts on all of humankind*".[3] This is also what Stocker, Co-Chair of IPCC Working Group I, tells us in Chapter 2. The scientific assessments carried out by the Intergovernmental Panel on Climate Change (IPCC) have delivered robust and rigorous scientific information for the complex negotiations to limit climate change and its impacts and risks, particularly those that threaten the livelihoods of humans and the functioning of critical ecosystems.

However, climate change is not only a threat to ecosystems, glaciers, coastal zones, and agricultural yields; climate change is above all a threat to our economic systems and our societies. It is not only a threat to future generations, but also a problem for the present. Combating climate change is therefore important for sustaining and improving the standard of living of all the world's peoples.

In Chapter 3, Edenhofer, former Co-Chair of IPCC Working Group III, and his collaborators emphasise not only the risks and costs of climate change, but also the risks and costs of mitigation, namely of reducing GHG emissions to limit the impacts of climate change. In principle, the risks of mitigation differ fundamentally from the risks of climate change in terms of their nature, timescale, magnitude, and persistence. Humankind has the technological means to solve the problem. However, this requires a large-scale transformation in the way we produce and use energy, as well as how we use land. A further delay in mitigation action substantially increases the difficulty of, and narrows the options for, this transformation. For example, delays will inevitably increase mitigation costs and will require an even wider adoption of CO_2 removal technologies later in the future. Time is therefore another important challenge, though there are numerous reasons why countries may want to adopt climate policy unilaterally.

Delays and policy uncertainties are discussed by Flannery in Chapter 4, which focuses on the state of climate negotiations. Political leaders express confidence that a deal in

3 https://www.whitehouse.gov/climate-change

Paris is achievable, but the real challenge is to design pathways and procedures for incremental mitigation efforts in the years following COP21. Residual acrimony and distrust from Copenhagen hamper the process, which must resolve many complex and contentious issues, such as the legal form of an agreement, compliance, the role (if any) for GHG markets and offset projects, intellectual property rights, compensation for loss and damage, transparency and associated measurement, and monitoring, reporting and verification (MRV) and review procedures. Overshadowing all remains the question of how the principle of 'common but differentiated responsibilities' (CBDR) will manifest itself throughout the agreement, from mitigation to reporting and from review to finance.

Nevertheless, some aspects are solidifying. Mitigation efforts will not be negotiated; rather, they are being submitted as INDCs, and, ultimately, recorded. Total financial aid appears set by the Copenhagen pledge of developed nations to mobilise US$100 billion per year by 2020, provided that private-sector finance complements official assistance. Also, negotiators appear resolved to creating a durable framework based on cycles of review and renewal over intervals of, perhaps, five or ten years.

Despite these efforts, however, the Paris agreement is unlikely to put the world 'on track' to limiting warming to less than 2°C (or 1.5°C). Only recently have political leaders begun to temper expectations. They will need to manage expectations thoughtfully to avoid a backlash from a range of nations, stakeholders and media, and to restore the credibility of the UNFCCC as an effective process. The Paris agreement will be but another (although very important) step in a long journey. It is crucial to set the rules of this journey, through effective monitoring, verification, and comparison of domestic implementation, rather than complaining about the likely incomplete effectiveness of the Paris agreement.

Part II: Views from the regions

Perceptions about the relevance of past contributions to climate change to future obligations vary greatly across regions and countries, as do the political processes leading to countries' negotiating positions. To give a sense of this diversity, we invited 'views' from two regions and three countries, asking contributors to describe briefly likely country/regional positions and to assess the set of desirable/feasible policies. These contributions, reflecting the mosaic of interests across countries and regions, are collected in Part II.

If Africa contributes the least to climate change, in Chapter 5 Mekonnen notes that it is also the region that is estimated to lose the most (in relative terms) as a result of climate change (2-4% of GDP) in the coming 10-50 years, as 50-80% of the land, livestock and population in this region are already in drylands, with the poor being the most exposed to climate shocks. Of the 48 least developed countries (LDCs) that are most vulnerable to natural and economic shocks, 34 are in Africa. Citing evidence that past shocks from extreme temperatures have only affected agricultural productivity in low-income countries, Mekonnen foresees a lack of resilience to the high projected costs of damage from extreme temperatures. Growth-oriented domestic policies will shape countries' strategies, with mitigation activities that exploit Africa's latecomer advantage in the building of infrastructure needed for the rapid urbanisation projected across the continent. This will necessitate external financing that far exceeds current committed levels and that should be allocated on the basis of indicators to climate vulnerability. Mekonnen urges greater cooperation at the regional and continental levels, including greater participation in the Lima Challenge established by a group of tropical forest countries.

In Chapters 6 and 7, Fei and Somanathan, respectively, document that domestic policy priorities guide China's and India's climate policies, which, until recently, were defensive towards an international climate agreement, with both countries being members of the 'Like-Minded Countries' (LMDC) group. Both countries are preoccupied with growing energy demands (rural-urban migration approximately triples per capita energy consumption) and energy security. China has only very recently come to realise that balancing energy security and environmental protection presents a huge challenge for its energy system. China and India are also coming to terms with the growing evidence of damage from climate change and from poor air quality.

Somanathan attributes India's slow start at mitigation to internal political costs and to the lack of action by developed countries. India's ambitious National Action Plan of 2008 and more recent announcements have established very ambitious targets for electric generation of installed renewable energy capacity of 175 GW by 2022 (close to current worldwide installed capacity). Sizable steps have also been taken towards carbon and oil pricing, with revenues earmarked for removing unmetered and subsidised electricity in agriculture, which accounts for 18% of electricity consumption. But Somanathan warns that any politically feasible increase in the carbon price will require compensation that will only be possible with offsets from developed country carbon-trading programmes.

Fei acknowledges that without China's active engagement, the world will be unable to limit climate change. From the perspective of the bottom-up approach, this implies that China's climate policy will be rooted in its three domestic priorities: development, air quality, and energy security. These three targets are a tall order, since better air quality calls for a sharp reduction in coal consumption, which is currently necessary for energy security, especially as energy demand is set to grow under rapid urbanisation. In its international position, China also wishes to align its greater mitigation ambitions with its desire to stand with other developing countries, notably as a member of the LMDC group. Fei sees encouraging signs in the recent fact that a transition towards a low-carbon economy is no longer viewed as a costly effort driven by international pressure. He concludes that market-based policies and measures are needed to reduce the economic and political costs of command and control measures regulating the state-owned energy enterprises that dominate energy-intensive industries.

The EU and Japan both participated in the Kyoto Protocol. In Chapter 8, Yamaguchi and Akimoto tell of Japan's successful experience in reducing emissions by 12% from 1990 levels during the Kyoto Protocol period under a totally voluntary 'agreement' between the government and industry sectors. They conclude that careful consideration of a country's political, economic, and cultural environment should weigh heavily in the design of its climate policy strategy. They also note that, under the Kyoto Protocol, Japan had to compete fiercely with rapidly industrialising countries in the region that did not face an emissions cap. Japan also had to prepare its INDC in the aftermath of the Fukushima meltdown. The government's new '3E+S' plan (economy, energy security, environment, and safety) will be a huge implementation challenge, as the Japanese people do not want a return to nuclear energy and marginal abatement costs are very high in the energy-efficient Japanese economy. Acknowledging the extremely high costs of stabilising temperature at any level, Japan has launched the Innovation for Cool Earth Forum (ICEF) to develop innovative technologies. As to diffusion of highly energy efficient technologies, Japan has promoted sectoral approach focusing on energy-intensive sectors.

The EU took leadership on climate change in the negotiations leading to the Kyoto Protocol. Following Europe's failure to put a tax on CO_2 in 1990 – a step that would have required unanimity among members on the tax rate – Brussels set up the EU Emissions Trading System (ETS), which only required majority approval. In Chapter 9, Guesnerie notes that legal and political feasibility concerns, rather than economic considerations, dictated this choice. The economic recession, political pressure and lobbying for free emissions quotas rapidly led to an oversupply of licenses and to the collapse of the market price, even though climate policy in Europe succeeded in reducing EU emissions (the EU is likely to reach its -20% target in 2020). Having extolled the superiority of a carbon tax over a cap-and-trade (CAT) system on economic grounds, Guesnerie recognises that reaching a worldwide carbon price is beyond political feasibility, but that linking separate carbon markets might help us on the path towards a unique carbon price. Climate clubs could also help if credible punishment is in the offing to prevent free-riding, an option to be considered for EU climate diplomacy but still beyond reach under the current difficulties of the EU ETS.

Kotchen reviews the US position in Chapter 10. In spite of increased awareness among the public that global warming is due to human activities, scepticism and sharp differences between the executive and legislative branches of the government that led to the non-ratification of the Kyoto Protocol continue to complicate the US international position on climate for the Paris summit. The US nonetheless managed to reduce CO_2 emissions by 10% in 2013 from 2005 levels, with half of this reduction due to the recession and the rest coming from a lowering of the carbon content of energy through a shift to natural gas and an increase in overall energy efficiency. Because most aspects of the Climate Action Plan are taking place under executive authority (see also Chapter 17), they are subject to legal challenges (these do not apply to the Californian and north-eastern states' initiatives, which account for more than half of the US economy). Kotchen notes that legal challenges will be stronger if there is a lack of ambitious INDC commitments by other countries at COP21. In the longer run, however, he foresees that the greatest challenges to advancing an ambitious agenda will be from the large and growing developing countries rather than from domestic politics. While developing countries are waiting for substantial increases in climate finance prior to starting to mitigate, Kotchen is optimistic that both Democrats and Republicans will recognise the value of climate-related assistance to poor countries. The key to success from the US perspective, then, is that all countries submit reasonably ambitious emissions reductions plans and that the agreement be viewed as the beginning of a process of pledge and report (rather than commit and comply), leading to transparency and regular reporting of emissions.

Part III: Architecture and governance

The chapters in Part III focus on the architecture of institutions designed to reduce global emissions of greenhouse gases. Some chapters are concerned with the UNFCCC/Paris process, but others go beyond this approach and look to other opportunities to limit emissions.

In Chapter 11, Bodansky explores one of the key legal issues facing the climate negotiations. Many observers have long argued that an agreement to limit emissions must be legally binding. However, under international law countries are free to participate in any agreement or not as they please, and making an agreement legally binding may cause some countries not to participate. The Kyoto Protocol was 'legally binding', but that didn't stop the US from declining to ratify the agreement, or Canada from withdrawing from it later. Bodansky notes that there is no clear evidence that a legally binding agreement has more of an effect on state behaviour than a non-legally binding agreement. Probably more important than the legally binding nature of an agreement are its precise terms, particularly with regard to the agreement's ability to enforce participation.

In the run up to COP21, countries have been submitting their INDCs. As previously emphasised, one issue is whether the aggregate of emission reductions implied by these pledges are on the right track to meet the goal of limiting mean global temperature change to 2°C. Another issue is whether similar countries are making similar pledges. Are countries pledging to contribute their fair share? In Chapter 12, Aldy and Pizer focus on this second question. They find that it is a difficult question to answer, because the INDCs are expressed in different ways and no single metric exists for effort. They suggest that comparability of pledges should be based on multiple data sources and analyses by a set of independent experts.

While the emission limits pledged by countries will not be legally binding, one plan under consideration is to make provisions for monitoring, reporting, and verification legally binding. It is essential to know whether countries' actual behaviour is tracking their pledges and, as Wiener notes in Chapter 13, greater accountability can also cause behavioural change. States may be more likely to meet their pledges if their actions can be observed. Indeed, Wiener argues that monitoring, reporting, and verification should extend beyond emission levels and related outputs, to include policies and measures for reducing emissions, investment in technology R&D, financing, adaptation, and geoengineering. In Paris, countries may be reluctant to go as far as Weiner recommends, but as time passes and future climate agreements come to address more and more issues, the provisions for monitoring, reporting, and verification agreed in Paris may also need to change.

The Kyoto Protocol tried to address climate change in a top-down way, and failed. Paris will try to build cooperation with a larger role for the bottom up. Victor and Keohane do not think this will quickly lead to deep changes in emissions, but they do see a silver lining to this cloud. As they note in Chapter 14, Paris could "help governments and other critical players determine what is feasible through coordination and it could establish some momentum in negotiations, so that countries not making serious efforts could be embarrassed as laggards". In an optimistic scenario, they say, "this process could, through a series of increasingly serious steps, move pledge and review to a more coordinated and effective effort in the long run". The approach they advocate involves "experimental governance," requiring, first, that goals be related to actions; second, that participants who fail to act face significant costs; and third, that connections be made between various national pledges and the overall goal.

In Chapter 15, Stewart, Rudyk and Oppenheimer suggest that the world can do more than just build on the Paris agreement. States and other actors – including firms, NGOs, international organizations, and subnational authorities – can pursue a 'building block strategy' that relies on clubs, institutional linkages, and dominant market actors. These efforts would not undermine the UNFCCC approach, but would complement it by pursuing related approaches. Examples include multilateral banks agreeing not to finance new coal-fired electricity generation projects, industry groups setting standards for wind turbines that confer upon them a competitive advantage, and the sharing of technical information on opportunities to reduce emissions.

In Chapter 16, Mavroidis and Melo maintain that a reform of the World Trade Organization could also help. They argue that interpretations of the trade rules reflected in previous decisions constrain the ability of countries (alone or in groups) to develop climate change-friendly policies, such as labelling of an energy-efficient technology and efforts to limit fossil fuel subsidies. The WTO, they believe, needs to be reformed towards a 'positive contract' whereby countries have less leeway, and they propose reforms in that direction at the plurilateral and multilateral levels. Trade rules will then serve the purpose of reducing emissions and not just liberalising trade. They also explain that proposals for a climate club relying on tariffs would face legal obstacles under the current WTO rules, but that there are alternative ways to stimulate emission reductions by a subset of the WTO membership – a 'coalition of the willing' seeking to limit emissions.

Our own assessment of the situation, consistent with all of these chapters, is that the Paris agreement is unlikely to be an obstacle to making progress in limiting emissions, and could even help. It could help directly by encouraging participation, increasing ambition, and developing systems for MRV and for promoting experimentation and learning. It could also help indirectly by not standing in the way of, or by even promoting, complementary efforts, such as for taking action in particular sectors or for reforming the world trade rules. The climate change problem is simply too big and complex for a single approach to suffice.

Part IV: Policy options

Whatever is agreed upon in Paris and beyond in terms of a new climate regime, success in limiting emissions will ultimately require 'putting a price' on carbon by some means. Such a price will not only reduce emissions directly, but stimulate investment and even R&D into new technologies. The contributions in Part IV concern policies that 'put a price' on carbon. The chapters in Part V address technology-related policy issues.

Conceptually, the need for carbon pricing has long been understood. The difficulty has been in translating concepts into real policies. As Gro Harlem Bruntland noted regarding the outcome of the Rio 1992 conference, "[w]e knew the basic principles on which to build: cost-effectiveness, equity, joint implementation and comprehensiveness but not how to make them operational" (cited in Schmalensee 1998). Fortunately, in the years since then, many efforts have been made to adopt carbon pricing, and we are starting to have a better idea of what has worked and the hurdles ahead. The contributions here cover two approaches. Under the regulatory approach, which is based on law and engineering, economics can enter through the back door, in the implementation stage, as in the US Clean Power Plan (CPP). Under the 'straight' economic approach, based either on taxing emissions or imposing a cap on emissions and allowing trading, politics can enter in the design stage, as demonstrated by the experience of allocating entitlements under the EU emissions trading system.

In Chapter 17, Burtraw notes that the structure of the CPP is relevant for an international audience of policymakers because the process it inaugurates, in which implementation flexibility is strong, mirrors the one that is taking place in international negotiations. Recounting the political failure in the US of adopting a legislative approach to cap-and-trade to meet President Obama's pledge in Copenhagen in 2009 to cut emissions by 17% from 2005 levels by 2020, Burtraw reviews evidence showing that this pledge will be met by the CPP. He also thinks that the regulations adopted by the US Environmental Protection Agency are unlikely to be politically overturned. Importantly, Burtraw notes that the flexibility in the CPP gives regulated entities (i.e. the US states) the tools to negotiate a cost-effective outcome and empowers and reinforces the actions of first-movers and bottom-up leadership. It is in this sense that the CPP may bring about a cost-effective outcome 'through the back door'.

The challenges of carbon pricing are starkly exposed by Sterner and Köhlin in Chapter 18. All the evidence – *primo loco* in Sweden, which has a carbon price of over \$100/tCO_2 and a carbon intensity of GDP that is only a third of the world average – is that a carbon tax (when applied at a sufficiently high rate as in Sweden), along with complementary measures, is very effective at reducing emissions and encouraging the development of substitutes for fossil fuels.[4] But Sweden stands out as an exception. In most countries, taxes are unpopular, so politicians, helped by strong lobbying activity by the fossil fuel industry, deny the need to act and procrastinate. And at the international level, burden sharing and fairness also account for the lack of progress in taxing carbon.

Against this background, Sterner and Köhlin review four variations to direct carbon pricing: (1) the removal of fossil fuel subsidies; (2) fuel taxation; (3) cap and trade, and direct regulation; and (4) the promotion of renewable energy, as has been done by Germany over the last 15 years. They conclude that the negotiation process in Paris might want to include many instruments for different parts of the climate change complex, possibly using a price floor to complement the quantitative commitments made so far.

Taxing carbon started 25 years ago and is now widespread, with 40 national and 20 sub-national jurisdictions engaged in taxing carbon or involved in cap and trade (CAT) schemes. These efforts apply to a significant share of global emissions, and amount to an average price of carbon \$7Gt/CO_2. In Chapter 19, Wang and Murisic review this experience, focusing on 15 cases of implementation. They argue that hybrid elements in both the carbon tax and CAT schemes appear to blur the differences between the two approaches. Among the lessons they draw from their survey, they urge an expansion of bottom-up initiatives to foster greater cooperation on carbon pricing that would help promote transparency in the process of price-setting and also overcome concerns about carbon leakage.

The hybrid architecture that will emerge from the Paris negotiations will include bottom-up (INDCs) and top-down (MRV) elements. Policy instruments will differ across jurisdictions. Linkages across jurisdictions (e.g. acceptance of allowance or

4 The advantages of a tax are well known: (1) the transparency of the price system reaches billions of people that do not have to worry about their taking climate-friendly decisions; (2) it goes a long way towards re-establishing Pareto optimality; (3) it is more easily verifiable than other approaches; (4) if the tax is the same, or there is an agreement on convergence, the leakage problem is quasi-solved; (5) the thorny issue of burden sharing is greatly reduced; (6) because of the nature of the underlying uncertainty, the welfare benefits from the price system are greater than those associated with a quantity system; and (7) moving towards a uniform carbon tax would reduce the incentives and possibilities for lobbying activity (see, for example, Cooper 2008).

credits in another jurisdiction or crediting for compliance) that are required for this architecture to be effective are discussed by Stavins in Chapter 20. Linkage facilitates cost-effectiveness and can have potential political advantages, though to be effective, sufficient environmental integrity is required among the parties that are linking. Stavins recognises that the policy architecture developing under the Paris agreement will have elements that inhibit linkage (e.g. overly restrictive rules on allowable trading or adding objectives such as a sustainable development condition under the CDM), while other elements should facilitate linkage (e.g. international compliance units to help the tracking, reporting and recording of allowance unit transactions at the national level). If linkage has a sufficiently important role in the agreement and if operating rules are not too strict, mitigation costs would be reduced, which in turn would encourage ambition later on. As an example, Stavins would like to see the explicit inclusion of a statement that parties may transfer portions of their INDCs to other parties.

With countries contributing their INDCs individually, convergence to multilateral carbon pricing will be a long time coming. Effective carbon prices are likely to differ markedly, making leakage (i.e. the increase in foreign emissions that result from domestic actions) a real concern. In Chapter 21, Fischer examines the three channels through which leakage occurs: energy markets via the price for fossil fuels; the competitiveness channel as higher energy prices are transmitted to producers; and the innovation channel if carbon mitigation policies induce innovation. She also considers various ways in which policies can limit leakage, including border carbon adjustments, output-based rebating, exemptions, and sectoral treaties as alternatives. She notes, however, that all of these alternatives are unattractive, so long as they are adopted unilaterally. Fischer recommends a coordinated – perhaps multilateral – approach to anti-leakage measures.

Part V: Technology options

Stabilising temperature requires stabilising concentrations of greenhouse gases in the atmosphere, or offsetting the effect of rising concentrations through reducing radiative forcing by reflecting sunlight away from the earth. In turn, stabilising concentrations requires progressively reducing emissions to zero, or offsetting positive emissions with an equivalent removal of CO_2 directly from the atmosphere. These are the only possibilities.

So far, the climate negotiations have focused exclusively on the mainstream option of reducing emissions. However, emissions have increased steadily since negotiations began in 1990. Past efforts to limit emissions – let alone to bring them to zero – have failed. Paris will improve on this record, but bringing global emissions to zero will clearly be a great challenge. For this reason, it seems sensible to begin to consider the other ways to limit climate change.

This section puts the emphasis where it has always been – on mainstream efforts to limit emissions. The technological potential to reduce emissions remains very large. The last chapter however considers alternative ways of limiting global mean temperature change.

The world can certainly make a start in reducing emissions now, using the technologies already at hand (Pacala and Socolow 2004). However, as Toman explains in Chapter 22, new technologies will be needed to close the gap between the cost of fossil fuels and alternative energy sources as the scale of effort increases over time. Standard policy approaches, such as the adoption of a carbon tax, will help. But direct funding of research and development and demonstration will also be needed. Current funding of research into alternative energy technologies is very low and needs to be scaled up; Toman suggests that it needs to be as much as 20 times greater than the current level. This is a gap that the current round of negotiations is not seeking to bridge – at least not directly.

There are different ways to reduce emissions, including energy conservation and substitution of nuclear power for fossil fuels. However, these approaches are limited for various reasons, which is why so much attention has been given to renewable energy. In Chapter 23, Bosetti describes the current situation and explains why this must change in the future if emissions are to be reduced substantially. In recent years, solar and wind energy have grown enormously, but this growth is starting from a very small base. If the world is to have a chance of limiting climate change to 2°C, renewable energy will need to be scaled up to a much higher level. In addition, CO_2 will need to be removed from the atmosphere. One such option involves using biomass, a renewable form of energy, to produce electricity, and then capturing and storing the carbon released in the process of combustion. However, the problem here is scale. More fundamentally, a key problem for renewables is that the economics of adopting these technologies depends on the economics of the fossil fuel alternatives – a reason why R&D is needed, as discussed above, in addition to policies like carbon taxes that favour renewables over fossil fuels.

Even if renewable energy reaches its potential, more will need to be done to limit temperature change to 2°C. If the world continues to burn fossil fuels, the emissions associated with this can be reduced substantially by capturing the carbon emissions and storing it somewhere other than in the atmosphere. As Tavoni discusses in Chapter 24, the problem is that carbon capture and storage technology is an add-on cost. It will only be economic if accompanied by policies like carbon taxes that favour the use of the technology.[5] So far, and in contrast to renewables, carbon capture and storage technology has not taken off. In many countries, plans have been drawn up to build such plants but then cancelled. The reasons have been cost, the falling price of natural gas, and local objection to storing CO_2 near power plants. However, carbon capture and storage has one other advantage over other technologies: use of this technology reduces the 'leakage' associated with reductions in fossil fuel use by a coalition of countries (see Chapter 21).

All of the above chapters indicate that limiting temperature change to 2°C is an enormous challenge. Including analyses of other options, such as nuclear power, will not change this picture; nuclear and all the other options also have their limitations.

This is why Barrett and Moreno-Cruz consider in Chapter 25 alternative ways of limiting climate change – ways that would work independently of the world's energy system. The first approach is carbon geoengineering, which involves removing CO_2 from the atmosphere directly. The approach they focus on is industrial, with the potential to remove CO_2 at virtually any scale. One problem with this technology is storage, but unlike carbon capture at the power plant, there is more flexibility in locating direct CO_2-removal technologies away from population centres. New ideas on re-using the captured CO_2 are also emerging. The bigger problem with this technology may be its high cost. However, carbon geoengineering is the only true backstop technology

5 Not only is CCS costly, it also requires a vast infrastructure at the scale required to make a meaningful difference to global CO2 emissions. This is true for the logistics of pipelines and reservoirs and compounded if the approach is to use biomass plantations for BECCS. Obtaining permits to construct and operate the entire system may be even a bigger challenge than cost, and it is not "just" an economic issue.

for addressing climate change. The other approach is solar geoengineering, in which sunlight is reflected away from the earth, offsetting the effect of rising concentrations. This technology can control mean global temperature but it isn't a backstop, as it would affect the climate differently than limits on concentrations. Most obviously, it would not limit ocean acidification. Ironically, a problem with this approach is its low cost. Solar geoengineering would likely be cheap, meaning that it may be in the interests of a single country to deploy it. The primary problem with this technology is therefore governance.

To conclude, taken together, the chapters in this part of our book all suggest that there are no easy technological options for limiting global temperature change. More R&D efforts are certainly needed.

Part VI: Development and burden sharing

Developing countries, especially the very poorest, have contributed the least to climate change. As they will be hardest hit by its effect, the poorest will need to put aside large amounts of resources for adaptation purposes. At the same time, many easily implementable mitigation activities in the near future can be carried out at least cost in the poorest countries. Burden sharing, including the availability of finance for the poorest countries to mitigate and adapt while fulfilling their aspirations to grow, continues to be the main obstacle to reaching a compromise at the COP meetings. Without discussion on loss and damage, the Technology Mechanism, the Green Climate Fund and the Adaptation Fund, developing countries would not have accepted to break down the firewall between Annex I and non-Annex I countries, as was agreed in Durban in 2011. In short, developing countries would not have agreed to submit their INDCs along with all other countries.

Developing countries, especially the poorest, feel that it is iniquitous to expect that they will slow their development when they will be the hardest hit, while the rich are responsible for most of the excess of carbon stock and have the means to pay for mitigation. Any agreement/outcome on burden sharing reflected in the INDCs will reflect perceived future damages, the costs of mitigation and adaptation, and, for the developing countries, the amount of finance for adaptation that will be forthcoming.

Part VI covers damages, costs, and non-financial aspects of burden sharing. Part VII covers mobilisation of finance, the split between mitigation and adaptation, and the split between developed and developing countries.

In Chapter 26, Hallegatte and his co-authors explain that the poorest countries have been the most severely hit by climate shocks so far, and are projected to be more vulnerable in the future because they are situated in the hottest regions. Moreover, within these countries, the poorest communities are at greatest risk. They settle in the riskiest areas, for reasons of affordability, represent the least resilient segment of society, and receive smaller shares of social protection. To achieve low-carbon resilient development, Hallegatte and his co-authors urge long-term planning for investment, especially in urban areas, improved access to health care, and the adoption of well-targeted social safety nets.

To meet their national development targets, including those related to growth, social development, and access to natural resources such as water, low-income countries will need to devote considerable resources to adaptation. In Chapter 27, Kaudia recognises that the growth-related objectives of the high-emitting, fast-growing middle-income countries is driving a wedge in the negotiation pathways of the different groups of low-income countries (the Alliance of Small Island States, the Africa Group of Negotiators, and the Least Developed Country group) and those of the (largely middle-income) LMDC group. This will make it difficult to build a common position in the negotiations.

Kaudia states that low-income countries' submissions have been pushed by developed countries. In Kenya's case, and for many other low-income countries, forestry has the highest GHG abatement potential. While domestic policies that are in the national interest should be pursued anyway, Kaudia argues that submissions by low-income countries should be voluntary and contingent on financial resources and technological capability enhanced by involvement from developed countries that, so far, have not honoured the principles of fairness and equity enshrined in the UNFCCC. The principle of common but differentiated responsibilities (CBDR) should then be the underpinning principle if the world is to reach the objective of a socially inclusive and sustainable development path that is equitable, as the low-income countries are the most vulnerable to climate change.

The contribution of forest conservation to climate change policies is reviewed by Angelsen in Chapter 28. A decade ago, high hopes were placed on reductions in rates of deforestation, with its low cost (at $5 per t$CO_2$, reducing deforestation rates by half would only cost $9-10 billion per year) and a promising outlook for results-based payments mechanisms. Ten years on, vested interests still hold the power to block the policy reforms that are needed to shift the balance of interests towards forest conservation. A flawed process for allocating concessions and land rights – reflecting a lack of ownership at the national level combined with REDD+ processes run at the international level – has resulted in few results on the ground. Yet, forest conservation will have to play a central role in the contribution of REDD+ countries to the global effort to limit climate change.

To extend REDD+ activities beyond the initial vision of a vehicle of international transfers, Angelsen singles out improvements leading to national commitment policies, pressure from consumers on corporations, and 'entrepreneurial authority' coming from private actors defining new standards. Combined with assessment and review, REDD+ would become an integral part of countries' national contributions to the global efforts to curb climate change. For forest conservation to generate the hoped-for contribution to arresting climate change, Angelsen concludes that REDD+ countries will have to take the driver's seat – something they may be reluctant to do until financial resources from developed countries are truly forthcoming.

Starting from the observation that coal is both a high emitting source of CO_2 and an inefficient source of energy that is only extracted by a few countries, whereas energy is consumed by all countries, in Chapter 29, Collier proposes shutting down coal production progressively, starting in the high-income countries (US, Germany, Australia) and then moving down the ladder (middle-income countries would be required not to expand production once closure starts). On equity grounds, this would be better than freezing discovery and new investment, as suggested by the Board of the World Bank. If the parties involved were to cooperate by "harnessing the moral energy generated by popular concern about climate change", Collier argues that it would be easier to curb coal supply than demand.

The challenges of urban adaptation come on top of massive and as yet unmet development needs, especially in the least developed countries. Globally, cities account for over 70% of global GHG emissions while supporting 54% of the world's population. In addition, 90% of the projected population increase by mid-century is expected to be headed towards cities, especially in developing countries where vulnerability to climate impacts is highest. In Chapter 30, Bigio reviews the mitigation and adaptation strategies that are needed to reduce the carbon footprint of urban growth. To address the magnitude of the challenge, he proposes applying the average carbon replacement value for key construction materials of Annex I countries to all new urban construction expected to take place in the 21st century. This would require one-third of the available carbon budget for limiting climate change to +2°C (40% of the budget share has already been emitted during the period 2000-2011). Bigio identifies the synergies that can be achieved between urban adaptation to climate change and mitigation achieved by investing in energy-efficient infrastructure, both of which can improve the welfare of the urban poor. Obtaining finance and using it effectively is a big challenge ahead, as most urban growth momentum is expected to occur in small and medium-sized cities where governance and institutional capacities are usually weakest.

In Chapter 31, Coninck and Bhasin review the role that technology development and transfer, or 'technology cooperation', could play in facilitating climate change mitigation and adaptation. This process was initiated with the establishment of the Technology Mechanism (TM) in Cancun in 2010. However, due to lack of funding, vested interests, and lock-in, the TM has not yet achieved the hoped-for technological cooperation. One reason for this is that technology transfer requires more than scaling up R&D. As Coninck and Bhasin point out, "technology = hardware + software + orgware", where "orgware" stands for institutional policy and policy capabilities. Moreover, the TM's Technological Executive Committee is populated with climate negotiators who reproduce the deadlocks observed in climate negotiations. The authors identify provisions that would help developed countries see that it is in their self-interests to assist developing countries to enhance their capabilities. A 'technology window' in the Green Climate Fund, combined with making technology part of the portfolio of agreements, would help establish technology as one of the essential building blocks identified by Stewart and co-authors for the transformation in the energy sector that is needed for a workable climate regime.

Part VII: Climate finance

It is clear that most of the economic effects of the policies proposed in earlier chapters require a 'redirection' of future investments towards low-carbon options. Around \$90 trillion will need to be invested in infrastructure in the world's urban, land use and energy systems in the next two decades; this amounts to about \$5-6 trillion a year. About \$1.6 trillion will need to be invested every year in energy supply, half to meet energy demand and half to replace existing plants. How these investments are managed will shape future patterns of growth, productivity, and living standards. It is therefore necessary to redirect these investments towards low-carbon technological and organisational solutions. This is what most earlier chapters were concerned about.

Nevertheless, additional investment will also be necessary to transition our economic and social systems towards a low-carbon future. The first questions are therefore: What is the size of the required additional investments, and what is the sectoral distribution of these investments? Massetti addresses these questions in Chapter 32, in which he analyses the distribution of investment needs across countries and over time. He also provides an overview of the expected financial flows from carbon pricing. These financial flows are crucial to cover the costs of the investment needs and to finance the necessary transfers to developing countries.

Massetti's main message can be simply summarised as follows: additional investments to cope with societal transformations required to achieve the +2°C target amount to about \$0.6 trillion a year from now to 2030, i.e. 0.75% of world GDP in 2013. By contrast, a +2°C-consistent carbon tax would generate up to \$1.3 trillion per year of revenues in OECD economies in 2030. This is equivalent to 2.1% of OECD aggregate GDP in 2013. Non-OECD countries may need (as a median estimate) about \$50 billion in power generation capacity per year until 2030.

These figures seem to suggest that, provided adequate carbon pricing is introduced, financial resources may be sufficient to address the climate change problem. However, the macroeconomic dimension is just one facet of the problem. Implementation always remains the big issue. The regulatory framework and economic incentive schemes should be designed to favour the development of climate finance, both in the public and private sectors. Another key challenge is indeed assuring confidence that projects will deliver an appropriate, risk-adjusted rate of return and that they can be built and operated with all necessary approvals and permits in a timely fashion.

Chapter 33 by Buchner and Wilkinson discusses the above issues. They review needed improvements in the regulatory environment such that climate finance will extend beyond national borders (currently three-quarters of climate finance is spent in the originating country/region). So far, the 'alternative sources' of finance identified in 2009 (carbon markets and prices, taxes on transport and international financial transactions, and the green bond market) have been disappointing. Buchner and Wilkinson conclude that strong government leadership will be needed to steer finance towards a low-carbon future, and suggest steps to take in that direction in Paris.

Since the aftermath of the 2008 crisis, the world is awash with savings and the cost of finance is low. This should be favourable for financing a transition to a low-carbon economy, but the investments are not forthcoming. In Chapter 34, Hourcade argues that we need new tools to kick-start this transition. The creation of government-backed 'climate remediation assets' would provide the guarantee that is currently lacking for private investments. New financial tools are indeed needed to trigger a massive wave of low-carbon investments, and carbon prices alone cannot do the job. Hourcade points out that, in the absence of a benevolent lender, high upfront costs of low-carbon projects, under uncertainty about the cost of equipment and the duration of the maturation phase of the projects, mean that investments that could be profitable are frozen. The creation of 'climate remediation assets' based on a governments' public guarantee, along with carbon pricing, would remove this barrier to investing in low-carbon activities.

The distribution of financial resources is a final issue that needs to be addressed. How should additional – beyond official development assistance, or ODA – concessional climate finance be allocated between countries? Assuming that the split of funds between mitigation and adaptation has been decided, Guillaumont discusses in Chapter 35 the principles that should guide the distribution of funds for adaptation. These principles should be informed by an assessment of a country's vulnerability to weather shocks and natural hazards resulting from changes in the climate. Any resulting index should also be independent of a country's policies. He presents such an index of countries' vulnerability to climate change that he then plugs them into a formula similar to the ones used by the multilateral development banks for the allocation of ODA funds. A large dispersion in per capita allocations result within and across country groupings, reflecting the great heterogeneity in exposure to climate shocks across countries.

Research on climate finance is still in its infancy. Nevertheless, the four chapters in this section emphasise research directions and policy proposals that could effectively address the problem of identifying the sources of funding to cover the costs of climate related investments.

Final reflections

Climate change is a formidable challenge – probably the most difficult challenge the world has ever faced. There are some positive signs, such as the spread of carbon pricing worldwide and the large number of countries submitting their own INDCs at COP21 in Paris. However, with few exceptions (such as Sweden), far too little is being done. The world has set a high bar for action – the +2°C target – but the INDCs submitted so far fall short of the pledges that are needed to meet this goal, particularly because INDCs refer only to 2025-2030, and it is not clear that countries will even meet their pledges. Clearly, the commitments adopted in Paris will be just the first step in a long journey. Additional emissions reduction efforts will need to be implemented in the coming years, and more effective policy measures will need to be adopted, both domestically and internationally. The adoption of robust systems for measurement, reporting, and verification will facilitate compliance, but without supporting enforcement measures, countries are unlikely to achieve large emissions reductions. What is missing is both enforcement and vision. It is not enough to agree on a temperature target. It is now urgent to agree on a societal transformation path, which, in market economies at least, can be driven only by a change in relative prices. Countries should therefore agree on a reference carbon price – to be implemented progressively and through country-specific measures – that would drive investments towards low-carbon options.

The development of new technologies that lower the cost of alternative energy sources relative to fossil fuels will also help to reduce emissions, but contributions to R&D need to be scaled up considerably. The current level of public R&D investment in energy technologies is only a quarter of the equivalent level in the 1980s. Therefore, a four-fold increase in investment would not be unrealistic.

Distributional concerns must also be addressed. To be effective, any new agreement must be perceived by its parties as being fair. A priority for investment must be development of the world's poorest countries without increasing global emissions – a task that will require massive investment and financial support from the industrialised countries. This is not development assistance in the conventional sense of the term; it is development assistance that pays off globally, for the countries that contribute financially as well as for the recipient countries. Cooperation must therefore occur in multiple areas simultaneously – for reducing emissions, for undertaking R&D, and for financing investment and development. The scale, breadth, and complexity of the task are unprecedented, but we have no alternative but to face this challenge directly.

The negotiations leading up to COP21 in Paris have raised many of these issues. The arrangements adopted in Paris will need to be developed and improved upon over time. Additional efforts will also need to be pursued – whether 'building blocks', trade restrictions, or measures of some other description. The UNFCCC process will remain central to any global effort, but it will not be the only game in town. The climate problem is too complex, too far-reaching, and too important for any one institutional arrangement to address on its own. This book provides some guidance for how the world can navigate the unchartered territory that lies ahead of us. It is our hope that it will also stimulate even more ideas for how the world can develop a workable and effective climate regime.

References

Arrow, K. (2009), "*Global Climate Change: A Challenge to Policy", Economists' Voice*, 4(3): 1-5.

Cooper, R. N. (2008), "The Case for Charges on Greenhouse Gas Emissions", Discussion Paper No. 08-10, Harvard Project on International Climate Agreements, Cambridge, MA.

International Energy Agency (IEA) (2015), *World Energy Outlook Special Report: Executive Summary*, Paris.

Pacala, S. and R. Socolow (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science* 305(5686): 968-972.

Schmalensee, R. (1998) "Greenhouse policy architecture and institutions", in W. Nordhaus (eds), *Economics and Policy Issues in Climate Change*, New York: Routledge, p137-158.

UNDP, UNICEF, OXFAM and GFDRR (2014), "Disaster risk reduction makes development sustainable", conference paper, UN Development Programme.

Full references for IPCC reports cited in the chapters

IPCC (2012), Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Geoengineering [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, C. Field, V. Barros, T.F. Stocker, Q. Dahe, J. Minx, K. Mach, G.-K. Plattner, S. Schlömer, G. Hansen, M. Mastrandrea (eds)], IPCC Working Group III Technical Support Unit, Potsdam, Germany: Potsdam Institute for Climate Impact Research.

IPCC (2013a), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2013b), "Summary for Policymakers", in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014a), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R.

Mastrandrea, and L.L. White (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014b), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014c), *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge [Core Writing Team: R.K. Pachauri and L.A. Meyer (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014d), "Summary for Policymakers", in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R.Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J.Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014e), "Summary for policymakers", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds)], Cambridge, UK and New York: Cambridge University Press.

IPCC (2014f), "Summary for policymakers", in *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, UK and New York: Cambridge University Press.

About the authors

Scott Barrett is the Lenfest-Earth Institute Professor of Natural Resource Economics at Columbia University in New York City, with appointments in the School of International and Public Affairs and the Earth Institute. He taught previously at the Johns Hopkins University School of Advanced International Studies in Washington, DC and, before that, at the London Business School. He has also been a visiting scholar at Princeton, Yale, and Université de Paris 1 Panthéon-Sorbonne. He is the author of *Environment and Statecraft: The Strategy of Environmental Treaty-Making* and *Why Cooperate? The Incentive to Supply Global Public Goods*, both published by Oxford University Press. He received his PhD in Economics from the London School of Economics.

Carlo Carraro is Professor of Environmental Economics at Ca' Foscari University of Venice. He holds a PhD from Princeton University. He was President of the University of Venice from 2009 to 2014 and Director of the Department of Economics from 2005 to 2008. In 2008, he was elected Vice-Chair of the Working Group III and Member of the Bureau of the Nobel Laureate Intergovernmental Panel on Climate Change. He was re-elected in 2015 for a second term. He is Scientific Director of the Fondazione Eni Enrico Mattei (FEEM), Director of the International Centre for Climate Governance (ICCG) and member of the executive board of the EuroMediterranean Center on Climate Change (CMCC). He is Co-Chair of the Green Growth Knowledge Platform (GGKP) Advisory Committee and Editor of the *Review of Environmental Economics and Policy*, the most important international journal in its field.

Jaime de Melo, Emeritus Professor at the University of Geneva, is Scientific Director at Ferdi, an invited professor at the Johns Hopkins University Bologna Center, and a non-resident scholar at Brookings. He worked at USAID from 1972 to 1976, taught at Georgetown University from 1976-80 and at the University of Geneva from 1993-2012. From 1980 to 1993, he held various positions in the research Department at the World Bank. He serves on several editorial boards and was editor-in-chief of the *World Bank Economic Review*, 2005-2010.

PART I

The Challenge

2 Implications of climate science for negotiators

Thomas F. Stocker
Physics Institute, University of Bern

The scientific assessments carried out by the Intergovernmental Panel on Climate Change have delivered robust and rigorous scientific information for the complex negotiations that should produce a binding agreement to limit climate change and its impacts and risks. Understanding climate change as a threat to key resources for the livelihood of humans and the functioning of ecosystems provides a more appropriate perspective on the scale of the problem. Model simulations suggest that many options exist today to limit climate change. However, these options are rapidly vanishing under continued carbon emissions: Temperature targets must be revised upwards by about 0.4°C per decade for constant mitigation ambitions. Mitigating climate change has the important benefit of creating favourable conditions to reach many of the Sustainable Development Goals; business-as-usual and consequent unchecked climate change will make these important universal goals unreachable.

1 Introduction

"*Climate change is one of the greatest challenges of our time*" – this is the assertion of the parties to the United Nations Framework Convention on Climate Change (UNFCCC 2009). The Fifth Assessment Report of the IPCC (AR5), which was completed in November 2014 with the publication of the Synthesis Report (IPCC 2014c), gives a comprehensive snapshot of the knowledge science has to offer to quantify, understand, and confront this problem. The four key messages from the "Summary for Policymakers" of the Synthesis Report are:

1. Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.
2. Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.
3. Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term, and contribute to climate-resilient pathways for sustainable development.
4. Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales , and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

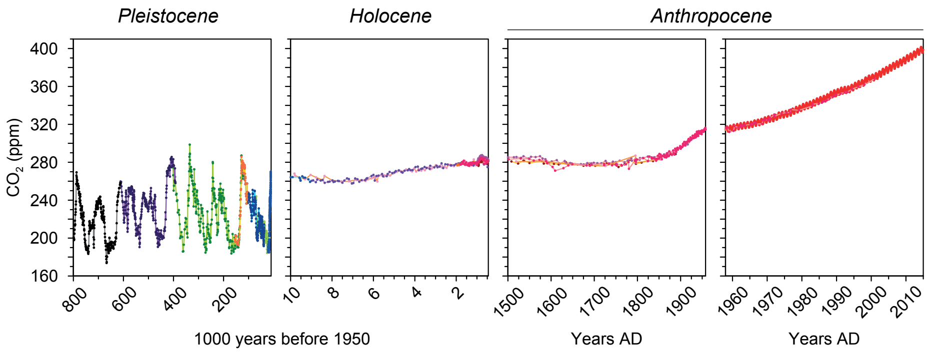
The power of these statements, which reflect the scientific assessment, lies in the fact that the member countries of the IPCC have formally approved the formulations by consensus.

The purpose of this chapter is to briefly introduce the reader to important insights from the physical climate science (Section 2) and consider them with the perspective of threats to primary resources for human and ecosystems. Section 3 revisits projections of climate change and establishes a link to the requirements of adaptation and their limits. In Section 4, cumulative carbon emissions are considered as a framework to assess the options that are available to confront climate change. Section 5 sheds light on the rapid disappearance of these options. Future challenges and conclusions are presented in Section 6.

2 Anthropogenic climate change as a threat to primary resources

Carbon dioxide concentrations in the atmosphere are now unprecedented and 30% higher than during at least the last 800,000 years, and they are rising more than 100 times faster than during the past 20,000 years (Figure 1). Similar observations hold for methane and nitrous oxide, the two other important greenhouse gases. The chemical composition of the Earth's atmosphere is now fundamentally different from that which prevailed before the Industrial Revolution (Hartmann et al. 2013).

Figure 1 Atmospheric CO_2 concentrations over the past 800,000 years

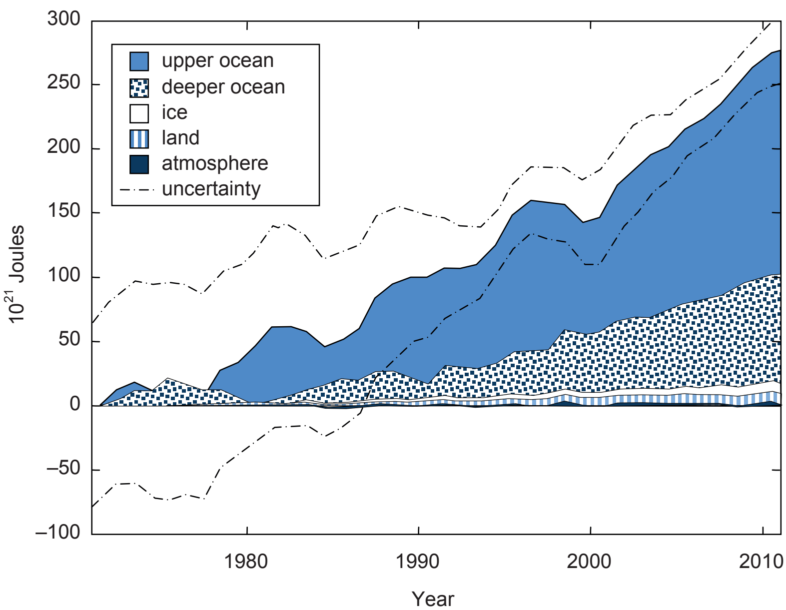


Notes: Measurements of atmospheric CO_2 concentrations on air trapped in bubbles in various Antarctic ice cores (left three panels), and direct measurements at Mauna Loa since 1958 (rightmost panel). Current concentrations are far outside the natural range of variations during the past eight ice age cycles. The stretched time scale highlights the rapid acceleration of the CO_2 increase: in the past 60 years CO_2 increased by about twice the amount it increased in the preceding 400 years, and by about four times that over the previous 10,000 years.

Source: Data from Lüthi et al. (2008), Bereiter et al. (2015) and NOAA ERSL; figure made by B. Bereiter.

Turning back to the physical climate system, based on multiple lines of independent evidence from the atmosphere, the ocean and the cryosphere, IPCC has concluded that *warming in the climate system is unequivocal*. Since 1951 the Earth has warmed by about 0.6 to 0.7°C, which is the most easily accessible manifestation of a change in its global energy balance. This has resulted from positive radiative forcing since 1750 AD caused by a large warming contribution from the increase in the concentrations of the major greenhouse gases in the atmosphere (Figure 1), and a smaller cooling contribution from aerosols. A much more convincing manifestation of the consequence of this positive radiative forcing is the detection of this extra energy that has accumulated in the Earth System. Since 1970, the energy content of the Earth System has increased by about 250·10^{21} J (Figure 2). Thanks to the unprecedented effort of the international scientific community to measure ocean temperatures on a global scale from the sea surface to a depth of about 2 km, we know that more than 90% of this stored energy is found in the ocean (Roemmich et al. 2012). It is somewhat paradoxical that the public is almost exclusively fixated on atmospheric temperatures, and in particular their recent decadal variability (Boykoff 2014), while the ocean is a natural integrator and recorder of the warming.

Figure 2 Heat accumulation in the Earth System: Change in the energy content of the Earth System since 1970



Note: More than 90% of the additional energy is stored in the top 2 km of the world ocean. In contrast to identifying the warming in the atmosphere where even on the global scale decadal variations are important, the ocean is an effective integrator of the signal.

Source: Figure modified from Stocker et al. (2013) and IPCC (2014c).

The increase of atmospheric CO_2 concentrations has further, far-reaching consequences: it acidifies the entire world ocean (Orr et al. 2005). This global-scale change has not generally received adequate attention from policymakers, negotiators and the public. However, it is now recognised as one of the most profound and long-lasting changes that humans are inflicting on the Earth System. This is due to the fact that much of the emitted CO_2 remains in the atmosphere for many millennia owing to the buffering effect of the ocean water with respect to CO_2. Consequences of ocean acidification, compounded with the world-wide warming, are little known, but they will affect marine ecosystems on a world-wide scale with growing risks for marine life (Gattuso et al. 2015).

The warming also increases sea levels both directly and indirectly. The thermal expansion of the warming water, the melting of the glaciers on land, and the loss of mass from Greenland and Antarctica are all contributing to the rapid increase of sea level (Church et al. 2013).

Numerous other changes have been detected over the past 50 years in all components of the Earth System. Among these observations are reductions in the Arctic sea ice cover in terms of both extent and thickness, melting of the Greenland and Antarctic ice sheets, shrinking of glaciers worldwide, changes in the global water cycle, and increases in the occurrence and strength of extreme events such as a doubling in the frequency of heat waves. The warming and many of the consequent changes are being caused by the increase in greenhouse gas concentrations and other substances in the atmosphere. This conclusion arises from the combination of global model simulations and observations, which permits the attribution of the observed changes to various drivers and causes (Bindoff et al. 2013). Recognising this robust scientific evidence, IPCC concludes in AR5 that the '*human influence on the climate system is clear*'. This surprisingly blunt and simple statement is the succinct summary of thousands of scientific studies that were considered in the latest assessment and represents language that was approved by the member states of the IPCC.

The importance of these physical changes and their consequent impacts around the globe becomes prominently evident to negotiators and the public if we understand them as changes to key resources available to humans. The primary resources for human subsistence are land, food and water. These are all directly threatened by climate change:

- The availability of land is diminished by the rising level of the sea.
- The availability of food on land is challenged by changes in fundamental ecosystem conditions such as mean temperature and precipitation and their seasonal expression.
- The availability of food from the ocean is threatened by the compound effect of warming, acidification and circulation changes.

- The availability of water is impacted in many regions of the world due to changes in precipitation and evaporation on a global scale, with a tendency to exacerbate existing stresses such as drought or flooding.

It is against this backdrop that we must consider Article 2 of the UN Framework Convention on Climate Change (UNFCCC 1992), which reads:

> *The ultimate objective of this Convention [...] is to achieve [...] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.*

The notion of 'dangerous' in the context of '*dangerous anthropogenic interference with the climate system*' has been notoriously difficult to describe and constrain, for it cannot be determined or quantified by science. Undisputedly, there is an inherent and evident danger associated with changes in resources. Social systems have developed and were optimised over a long period of resource stability, that is, availability within relatively bounded variability ranges. If the mean supply of resources or its variability leave this range of tested and experienced resilience, the finely equilibrated network of systems is at serious risk.

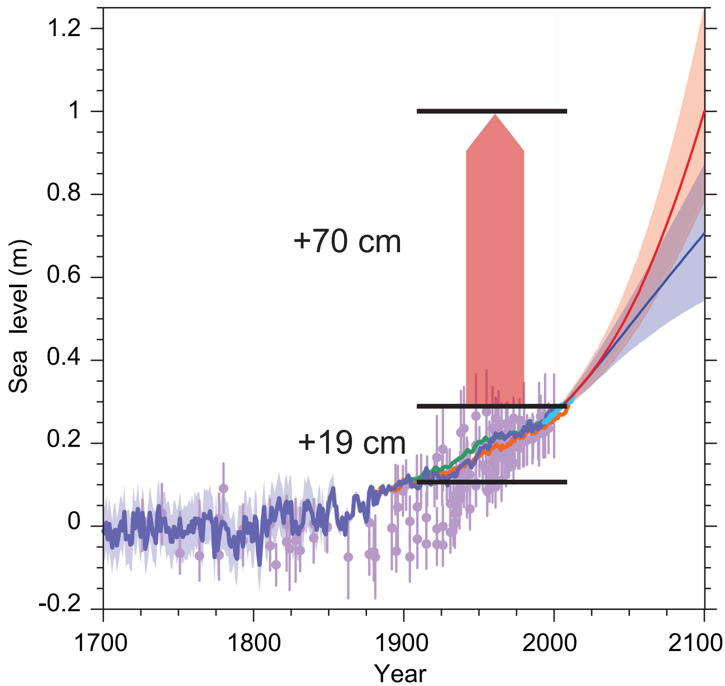
3 Climate change projections and the threat of adaptation limits

The long-term character of climate change projections over many decades is often difficult to comprehend for the policymakers and the public. How can scientists estimate future changes in the Earth System when there is an inherent limit in the predictability of the weather to about the next ten days? A simple analogy from classical physics may clarify this constantly recurring question. Consider a container of water that is put on a heating plate. We know the physical dimensions of the container, the amount of water, and the power of the heating plate. No one would doubt that we can deliver a fairly accurate estimate of the mean temperature of the water after, say, five minutes of heating at a selected level of power. What we will not be able to tell the cook is at what moment a water vapour bubble will form at the bottom of the container and rise to the surface. Fortunately, the cook will likely not be interested in knowing this. Our inability to provide this information is due to the turbulence of the fluid and the chaotic processes associated with convection when heat is supplied to the fluid from below (Lorenz 1963). The existence of internal chaotic processes, however, does not prevent us from estimating quite accurately the mean temperature of the water using energy balance, and with some extra effort one may also calculate the statistics of bubble formation at the bottom of the container as a function of time.

This is an appropriate analogy to the climate change predictability problem. The example makes evident why we are confident in providing rather robust estimates on the future state of the Earth System, even though we are unable to quantify the complete internal dynamics at each point in time. To estimate the future temperature of the water in the container, the power we select for the heating plate is the key information. To estimate climate change, it is the greenhouse gas emissions scenario.

Based on a new set of emissions scenarios, comprehensive climate models project the changes in the climate system during the 21st century and beyond (Edenhofer et al. 2015). The global surface temperature will increase in all scenarios and by the end of the 21st century will *likely* exceed 1.5°C relative to 1850-1900 for all but the lowest emissions scenario (IPCC 2013a,b). This low emissions scenario assumes effective policy intervention that would result in aggressive emissions reductions of about 50% by the mid-21st century and complete decarbonisation thereafter. Conversely, a business-as-usual scenario projects a global mean temperature increase exceeding 4.5°C relative to 1850-1900, with profound changes in all components of the climate system. The sea level would rise by between 0.52m and 0.98m by 2100 relative to 1986-2005, at a rate of 8-16 mm per year, caused by increased ocean warming and loss of mass from glaciers and ice sheets. In this scenario, a nearly ice-free Arctic Ocean in September is *likely* before the middle of the century. Furthermore, the contrast between wet and dry regions, and between wet and dry seasons, will increase. Climate change will also affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere. Further uptake of carbon by the ocean will increase ocean acidification.

Figure 3 The scale of committed adaptation to sea level rise



Notes: Compilation of paleo sea level data (purple), tide gauge data (blue, red and green), altimeter data (light blue) and central estimates and likely ranges for projections of global mean sea level rise from the combination of CMIP5 and process-based models for RCP2.6 (blue) and RCP8.5 (red) scenarios, all relative to pre-industrial values. During the past 100 years adaptation to a 19cm rise was required, much less than the additional 70 cm estimated for 2100 under a business-as-usual scenario.

Source: Modified from Stocker et al. (2013).

Considering these changes, a key question for policymakers and negotiators concerns the capacity for adaptation. We illustrate this with the projected sea level rise (Figure 3). So far, adaptation to sea level rise of 19cm has taken place since the beginning of the 20th century, although it should be noted that complete adaptation to this change was not necessary since many coastal infrastructures were only built over the course of the 20th century. Comparing this with the committed adaptation required under a business-as-usual scenario (an additional 70 cm), while also considering the mature infrastructure and established coastal settlements that are already in place and that must adapt, indicates the dramatic challenges ahead. The mitigation scenario (RCP2.6) still requires adaptation to sea level rise, but of about half this amount. Note that successful adaptation to 21st century conditions will not be sufficient because the sea level will continue to rise long beyond 2100. Many regions are likely to have already encountered the limits to their adaptation capacity in the 21st century (Klein et al. 2014). As with the sea level, adaptation limits also exist for ecosystems on land and in the ocean (Burrows et al. 2011).

The limits of adaptation that we may reach in the course of the 21st century will depend on our choices and actions today. Limits of adaptation form part of the more fundamental insight that the Earth System offers habitability only within restricted bounds, or 'planetary boundaries' (Rockström et al. 2009). If these boundaries change through human activity, or if we push the state of the Earth System beyond these boundaries, the well functioning of the world as we know it today is seriously threatened.

4 Current options to address the problem

In AR5 various emission scenarios have been developed for a hierarchy of climate and Earth System models to project the changes in the Earth System (IPCC 2013a), to assess the impacts and risks (IPCC 2014a), and to inform about technological options and economic and societal requirements (IPCC 2014b). This palette of results, communicated through the four Representative Concentration Pathways (the RCP scenarios), suggest that we have a full choice of options. Indeed, there exists today a choice between a profoundly altered Earth System in which the availability of the two primary resources for human communities and ecosystems will be different, or alternatively an Earth System with limited changes and in which adaptation still appears feasible in many regions. In the case of the former, land area will diminish through further sea level rise with severe and pervasive impacts on coastal settlements, and changes in the global water cycle will accentuate the differences between dry and wet areas with particularly severe effects on regions that are already challenged by droughts.

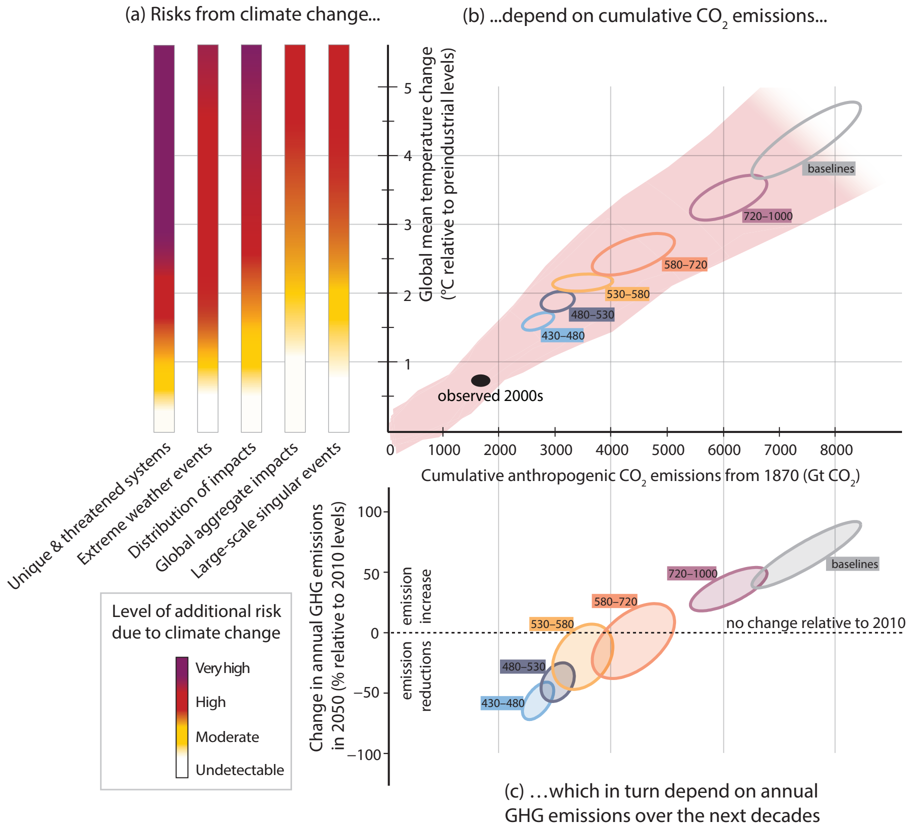
These options, however, have an expiration date – with continuous greenhouse gas emissions, growing at a rate of about 1.8% per year as during the past 40 years, the options are gradually vanishing. AR5 now equips the negotiators with an instrument that links the climate change risk assessment with the requirements for climate change limitation. This is the key result from the Synthesis Report (IPCC 2014c). A key new element is the near-linear relationship between global mean surface warming by the late 21st century and the total cumulative emissions of CO_2 since industrialisation (IPCC 2013b). The larger the cumulative emissions, the higher the peak temperature in the 21st century will be. The important point is that the warming is recognised as a function of all effected emissions, bringing an important and hitherto missing historical perspective to the origin of the future warming.

Figure 4 illustrates this highly policy-relevant result. Risks associated with climate change increase at specific rates with the warming (panel (a)). Therefore, a risk limit that may be established through the political negotiation process translates into an amount of allowable cumulative emissions (panel (b)), i.e. a limited carbon budget. The metric here is temperature, but it is clear from Article 2 of the UNFCCC that temperature alone does not comprehensively address the declared goal. For example, any risks caused by ocean acidification would be ignored if temperature were the sole indicator of change. Likewise, the long-term consequences of sea level rise are not directly proportional to the warming in the 21st century. The agreement to limit climate change and its impacts and risks implies not overspending the carbon budget, and hence emissions must be reduced. These reductions are quantified in panel (c) for the time horizon of 2050. The carbon budget is also clear about the fact that complete net decarbonisation must be achieved beyond 2050 if warming is to be kept below an agreed target.

The Working Group I assessment finds that in order to have a fair chance of keeping global mean warming below 2°C, the maximum total amount of carbon that can be emitted in the atmosphere since the late 19th century is about 1,000 billion tonnes,[1] of which 545 billion tonnes had already been emitted by 2014. To comply with this target, therefore, only 455 billion tons of carbon can be emitted in the future. If the effects of additional greenhouse gases – such as methane and nitrous oxide coming from food production – are taken into account, this amount falls to only 245 billion tonnes of carbon. This is equivalent to less than 25 years of emissions at 2014 levels. While this estimate is simplistic, it illustrates the fact that the options have an expiration date that is imminent.

1 Note that WG I reports emission reductions in gigatonnes of carbon (GtC), while WG III reports emissions in gigatonnes of carbon dioxide ($GtCO_2$) (1GtC = 3.667 $GtCO_2$). Also note that uncertainty estimates are comprehensively given in the reports of Working Groups I and III.

Figure 4 The most policy-relevant finding from the synthesis of the three working group assessments

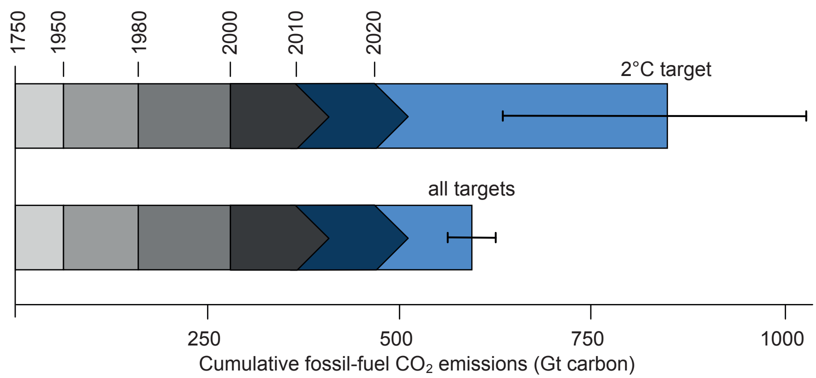


Notes: Panel (a) identifies five key climate change-related risks whose levels increase with rising temperatures. Due to the near-linear relationship between cumulative anthropogenic CO_2 emissions and warming (panel (b)), the risk level is tied to a total amount of CO_2 emitted. Based on the emissions up to now, requirements of emission reductions by 2050 can be estimated (panel (c)). For example, to have a chance greater than 66% of limiting the risks to those expected for a warming of no more than 2°C, emissions need to be reduced by 40-70% relative to 2010 levels. Uncertainty estimates are indicated by the shaded wedge (panel b) and the ellipses (panels b and c).

Source: Modified from IPCC (2014c).

The temperature target agreed by the parties to the UNFCCC (UNFCC 2010) is not a guarantee to fulfil Article 2 of the convention in a holistic sense. Adaptation and food production, as well as poverty eradication through sustainable development, all call for a more encompassing approach. One step towards this is the definition of additional climate targets, as proposed recently by Steinacher et al. (2013). Using an Earth System model of reduced complexity (the Bern3D model), various sets of combined climate targets were defined and the compatible cumulative carbon emissions were determined probabilistically. The set of climate targets comprised both physical and carbon cycle-related quantities, i.e. in addition to the global mean temperature limit, there are also limits to sea level rise, ocean acidification and loss of primary production on land. The detailed calculations showed that levels of comparable ambition in the individual targets result in a smaller overall budget if all targets are to be met – the reduction of the budget by 30% is substantial (Figure 5).

Figure 5 Effect of multiple climate targets on cumulative emissions



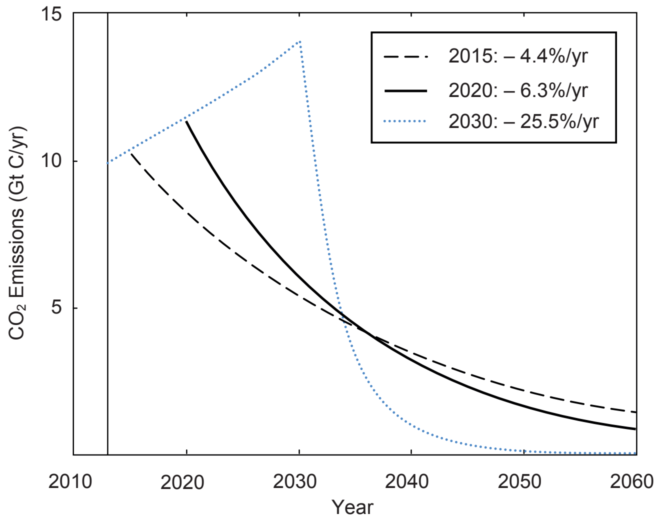
Notes: Cumulative fossil-fuel emissions, i.e. excluding past and future land use changes, that are compatible with a single temperature target (upper bar) are significantly larger than those consistent with a set of policy-relevant climate targets addressing more comprehensively Article 2 of the UNFCCC. The likely range (66%) of the probabilistic estimates is indicated by the uncertainty bars.

Source: Figure made by M. Steinacher, based on Steinacher et al. (2013).

5 While negotiations continue, climate mitigation and adaptation options are disappearing at an accelerating pace

The passing of time caused by the complexity of the negotiations is particularly detrimental to the ultimate goal of the UNFCCC of stabilising greenhouse gas concentrations in the atmosphere. That goal was agreed in 1992 and entered into force in 1994. Only since 1994, over 20% of the budget of cumulative carbon emissions that is compatible with the 2°C target, or 42% of the then remaining budget, has been consumed. The start time of the global emissions reduction pathway is crucial. To illustrate this, we consider idealised carbon emission pathways (Stocker, 2013), which are so simple that they lend themselves to an analytical evaluation. Three pathways for a global mitigation scheme, all compatible with the 2°C target but with different start times, are shown in Figure 6. It is evident that a delay in starting mitigation increases the level of ambition of the required mitigation rapidly. If it started now, emissions would need to drop at a constant rate of 4.4% per year, while if it started 15 years later, that rate grows to over 25% per year – a decarbonisation rate that is economically impossible (den Elzen et al. 2007).

Figure 6 Idealised exponential emission pathways compatible with a 2°C target



Notes: The pathways consist of a period of continued emission growth of 2 % per year, approximately the current long-term rate, and a subsequent sustained reduction starting at various times in the future. The cumulative CO_2 emissions, i.e. the area under the three curves, is the same for the three scenarios and is consistent with the 2°C target.

Source: Based on Stocker (2013).

A different way to look at the problem is to ask for the required emissions reduction rate given an agreed temperature target and a start year for the mitigation. Delaying mitigation for too long means that an agreed temperature target becomes more and more difficult to reach. In order to measure the speed of 'climate target loss', a new metric – mitigation delay sensitivity (MDS) – was introduced by Allen and Stocker (2014). This measure is of central policy relevance as it directly informs about the urgency of implementing mitigation measures for a target to remain achievable. MDS can also be determined for other policy-relevant quantities such as sea level rise or measures of ocean acidification (Pfister and Stocker 2015).

Model estimates show that in about ten years time, the 2.5°C target will have become as ambitious as the 2°C target is today (Allen and Stocker 2014). For a constant ambition, the achievable temperature target therefore increases at a rate that is 2 to 6 times faster than the observed warming during the past few decades. Due to the slow response of the sea level to the forcing, sea level mitigation delay sensitivities are 9 to 25 times larger than current observed rates (Pfister and Stocker 2015). Observed warming and sea level rise therefore create an overly optimistic impression of the urgency of the problem.

6 Future challenges and conclusions

In order to provide useful information for decision-makers, the information on Earth System changes must become more regional. The chain from global-scale models to regional, limited area models and to downscaled information will be the key to much better exchange of information between science communities concerned with the physical processes of the Earth System and those investigating impacts, vulnerability and risk. Quantitative risk maps would be a timely and most desirable product for negotiators, but would require quantification of vulnerability and exposure to climate change. It is suggested that the concerned science communities design a long-term strategy, for example under the stewardship of the Future Earth programme (www.futureearth.org), to develop, compare, evaluate and apply impact and risk models, very much following the successful approach of the series of coupled modelling intercomparison projects under the leadership of the World Climate Research Programme (wcrp-climate.org).

One of the greatest challenges for negotiators is the limited time that is available to realistically achieve the 2°C target. While solutions (see Part III of this book) are being sought, agreements formulated, and legal frameworks negotiated, global carbon emissions continue to grow. With every decade, about 0.4°C of the temperature target are lost given a constant level of ambition of emissions reductions. Once the carbon budget for a specific target is consumed, that target is lost permanently (barring global-scale negative emissions, which will be unavailable in the near future). This implies that at some stage, climate change targets will need to be corrected upwards. If this happens, how would we deal with such an evident failure of global stewardship?

Taking a broader perspective, we should recognise that addressing climate change is simply a necessity if we want to achieve the Sustainable Development Goals (SDGs) that countries have committed to. Effective climate change mitigation is a good start on the pathway towards the SDGs, and will allow many of them to be reached more quickly. Business-as-usual, on the other hand, will certainly make the SDGs unachievable. Addressing climate change must therefore be an integral part of a strategy to reach the Sustainable Development Goals.

References

Allen, M. R. and T.F. Stocker (2014), "Impact of delay in reducing carbon dioxide emissions", *Nature Climate Change* 4: 23-26.

Bereiter, B., S. Eggleston, J. Schmitt, C. Nehrbass-Ahles, T.F. Stocker, H. Fischer, S. Kipfstuhl and J. Chappellaz (2015), "Revision of the EPICA Dome C CO_2 record from 800 to 600 kyr before present", *Geophysiscal Research Letters* 42(2): 542-549.

Bindoff, N. L., P. A. Stott, et al. (2013), "Detection and Attribution of Climate Change: from Global to Regional", in *Climate Change 2013: The Physical Science Basis* (see IPCC (2013c) in the introduction to this volume for the report's full reference).

Boykoff, M. T. (2014), "Media discourse on the climate slowdown", *Nature Climate Change* 4: 156-158.

Burrows, M. T. et al. (2011), "The pace of shifting climate in marine and terrestrial ecosystems", *Science* 334: 652-655.

Church, J. A., P. U. Clark, et al. (2013), "Sea Level Change", in IPCC (2013), *Climate Change 2013: The Physical Science Basis* (see IPCC (2013c) in the introduction to this volume for the report's full reference).

den Elzen, M., M. Meinshausen and D. van Vuuren (2007), "Multi-gas emission envelopes to meet greenhouse gas concentration targets: Costs versus certainty of limiting temperature increase", *Global Environmental Change* 17(2): 260-280, 2007.

Edenhofer, O., S. Kadner, C. von Stechow and J. C. Minx (2015), "Beyond the 2°C limit: Facing the institutional challenges", in S. Barrett et al. (eds), *Towards a Workable and Effective Climate Regime*, Clermont-Ferrand: Ferdi.

Gattuso, J. P. et al. (2015), "Constrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios", *Science* 349.

Hartmann, D. L., A. M. G. Klein Tank, M. Rusticucci, et al. (2013), "Observations: Atmosphere and Surface", in *Climate Change 2013: The Physical Science Basis* (see IPCC (2013a) in the introduction to this volume for the report's complete reference).

IPCC (2013a), *Climate Change 2013: The Physical Science Basis* (see IPCC (2013a) in the introduction to this volume for the report's complete reference).

IPCC (2013b), "Summary for Policymakers", in *Climate Change 2013: The Physical Science Basis* (see IPCC (2013b) in the introduction to this volume for the report's complete reference).

IPCC (2014a), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (see IPCC (2014a) in the introduction to this volume for the report's complete reference).

IPCC (2014b), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this volume for the report's complete reference).

IPCC (2014c), *Climate Change 2014: Synthesis Report* (see IPCC (2014c) in the introduction to this volume for the report's complete reference).

Klein, R. J .T., G. F. Midgley, B. L. Preston et al. (2014), "Adaptation opportunities, constraints, and limits", in IPCC (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (see IPCC (2014a) in the introduction to this volume for the report's complete reference).

Lorenz, E. N. (1963), "Deterministic non-periodic flow", *Journal of the Atmospheric Sciences* 20: 130-141.

Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola et al. (2008), "High-resolution carbon dioxide concentration record 650,000-800,000 years before present", *Nature* 453: 379-382.

Orr, J. C. et al. (2005), "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms", *Nature* 437: 681-685.

Pfister, P. L., and T. F. Stocker (2015), "Earth System commitments due to delayed mitigation", *Environmental Research Letters* (submitted).

Rockström, J. et al. (2009), "A safe operating space for humanity", *Nature* 461: 472-475.

Roemmich, D., J. W. Gould and J. Gilson (2012), "135 years of global ocean warming between the Challenger expedition and the Argo Programme", *Nature Climate Change* 2: 425-428.

Steinacher, M., F. Joos and T. F. Stocker (2013), "Allowable carbon emissions lowered by multiple climate targets", *Nature* 499: 197-201.

Stocker, T. F. (2013), "The closing door of climate targets", *Science* 339: 280-282.

Stocker, T.F., D. Qin, G.-K. Plattner, et al. (2013), "Technical Summary", in IPCC (2013), *Climate Change 2013: The Physical Science Basis* (see IPCC (2013b) in the introduction to this volume for the report's complete reference).

UNFCCC (1992), United Nations Framework Convention on Climate Change (FCCC/INFORMAL/84 GE.05-62220 (E) 200705), New York.

UNFCCC (2009), The Copenhagen Accord, (FCCC/CP/2009/11/Add.1), New York.

UNFCCC (2010), The Cancun Agreements (FCCC/CP/2010/7/Add.1), New York.

About the author

Thomas Stocker obtained a PhD in Natural Sciences of ETH Zürich in 1987. He held research positions at University College London, McGill University (Montreal), Columbia University (New York) and University of Hawai'i (Honolulu). Since 1993 he is Professor of Climate and Environmental Physics at the University of Bern. From 2008 to 2015 he served as Co-Chair of Working Group I of the IPCC. Thomas Stocker has co-authored more than 200 publications; he holds an honorary doctorate from the University of Versailles. He is a Fellow of the American Geophysical Union and a Foreign Member of the Accademia Nazionale dei Lincei.

3 Beyond the 2°C limit: Facing the economic and institutional challenges

Ottmar Edenhofer, Susanne Kadner, Christoph von Stechow and Jan Minx
Mercator Research Institute on Global Commons and Climate Change (MCC), Potsdam Institute for Climate Impact Research (PIK) and Technische Universität Berlin; PIK; MCC, PIK and Technische Universität Berlin; MCC, PIK and Hertie School of Governance

With very high risk of severe, widespread and irreversible impacts globally due to unabated anthropogenic climate change, we argue in this chapter that the 2°C limit can be justified by the synthesis of available scientific evidence as an application of the precautionary principle. In principle, the risks of mitigation differ fundamentally from the risks of climate change in terms of their nature, timescale, magnitude and persistence. Humankind has the technological means to solve the problem. However, the challenges of stringent mitigation action are enormous and have been increasing over the last decade because of the ongoing renaissance of coal, which does not allow for a decoupling of economic and population growth from emissions. Keeping a greater than 66% probability of staying below the 2°C limit, for example, would require current emission levels to be reduced by 40-70% by 2050, and emission levels of zero and below by the end of the 21st century. This requires a large-scale transformation in the way we produce and use energy, as well as how we use land. The most fundamental challenges are the oversupply of fossil fuels and the risks associated with negative emissions technologies, or high bioenergy deployment. A further delay in mitigation action substantially increases the difficulty of, and narrows the options for, this transformation. Delays are associated with a growing dependence on negative emissions technologies as well as higher mitigation costs in the long run. In the near term, a fundamental departure from the business-as-usual development is required. Therefore, triggering

short-term climate policy action is instrumental for any reasonable long-term climate goal. While the institutional challenges are tantamount, there are multiple rationales for pricing carbon and introducing complementary policies.

1 Dangerous climate change – the rationale of the 2°C limit

Faced with an increasing likelihood of "very high risk of severe, widespread and irreversible impacts globally" due to unabated anthropogenic climate change (IPCC 2014c), decision makers from all countries will meet at the 21st Conference of Parties (COP21) in Paris to work on a new international climate treaty. Climate policy is locked in a race against time, with greenhouse gas (GHG) emissions growing faster in the first decade of this century than in previous decades, despite a growing number of mitigation efforts. One of the most important drivers is the ongoing renaissance of coal, which does not allow for a decoupling of economic and population growth from GHG emissions (IPCC 2014a, Steckel et al. 2015). The oversupply of fossil fuels is one of the most fundamental challenges of climate policy. Understanding the technological and economic implications of limiting the disposal space of GHGs in the atmosphere (see Section 2) and triggering short-term mitigation action (see Section 3) is key to a workable and effective climate regime.

As highlighted in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the global mean temperature increase is an almost linear function of the cumulative release of CO_2 emissions to the atmosphere (see Figures SPM.10 and 12.45 in IPCC 2013; and Figure SPM.10 in IPCC 2014d). As carbon emissions accumulate in the atmosphere, the long-term temperature increase is determined in an irreversible way, unless technologies are available that allow for the net removal of carbon from the atmosphere, so-called 'negative emissions technologies'. While these may be necessary and useful within a portfolio of mitigation options, the required large-scale deployment of such technologies is associated with important risks (see Section 2) and is not able to prevent climate change within a reasonable time frame (IPCC 2013). These and other mitigation risks need to be weighed against the risks of climate impacts when determining a climate goal.

Economists have frequently tried to estimate the optimal balance between mitigation, adaptation and residual climate impacts. However, the underlying differences in methodological approaches and important gaps in knowledge make it challenging to carry out direct comparisons of these impacts in the form of cost-benefit calculations (Kunreuther et al. 2013, IPCC 2014e). More fundamentally, the identification of an optimal climate goal is based on many implicit value judgements and ethical considerations, which may be contested in pluralistic societies. Such judgements and considerations are fundamentally important, for example, when the damages from climate change, which are mainly incurred by future generations, are counted against the costs of mitigation, which are largely borne by today's generations (Kolstad et al. 2014). It therefore seems appropriate to take a risk management perspective that evaluates the risks of climate change (in terms of impacts and adaptation limits) and the risks of mitigation action (in terms of mitigation costs and potential adverse side-effects of mitigation technologies). This ultimately leaves the decision about the most desirable temperature level to policymakers and the public, who may base their discussions on the range of different risks, information about which is provided in the AR5 (Edenhofer and Kowarsch 2015).

Increasing temperatures raise the likelihood of severe, widespread and irreversible impacts (IPCC 2014c). Without additional mitigation efforts, the global mean temperature will increase by about 4°C (3.7-4.8°C based on the median climate response) by the end of the 21st century and will lead to high to very high climate change risks even with adaptation (Clarke et al. 2014, IPCC 2014a, IPCC 2014e). These include inter alia the loss of the Arctic ice sheet, substantial species extinctions, consequential constraints for human activities and global and regional food insecurity (IPCC 2014c). Limiting warming to below 2°C would reduce these risks of climate change substantially compared to business as usual, particularly in the second half of the 21st century (IPCC 2014c, IPCC 2014d). The large differences in risk between a 4°C and a 2°C world were therefore clearly emphasised in the AR5, whilst the difficulties in understanding the differential climate impacts for small temperature changes – such as 1.5°C, 2°C, 2.5°C or 3°C – were also acknowledged. Even a temperature increase of 2°C and below is associated with some risks from climate damages irrespective of mitigation and adaptation efforts (IPCC 2014d).

In contrast to climate damages, the risks of mitigation are generally not irreversible (except, for example, nuclear accidents and biodiversity loss) because they allow for trial and error and therefore for a social learning process in climate policy implementation. Mitigation risks are thus seen as differing fundamentally from the risks of unabated climate change in terms of their "nature, timescale, magnitude and persistence" (IPCC 2014e). Mitigation risks, however, also differ across alternative mitigation pathways.[1] These differences mainly depend on the availability and choice of technologies as well as the stringency and timing of GHG emissions reductions (see Section 3) (Clarke et al. 2014, IPCC 2014a).

Once a certain temperature level has been exceeded, only two options remain to deal with climate change: adaptation and solar radiation management (SRM), the latter of which tries to intentionally modify the earth's radiative budget. Some environmental impacts of climate change, such as ocean acidification, cannot be addressed by SRM technologies. There may also be other adverse side-effects that need careful assessment (IPCC 2013). Given the inherent uncertainties of the impacts of these options and the future impacts of climate change, aiming for the 2°C limit can thus be seen as an application of the precautionary principle, which emerges from the synthesis of scientific evidence and the value judgements by experts of how to avoid dangerous climate change. Whilst the global mean temperature cannot be controlled directly, a carbon budget can be defined which allows the limitation of the global mean temperature with a specific probability (see Table SPM.1 in IPCC 2014b). However, the window of opportunity to stay below the 2°C limit is rapidly closing, as the next section shows.

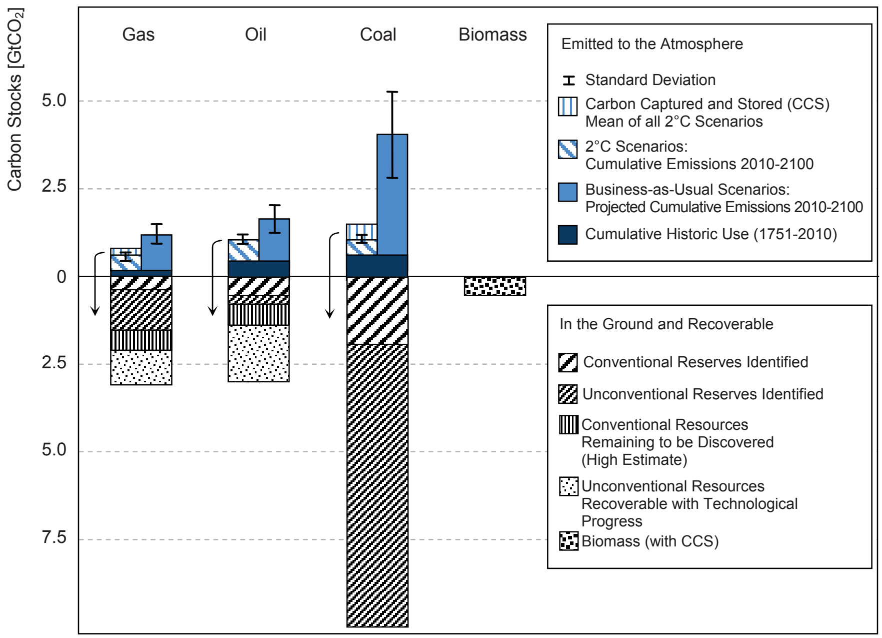
2 Technological and economic implications of the 2°C limit

Limiting climate risks by keeping global mean temperature increase below 2°C (with a greater than 66% probability) implies a remaining carbon budget of about 1,000 (750-1,400) $GtCO_2$ (IPCC 2014e). If current trends continue, this budget will be completely

1 Many mitigation technologies also entail co-benefits for non-climate policy objectives (von Stechow et al. 2015). These often accrue locally and may provide incentives for unilateral mitigation action; they are discussed in Section 3.

used up within the next 20-30 years. With more than 15,000 $GtCO_2$ in fossil fuel reserves and resources in the ground, it is clear that we will not run out of fossil fuels. Rather, it is the limited disposal space for waste GHGs of the atmosphere that constitutes the ultimate scarcity of the 21st century (see Figure 1).

Figure 1 Challenge for climate policy – there are more fossil fuels in the ground than disposal space for waste greenhouse gases remaining in the atmosphere for a 2°C limit



Notes: Columns below the zero line indicate the carbon contained in the estimated global reserves and resources of fossil fuels. The columns above the zero line are based on the scenario database used in the IPCC WGIII AR5 and indicate cumulative historical and projected emissions. For more details, see Edenhofer et al. (2015a).

Staying within this tight carbon budget implies that annual GHG emissions would need to be reduced by 40-70% by 2050 and decline towards zero and below thereafter. This requires rapid improvements in energy efficiency and a 3-4 fold increase in the share of zero- and low-carbon energy supply from renewables, nuclear energy and carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by 2050 (Clarke et al. 2014). The majority of scenarios with a greater than 66% probability of keeping average global temperature rise below 2°C can only stay within the carbon budget if the carbon debt is repaid through global net negative emissions towards the end of the 21st century. In other words, more CO_2 would need to be removed from the atmosphere through large-scale deployment of negative emission technologies, such as BECCS or afforestation, than is released by all human activities. These challenges can be alleviated to some extent through reductions in final energy demand in the near term, decreasing the amount of fossil fuels used and thus reducing the immediate pressure for decarbonising energy supply. This would also entail co-benefits that outweigh the few adverse side-effects of mitigation action in the transport, buildings, and industry sectors. On the energy supply side, the balance depends to a larger extent on the specific technology and implementation context (Clarke et al. 2014, von Stechow et al. 2015).

In addition to these technological challenges, staying within the remaining carbon budget would also imply a devaluation of coal, oil and gas assets.[2] Compared to business as usual (in the AR5 scenario database), 70% of coal reserves and resources would need to remain underground as well as 35% of oil and 32% of gas. As Figure 1 shows, this effect can be buffered to some extent by the deployment of BECCS, which has the potential to remove some of the emissions from the additional combustion of fossil fuels. If CCS is not available, however, this flexibility would be removed, calling for immediate GHG emissions reductions. This would have important implications for the allowed extraction rates and the above numbers would increase to 89%, 63% and 64%, respectively (Bauer et al. 2013, Jakob and Hilaire 2015).

One critical constraint on BECCS deployment is the large-scale availability of various bioenergy feedstocks (see the Chapter by Tavoni in this book). Deployment levels of total (modern) bioenergy in 2°C scenarios without delay and limits to technological availability are in the range of 10-245 EJ/yr by 2050 and 105-325 EJ/yr in 2100, increasing the share of bioenergy in total primary energy from 35% in 2050 to as much as 50% in 2100 (Creutzig et al. 2014, Smith et al. 2014). Whether or not these amounts of bioenergy can be supplied in a sustainable manner is highly contested, with some experts emphasising the large mitigation potential of bioenergy and others highlighting

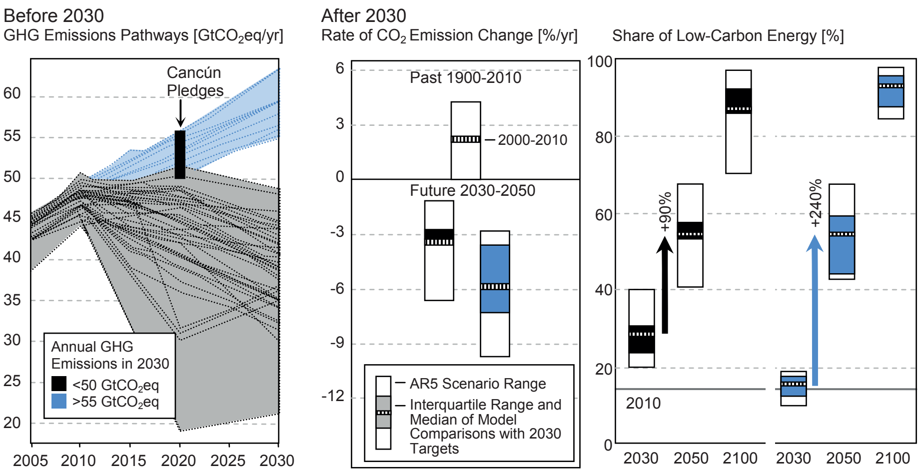
2 By reducing the disposal space for waste GHGs in the atmosphere, climate policy not only reduces the resource rents of the owners of coal, oil and gas assets, but it also creates a 'climate rent'. These revenues from carbon pricing overcompensate the loss in resource rents (Bauer et al. 2013); they are discussed in more detail in Section 3.

the risks associated with such high bioenergy deployment levels (Creutzig et al. 2012a, 2012b). The main adverse side-effects discussed relate to possible reductions of land-carbon stocks, as well as negative impacts on ecosystems, biodiversity, food security and livelihoods. The sustainable technical bioenergy potential is estimated to be around 100 EJ/yr in 2050, with high agreement in the literature, and up to 300 EJ/yr with medium agreement (Creutzig et al. 2014, Smith et al. 2014).

The technological challenges and adverse side-effects of staying below the 2°C limit increase further as stringent emissions reductions are delayed. This results from the faster timescales over which the required technologies need to be implemented. Figure 2 highlights that unless GHG emissions are reduced below current levels in 2030, the technological challenges of the 2°C limit increase substantially – particularly between 2030 and 2050 (Bertram et al. 2015, Riahi et al. 2015). Using a larger share of today's tight emissions budget also reduces the flexibility of technology choice, as staying below the temperature limit increasingly depends on the availability of potentially risky negative emissions technologies. Overall, the ability to hedge against the risks of mitigation across a broad technology portfolio becomes more and more constrained with increasing delays.

Mitigation costs increase with growing mitigation ambition, but are characterised by large uncertainties. Staying below the 2°C limit with a greater than 66% probability would imply reducing global consumption levels relative to business as usual by 5% (3%-11%) by 2100. Staying below a 2.5°C and 3°C limit would imply decreasing consumption levels by 4% (1%-7%) and 2% (1%-4%), respectively. For comparison, business-as-usual consumption itself grows between 300% to more than 900% over this period (IPCC 2014a). While these reductions in consumption levels are by no means negligible, they seem comparatively moderate. They also hinge on the assumption of effective global institutions and the establishment of a global, uniform carbon price.

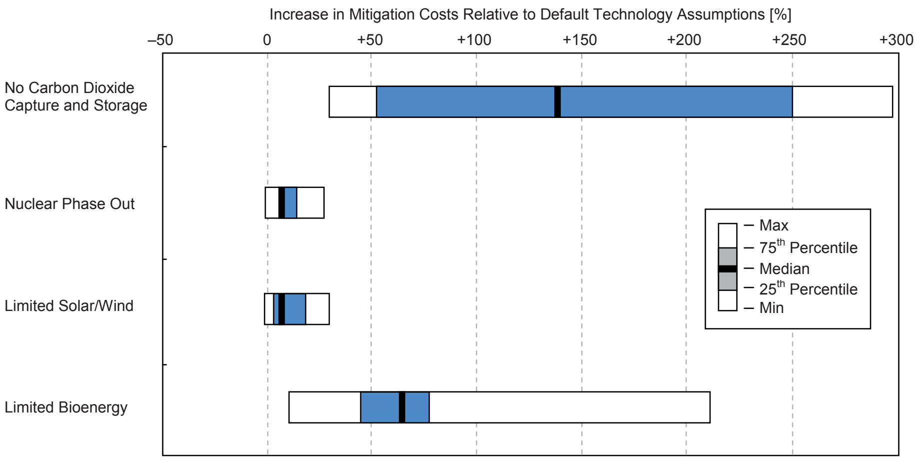
Figure 2 Increasing technological challenges associated with the energy system transformation in delayed relative to immediate mitigation scenarios consistent with staying below the 2°C limit with a roughly 50% probability



Notes: Technological challenges are represented in terms of the average annual rate of carbon emissions reductions (2030-2050, middle panel) and low-carbon energy upscaling (2030-2050/2100, right panel). Left panel shows GHG emission pathways between 2005 and 2030. Compared to immediate mitigation scenarios (grey, GHG emissions <50 Gt CO_2-equivalent in 2030), delayed mitigation scenarios (blue, GHG emissions >55 Gt CO_2-equivalent) are characterised by much faster emissions reductions and much faster upscaling of low-carbon energy technologies between 2030 and 2050. The black bar shows the uncertainty range of GHG emissions implied by the Cancún Pledges. For more details, see IPCC (2014b).

Limiting the availability of key mitigation technologies such as CCS and bioenergy might reduce some of the adverse side-effects of these technologies, but would increase discounted mitigation costs by approximately 140% (30-300%) and 60% (40-80%) by the end of the century, respectively (Figure 3). Delaying emissions reductions further increases the costs of reaching specific climate goals. A delay would protect the rents of fossil fuel owners, today's cost savings would thus be eclipsed by future cost increases. For example, delaying stringent mitigation through 2030 could raise the aggregate costs of mitigation by 30-40% (2-80%) by 2050 and by 15-40% (5-80%) by 2100 (in scenarios with a roughly 50% probability of staying below the 2°C limit) (Clarke et al. 2014).

Figure 3 The impacts of a limited mitigation technology portfolio on the relative increase in mitigation costs compared to a scenario with full availability of technologies in mitigation scenarios consistent with staying below the 2°C limit with a roughly 50% probability



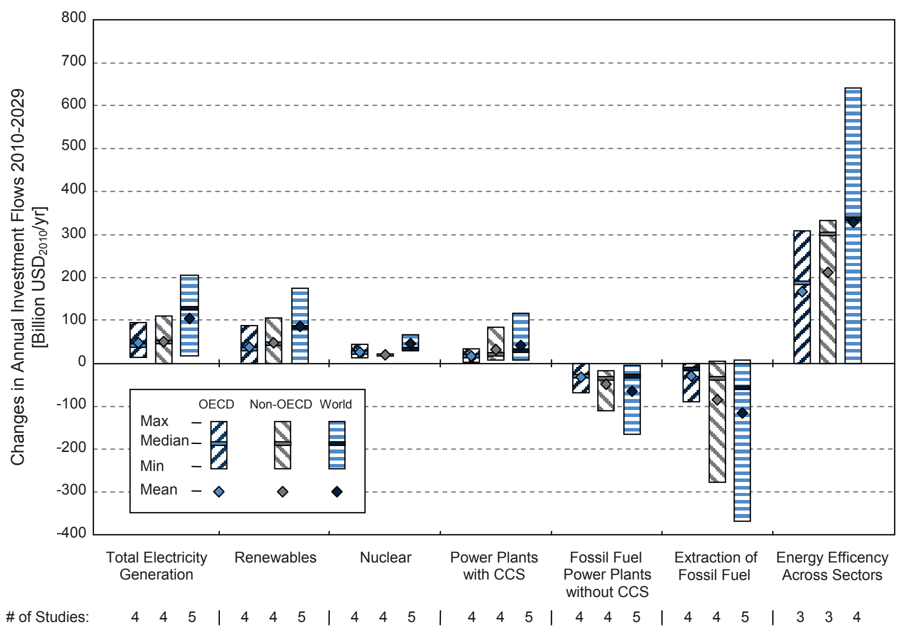
Notes: The cumulative mitigation costs (2015-2100) are presented as net present value, discounted at 5% per year. Nuclear phase out = No addition of nuclear power plants beyond those under construction and existing plants operating until the end of their lifetime; Limited Solar / Wind = a maximum of 20 % of global annual electricity supply from solar and wind; Limited Bioenergy = a maximum of 100 EJ/yr modern bioenergy supply globally. For more details, see Clarke et al. (2014).

3 Triggering short-term mitigation action

A fundamental departure from business-as-usual development is required to leave the window of opportunity open to stay below the 2°C limit. Triggering short-term climate policy action is instrumental to achieving any reasonable long-term climate goal – short-term action reduces the risks of increasing future mitigation costs and the risks of relying on negative emissions technologies with potentially large adverse-side-effects.

As discussed by Sterner and Kohlin and Stavins in their chapters in this volume, the necessity for introducing a clear price signal through carbon taxes or emissions trading becomes evident when considering the required changes in the different sectors and looking at the required reallocation of investment flows. In the energy sector, for example, new investment strategies away from fossil fuel extraction and use towards energy efficiency and low-carbon technologies for energy generation are urgently needed (Figure 4). But despite its necessity, carbon pricing is perceived as extremely demanding. The feasibility of an optimal global carbon price is currently limited as free-rider incentives seem to undermine the willingness of parties to participate in an ambitious international climate agreement (Carraro 2014, Cramton et al. 2015). It is therefore even more remarkable that a number of countries – including the majority of the world's 20 largest emitters – have started implementing GHG emissions reduction policies on their own accord.

Figure 4 Change in annual energy sector investment flows towards low-carbon energy technologies in mitigation scenarios consistent with staying below the 2°C limit with a roughly 50% probability relative to the average business-as-usual level (2010–2029)



Notes: Results are based on a limited number of model studies and model comparisons (numbers in the bottom row) highlighting that investment needs are an evolving area of research. The extent to which the investment needs in one region translate into regional mitigation costs depends on the effort-sharing regime, which has important effects on the relative cost burden (Tavoni et al. 2013, Höhne et al. 2014). For more details, see Gupta et al. (2014).

Several unilateral and often short-term incentives for introducing climate policies and establishing GHG emissions pricing schemes exist: i) the efficient generation of additional revenues for government budgets; ii) the use of carbon-pricing revenues for the provision of public goods or infrastructure investments in welfare-enhancing ways; iii) the introduction of Pigouvian carbon pricing to internalise national climate impacts;

and iv) the realisation of co-benefits from GHG emissions reductions (Edenhofer et al. 2015b). Interestingly, all of these unilateral incentives for domestic carbon prices are particularly relevant for developing countries.

1. Carbon pricing helps to broaden the often thin tax base in countries with large informal sectors (Bento and Jacobsen 2007, Bento et al. 2013, Markandya et al. 2013). With the possibility to recycle these additional carbon price revenues, potentially regressive effects may be compensated and/or existing distortionary taxes (that particularly affect low-income groups) may be reduced. Carbon pricing can therefore enhance economic growth without adverse distributive effects (Casillas and Kammen 2010, Goulder 2013, Somanathan et al. 2014). As a recent IMF report shows, however, one ton of carbon emissions receives, on average, more than 150 US$ in subsidies. The removal of all such subsidies, accompanied by an appropriate price on carbon, would benefit especially developing countries (Coady et al. 2015).
2. Carbon-pricing revenues could reduce the large investment gap in public infrastructure that provides access to basic needs, such as universal access to water, sanitation, and clean energy (Edenhofer et al. 2015b). For example, the investment needs for energy efficiency and low-carbon technologies (see Figure 4), universal energy and water access and sanitation access in non-OECD countries are well within expected revenues from climate policy (Hutton 2012, Pachauri et al. 2013, Jakob et al. 2015a). It is worth noting that the removal of fossil fuel subsidies also has a remarkable potential to raise revenues. If these subsidies of approximately US$550 billion were to be redirected to investments in basic infrastructure over the next 15 years, substantial improvements could be made in reducing poverty. This includes universal access to clean water in about 70 countries, improved sanitation in about 60 countries, and access to electricity in about 50 countries (out of roughly 80 countries that do not yet have universal access). Such investments would also increase the long-term growth prospects of poor economies (Jakob et al. 2015b). Additionally, the removal of these subsidies would cut global carbon emissions by more than 20%, and reduce pre-mature deaths related to air pollution by more than half (Coady et al. 2015).

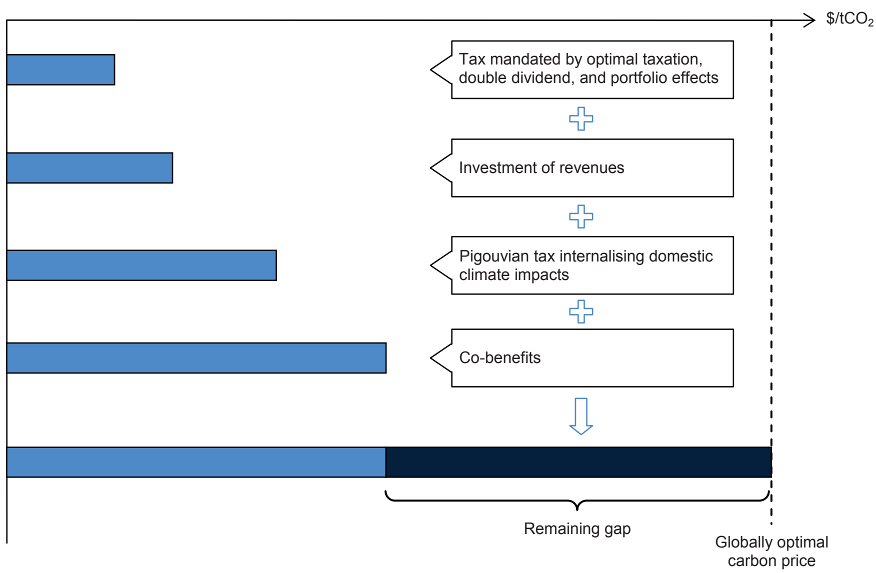
3. A substantial share of optimal carbon prices (with maximum values of 10-40%) could internalise the expected domestic damages from climate change in developing regions (Figure 3 in Edenhofer et al. 2015b).
4. Co-benefits, for example those related to reducing the health and environmental externalities from currently high air pollution, further increase the incentives to trigger short-term mitigation action in developing countries (Nemet et al. 2010, West et al. 2013).

Most of the aforementioned unilateral incentives to introduce climate policies are also particularly relevant for industrialised countries. The introduction of a carbon price provides the flexibility to reduce existing distortionary taxes and thus increase the overall efficiency of the economy. In addition, a tax on fixed production factors such as fossil fuels could stimulate the redirection of investments towards producible capital (Edenhofer et al. 2015b). The revenues from carbon pricing could also provide ample funds for the investments required in the energy sector (see Figure 4), or for addressing investments needs in the transport sector and existing market failures in technology R&D. Finally, revenues may be used for financing adaptation needs resulting from the unavoidable impacts from climate change (Malik and Smith 2012), which may range between US$25-100 billion per year by 2015-2030 (Fankhauser 2010).

These unilateral incentives show that finance ministers might be interested in carbon pricing even though they are not primarily interested in emissions reductions (Franks et al. 2014). Still, mitigation efforts that are purely motivated by national interests are not expected to achieve the globally optimal carbon price. They could nonetheless contribute towards closing the 'emission price gap', i.e. the difference between the level of current GHG prices and a globally optimal carbon price (see Figure 5, Edenhofer et al. 2015b). The crucial question remaining is to what extent unilateral action by some countries, regions or industries can promote collective action and can facilitate cooperation on the international level (Ostrom 2010, Urpelainen 2013, Cramton et al. 2015).

It has been shown above that the prospects of carbon pricing are less bleak when the investment gap in public infrastructure is financed by carbon-pricing revenues, co-benefits can be realised, and the removal of distortionary taxes is taken into account. This will not lead automatically to international cooperation and to a global carbon price. However, should domestic carbon pricing no longer be perceived as committing political suicide, the remaining carbon price gap will be easier to close by international agreements. Admittedly, the challenge of international cooperation remains and innovative proposals are needed to solve this globally pressing problem (e.g. Cramton et al. 2015, Barrett and Dannenberg 2012, and the contributions by Stewart, Keohane and Victor, and Stavins in this volume). However, the potential for domestic carbon pricing as a short-term entry point to a longer-term solution has been widely underestimated. It would open up new perspectives for tackling the climate problem if finance ministers were to become much closer allies of environmental ministers, working together to close the emission price gap and thus triggering short-term mitigation action.

Figure 5 Incentives for unilateral introduction of carbon prices and their role in closing the emission price gap.



Note: For more details, see Edenhofer et al. (2015b).

References

Barrett, S. and A. Dannenberg (2012), “Climate negotiations under scientific uncertainty”, *Proceedings of the National Academy of Sciences* 109(43): 17372-17376.

Bauer, N., I. Mouratiadou, G. Luderer, L. Baumstark, R. Brecha, O. Edenhofer and E. Kriegler (2013), “Global fossil energy markets and climate change mitigation - an analysis with REMIND”, *Climatic Change* 10.1007/s10584-013-0901-6: 1-14.

Bento, A. M. and M. Jacobsen (2007), “Ricardian rents, environmental policy and the “double-dividend” hypothesis”, *Journal of Environmental Economics and Management* 53(1): 17-31.

Bento, A. M., M. R. Jacobsen and A. A. Liu (2013), “Environmental Policy in the Presence of an Informal Sector” (available at http://works.bepress.com/antonio_bento/25).

Bertram, C., N. Johnson, G. Luderer, K. Riahi, M. Isaac and J. Eom (2015), “Carbon lock-in through capital stock inertia associated with weak near-term climate policies”, *Technological Forecasting and Social Change* 90, Part A: 62-72.

Carraro, C. (2014), “International Environmental Cooperation”, in *Handbook of Sustainable Development*, Cheltenham, UK: Edward Elgar Publishing.

Casillas, C. E. and D. M. Kammen (2010), “The Energy-Poverty-Climate Nexus”, *Science* 330(6008): 1181-1182.

Clarke, L., K. Jiang et al. (2014), “Assessing transformation pathways”, in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report’s full reference).

Coady D., I. Parry, L. Sears and B. Shang (2015), “How Large Are Global Energy Subsidies?”, IMF Working Paper No. 15/105, Washington, DC.

Cramton, P., A. Ockenfels and S. Stoft (2015), “An international carbon price committment promotes cooperation”, in *EEEP Symposium: International Climate Negotiations*, Cleveland, OH: International Association for Energy Economics.

Creutzig, F., A. Popp, R. Plevin, G. Luderer, J. Minx and O. Edenhofer (2012a), "Reconciling top-down and bottom-up modelling on future bioenergy deployment", *Nature Climate Change* 2(5): 320-327.

Creutzig, F., C. von Stechow, D. Klein, C. Hunsberger, N. Bauer, A. Popp and O. Edenhofer (2012b), "Can Bioenergy Assessments Deliver?", *Economics of Energy & Environmental Policy* 1(2): 65-82.

Creutzig, F, N. H. Ravindranath, G. Berndes, S. Bolwig, R. Bright et al. (2014), "Bioenergy and climate change mitigation: an assessment", *GCB Bioenergy* 7(5): 916-944.

Edenhofer, O. and M. Kowarsch (2015), "Cartography of pathways: A new model for environmental policy assessments", *Environmental Science & Policy* 51: 56-64.

Edenhofer, O., C. Flachsland, M. Jakob and J. Hilaire (2015a), "Den Klimawandel stoppen. Es gibt nicht zu wenig, sondern zu viel fossile Ressourcen – sie müssen in der Erde bleiben", Berlin: taz Entwicklungs GmbH & Co. Medien KG.

Edenhofer, O., M. Jakob, F. Creutzig, C. Flachsland, S. Fuss, M. Kowarsch, K. Lessmann, L. Mattauch, J. Siegmeier and J. C. Steckel (2015b), "Closing the emission price gap", *Global Environmental Change* 31(0): 132-143.

Fankhauser, S. (2010), "The costs of adaptation", *Wiley Interdisciplinary Reviews: Climate Change* 1(1): 23-30.

Franks, M., O. Edenhofer and K. Lessman. "Why Finance Ministers Favor Carbon Taxes, Even if They Do Not Take Climate Change into Account", Discussion Paper No. 2015-67, Harvard Project on Climate Agreements, Belfer Center for Science and International Affairs.

Goulder, L. H. (2013), "Climate change policy's interactions with the tax system", *Energy Economics* 40, Supplement 1(0): S3-S11.

Gupta, S., J. Harnisch et al. (2014), "Cross-cutting Investment and Finance Issues", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Höhne, N., M.G.J. den Elzen and D. Escalante (2014), "Regional GHG reduction targets based on effort sharing: a comparison of studies", *Climate Policy* 14: 122–147.

Hutton, G. (2012), "Global Costs and Benefits of Drinking-Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage", World Health Organization, Geneva.

IPCC (2013), *Climate Change 2013: The Physical Science Basi*s (see IPCC (2013a) in the introduction to this book for the report's full reference).

IPCC (2014a), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

IPCC (2014b), "Summary for Policymakers", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

IPCC (2014c), "Summary for policymakers", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (see IPCC (2014a) in the introduction to this book for the report's full reference).

IPCC (2014d), "Summary for policymakers", in *Climate Change 2014: Synthesis Report* (see IPCC (2014c) in the introduction to this book for the report's full reference).

IPCC (2014e), *Climate Change 2014: Synthesis Report* (see IPCC (2014c) in the introduction to this book for the report's full reference).

Jakob, M. and J. Hilaire (2015), "Using importers' windfall savings from oil subsidy reform to enhance international cooperation on climate policies", *Climatic Change* 131(4): 465-472.

Jakob, M., C. Chen, S. Fuss, A. Marxen, N. Rao and O. Edenhofer (2015a), "Using carbon pricing revenues to finance infrastructure access", paper presented at the European Association of Environmental and Resource Economists 21st Annual Conference, Helsinki, 24-27 June.

Jakob, M., C. Chen, S. Fuss, A. Marxen and O. Edenhofer (2015b), "Development incentives for fossil fuel subsidy reform", *Nature Climate Change* 5:709–712.

Keohane, R. O. and D. G. Victor (2015), "After the failure of top-down mandates: The role of experimental governance in climate change policy", Chapter 14 in this book.

Kolstad, C., K. Urama et al. (2014), "Social, Economic and Ethical Concepts and Methods", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Kunreuther, H., G. Heal, M. Allen, O. Edenhofer, C. B. Field and G. Yohe (2013), "Risk management and climate change", *Nature Climate Change* 3(5): 447-450.

Malik, A. S. and S. C. Smith (2012), "Adaptation to climate change in low-income countries: lessons from current research and needs from future research", *Climate Change Economics* 03(02): 1250005.

Markandya, A., M. González-Eguino and M. Escapa (2013), "From shadow to green: Linking environmental fiscal reforms and the informal economy", *Energy Economics* 40, Supplement 1(0): S108-S118.

Nemet, G. F., T. Holloway and P. Meier (2010), "Implications of incorporating air-quality co-benefits into climate change policymaking", *Environmental Research Letters* 5(1): 014007.

Ostrom, E. (2010), "Polycentric systems for coping with collective action and global environmental change", *Global Environmental Change* 20(4): 550-557.

Pachauri, S, B. J. van Ruijven, Y. Nagai, K. Riahi, D. P. van Vuuren, A. Brew-Hammond and N. Nakicenovic (2013), "Pathways to achieve universal household access to modern energy by 2030", *Environmental Research Letters* 8(2): 024015.

Riahi, K., N. Kriegler, C. Johnson, C. Bertram, M. den Elzen et al. (2015), "Locked into Copenhagen pledges – Implications of short-term emission targets for the cost and feasibility of long-term climate goals", *Technological Forecasting and Social Change* 90, Part A: 8-23.

Smith, P., M. Bustamante et al. (2014), "Agriculture, Forestry and Other Land Use (AFOLU)", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Somanathan, E., T. Sterner, T. Sugiyama et al. (2014), "National and Sub-national Policies and Institutions", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Stavins, R. N. (2015), " Linkage of regional, national, and sub-national policies in a future international climate agreement", Chapter 20 in this book.

Steckel, J. C., O. Edenhofer and M. Jakob (2015), " Drivers for the renaissance of coal", *PNAS* 112(29): E3775-E3781.

Sterner, T., G. Köhlin (2015), "Pricing carbon: The challenges", Chapter 18 in this volume

Stewart, R. B., M. Oppenheimer and B. Rudyk (2015), "A building blocks strategy for global climate change", Chapter 15 in this book.

Tavoni, M. et al. (2013), "The distribution of the major economies' effort in the Durban platform scenarios", *Climate Change Economics* 4(4): 1340009

Urpelainen, J. (2013), "A model of dynamic climate governance: dream big, win small", *International Environmental Agreements: Politics, Law and Economics* 13(2): 107-125.

von Stechow, C. et al. (2015), "Integrating global climate change mitigation goals with other sustainability objectives: A synthesis", *Annual Review of Environment and Resources* 40.

West, J. J., S. J. Smith, R. A. Silva, V. Naik, Y. Zhang, Z. Adelman, M. M. Fry, S. Anenberg, L. W. Horowitz, and J.-F. Lamarque (2013), "Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health", *Nature Climate Change* 3(10): 885-889.

About the authors

Ottmar Edenhofer is Deputy Director and Chief Economist at the Potsdam Institute for Climate Impact Research (PIK) and Professor of the Economics of Climate Change of the Technical University Berlin. Moreover, he is director of the Mercator Research Institute on Global Commons and Climate Change (MCC) as well as adviser to the World Bank regarding issues of economic growth and climate protection. Co-chairing the Energy Platform by the European Council of Academies of Applied Sciences, Technologies and Engineering (Euro-CASE), he is also member of the National Academy of Science and Engineering (acatech), member of the Science-Industry Cooperation and member of the German National Academy of Sciences Leopoldina, Workgroup Climate, Energy and Environment. Ottmar Edenhofer's research explores the design of instruments for climate and energy policy, long-term scenarios of the climate and energy system, the impact of induced technological change on mitigation costs and mitigation strategies, as well as the science-policy interface.

Susanne Kadner is former Deputy Head and Head of Science at the Intergovernmental Panel on Climate Change (IPCC) Working Group III (WGIII) Technical Support Unit. She managed the contribution of WGIII to the IPCC Fifth Assessment Report on the *Mitigation of Climate Change* and co-coordinated the preparation of the IPCC's Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN). Before joining the IPCC, Susanne worked for several years as a research analyst and scientific policy advisor, inter alia for the German Advisory Council on Global Change and the Parliamentary Office of Science and Technology in London. She holds a PhD in environmental sciences from the University of East Anglia. Susanne is an editor and author of several reports and books related to the broad field of climate change, i.e. the physical science basis, the impacts and prospects for adaptation, as well as possible mitigation strategies.

Christoph von Stechow is a doctoral researcher at the Working Group Applied Sustainability Science at the Mercator Research Institute on Global Commons and Climate Change (MCC) and guest scientist at the Potsdam Institute for Climate Impact Reseach (PIK). His research interests include the science-policy interface in climate and energy policy, the co-effects of alternative mitigation strategies on sustainability objectives, and the analysis of policy instruments for innovation in low-carbon energy such as carbon capture and storage (CCS) and bioenergy. Christoph studied history and economics, holds a degree in economics from Humboldt University Berlin and a MA in European Studies from King's College London. As a scientist in the Technical Support Unit for Working Group III of Intergovernmental Panel on Climate Change (IPCC) he helped to coordinate the assessment process for the Fifth Assessment Report and the Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN).

Jan Christoph Minx, PhD, is Head of the Working Group Applied Sustainability Science at the Mercator Research Institute on Global Commons and Climate Change (MCC) and Professor for Science-Policy and Sustainable Development at the Hertie School of Governance. He takes an interdisciplinary research approach to issues of energy, climate change and sustainable development with applications to cities and infrastructure, global supply chain networks as well as historic and future transformation processes of societies and their governance. He is former Head of the Technical Support Unit of Working Group III of the Intergovernmental Panel on Climate Change (IPCC), where he coordinated the Working Group's contribution to the IPCC Fifth Assessment Report that was published in 2013/2014. Jan has co-authored articles in a variety of scientific journals including *Science, Nature Climate Change* and the *Proceedings of the National Academy of Sciences,* among others, and is a member of the Editorial Board of *Economic Systems Research*.

4 The state of climate negotiations

Brian P. Flannery[1]
Resources for the Future

Today, with little time remaining before the 21st meeting of the Conference of Parties to the UNFCCC in Paris, negotiators confront a disorganised text that is far too long and replete with conflicting proposals that cross red lines for major players. Nonetheless, political leaders express confidence that a deal is achievable. Unlike the task of Kyoto – producing politically feasible mitigation targets for developed nations – the post-2020 agreement covers (at least) six themes: mitigation for all nations, adaptation, finance, technology transfer, capacity building and transparency. Residual acrimony and distrust from Copenhagen hamper the process which must resolve many complex, contentious issues, such as legal form and compliance, the role (or not) for greenhouse gas markets and offset projects, intellectual property rights, compensation for loss and damage, transparency and associated measurement, and reporting and verification and review procedures. Overshadowing all remains the question of how the principle of common but differentiated responsibilities will manifest throughout the agreement, e.g. from mitigation to reporting and review to finance.

Some aspects are solidifying. Mitigation efforts will not be negotiated; rather, they are being submitted (as Intended Nationally Determined Contributions) and, ultimately, recorded, perhaps dropping the 'I' to become NDCs. Total financial aid appears set by the Copenhagen pledge of developed nations to mobilise US$100 billion per year by 2020. Also, negotiators appear resolved to create a durable framework based on cycles of review and renewal over intervals of, perhaps, five or ten years.

1 The views in this chapter are based on personal observations and conversations with colleagues from national delegations, business, academia, intergovernmental organisations, think tanks and other observers.

However, the Paris Agreement appears unlikely to fulfil the long-established narrative to be 'on track' to limit warming to less than 2°C (or 1.5°C). Only recently have political leaders begun to temper expectations. They will need to manage expectations thoughtfully to avoid a backlash from a range of nations, stakeholders and media, and to restore the credibility of the United Nations Framework Convention on Climate Change as an effective process.

1 Introduction

With only months remaining before the 21st meeting of the Conference of Parties to the UNFCCC in Paris (COP21), negotiators find themselves in a familiar spot: at loggerheads, with an unstructured, disorganised text that is far too long and replete with conflicting proposals that cross red lines for various nations. Nonetheless, most delegations appear confident that political will exists to reach an agreement.

The agreement faces challenges to achieve consensus and public acceptance. Little time remains to resolve contentious issues, including ambition in mitigation and finance, legal form, how to reflect the principle of common but differentiated responsibilities (CBDR), the future of markets and offsets, and treatment of intellectual property rights (IPR). The clock may simply run out, especially if reluctant factions use procedural tools to delay progress. Recent COP meetings ended with controversy as disgruntled nations strenuously objected to declarations of consensus. Some have banded together, so objections may be more visible and difficult to ignore in Paris. The greatest challenge will be to restore confidence that the UNFCCC can be a credible and effective vehicle to manage the global response to climate change.

The feasible deal in Paris looks to be modest, not consistent with the long-established narrative to avoid climate catastrophe by putting the world 'on track' to limit warming to less than 2°C (or 1.5°C) (Jacoby and Chen 2014). Only recently have political leaders sought to lower expectations. It may be too late. Forces that created powerful external pressure that led to the painfully visible, far-reaching failure in Copenhagen only six years ago are rallying again, calling for a far more ambitious deal. Consequently, the achievable deal may prove to be unsatisfactory to many nations, advocacy groups, the media and the public.

In this chapter, Section 2 provides a scene set on developments since milestone meetings marking success in Kyoto (1997) and failure in Copenhagen (2009); Section 3 describes major issues in the negotiation; and Section 4 discusses steps after Paris.[2]

2 Scene set

The dynamic and discussions for the post-2020 agreement bear little resemblance to those at the time of Kyoto or Copenhagen. Those focused on national mitigation targets; Paris will not. Mitigation efforts will be set in advance through domestic deliberations, and submitted before Paris as Intended Nationally Determined Contributions (INDCs) that contain voluntary, self-defined proposals for mitigation (and other efforts).

Kyoto sought agreement on politically feasible, legally binding mitigation targets for developed nations and the establishment of market mechanisms based on emissions trading and credits from offset projects. As with the UNFCCC, Kyoto fully embraced CBDR. Developed countries (listed in Annex 1) took on mitigation obligations and those in Annex 2 agreed to provide aid; developing countries (non-Annex 1 Parties) were promised financial support and exempted from mitigation commitments.

The Bali Mandate (2007) provided a broader remit for two negotiations to be completed in Copenhagen. Bali set 2009 as the deadline for the Ad Hoc Working Group on Further Commitments for Annex 1 Parties (AWG-KP) to prepare a second Kyoto commitment period (KP CP2). Bali also launched negotiations under the Ad Hoc Working Group on Long term Cooperation (AWG-LCA) for a comprehensive, new agreement involving all Parties. In an important (potential) breakthrough, Bali signalled the possibility for the evolution of CBDR: AWG-LCA refers to *developed* and *developing* nations and to *all Parties*, rather than to nations grouped as Annex 1 and non-Annex 1. However, this will require contentious change from the writ of the 1992 UNFCCC.

2 For a more detailed discussion of the negotiations, see Flannery (2015).

2.1 Copenhagen and the demise of the top-down approach

Ahead of Copenhagen, a number of actors – including European nations, the Alliance of Small Island States (AOSIS), Least Developed Countries (LDCs), the UNFCCC Secretariat, advocacy groups, foundations and others desiring strong action – encouraged public pressure and media attention to galvanise political momentum. However, even before COP15, at the Asia Pacific Economic Cooperation summit in Singapore leaders of many nations (including the US and China) announced that they would agree only to a political deal based on voluntary national pledges, rather than the legally binding outcome specified in Bali.[3] In the resulting Copenhagen Accord, developed nations also agreed by 2020 *to mobilise* US$100 billion per year in financial aid to developing nations.

Outside UNFCCC procedures, Heads of State from a handful of nations created the Copenhagen Accord. Many nations excluded from those deliberations voiced profound objections to what they regarded as a betrayal of the UNFCCC process. Distrust continues not only over unmet expectations for mitigation and financial aid, but also from concerns over transparency, inclusiveness and commitment to the multilateral process.

Copenhagen dealt a deathblow to the top-down approach in which nations negotiated terms for one another's actions as the basis for agreement. Going forward, national pledges will be based on voluntary submissions that reflect national circumstances and priorities – a situation that I describe as a mosaic world (Flannery 2014). In the mosaic world, this bottom-up approach encourages participation by all nations that will be essential for long-term effort. However, just as the top-down approach cannot force effort on unwilling nations, so too voluntary contributions appear unlikely to deliver aggregate outcomes aligned with ambitious long-term goals.

3 See "APEC leaders drop climate target", BBC News, 15 November 2009; and "APEC Concedes Copenhagen Climate Treaty Out of Reach", Bloomberg News, 16 November 2009.

2.2 Developments shaping negotiation of the post-2020 agreement

After Copenhagen, Parties spent years seeking to restore confidence in the multilateral process. As well, the negotiating landscape became more complex as COP 17 established the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) with efforts in two workstreams: 1) negotiating by 2015 a comprehensive, global agreement to take effect in 2020; and 2) enhancing ambition of mitigation (and finance) in the period before 2020. Finally, in Doha in 2012 COP18 adopted a 2nd Kyoto commitment period (2013-2020), bringing AWG-KP to a close, and terminated AWG-LCA, leaving ADP as the sole ongoing negotiation.

Many essential aspects in the Bali Mandate remained unresolved. These orphans found homes in the permanent Subsidiary Bodies or ADP. Mechanisms for mitigation moved from LCA to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Reform and extension of the Clean Development Mechanism (CDM) landed in the Subsidiary Body for Implementation (SBI).

Several new national groups now play important roles in the negotiations. Before Copenhagen, positions were characterised largely by the views of the EU, the Umbrella Group (comprising most of the non-EU developed nations), and the Group of 77 and China (G77 & China) representing developing nations. At and after Copenhagen, other groups emerged. In particular, significant differences divide G77 & China. BASIC nations (Brazil, China, India and South Africa) understand that demands by AOSIS and LDCs – to limit warming to less than 2°C (or 1.5°C) – would require major efforts by them, and soon, that could threaten their rapidly growing economies. Important divisions also exist on matters such as treatment of IPR, deployment of Carbon Capture and Storage (CCS), markets and efforts to protect and expand forests. The Like Minded Developing Countries (LMDCs) – including Bolivia, China, Cuba, Egypt, India, Iraq, Iran, Malaysia, Nicaragua, Philippines, Saudi Arabia, Thailand, Venezuela and others, but not Brazil or South Africa – strongly oppose the evolution of CBDR; more generally, they oppose the introduction of new concepts or terms that change or reinterpret the Convention.

Changes outside the UNFCCC have had even greater impact. These include: the dramatic shift in emissions growth to major developing nations; the recession and ongoing financial crises; the impact of the Fukushima disaster on Japanese nuclear policy (followed shortly afterwards by Germany's reaction); and the technology revolution in North American production of gas and oil. They have altered the political, economic and technological landscape and shifted priorities in many nations.

3 Issues under negotiation in the post-2020 agreement

ADP has many consequential, contentious matters to resolve. The agreement will incorporate six themes: mitigation, adaptation, transparency, finance, technology transfer and capacity building – the latter three jointly referred to as 'means of implementation'. Developing nations are pushing to add a seventh: compensation for loss and damage. Parties must also address framing issues including: long-term objectives, legal form and compliance, establishing the framework to update commitments, and how to reflect crosscutting principles (especially CBDR).

3.1 Mitigation: INDCs, mechanisms, offsets and carbon pricing

Nothing more strongly signals the UNFCCC's transition to a bottom-up process than the decision to convey proposed actions in advance through INDCs. INDCs alter the dynamic of the negotiation by essentially removing bargaining over mitigation from the immediate negotiation – though perhaps ongoing discussions, even after Paris, may affect final proposals. Also, they shift the burden of defining CBDR – for mitigation – to nations themselves, asking them to self-declare why their INDC is appropriate and ambitious, according to their national circumstances.

Developed nations contended that INDCs should focus solely on mitigation. Developing countries insisted that they should detail contributions for all six elements, especially means of implementation. By late July, 20 nations and the EU (covering 28 member states) had submitted INDCs. Submissions vary in scope, content and timing, making comparisons difficult (see the chapter by Aldy and Pizer in this book, and also Aldy and Pizer 2015b).

Many nations wanted ADP to conduct an ex ante review of INDCs, but others (notably LMDCs) objected. Nonetheless, many governments, academics and think tanks will review and analyse INDCs. These have several purposes, such as to understand each national proposal, to assess comparability and to evaluate aggregate global outcomes.[4] Apparently, *intended* proposals will become *final* only when nations submit them with their instrument of accession. If so, ex ante review could extend for several years before 2020.

Parties (and business) hold a range of views regarding international markets. Developing nations argued that, with the low levels of mitigation ambition in KP CP2, there is no need for new approaches at this time. Some developing nations oppose any future role for markets and some developed nations contend that they need no permission from the UNFCCC to create and utilise international markets. Neither the US nor the EU called for international markets at this time.

International carbon, actually GHG, markets have two aspects: emissions trading and offsets (see the chapters in this book by Stavins and by Wang and Murisic for perspectives on carbon markets). It remains unclear whether offsets administered under the UNFCCC will exist post 2020. Activities conducted through bilateral agreements may be more effective (both less bureaucratic and open to a wider range of projects) than CDM-like approaches. For example, Japan has proposed a Joint Crediting Mechanism[5] conducted through bilateral agreements to facilitate the diffusion of low-carbon technologies, and has signed agreements with 13 developing nations to do so.

Broadly, the ADP market debate includes three possibilities: 1) no markets; 2) an expanded role for the UNFCCC with authorized offsets as an extension of the CDM; or 3) nations may create and use markets without any enabling decision by the UNFCCC, though encouragement would be welcome.

Carbon pricing is not an integral part of ADP discussions. Domestic political institutions are unlikely to cede pricing authority to an international process. Virtues assigned to a global carbon price are not relevant to the real world where nations will implement a variety of policies, including no price at all. Business support (or not) for domestic programmes will depend on design – e.g. covered emissions, cap and trade or tax,

4 See Aldy and Pizer (2015b) for a discussion of comparability, metrics and review.

5 For more details, see https://www.jcm.go.jp

exemptions, revenue use, compensation, border adjustments, and so on – as well as interactions with other nations, many without carbon pricing or markets.

Unequal pricing raises questions regarding carbon leakage, competitiveness and border adjustments. The G77 & China firmly oppose border adjustments. Many developed nations support them to protect energy-intensive, trade-exposed industries and labour. Lately, the use of carbon clubs (Nordhaus 2015) has emerged for countries with pricing to induce others to join. They encourage participation by penalising free riders. Some in business welcome such approaches; others fear further complicating international trade. They prefer to use trade as a carrot, as in the environmental goods negotiations, rather than a stick (or club).

3.2 Adaptation, and loss and damage

Previous UNFCCC decisions place adaptation on an equal footing with mitigation. They call for nations to develop adaptation plans and for aid to apply equally to mitigation and adaptation. However, process and procedures remain unclear both to raise and to disburse funds.

Compensation for loss and damage has become a major stumbling block, with strong support from developing nations and resistance from developed nations. COP17 agreed to address loss and damage as an element of adaptation. Nevertheless, developing countries have raised compensation an issue in ADP. Discussions have not at all addressed the thorny issue of 'attribution' of specific natural events or incremental damages to human-induced climate change.

3.3 Transparency, MRV, and ex post review of effort

Transparency requires clear commitments, and methodologies for MRV and review of actual performance (see the chapter by Wiener in this book). While nations have long experience with GHG inventories, much work remains to characterise contributions of developing countries that may apply only to specific sectors of their economy, or be based on improvements over *business as usual* (see the chapter by Aldy and Pizer in this book, and Aldy and Pizer 2015b). Similarly, it may be challenging to design MRV for finance based on concepts to mobilize $100 billion per year by 2020 from public and private sources. Differences exist on how CBDR will apply to MRV and review processes.

Recently, recessions, financial crises, natural disasters, and unanticipated technology revolutions have caused national emissions to be lower or higher than anticipated. Ex post analyses, especially over short periods, will need to account for such unexpected developments.

3.4 Means of implementation: Finance, technology and building capacity

Negotiations include four areas where developing nations seek assistance. They request financial aid to support their actions to mitigate and adapt to climate risks, and compensation both for the impacts on them from mitigation measures in developed countries and for damages from climate change. Arguments have been made that claims in each of these areas already amount to hundreds of billions of dollars per year, and that they will grow in the future.[6]

In general, climate finance poses significant challenges (see the chapter by Buchner and Wilkinson in this book). Moreover, while the public is aware of the debate surrounding finance for domestic action, they are largely unaware of the scale of aid under discussion. The pledge of $100 billion per year seems both difficult to meet and far too little.

IPR has become a matter of great controversy. Developed nations stress their position that the UNFCCC should not address IPR – competent bodies (the WIPO and the WTO) already exist for such discussions. Private-sector representatives (at least those from developed nations) argue that IPR is essential to motivate R&D and to enable technology dissemination. Developing countries, led by India, argue that climate-friendly technologies should be a public good.

6 For mitigation alone, Jacoby et al. (2010) found that achieving the G8 goal of halving emissions by 2050 could require wealth transfers to developing nations of over $400 billion per year by 2020, rising to $3,000 billion per year by 2050.

3.5 Legal form and compliance

ADP is working t*o develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties*. Parties hold very different views on legal form. Many, perhaps most, call for an agreement that is legally binding in all aspects and with strong compliance provisions. For others, notably the US, legal form and obligations could pose an insurmountable barrier to participation. In the US view, nations have an obligation to submit proposals and report progress, but not to achieve outcomes. Starkly, the critical choice is between: commit and comply, or pledge and report. In either case, layering on of durable cycles (see Section 3.7) adds components to review and renew.

3.6 Objectives and long-term goals

The UNFCCC contains the well-known objective of stabilising GHG concentrations at levels that prevent dangerous human interference with the climate system. Additional mitigation proposals include: limiting warming to 2°C (or 1.5°C), a year for global emissions to peak, a reduction in annual emissions by a given year, and net zero emissions by 2100. It is unclear what status a goal would have – would it be aspirational, or would it have implications for action if the goal were not met?

3.7 A durable framework based on periodic cycles

Negotiators are discussing a durable framework for future commitments based on periodic cycles, perhaps at intervals of five or ten years. A tension exists between providing credibility to plan and implement investments and other actions, favouring a longer cycle, or creating flexibility to ratchet up commitments more rapidly, which may favour shorter periods. Cycles will pose challenges for institutional linkages and timely availability of information (Flannery 2015), for example, several nations call for the Intergovernmental Panel on Climate Change (IPCC) to provide assessments to inform periodic updates.

3.8 Workstream 2: Enhancing pre-2020 ambition

Workstream 2 has a prominent place, especially for developing nations. As a demonstration of good faith, they sought tangible evidence that developed countries would increase ambition in mitigation and finance before 2020. Developed countries have not done so. Instead, consideration has shifted to technical expert meetings (TEMs) that focus on opportunities in areas such as CCS, renewable energy and energy efficiency, rather than establishing new commitments that actually increase pre-2020 ambition.7

4 COP 21, Paris and next steps

In the few remaining days of formal negotiations, the ADP must complete the text of the agreement and produce mandates for follow on work.

4.1 Expectations for COP21

In June, current and future COP Presidents Manuel Pulgar-Vidal and Laurent Fabius provided their perspectives on COP21. They requested negotiators by October to develop a concise text with clear options for ministerial decisions in Paris. Minister Fabius proposed that Heads of State might attend at the start to lend political support, with ministers taking decisions in week two. They portrayed an outcome based on four pillars: 1) adopting the universal, legally binding, durable agreement; 2) incorporating INDCs for the first period; 3) delivering on support to developing nations through finance, technology and capacity building, including mobilising $100 billion per year by 2020; and 4) recognising actions by non-state actors, notably cities and local authorities and business.

7 For reviews of these areas, see the chapters by Biogo, Bosetti and Tavoni in this book.

4.2 Preparation of text

To date, Parties have basically assembled proposed input; they have not begun to negotiate text. The "Geneva negotiating text" (GNT) 8 – 90 pages with 224 paragraphs in 11 sections agreed in February this year – satisfied the obligation to circulate any proposed agreement to all Parties at least six months before the COP. Until now the process of developing and refining text has respected Parties' deep concerns that the negotiation must be Party-driven and based on text submitted by Parties. This insistence flows from experience and suspicion in the aftermath of Copenhagen. Unfortunately, progress has been far too slow.

In June, Parties requested the co-chairs to produce a streamlined text. This was released on 24 July as a *tool* to aid discussions. At 76 pages,9 it is only marginally shorter than the GNT. It is reorganised into language to be part of the agreement (19 pages, 59 paragraphs), accompanying decisions (21 pages, 98 paragraphs), or still to be determined (36 pages, 102 paragraphs). Parties face significant substantive and procedural challenges to commence negotiation of text.

4.3 Next steps and long-term goals

The path forward appears to provide a process to examine progress and increase ambition periodically. An academic and political debate has continued for years concerning the credibility and desirability of the 2°C goal (Victor and Kennel 2014). Note that the concentration of well-mixed GHGs today already exceeds the level conventionally associated that goal.10 This raises a central question going forward concerning how to motivate credible public policy over many decades: is it better to have ambitious

8 Available at http://unfccc.int/resource/docs/2015/adp2/eng/01.pdf

9 Available at http://unfccc.int/meetings/session/9056.php

10 Expressed as CO_2 equivalent concentrations; the conventional estimate for the 2°C goal requires stabilisation at 450 parts per million (ppm). In 2014 well-mixed GHG concentrations were 485 ppm and rising (MIT Joint Program on the Science and Policy of Global Change 2014). Also, see Huang et al. (2009) for methods and trends relevant to CO2 equivalence.

aspirational goals (that will be questioned because they appear not to be credible) or to pursue strong but feasible policies?

The package of results in Paris will set the stage for future steps. It will provide a new beginning for efforts before and after 2020. Hopefully, the Paris agreement will make the UNFCCC a more respected and effective institution for action on climate change.

References

Aldy, J. and W. Pizer (2015a) "Comparing emission mitigation pledges: Metrics and institutions", Chapter 12 in this book.

Aldy, J. and W. A. Pizer (2015b) "The Road to Paris and Beyond: Comparing Emissions Mitigation Efforts", *Resources Magazine* 189: 19-25.

Bigio, A. (2015), "Towards resilient and low-carbon cities", Chapter 30 in this book.

Bosetti, V. (2015), "The role of renewables in the pathway towards decarbonisation", Chapter 23 in this book.

Buchner, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional finance", Chapter 33 in this book.

Flannery, B. P. (2014), "Negotiating a post-2020 climate agreement in a mosaic world", *Resources Magazine* 185: 26–31.

Flannery, B. P. (2015), "State of the climate negotiations", FERDI Working Paper No. 134, Clermont-Ferrand, France.

Huang, J., R. Wang, R. Prinn and D. Cunnold (2009), "A semi-empirical representation of the temporal variation of total greenhouse gas levels expressed as equivalent levels of carbon dioxide", MIT Joint Program Report No. 174, Cambridge, MA.

Jacoby, H. D., M. H. Babiker, S. Paltsev and J. M. Reilly (2010) "Sharing the Burden of GHG Reductions", in J. E. Aldy and R. N. Stavins (eds), *Post-Kyoto International Climate Policy: Implementing Architectures for Agreement*, Cambridge, UK: Cambridge University Press.

Jacoby, H. D. and Y.-H. H. Chen (2014), "Expectations for a new climate agreement", MIT Joint Program Report No. 264, Cambridge, MA.

MIT Joint Program on Global Change (2014), *2014 Energy and Climate Outlook*, Cambridge, MA.

Nordhaus, W. (2015) "Climate clubs: overcoming free-riding in international climate policy", *American Economic Review* 105(4): 1339–1370.

Stavins, R. (2015) "Linkage of regional, national, and sub-national climate policies in a future international climate agreement", Chapter 20 in this book.

Tavoni, M. (2015) "Carbon capture and storage: Carbon Capture and Storage (CCS): promise or delusion?", Chapter 24 in this book.

Victor, D. G. and C. F. Kennel (2014) "Climate policy: Ditch the 2 °C warming goal", *Nature* 514: 30–31

Wang, X. and M. Murisic (2015) "Taxing Carbon: Current state-of-play and prospects for future developments", Chapter 19 in this book.

Wiener, J. (2015) "Toward an effective system of monitoring, reporting and verification", Chapter 13 in this book.

About the author

Brian Flannery is a Center Fellow at Resources for the Future. He retired from Exxon Mobil Corporation as Manager Science, Strategy and Programs. He has served as Lead Author IPCC WGIII (TAR, FAR); Vice Chair, Environment and Energy Commission, International Chamber of Commerce; and Co-chair of the International Energy Committee, United States Council for International Business; and on numerous advisory panels, including the Stanford Engineering School, NATO Science Committee, and US DOE and EPA. He helped create the Joint Program on the Science and Policy of Global Change at MIT and the Global Climate and Energy Project at Stanford University. He is co-author of the widely used reference *Numerical Recipes: the Art of Scientific Computing*.

PART II

Views from Different Parts of the World

5 A view from Africa

Alemu Mekonnen[1]
Addis Ababa University

Compared with other continents, Africa has contributed the least to climate change, while its impacts on the continent have been and will continue to be the greatest in the future. Africa generally has the least capacity to adapt. Thus, it should be the continent with the most interest in addressing the climate change problem and would benefit the most if the problem were to be addressed successfully through global cooperation. As Africa is growing fast, starting from a low base, this is also an opportunity to develop a climate-friendly infrastructure. Achieving the required mitigation and adaptation objectives will require external financial support. Given the difficulty of achieving an efficient and equitable solution to this global problem, African countries need to work towards the conclusion of a feasible, inclusive, effective and equitable climate agreement that considers Africa's situation in the identification of mitigation and adaptation options. Addressing climate fund governance issues and increasing the availability of climate funds will be key to success. Africa should also be supported in capacity building, technology development and transfer, and institutional reform. Meeting these objectives will require efforts at the global, national and local government levels.

In this chapter, I present a view from Africa of how I see the climate change problem and the role that African countries should play in addressing it. Section 1 compares Africa with other continents in terms of contributions to climate change, of vulnerability to extreme temperature rise and of expected damages in the coming decades. Section 2 deals with the role Africa can be expected to play in mitigation and the steps to be taken for adaptation. Section 3 deals with the required financing and criteria for its allocation. Section 4 concludes.

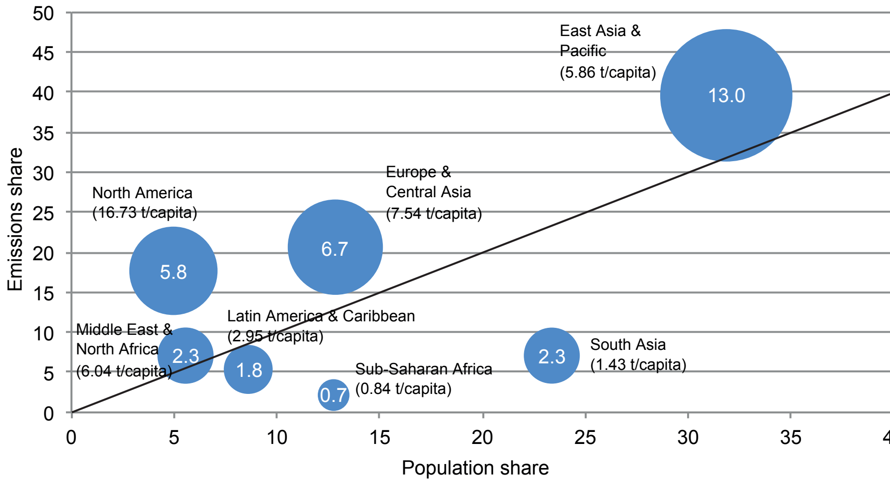
1 I thank the editors for helpful input and Adrien Corneille and Vincent Nossek for research assistance.

1 Africa and climate change

Evidence concurs that, compared with other continents, the impact of climate change on Africa (as a share of GDP) is generally the greatest and the continent generally has the least capacity to adapt (AfDB 2011, IPCC 2014, Mekonnen 2014). In spite of shortcomings in the estimates of impacts for various reasons including data limitations, a review of estimates suggests that "Africa stands to lose between 2-4% of its GDP due to climate change over the coming ten to fifty years" (Mekonnen 2014, citing Nordhaus and Boyer 2000, Tol 2002a and 2002b, Watkiss et al. 2010). Deeper consideration of the effects of climate change on poverty and income distribution also reveals that the poorer people in Africa would suffer even more (Hallegatte et al. 2015). For example, citing Winsemius (2015), Hallegatte et al. (2015) note that when large-scale floods hit the Shire River Basin in Malawi in January 2015, the poorest areas were the most exposed. In spite of progress over the last 15 years, with a poverty headcount (below US$1.25 per capita per day in 2011 at 2005 prices) of 41%, Africa's poverty rate is more than 20 percentage points higher than that of South Asia, and East Asia and the Pacific (Corneille et al. 2015).

On the other hand, relative to other continents and to the developed world in particular, Africa has contributed very little to climate change. Supposing that convergence towards equal CO2 emission shares per capita is a relevant indicator, Figure 1 shows that Africa makes the lowest absolute contribution and, with 0.84t/capita, has the lowest per capita emissions. Also Africa is furthest below the 45° line, an indication of its low contribution in relative terms. The continent's low emissions share also indicates that, even if the costs of abatement are low relative to other regions, its contribution will necessarily be marginal relative to the mitigation task especially if, as in Figure 1, emissions related to land use and livestock are not included.

Figure 1 CO_2 emissions from fossil fuels and manufacture of cement by regions, 2011



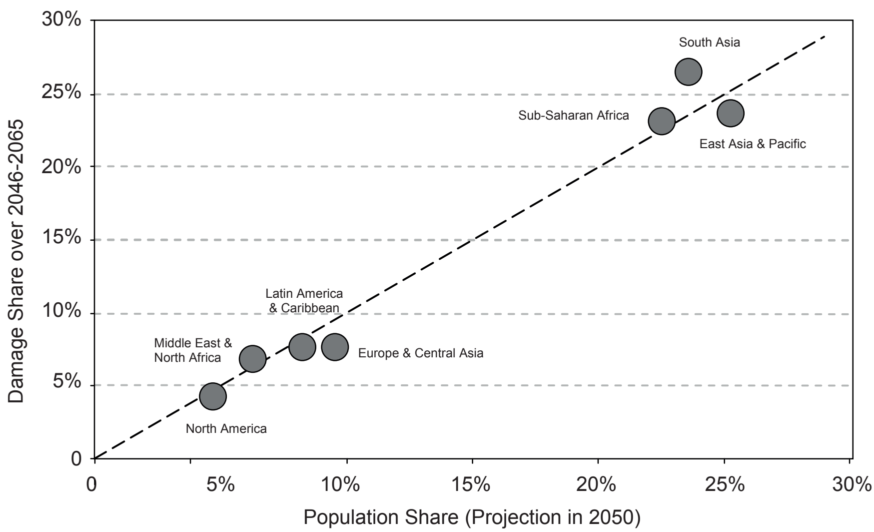
Notes: Numbers in blue circles are in Gt and blue circles show position of region relative to 45° line
Source: Author's calculation from World Development Indicators 2015

Because of its geography, Africa is also likely to be the region most strongly affected by climate change. About 43% of Africa's land area, 70% of its cropland, 80% of its livestock holdings and 50% of its population are already in drylands (including arid, semi-arid and dry-humid areas) (Cervigni and Morris 2015). African countries' projected reduction in agricultural yields due to climate change could be as high as 50% by 2020 (Boko et al. 2007, p. 435). As discussed below, the temperature is already high in most of Africa; projected above average increases in temperature for the continent due to climate change, combined with limited capacity to adjust, imply that adaptation is a huge challenge for Africa.

Using panel data over a 50-year period, Dell et al. (2012) estimate that a temperature of 1ºC higher relative to trend in a given year reduces per capita income by 1.4%, but this holds only for poor countries. When the model is estimated with lags, this large effect is not reversed when the temperature shock is over, suggesting a negative effect on growth from the lower resilience in poor countries.

Predicted temperature changes can be used to estimate potential damage across continents. Drawing on Sauter et al. (2015), Figure 2 gives a very rough estimate of the potential geographical damage from excessive heat towards mid-century using the A2 scenario from Randall et al. (2007). The estimate draws on projected extreme temperatures, viewing the planet as grid with 1° degree latitude and longitude intervals, where extreme temperatures are defined as the number of days when temperatures are above the 90th percentile of the temperature distribution, and the distribution of damage costs is simply the projected population share times the above measure of extreme temperature. While the estimate is rough because the population shares on the grid are for 2008, it is clear that damage costs are projected to be highest in Africa, South Asia, and East Asia and the Pacific, and above the respective population shares for South Asia and sub-Saharan Africa.

Figure 2 Potential damage share and population projections in 2050, by region



Source: Author's calculation adapted from Sauter et al. (2015).

Summarising Africa's predicament, the latest report by the Africa Progress Panel (2015) states that "[n]o region has done less to contribute to the climate crisis, but no region will pay a higher price for failure to tackle it." The report also notes that "Africa is already experiencing earlier, more severe and more damaging impacts of climate change than other parts of the world".

2 Africa's role in adaptation and mitigation

African countries are starting to address climate change in their domestic policies (Federal Democratic Republic of Ethiopia 2011, Republic of Rwanda2011). The removal of subsidies on fossil fuels is a prime example of a policy with multiple gains. Though this is politically sensitive, research in developing countries has shown that such an action may not hurt the poor (Sterner 2011, Mekonnen et al. 2013). Ex ante measures, such as strengthening early warning systems and weather-indexed insurance in agriculture, are also important domestic policy measures to consider (see the chapter by Hallegate et al. in this book).

Africa's recent fast growth is an opportunity to avoid a development path relying on old, high-carbon technologies. This will contribute both to mitigation and adaptation. Starting from a low infrastructure base is also a late-comer advantage. This is particularly important for Africa, where the urban population is expected to triple by mid-century. In his chapter in this book, Bigio notes that emerging cities and small urban areas in developing countries – of which there are many in Africa – that are starting from a primitive infrastructure base have the greatest potential for avoiding lock-in to long-lived, high-carbon urban infrastructure. As Africa is expected to continue growing rapidly, the opportunity is there to invest in activities that are climate friendly.

Such a development path requires leapfrogging into modern technologies including reliance on clean renewable energy technologies such as hydropower, solar and wind, for which there is a huge potential in Africa. The costs of technologies to enable the use of renewable energy sources such as solar and wind are going down. If assisted by measures that keep a significant amount of fossil fuels unextracted, as suggested by Collier (2015) in his chapter in this book, the shift to clean renewable energy technologies would be faster, although, as noted below, this poses a problem of burden sharing. There are also opportunities for Africa in other areas – such as forestry and agriculture – where development, mitigation and adaptation could be combined.

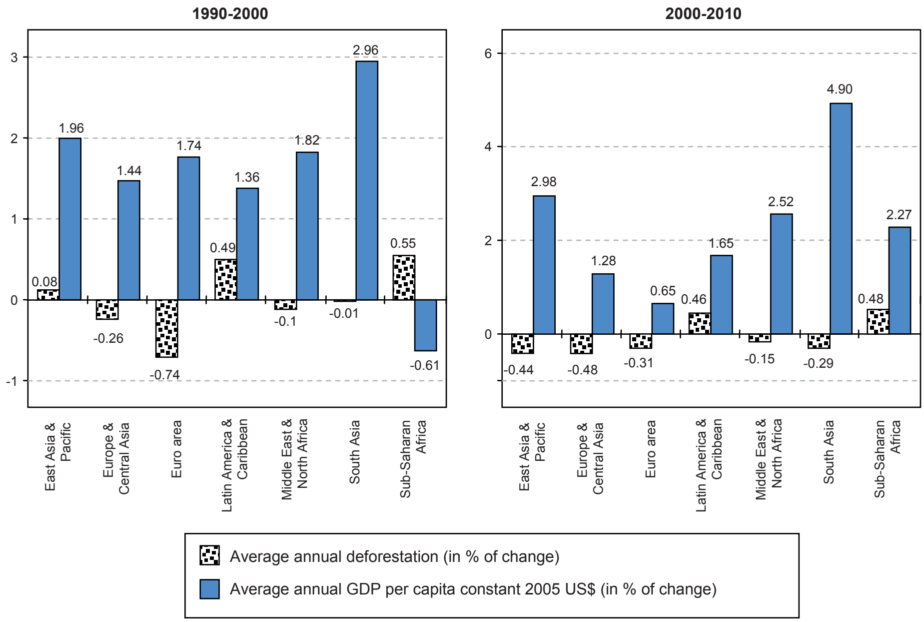
Such a strategy will provide several climate-related benefits. First, the construction of infrastructure will be less carbon-intensive (e.g. cook stoves with higher thermal efficiency; see the chapter by Kaudia in this book). Second, the operation of that infrastructure will also be less carbon-intensive. Third, the infrastructure will be better adapted for temperature rise. Fourth, there will be co-benefits in terms of improved health and livelihoods in general.

Mitigation being a global rather than national public good, it is globally beneficial if mitigation takes place where it is least costly. As discussed by McKinsey (2009), GRICCE (2009) and the World Bank (2010), Africa has negative or only small abatement costs for a number of mitigation options. The most important area for mitigation for Africa is forestry, but it has been excluded from the Kyoto Protocol and hence from the Clean Development Mechanism (CDM), the main instrument for increasing the efficiency of mitigation activities.

Africa has not participated much in mitigation activities under the Kyoto Protocol as the Clean Development Mechanism was not adapted to Africa's situation, not only because activities avoiding deforestation were not allowed, but also because the requirements for qualification were too stringent for African countries. Of the 8,592 CDM projects submitted and registered over the period 2004-2015, the bulk (6,343, or 74%) went to China, India, Mexico and Malaysia, and only 238 (2.8%) to Africa. An analysis of the determinants of qualifying projects shows that high tariffs on environmental goods imports and burdensome procedures to start a business were negatively associated with the likelihood of a technology transfer (Schmid 2012). Proposed reforms to increase participation in CDM projects by African countries would include mitigation in forestry, agriculture, and other land use projects (ACPC 2011, Haites 2011, Gebreegziabher et al. 2012).

Regarding GHGs, by 2030, Africa's comparatively low-cost mitigation potential is estimated to be close to two-thirds, or 2.8 $GtCO_2e$, of its projected GHG emissions under a business-as-usual scenario (4.2 $GtCO_2e$) (McKinsey 2009, exhibit 3.2.1). GRICCE also suggests that mitigation in Africa could focus on forestry (including REDD+, afforestation/reforestation and forest management), agriculture (including restoration of degraded land and reduced tillage) and energy (including hydropower, solar power, and energy efficiency programs), as well as transport. As shown in Figure 3, during the 1990s Europe reforested, and South Asia experienced an average per capita growth of 2.9%while avoiding deforestation. On the other hand, Africa experienced negative growth and the highest rate of deforestation. In the next decade, Africa's growth picked up, but deforestation continued at a similar rate to the previous decade.

Figure 3 GDP per capita and deforestation (decadal averages)



Note: Negative values correspond to reforestation rates.

Source: Author's calculation using deforestation rates from Food and Agriculture Organization, Global Forest Resources Assessment and GDP per capita (constant 2005 US dollars) from the World Bank.

As discussed by Angelsen in his chapter in this book, there are local benefits from good management of forests, but given the multiple values of land-use conversion for local communities, financial incentives should be provided to compensate for the global benefits resulting from successful implementation of REDD+, as urged by the 'Lima Challenge' signed by 14 tropical forest countries, including the Democratic Republic of Congo, Ethiopia and Liberia.

As of August 2015, three African countries, Gabon, Kenya and Ethiopia had submitted their INDCs. Ethiopia's INDC includes reducing GHG emissions in 2030 by 64% compared with a BAU scenario, assuming sustained double digit growth in the economy up to 2030. If the assumption of growth at or above 10% for such a long period is realistic, this would be an example of very significant intended action by an African Least Developed Country (LDC), as the required investment is projected to be over US$150 billion by 2030.

3 Financing requirements in response to climate change

Of the 48 LDCs, 34 are in Africa. This category is highly vulnerable to natural and external economic shocks. As forcefully argued by Guillaumont in his chapter in this book, concessional funding should be formula-based and the allocation of funds should take into account a country's vulnerability. This implies that Africa should be receiving a sizable share of concessional financing for the Sustainable Development Goals (SDGs) recently agreed by the UN. Such a formula-based approach towards allocating funds should also be applied to climate funds, taking into account vulnerability to climate change. This would lend transparency and address the issue of equity in the allocation of funds.

Though insufficient, recent efforts to increase the relative importance of adaptation funding are to be commended. These include the Green Climate Fund's decision to allocate 50% of funds for adaptation and 50% for mitigation, which should be maintained. Unlike mitigation, the benefits of adaptation go to those who are adapting and are specific to a country, or even to a locality within a country. Using such criteria for the allocation of funds to adaptation would serve several purposes, including reducing transaction costs, supporting a results-based agenda based on measurable yardsticks, and supporting mutual accountability through transparency in allocations (Barr et al. 2010, World Bank 2010, Mekonnen 2014).

As has been learned from the aid evaluation experience, where multiple sources of financing and competition among donors hindered evaluation, facing the problems of fragmentation in climate funding will require commitment by donors and recipients alike to incorporate the key tenets of ownership, alignment, harmonisation, results orientation, and mutual accountability into their development activities (World Bank 2010). Recent developments in this regard, with the establishment of the Green Climate Fund (GCF), should be strengthened (Bird et al. 2011). For example, this could help address issues of fragmentation. At the regional and country levels, this requires strong leadership, capacity building/strengthening, good governance and institutional reforms.

In a new global deal on climate change, more attention also needs to be paid to issues of power, responsibility and accountability between recipient and traditional contributor countries (Ballesteros et al. 2010). This would involve introducing a power balance while also ensuring that developing countries take responsibility and are accountable. A complementary source of transfer, proposed by Collier in his chapter in this book, could be to proceed with staggered closing of coal mines, starting with developed countries (i.e. the US, Germany and Australia) while not freezing new carbon discovery in low-income countries (about 80% of known coal reserves should stay stranded to reach the 20 target). Not only is controlling carbon emissions easier at the point of extraction than at the point of consumption, and developed countries would move first, but oil producers in developed countries would also have to buy rights for increasing emissions in coal mines in middle-income countries that would be scheduled to close. At the same time, low-income producers would have more time to close and capture some rents, and low-income users could exploit alternative sources of energy. Bottlenecks and power shortages are estimated to cost Africa 2-4% of GDP annually (Africa Progress Report 2015).

4 Concluding remarks

Africa is still the poorest continent, with a poverty rate double that of the next poorest regions in the world (South Asia, and East Asian and the Pacific). Since the poor are generally the most vulnerable to climate change, as they have limited capacity to adapt, Africa has the greatest need to carry out adaptation activities, which will require financing beyond that available domestically. Africa is also the continent that has contributed the least to climate change, while it is the continent that will be the most severely affected by global warming. External funding will be needed to carry out adaptation and mitigation activities. Because Africa is also characterised by a great degree of heterogeneity across geographical, economic and institutional dimensions, indicators of vulnerability to climate change should be used to allocate external funds.

Beyond these general observations, for a start, actions such as REDD+ should be supported financially by the international community. This is a clear potential ‘win-win’ situation because, if properly designed, these actions provide global benefits including to the countries participating if the financial compensation is adequate, as suggested by Angelsen in his chapter in this book. In this regard, while Ethiopia, Liberia and the Republic of Congo are signatories to the Lima Challenge involving 14 tropical-forest countries, greater participation by other African countries should be encouraged.

In general, African countries should work more closely towards ensuring commitment to financial and technical support for low-income countries. As indicated in other contributions to this book, together African countries need to exert pressure on the global community to commit to reducing emissions by a ‘sufficient amount’ (keeping global warming within the 2ºC threshold) with compliance mechanisms that should be enforced (see the chapters by Flannery and Wiener in this book). Individually, African countries should work towards addressing the climate change problem by designing appropriate policies, strategies and policy instruments, and implementing them. This should include paying attention to institutional reforms, policy reform, capacity building, research and good governance. Examples of measures that could be taken in the near future and that are beneficial in addressing climate change include the removal of fossil fuel subsidies, land use policies, and increasing the share of renewable energy.

References

ACPC (2011), “Climate financing: global imperatives and implications for sustainable climate resilient development in Africa”, Working Paper No. 16, ACPC at UNECA, Addis Ababa.

African Development Bank (AfDB) (2011), “The cost of adaptation to climate change in Africa”, Abidjan, Côte d’Ivoire.

Africa Progress Panel (2015), *Power, People, Planet: Seizing Africa’s energy and climate opportunities*, Africa Progress Report 2015, Geneva.

Angelsen, A. (2015), “REDD+: What should come next?”, Chapter 28 in this book.

Ballesteros, A., S. Nakhooda, J. Werksman and K. Hurlburt (2010), Power, Responsibility, and Accountability: Re-Thinking the Legitimacy of Institutions for Climate Finance, Washington, DC: World Resources Institute (available at http://www.wri.org).

Barr, R., S. Fankhauser and K. Hamilton (2010), “The allocation of adaptation funding”, background material for World Bank *World Development Report 2010*.

Bigio, A. (2015), “Towards resilient and low-carbon cities”, Chapter 30 in this book.

Bird, N., J. Brown and L. Schalatek (2011), "Design challenges for the Green Climate Fund", Climate Finance Policy Brief No. 4, Heinrich Boll Stiftung and ODI (available at www.climatefundsupdate.org).

Boko, M., I. Niang, A. Nyong, C. Vogel, et al. (2007),"Africa", in *Climate Change 2007: Impacts, Adaptation and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Cervigni, R. and M. Morris (2015), "Enhancing resilience in African drylands: Toward a shared development agenda", presentation at the IFPRI 2020 Conference, Addis Ababa.

Collier, P. (2015), "Curbing Carbon without Curbing Development", Chapter 29 in this book.

Corneille, A., J. He and J. de Melo (2015),"Will Africa Avoid the Environmental Trap?", mimeo, Ferdi, Clermont-Ferrand, France.

Dell, M., B. Jones and B. Olken (2012), "Temperature Shocks and Economic Growth: Evidence from the last half century", *American Economic Journal: Macroeconomics* 4(3): 66-95.

Federal Democratic Republic of Ethiopia(2011), "Ethiopia's Climate-Resilient Green Economy: Green economy strategy", Addis Ababa.

Flannery, B. P. (2015),"The state of climate negotiations", Chapter 4 in this book.

Guillaumont, P. (2015), "Identifying LDC vulnerabilities to climate change and providing finance", Chapter 35 in this book.

Gebreegziabher, Z., A. Mekonnen, A. Tuffa and A. Seyoum(2012), "Carbon markets and mitigation strategies in Africa/Ethiopia: A literature review and the way forward", EDRI Research Report 14, Addis Ababa.

Grantham Research Institute on Climate Change and the Environment (GRICCE) (2009), "Possibilities for Africa in global action on climate change, fact pack", London.

Haites, E. (2011), "Climate change finance", *Climate Policy* 11(3): 963-969.

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer and A. Vogt-Schilb (2015), "Poverty and climate change: Natural disasters, agricultural and ecosystem impacts, and health shocks", Chapter 26 in this book.

IPCC (2014), *Climate Change 2014: Synthesis Report* (see IPCC (2014c) in the introduction to this book for the report's full reference)

Kaudia, A. (2015), "Policy options in low-income countries: Achieving socially appropriate climate change response objectives", Chapter 27 in this book.

Mekonnen, A., R. Deribe and L. Gebremedhin (2013),"Fossil fuel and food tax incidence in Ethiopia", *Eastern Africa Social Science Research Review* 29(2): 1-23.

Mekonnen, A. (2014),"Economic costs of climate change and climate finance with focus on Africa", *Journal of African Economies* 23(suppl. 2): ii50-ii82.

McKinsey (2009), *Pathways to a Low-Carbon Economy*.

Nordhaus, W.D. and J.G. Boyer (2000), *Warming the World: Economic Models of Global Warming*, Cambridge, MA: MIT Press.

Randall, D., R. Wood et al. (2007), "Climate Models and Their Evaluation", in IPCc (2014), *Climate Change 2007: The Physical Science Basis*, Cambridge, UK: Cambridge University Press, pp. 589–662.

Republic of Rwanda (2011), "Green growth and climate resilience: national strategy for climate change and low carbon development", Kigali.

Sterner, T. (ed.) (2011), *Fuel taxes and the Poor*, Washington, DC: RFF Press.

Sauter, C., J.-M. Grether and N. Mathys (2015),"Geographical Spread of Global Emissions: Within-country Inequalities Are Increasing", IRENE Working Paper No,15-01, Neuchâtel.

Schmid, G. (2012) "Technology Transfer in the CDM: The Role of Host Country Characteristics", *Climate Policy* 12: 722-40.

Tol, R. S. J. (2002a), "Estimates of the Damage Costs of Climate Change—Part 1: Benchmark Estimates", *Environmental and Resource Economics* 21(1): 47–73.

Tol, R. S. J. (2002b), "Estimates of the Damage Costs of Climate Change—Part II: Dynamic Estimates", *Environmental and Resource Economics* 21(2): 135–60.

Wiener, J. (2015), "Towards an effective system of monitoring, reporting and verification", Chapter 13 in this book.

Watkiss, P., T. Downing and J. Dyszynski (2010), *AdaptCost Project: Analysis of the Economic Costs of Climate Change Adaptation in Africa*, Nairobi: UNEP.

Winsemius, H. (2015), "Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts".

World Bank (2010) *World Development Report: Development and Climate Change*, Washington, DC.

About the author

Alemu Mekonnen is an Associate Professor of Economics at Addis Ababa University and a Senior Research Fellow at the Environment and Climate Research Center at the Ethiopian Development Research Institute. He has extensive teaching, research and consultancy experience in Ethiopia in particular and Africa in general. His areas of research include energy and forestry, climate change, and sustainable land management. Courses he teaches include resource and environmental economics and microeconomics. He has published several articles in reputable journals and book chapters.

6 A view from China

Teng Fei
Tsinghua University

The Paris climate conference is approaching. The concept of Intended Nationally Determined Contributions (INDCs) not only shifts the Paris agreement to a bottom-up approach built on national pledges, but also links international climate pledges with the domestic interests of Parties. Seeing a country's INDC submission as being rooted in its domestic interests provides the means for understanding ways in which it can be enhanced in the future. In this chapter, we provide a view from China on the factors that shape its climate pledges and policies. The three major pillars of China's climate policy are economic development, air quality, and energy security. Mitigation actions were traditionally framed as necessitating a sacrifice in China's economic development. The changing narrative is more positive, focusing on the benefit that China obtains from its own climate actions. China is not only adjusting its pledges but also its policies and measures in response to its changing economic and political circumstances. In particular, market-based policies will replace command and control regulation.

1 Introduction

China was the first emerging economy to submit its Intended Nationally Determined Contribution (INDC) – it did so on the last day of June 2015 (Government of China 2015). China's submission includes four key points: first, China's emissions level is to peak by around 2030, which is consistent with the joint announcement China made with the US in November 2014 (White House 2014); second, China's carbon intensity (emissions per unit of GDP) is to fall by 60-65% from the 2005 level by 2030; third, China's share of non-fossil fuel primary energy (including nuclear, renewables and hydro) is to rise to around 20% by 2030; and, finally, China's stock of forests is to increase by around 4.5 billion cubic metres by 2030.

China’s position in the climate negotiations is unique. It is the biggest emitter, accounting for 26% of world emissions in 2014. However, China’s per capita emissions and per capita cumulative emissions are still lower than the OECD average. China’s income per capita has increased in recent decades, but even in eastern China, where the level of development is much higher than the national average, income per capita is still well below that of developed countries. According to most indicators, China remains a developing country, but because of its scale, China’s emissions exceed those of every *developed* country. The world will not be able to limit climate change without China‘s active engagement, so it is important for other countries to understand the context in which China is developing its own climate policies.

2 Key policy context to understand China’s climate policy

2.1 Growing China’s economy is still at the top of political agenda

The government of China continues to maintain a growth-first economic model. This is due to several pragmatic reasons. First, China still needs rapid growth to alleviate poverty, despite three decades of miraculous development. As of 2011, nearly 6.3% of the total population – approximately 85 million people – was still living on less than US$1.25 (2005 PPP) a day, i.e. below the poverty line drawn by the World Bank (World Bank 2015). Second, local governments in China, especially in the western provinces, need to maintain high growth in order to generate sufficient revenue to cover the costs of various responsibilities required by upper level governments. These responsibilities include, but are not limited to, social security, education, medical care, public security, environmental protection, and rural and urban infrastructure. The current taxation system is very effective at concentrating the majority of tax revenue in the budgets of the central government, but the existing system of transfer payments is not particularly effective or efficient at distributing financial resources to where they are needed. It has been an open secret that local governments have to generate their own revenue by encouraging business growth and investment as well as infrastructure development. Finally, local government officials are highly motivated to expand the economy rapidly because their promotions are closely linked to the growth rate. However, there is increasing recognition that the goal of economic growth may conflict with that of environment protection, including climate mitigation, suggesting that the current economic model must somehow be changed.

2.2 Ongoing urbanisation and industrialisation processes will have long-term implications for China's emissions trajectory and energy consumption

Industrial production coupled with economic growth has boosted China's massive urbanisation to a rate and scale unprecedented in the world. Each year, millions of rural workers move into cities, motivated by the prospects of higher wages. In 2011, China's urban population exceeded its rural population for the first time; by 2030, close to another 330 million people are expected to move into cities. These new urban residents will increase the demand for infrastructure, building materials and consumer goods. Consequently, more energy will be consumed and more carbon will be emitted. On average, an urban resident consumes more than three times the energy of a rural resident in China (see the chapter by Bigio in this book). There are long-term implications for climate policy from these trends in urbanisation. The investments in capacity necessitated by rising urban demand may lock in energy-intensive infrastructure and industrial arrangements that will be difficult to alter in the near future. In parts of western and central China, where the growth has been particularly strong in recent years, this ossification of energy and emissions standards is already taking place.

2.3 How to balance energy security and environmental protection is a significant challenge for China's energy system

China's energy system faces many problems, among which three are particularly prominent: (1) difficulties in the adjustment of the energy structure; (2) the dilemma of fossil energy's growth; and (3) increasing dependence on foreign energy.

China's total energy demand continues to grow. Although investment in renewable energy and energy conservation has developed rapidly in recent years, overall energy demand has increased even faster, leading to increases in the consumption of coal, oil and other fossil fuels. Growth in fossil energy has caused serious problems for the environment, which has attracted more and more attention. The thick fog and haze that fills the air of Beijing, Tianjin and Hebei Province contains dangerous levels of particulate matter (PM2.5) and is caused by both coal combustion and vehicle exhaust emissions. China's growing energy demand has also caused the country to rely more and more on foreign sources of energy. By 2020, the share of imported oil is expected to reach 70% and the share of imported natural gas 50%, creating problems for China's energy security (New Climate Economy 2014). Conflicts and geopolitical tensions in energy-supplying countries could cause a temporary shortage in supply and price rises, thus posing a risk to the stability of China's economy. China could reduce its dependence on foreign energy by producing more coal domestically, but this would be detrimental to health and to the environment.

2.4 Air quality has become the number one cause of social instability in China, and the way in which China controls its air pollution will have significant impacts on efforts to address global climate change

China's poor air quality has been become the number one cause of social unrest and a threat to political stability. It is also causing millions of premature deaths every year and billions of dollars in environmental damages. Fine particles — including soot, organics and sulphates — have a severe effect on human health and are implicated in climate change. They are emitted by combustion and industrial processes, and formed from the reactions of gaseous pollutants. If China's proposed air quality standard were achieved everywhere in the country, there would be far-reaching benefits: in addition to protecting human health, air and mercury pollution in the Northern Hemisphere would fall and global warming would slow.

To improve air quality, coal consumption must fall. Coal currently accounts for about 60-70% of $PM_{2.5}$ (primary and secondary particular matters) emissions in China, leading to 700,000 premature deaths every year (Teng et al. 2015). Coal also accounts for 83% of China's carbon emissions due to the combustion of fossil fuels. Efforts to improve air quality by reducing coal consumption will therefore also deliver significant climate benefits. For China's emissions to peak by around 2030, coal consumption will need to be stabilised before 2020 and then to decline after 2020 (He 2014). The external environmental cost of coal consumption is about $40/tonne, but only a small share of this external cost is reflected in current prices (Teng et al. 2015). To reduce air pollution in China, the external environment cost of coal must be internalised further.

Many local governments in coal-rich provinces view coal-to-gas technology as an option for reducing air pollution, but the heavy water demands of this technology make the central government cautious. Although only few coal gasification plants currently operate in China, around 50 projects are being planned and some of these are under construction. If all of the planned coal gasification plants are built and in operation, they will emit another 1 billion tonnes of CO_2 every year. Thus, the way in which air quality is controlled in China will affect global climate change, but in complicated ways. On the one hand, reducing soot emissions by cutting coal use or using cleaner stoves will lessen radiative forcing and thus limit warming, benefiting both the climate and public health. Stricter emissions standards for diesel vehicles, which emit soot, is another win–win solution. On the other hand, reductions in SO_2 emissions from power plants would reduce atmospheric sulphate concentrations, thereby increasing radiative forcing, which has a short-term detrimental effect on the climate. Consideration is therefore needed of how the various pollutants and their sources should be best controlled. Clearly, a multi-pollutant abatement strategy must be developed (IPCC 2014).

2.5 International and domestic drivers for further action

Emissions of atmospheric pollutants pose a serious challenge to China's economic and social sustainable development. Besides the domestic drivers, international drivers are also impacting China's climate change policies. The relationship with the US is the most important bilateral relationship for China. The BASIC (Brazil, South Africa, India and China) ministerial meeting and the Like-Minded Developing Countries (LMDC) are the two most important plurilateral processes influencing the country's position in the climate negotiations. China faces two sources of pressure: on the one hand its volume of emissions requires it to take more ambitious action to shoulder its responsibility; on the other hand, China also has to stand with its developing country friends to safeguard their common interests (such as common but differentiated responsibilities, or CBDRs). The IPCC and UNFCCC are the two multilateral processes that have a notable scientific and political influence on China's decision-making process. But compared with other goals, climate change is not a high priority for Chinese political leaders. China's mitigation actions are largely driven by domestic drivers, not international pressures. Thus the best way to strengthen China's mitigation ambition is to align this goal with China's top domestic priorities, that is, growth, energy security, and environment quality.

3 The way forward

3.1 Change of narratives: Not only cost, but also benefit

Traditionally, the climate issue has been closely linked with development in China. The 'carbon space' has been interpreted as a development space, which may limit the development of China's economy. The costs associated with carbon emissions reductions have gained more attention from both researchers and decision makers. However such old thinking is now changing in China due to combined pressure from a slowing down of economic development, more serious energy security concerns, and the challenge of improving air quality (Li 2015). The slowing down of growth makes China interested in new driving forces for its economy. The new energy industry and low-carbon infrastructure has been considered an emerging industry that can drive future growth. Reflecting these new priorities, China has become the world's top investor in wind turbines, solar PV, nuclear energy and high-speed rail systems. Those technologies are all linked with a low-carbon transition that may bring more business opportunities for Chinese enterprises. The promotion of a low-carbon transition is no longer regarded as a costly effort, driven mainly by international pressure. Instead, it is considered as an opportunity – a means for propelling China's growth and for avoiding the middle-income trap. The increasing preoccupations with air quality and energy security are also causing decision makers to hedge those risks by improving energy efficiency and reducing dependence on fossil fuel.

3.2 Responding to changing policy circumstances

The thinking about climate action has changed in China. Addressing climate change is no longer seen as a threat to development, but rather as an opportunity for better growth. However, it is unclear how China can achieve the required transition towards a low-carbon growth. China has been transitioning to a market economy, but still has many regulations. The challenge faced by the Chinese government in the future will be how to make the market play a constructive role in bringing about a low-carbon transition, reducing the need for command and control regulation.

With a powerful central government, the Chinese government favours the command and control regulation and allocates different targets to local government, then to companies and enterprises. Such policies and measures perform well because the government controls project approval and state-owned companies dominate the energy-intensive industries. But in recent years, the government has started to streamline administration and to delegate power to lower administrative levels. At the same time, the liberalisation of the energy market is attracting more private companies into energy-intensive industries. Those private companies are driven more by economic than political considerations. The effectiveness of command and control policies in China is decreasing, but the economic and political costs of such measures are significant. To respond to China's new circumstances, market-based policies (taxation and cap and trade) and measures should replace the traditional command and control regulation.

References

Bigio, A. (2015), "Towards resilient and low-carbon cities", Chapter 30 in this book.

New Climate Economy (2014), *China and the New Climate Economy*, Global Commission on the Economy and Climate and Tsinghua University.

Government of China (2015), "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contribution", Beijing (unofficial translation available at http://www.ndrc.gov.cn/xwzx/xwfb/201506/W020150630783447810119.doc).

He, J. K. (2014) "Analysis of CO2 Emissions Peak of China: Targets and Strategies", *Chinese Journal of Population Resources and Environment* 12(3): 189-198.

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's complete reference).

Li, K. (2015) "Escalate Development Quality and Strengthen Actions to Address Climate Change", http://www.gov.cn/guowuyuan/2015-06/12/content_2878792.htm.

Teng, F. et al (2015), "Co-benefits of Coal Consumption Cap Targets", project report to the NRDC (http://www.nrdc.cn/coalcap/index.php/English/project_content/id/576).

White House (2014) "US-China Joint Announcement on Climate Change", 12 November, Washington, DC (http://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change).

World Bank (2015), Poverty and Equity Databank, Washington, DC.

About the author

Teng Fei is Associate Professor at the Institute of Energy, Environment and Economy, Tsinghua University, China. He has been the advisor to the Chinese delegation on climate negotiations since 2007. He is also lead author for the IPCC Fifth Assessment Report in Working Group III. In 2014, he served as the chair of consultative group of experts (CGE) organised by the UNFCCC to help developing countries prepare their national communication to the UN. His research interests include international climate regime, climate equity and energy modelling.

7 A view from India

E. Somanathan
Indian Statistical Institute

India's primary concern in the climate negotiations is to avoid having to make commitments it may come to regret. While this is a concern for all countries to some degree, it is much greater in a low-income country because the human and political cost of slowing economic growth is enormous at low income levels.

Fortunately, the need for secure energy access, and to a lesser extent, local environmental concerns, are driving Indian policy in the direction of a massive expansion of renewable energy. While continuing to exhort richer countries to own up to their responsibilities to finance mitigation and adaptation, India can be expected to propose mitigation actions that are consistent with domestic policy priorities. These include ambitious near-term renewable energy targets that have already been announced.

India should also announce gradually rising taxes on coal and oil. These would be an extension of existing programmes such as the coal tax and of policies aimed at fiscal rationalisation such as the recent elimination of the subsidy to diesel and its replacement by a net tax. Revenue from the coal tax should be used to create a flagship programme to replace power subsidies to farmers with capital subsidies for solar-powered pumps. Rich countries should be asked to meet their financial obligations for mitigation assistance by contributing via offsets from their carbon trading programmes. The creation of a credible mitigation programme to which funds can flow makes it much more likely that developed countries will be motivated to make good on their promises of financial assistance.

1 India and the 'like-minded' countries

India's policy towards an international climate agreement has historically been largely defensive. Climate change has not been an issue that has arisen from domestic concerns. It is one that India has reluctantly engaged with in response to demands made upon it in international fora. India's stance was that it would be iniquitous to expect poor countries to slow their development by restricting emissions when the rich countries were responsible for most of the excess stock of carbon dioxide, and could much more easily afford to pay for mitigation. This position was acknowledged in the UN Framework Convention on Climate Change in 1992 when it referred to "common but differentiated responsibilities", and further enshrined in the Kyoto Protocol.

India's approach was developed in the 1990s when the cost of mitigation actions was thought to be very high. This was never entirely true, of course. In fact, some mitigation at negative economic cost via elimination of subsidies to fossil fuels was always available. This was not taken up because it would require political energy to implement reforms, and because there was no significant action by the developed countries and, therefore, little pressure to act. Instead, India allied with a group of 'Like-Minded Countries' including many developing countries, China, and several fossil fuel exporters in resisting any mitigation actions at all by developing countries.

This approach has gradually become untenable with changing circumstances. The rich countries, with their vastly greater influence over the news media, successfully framed the debate in terms of their positive promised percentage emissions cuts against the developing countries' unwillingness to act, while downplaying their vastly higher per capita contributions to the stock of greenhouse gases. The fact that the Like-Minded Countries included some very wealthy oil exporters helped to take India down from the moral high ground. Gradually, developed country rhetoric began to be translated into action, for example, with the starting of the EU Emissions Trading System in the mid-2000s. The recent pledge by China that its carbon emissions will peak by 2030 and possibly earlier has increased the international expectations from India. Finally, awareness of climate change and its adverse consequences has grown in India and this has contributed to the sense that some action is needed.

2 India's ambitious pledge to reduce carbon intensity

Anxious to escape the obstructionist label pinned on it by the northern news media, India developed a National Action Plan on Climate Change in 2008 that included eight National Missions. None of them has amounted to much except for the National Solar Mission, which has been a dramatic success. The Government of India and some state governments auctioned long-term contracts for the purchase of electricity from private developers of large-scale solar PV plants. Prices in the auctions have fallen rapidly over the last four years as investment in the sector has grown rapidly. By the time of the most recent auctions (in July and August 2015), solar electricity prices had fallen considerably. They are now only 10-25% higher than the price of power from new coal-fired plants. India has reached 3.5 GW of capacity in solar PV from a starting point of virtually zero in 2010.

At the Copenhagen meeting in 2009, India pledged to reduce the carbon intensity of GDP by 20-25% from the 2005 level by 2020. A carbon-intensity target rather than a target for total emissions is appropriate for India because GDP growth is expected to be high and uncertain. Most recently, at the December 2014 meeting in Lima, the government confirmed the domestic policy announcement of a target for installed capacity of renewable energy of 175 GW by 2022, of which 100 GW is to be solar and 60 GW wind.

How ambitious are these targets? Are they likely to be met? Should India go further in this direction, or has it promised too much already? Should it take a different approach?

These *are* ambitious targets. Emission intensity tends to rise rapidly with per capita income at low levels of income, and then more slowly at higher levels.[1] By way of example, in 2013 India's carbon intensity was 139 kg CO_2/US$1000 while PPP GDP per capita was $5,200. China was approximately twice as rich with a per capita GDP of $11,500 and a carbon intensity of 229 kg CO_2/$1,000. The US was ten times as rich with a per capita GDP of $51,300 and a carbon intensity of 334. Thus, India has promised to

1 This can be seen from the EDGAR database from which the following numbers are taken. GDP numbers are in 2011 PPP US dollars from the World Bank.

deviate from this pattern. It has had some success so far, with carbon intensity falling by 10% between 2005 and 2013.[2] It is, however, far from clear that this will continue without strong policy measures.

Turning to the renewables targets, there is no doubt that they are ambitious. Global installed capacity of solar PV is now 180 GW, of which India's share is only 3.5 GW. Moreover, India's entire electric power-generating capacity (mostly coal-based) is currently only 280 GW. To add 100 GW of solar PV in seven years, when PV is still not fully competitive with coal, will require strong policy action. Although wind power is competitive, 60 GW is still a very large capacity addition, given the time frame.

We can already see that these targets may not be met if circumstances are adverse or policy is not strong enough. It would, therefore, be a mistake for India to make further quantitative commitments by following the developed countries' announcements in terms of absolute emissions. It would also not be realistic to promise a peak year for aggregate emissions as China has done. It is safer to make promises about the more distant future, of course. But such promises would not be very meaningful or credible, because the capability to take action will depend to an enormous degree on how much India's per capita income rises in the next decade.

3 From targets to action: Towards carbon pricing…

Should India then stop at what it has so far laid out? I believe we should not. There is more that can and should be done. Most importantly, it is becoming clearer than ever that climate change has hurt the Indian economy and can become extremely dangerous in the next few decades. Global warming has already lowered the yields of the two most important Indian crops, rice and wheat, by a few percentage points each (Auffhammer et al. 2006, Gupta et al. 2014) and lowered labour productivity in manufacturing by 3% (Somanathan et al. 2014). India, therefore, has a strong stake in a meaningful climate agreement.

2 By way of comparison, China's carbon intensity fell by 29% while that of the US fell by 2.6% over the same period.

Rather than announcing *targets*, it would be much more helpful and credible for India to announce *actions*. First, India should announce a move towards carbon pricing that builds on recent domestic energy policy. Second, rather than only calling for more transfers from developed countries, India should call for transfers for specific programmes that credibly demonstrate mitigation and that can be scaled up with external finance. Some possibilities are spelled out below.

The Indian government has initiated carbon pricing in the oil and coal sectors in the last few years. Starting in 2013, the government decided to eliminate the implicit subsidy to diesel gradually by allowing state-owned oil companies to raise the price by a small amount every month.[3] This has been followed by increasing excise taxes on diesel and petrol over the last year as world oil prices fell. The result has been a move from a net subsidy for diesel of Rs 9/litre to a net tax of Rs 10/litre.[4] The resulting carbon tax is \$64/tCO_2e (Ministry of Finance 2015). This tax is still well below European transport fuel taxes, while being well above that of the US. The gap between Europe and the US in fuel taxes has resulted in European transport sector CO_2 emissions being 50% lower than what they would have been if Europe had US tax rates (Sterner 2007, Sterner and Köhlin 2015), thus demonstrating the importance of fuel taxes for climate policy.

India's road and rail networks are highly congested due to chronic under-investment and policymakers recognise that there will be a substantial economic boost from improving them (Ministry of Finance 2015). In fact, it is impossible to imagine a scenario in which India doubles its per capita income in a decade without an enormous expansion in rail and road capacity and a reduction in congestion.

It makes sense, therefore, for India to couple the two objectives of raising revenue for transport infrastructure and reducing carbon emissions by announcing a continued steady hike in liquid fuel taxation until the resulting revenue can entirely finance the building and maintenance of roads as well as some local public transport and at least a part of the capital investment needed to expand the rail network. The experience so far

3 http://timesofindia.indiatimes.com/business/india-business/Diesel-prices-to-be-hiked-40-50-paise-every-month-Veerappa-Moily-says/articleshow/18287874.cms

4 1 US dollar is about 65 rupees.

shows the political feasibility of gradual price increases. Announcing this in the climate venue will help commit the government to the policy.

The government has put in place a tax on coal and raised it twice over the last two years to the current rate of Rs 200/tonne, about 8% of the current price of coal and equivalent to about 1.15 \$/tCO_2e. Revenues have been earmarked for a fund for 'green projects'.

This policy should now be extended by announcing an annual increase in the tax by, say, 50-100 rupees per tonne, to be continued indefinitely. Part of the proceeds should be earmarked for removing one of the most intractable problems for the Indian electricity sector – free (but rationed) electricity for farmers for irrigation pumpsets. Agriculture accounts for 18% of electricity consumption in India (Central Statistical Organisation 2015) and very little of it is paid for. Removing the subsidy without compensation would be political suicide for any government. However, the proceeds of the coal tax can used to subsidise solar PV powered pumps for farmers in return for getting their electricity connections metered at the commercial rate.[5] Farmers could also sell electricity back to the grid at a slightly lower rate to cover utility costs. The programme should be voluntary. This will help build political support for it.

From the point of view of domestic policy priorities, removing the un-metered and subsidised electricity for agriculture is a crucial step for putting an end to the chronic blackouts and under-investment that characterise India's electricity sector. This summer has been characterised by a shut-down of many power plants due to lack of demand even as the country reels under power blackouts. The parlous state of the public distribution companies' finances are the reason for this – they have no reason to buy power when they would have to give away substantial portions of it.[6]

5 Irrigation pumpsets are a natural source of demand for solar power because they do not require a 24-hour supply.

6 http://gulzar05.blogspot.in/2015/06/more-on-indias-power-sector-woes.html

4 …with mitigation financing via offsets from carbon trading programmes

It would take decades for such a coal tax to raise enough revenue to buy out all the 18 million farmers with electric pumpsets.[7] However, India can ask the developed countries to make good on their promises to finance mitigation in developing countries by contributing to the solar subsidies. Emission reductions from the programme can be easily measured and so they can be priced. This will enable financing via offsets from carbon trading programmes, an option that developed countries are likely to find far more politically attractive than government-to-government transfers. By transparently laying out the domestic outlays for the scheme from projected coal tax revenues, disputes over baseline emissions can be avoided. This may actually engender some real international cooperation in an arena that has so far been characterised mostly by conflictual rhetoric.

The incentive effect of a gradually rising tax on coal will be very important in helping India make the transition away from (locally and globally) polluting coal to renewables. By lowering the prospective returns from investment in new coal plants, more investment will be forthcoming in renewable alternatives. By anchoring expectations without any abrupt shifts, it will make for an economically painless transition. In fact, it is clear that in order to increase renewable capacity by two orders of magnitude in less than a decade, the existing procurement policies will not do. The only viable route is by making investment in coal less attractive. So the renewable capacity target to which the government is already committed makes some policy of the sort proposed here almost inevitable if the target is to be met.

7 Not to speak of the 8 million farmers with diesel-powered pumpsets (http://mnre.gov.in/file-manager/UserFiles/Scheme-for-Solar-Pumping-Programme-for-Irrigation-and-Drinking-Water-under-Offgrid-and-Decentralised-Solar-applications.pdf).

References

Auffhammer, M., V. Ramanathan and J. R. Vincent (2006), "Integrated Model Shows That Atmospheric Brown Clouds and Greenhouse Gases Have Reduced Rice Harvests in India", *Proceedings of the National Academy of Sciences* 103 (52): 19668–72.

Central Statistical Organisation (2015), *Energy Statistics*, Delhi: Government of India.

Gupta, R., E Somanathan and S. Dey (2014), "Global Warming and Aerosol Pollution Have Reduced Wheat Yields in India".

Ministry of Finance (2015), *Economic Survey*, Delhi: Government of India.

Somanathan, E., R. Somanathan, A. Sudarshan and M. Tewari (2014), "The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing."

Sterner, T. (2007), "Fuel Taxes: An Important Instrument for Climate Policy", *Energy Policy* 35 (6): 3194–3202.

Sterner, T. and G. Köhlin (2015), "Pricing carbon: The challenges", Chapter 18 in this volume.

About the author

E. Somanathan is Executive Director of the South Asian Network for Development and Environmental Economics (SANDEE) and Professor in the Economics and Planning Unit of the Indian Statistical Institute, Delhi. He is currently Gilbert White Fellow at Resources For the Future. He was a Co-ordinating Lead Author for Working Group III of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, and is the Editor of the journal *Environment and Development Economics,* published by Cambridge University Press. His research is in development and environmental economics including common property resources, climate impacts, and climate policies.

8 The view from different parts of the world: A view from Japan

Mitsutsune Yamaguchi and Keigo Akimoto
Research Institute of Innovative Technology for the Earth

In this chapter, we first review Japan's perspective on the Kyoto Protocol, focusing on the agreement's implications for flexibility, competitiveness, and the design and operation of the Clean Development Mechanism. We then analyse Japan's Intended Nationally Determined Contributions, taking into consideration the Fukushima nuclear accident. We also discuss the importance of accepting diversified views in implementing policy objectives, with restrictions on the financing of new coal-fired plants and voluntary initiatives given as examples. After this, we discuss the importance of technology innovations and diffusions, including the example of a sectoral approach, followed by a proposal asserted by Japanese experts on revisiting climate sensitivity, in order to make the Paris conference workable and effective. Japan recognises that its major role in effective global emission reductions is to deploy high energy-efficiency technologies in the world and to develop innovative technologies.

1 The Kyoto Protocol: Japan's perspective

Though the top-down style Kyoto Protocol was the first step to cope with climate change globally, it was not as effective as expected (IPCC 2014). In this chapter, we would like to discuss in particular Japan's view on the Protocol. There are three points: lack of flexibility, lack of competitiveness concern among developed countries, and bitter experience with the Clean Development Mechanism (CDM).

Several months after the Fukushima disaster caused by the tsunami on 11 March 2011, all 54 nuclear power plants including those in Fukushima were forced to stop operations. As of June 2015, the situation remains unchanged. As a result, Japan's energy-related

CO_2 emissions in 2013 were 1235 $MtCO_2$, an increase of about 100 $MtCO_2$ compared to 2010. Annual average emissions for the first commitment period of the Protocol have slightly exceeded those of 1990. Because of the lack of flexible provisions to cope with such an unforeseeable situation in the Protocol, however, Japan had to comply with its commitment by purchasing 74 $MtCO_2$eq. credits. It is our view that for the coming new accord in Paris, *clausula rebus sic stantibus* (the principle of changed circumstances) should be applied to all countries' pledges.

Only industrialised countries assumed emissions caps under the Protocol, though the US did not ratify it. There were several concerns among participating countries. These included, but were not limited to, equity with respect to their commitments and competitiveness issues among developed and developing countries. Throughout the first commitment period of the Protocol, Japanese energy-intensive sectors felt that they were disadvantaged. Take the global merchandise trade in 2013, for example. Japan competes fiercely with China and Korea in exporting to the US and the EU, and among the top five countries for Japan's exports, three (China, Korea and Chinese Taipei, representing 31.8% of Japan's exports) assume no emissions cap. In contrast, around 60% of Germany's exports go to European countries that assume a cap and the portion to China is only 6.1%. For the US, although China is its 4th largest export market, the share of US exports going to China is still rather small at 7.7% (WTO 2015).[1]

It is our view that, in evaluating each country's Intended Nationally Determined Contribution (INDC), the issue of competitiveness should definitely be taken into account.

The environmental and cost effectiveness of the CDM were not as high as expected due to controversy over additionality (baseline setting), leakage, transaction costs, and so on (Okazaki and Yamaguchi 2011, IPCC 2014). Here we focus on how Japanese industrial sectors were discouraged by this mechanism. Most of them are willing to contribute to reducing global emissions by providing state-of-the-art technologies to developing countries. What happened in reality, however, was quite different. Most

1 Another example is that most models calculated that Japan's carbon price to implement the target under the Kyoto Protocol was higher than *those* of the US and the EU, as shown in IPCC Third Assessment Report.

projects were concentrated in one country and Japanese manufacturers were forced to compete with other developed countries' manufacturers to obtain credits. If they had been asked to transfer their technologies at reasonable cost, they would have been happy and very proud to do so. They never intended to develop and diffuse technologies to obtain credits (i.e. for short-term gain); rather, the intention was to strengthen their competitive edge and, by doing so, long-term profitability.

2 The Fukushima accident and its impact on Japan's energy and climate policy: Background and analysis of Japan's INDC

The Fukushima nuclear power accident in March 2011 forced revisions to Japanese energy and climate policies, which had previously relied upon the expansion of nuclear power generation. As a result of much discussion after the Fukushima accident, the Japanese government formally decided on a new strategic energy plan in April 2014. This new plan seeks a balanced '3E+S' (economy, energy security, environment, and safety) approach. However, the plan did not specify an energy mix due to large uncertainties over perspectives on nuclear power plants, particularly regulatory and public acceptance issues.

The Japanese people fear that a return to nuclear power could invite another nuclear accident. However, it remains important for policy to evaluate different kinds of risks – not only the risk of a nuclear accident, but also the risks associated with increases in electricity costs (which can weaken industry's international competitiveness), energy security, and climate change – all at the same time. Very often, these risks conflict with each other. The government should clearly explain such risk-risk trade-offs to the people.

There are no operating nuclear power reactors in Japan as of June 2015, and as a result Japan's GHG emissions hit their worst record in 2013. Furthermore, additional costs for purchasing fossil fuels from overseas to substitute for nuclear power were 3.7 trillion yen in FY2013. Consequently, electricity prices are increasing. Renewable energy may be preferable for reducing CO2 emissions as well as to ensure energy security, but it is still very costly. In order to deploy renewable energies widely, the government introduced the Feed-in Tariff (FiT) in 2012. The tariffs for solar photovoltaics have been reduced gradually, but in FY2014 they were still as high as 37 and 32 yen/kWh for residential and non-residential photovoltaics, respectively. The total capacities of photovoltaics applied for and approved by the government reached 70.2 GW by the end of November 2014 (total power capacity in Japan was about 290 GW in 2012), and the additional cost burden due to the FiT is expected to be 1.3 trillion yen annually from 2015 and to accumulate yearly. In addition, large installations of intermittent wind power and photovoltaics entail large additional costs to stabilise grids, particularly in Japan where the electricity grid is not connected to any of those in other countries due to its geography. In this situation, nuclear power, still competitive in Japan, is deemed to contribute to Japan's energy independence and is indispensable to emissions reductions.

In order to prepare Japan's INDC for submission to the Paris conference, the INDCs were discussed in the Joint Expert's Meeting of the Central Environment Council and the Industrial Structure Council (discussions were open to the public). The government proposed a detailed energy mix plan and a draft INDC for 2030 at the meeting at the end of April 2015, and decided them at the beginning of July 2015 (Table 1). The proposed GHG emission target in 2030 is a 26% reduction relative to 2013 (a 25% reduction relative to 2005). The emissions reduction target for the INDC was submitted to the UNFCCC in July 2015. According to our analysis using the RITE DNE21+ model,[2] the marginal abatement cost for the proposed 26% emissions reduction is about $380 per tCO_2, while those for reductions in the EU by 2030 and the US by 2025 are about $166 per tCO_2 and $60-69 per tCO_2, respectively. It is considered that the estimated high abatement cost for Japan results from the large amount of energy saving required to achieve the target in a situation where high energy efficiency already widely prevails (Oda et al. 2012). Japan's emissions reduction target is very ambitious and one that will be extremely challenging to achieve (for discussions on the comparability of emissions reduction efforts across countries, see Aldy and Pizer 2015).

2 The DNE21+ model is a climate change mitigation assessment model that covers the whole world, divided into 54 regions, and treats over 300 kinds of technologies by bottom-up manner (Akimoto et al. 2010).

Table 1 Japan's energy mix and pledged target greenhouse gas emissions reduction for 2030

Primary energy	Electricity generation	Greenhouse gas emissions	
Share by source	Share by source	Relative to 2013	$MtCO_2$ (relative to 2013)
Oil: 32%	Oil: 3%	Total GHG: -26.0%	Total energy-related CO_2: 927 (-308)
Coal: 25%	Coal: 26%	Energy-related CO_2: -21.9%	Industry: 401 (-29)
Natural gas: 18%	Natural gas: 27%	Other GHGs: -1.5%	Commercial: 168 (-111)
Nuclear: 11-10%	Nuclear: 22-20%	Sink: -2.6%	Residential: 122 (-79)
Renewables: 13-14%	Renewables: 22-24%		Transport: 163 (-62)
			Conversion: 73 (-28)

Notes: Among industry and energy conversion sectors, major sub-sectors have individual commitments not formally included here. For example, emissions reduction targets by sub-sector are: iron & steel – 9 $MtCO_2$ from baseline; chemicals – 2 $MtCO_2$ from baseline; paper & pulp – 2.86 $MtCO_2$ from baseline; cement – energy-intensity improvement of 49 MJ/t-cement relative to 2010. These are voluntary commitments under the Japan Business Federation's (*Keidanren's*) 'Commitment to a Low Carbon Society'.

Source: Document submitted to the Government Committee on Japan's INDC, 30 April 2015.

3 The importance of accepting diversified views: The ideal versus the reality

Here we argue that for any policy to be effective and feasible, it is necessary to pay full attention to the diversity of each country's situation, values, and culture. Pursuing the idealistic situation may not necessarily lead to the expected outcome. We also stress the importance of balanced views between combatting climate change and satisfying basic human needs.

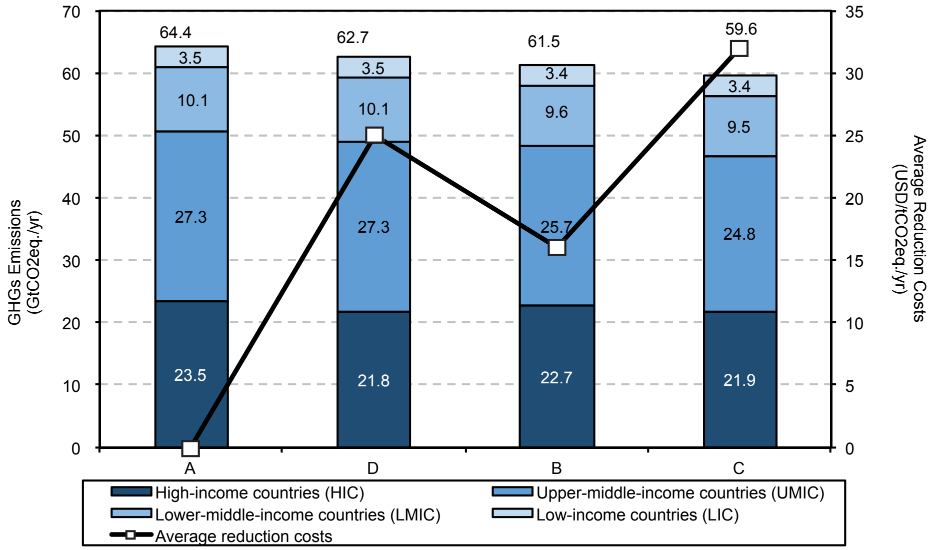
3.1 Analysis of the restrictions of financing for new coal-fired power plants

In June 2013, President Obama called for an end to US public financing of new coal power plants overseas that emit more than 500 gCO_2/kWh (White House 2013). This was a de facto ban on public financing for any new non-CCS coal power plant, excluding in the least developed countries. Several European countries and international institutions, including the World Bank, followed suit. The US, jointly with the UK and the Netherlands, proposed almost the same kind of restrictions on public financing of new coal plants to the OECD (White House 2014). The purpose of this is to reduce global CO_2 emissions. The policy will be very effective in achieving the objective if it works well and if the reduction of emissions in developing countries is prioritised over keeping the lights on. This will not be the case in developing countries, so we need to look for the second-best scenario.

Nagashima et al. (2015), using the DNE21+ model (Akimoto et al. 2010), shed light on the efficacy and efficiency of this policy. The authors compared four different cases focusing on GHG emissions and average reduction cost (see the definition of scenarios in Figure 1). Under case A, no ban is imposed (all new coal plants are eligible for public financing). Under case B, only new, high-efficiency coal power plants such as ultra supercritical (USC) and integrated coal gasification combined cycle (IGCC) plants are eligible for public financing. Case C corresponds to the imposition of the proposed ban (all new non-CCS coal power plants are excluded from public financing). Under case D, it is assumed that the ban by developed countries will have no effect in developing countries, as upper-middle-income countries (e.g. China) and some lower-middle-income countries (e.g. India) can finance building new coal power plants for themselves as well as for lower-middle-income and lower-income countries.

Figure 1 shows the global GHG emissions in 2030 under the different scenarios ranked by descending order of total GHG emissions in 2030 by income group, along with the corresponding average reduction cost relative to the BAU scenario (case A). It is clear that global emissions in case C are the lowest, followed by cases B, D and then A. In this sense, the de facto ban on public financing by developed countries should be the most idealistic policy to reduce global emissions among the cases discussed here. Emissions for case C in 2030 are 4.8 $GtCO_2eq$ (a figure 3.2 times Japan's emissions in 2013) below those in case A. When it comes to cost, however, case C is the highest.

Figure 1 GHG emissions and average reduction cost in 2030 for coal-fired plants under different scenarios



Notes: Country classification follows the World Bank classification, in which China is a UMIC whereas India is an LMIC. Scenarios are ranked by descending order of GHGs emissions. Case A: All new coal plants are eligible for public finance (BAU) Case B: Only new, high-efficiency coal power plants are eligible for public financing; Case C: Only new coal power plants with CCS are eligible for public financing; Case D: de facto ban by developed countries (i,e. case C) has no effect on new coal power plants in developing countries. In case D, it is assumed that developed countries will only build new coal power plants with CCS. Hence the emissions reduction of 1.7 $GtCO_2eq.$ in case D relative to case A (BAU) is solely realised by HICs.

Source: Nagashima et al. (2015).

What matters here is whether case C is realistic or not; in other words, will it be implemented as is? We have to note that maintaining economic growth and keeping the lights on are crucial needs, especially in developing countries. Yang and Cui (2012) found that three-quarters of new coal plants are expected to be built in China and India. They may be able to finance these by themselves if they wish, and China in particular may also be able to finance other coal power plants in other developing countries. In that case, it may be plausible to build less expensive, low-to-medium efficiency coal power plants to secure a stable supply of electricity, unless the China-led Asian Infrastructure Investment Bank (AIIB) follows the policy of developed countries on public funding, which is rather unlikely. Hence enforcing the de facto ban policy may result in case D above. In this case, from the viewpoints of both emissions reductions and average reduction cost, case B, which allows public financing for high-efficiency coal power plants, is better than case D.

The analysis shows that each country or region has its priorities, and enforcing an idealistic policy based on the views of developed countries may not be the best way to achieve the initial objective, let alone to confront the issue of equity as emphasised by Collier (2015) in his contribution to this eBook.

3. 2 Japan's experience with the voluntary initiative as a measure to respond to climate change

Japan, unlike other major economies, relied upon the voluntary initiative to implement its commitment under the Kyoto Protocol as far as emissions from energy and industry sectors are concerned. The initiative (called the Keidanren Voluntary Action Plan), in which 61 sectors participated, not only had no provisions for penalties but was also not a voluntary 'agreement' between the government and industry sectors. It was a unilateral commitment that industry as a whole committed to as an endeavour to stabilise its annual average emissions for 2008–2012 at the 1990 level, with each sector assuming its own target. This initiative was incorporated as one of the central measures into Japan's Kyoto Target Implementing Plan. In total, average emissions for the period were 12.1% (9.5% without credits) below 1990 levels. This does not necessarily mean that the initiative was environmentally effective, as various other factors affect emissions and we do not know what BAU emissions would have been without this policy.

Tokushige et al. (2015) analysed the emissions of major sectors and found that each sector had tried hard to implement its own target. While the energy intensity of many sectors was improved, there were a few sectors where emissions increased or energy intensity worsened. However, even in the latter case, the authors found that this was due to the impact of fluctuations of economic activity surpassing their efforts. In this sense, the voluntary initiative was environmentally effective, if not cost-effective, in Japan (see also IPCC 2014 and Purvis 2009). No other major country used the voluntary agreement as the central measure for industry in coping with climate change. As a matter of fact, voluntary agreements on climate change in the early days in Europe (e.g. German industry's voluntary agreement in 1995 and the UK's Climate Change

Agreement in 2000) did not work as expected, mainly due to lack of communication between industry and government (Yamaguchi 2012).[3]

Why, then, did the voluntary initiative without any legal penalty work in Japan? There are several reasons: information sharing between industry and the government (the key factor for evaluating whether levels of targets are challenging or not); regular reviews of compliance status by government committees; high efficacy of 'name-and-shame' in Japanese society; high willingness to avoid governmental intervention; and industry's dislike of economic incentives (Yamaguchi 2012, IPCC 2014).[4] As a matter of fact, industry's voluntary commitment will again be one of the major instruments for implementing Japan's INDC.

The above experience shows that policymakers, in planning their domestic response strategies, should take into careful consideration their countries' political, economic, cultural and traditional situations in order that they may work well. Likewise, they should also accept diverse values when evaluating other countries' policies. The best policy in theory does not necessarily end up with the best outcome.

4 Japan's contribution to tackling climate change: The 'Action for Cool Earth' initiative for technology development and diffusion

In order to stabilise the temperature at any level, we have to achieve near-zero emissions in the long run. According to the IPCC Fifth Assessment Report (AR5), in order to limit the GHG concentration at 430–530 ppm CO_2eq., which almost corresponds to a 2°C

3 Take the UK's Climate Change Agreement that started in 2000. A total of 44 sectors entered into agreement with the government with 'challenging' targets for 2010. In 2002, only two years since the scheme started, 13 sectors had already achieved their 2010 target. If the government knew each sector's real emissions figures, this may have never happened. Also note the steep decline of the price of carbon in the EU Emissions Trading Scheme (EU ETS) when actual emissions figures were disclosed.

4 Most industry leaders feel that promoting R&D and long-term investment is the key to coping with climate change, and complying with their obligations by purchasing permits or paying tax would work as a disincentive for this purpose. As this may be the cheap way to satisfy their obligation, this may impede R&D and long-term investment. This is a matter of comparison, but generally speaking Japanese industry leaders put more value on the long-term view than the short-term one.

rise by 2100, marginal abatement costs will be about \$1,000–3,000 per tCO_2 in 2100 (IPCC 2014, Figure 6.21). The high costs may be interpreted as meaning that the target will be extremely costly unless new innovative technologies, unknown at this moment, emerge and revolutionary change occurs within society.

Recognising the above, the Japanese government has already launched the Action for Cool Earth initiative that focuses on, but is not limited to, innovations and diffusions of climate friendly technologies. In line with the emphasis on technology innovations, Prime Minister Shinzo Abe initiated in 2014 the Innovation for Cool Earth Forum (ICEF). The Forum hosted the first international conference in Tokyo in 2014 and is scheduled to host one every year in Tokyo.[5]

As to diffusion of state-of-the-art energy-efficient technologies, Japan has advocated a so-called sectoral approach, one of the bottom-up approaches, for several years. High energy efficiency has been achieved in many sectors among energy conversion and energy-intensive industries in Japan (Oda et al. 2012), and these experiences will contribute to global energy efficiency improvements in various sectors through global and regional sectoral cooperation for this purpose. For example, the expected global emissions reduction potentials are about 2.1, 0.43, and 0.18 $GtCO_2$ in the power, iron and steel, and cement sectors, respectively, through the broad diffusion of high energy-efficient technologies throughout the world (Akimoto 2012). Large differences in marginal abatement costs across countries may act as an impediment to realising such emission reductions, as the situation will induce industrial relocation from Japan to other countries, which will result in increased global emissions. Fair and equitable emissions reduction efforts among participants are important also from this viewpoint (see Aldy and Pizer 2015). The sectoral approach focuses on the real energy-saving and emissions reduction activities of each sector, and this way of thinking is also essential for setting each country's INDC. Note that this is quite different from the sectoral crediting mechanism, in that credit acquisition is not the purpose of the activities. One of the early platforms to advance public/private sector-based partnership was the Asian Pacific Partnership (APP), which aimed to share best practices in targeted energy-

5 See www.icef-forum.org/.

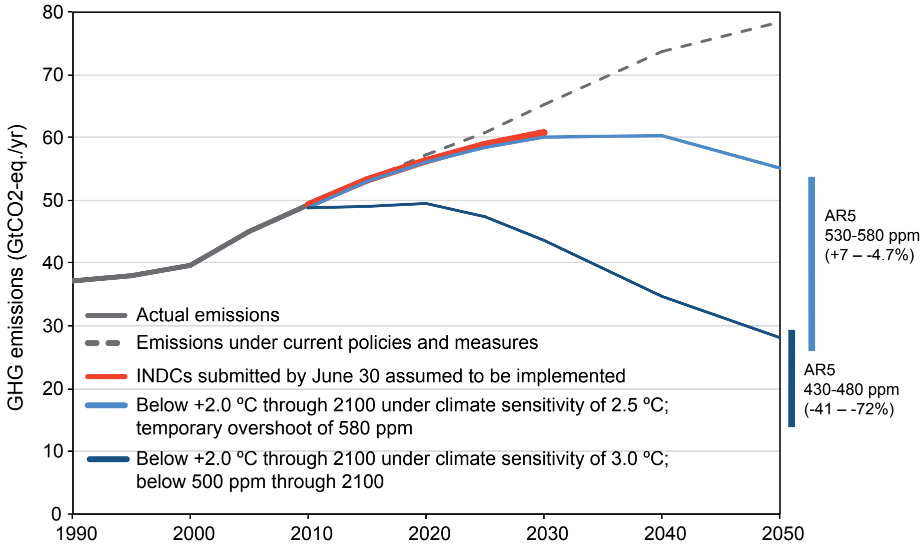
intensive sectors – such as iron and steel and cement – among seven countries, including the US, China, India, and Japan (Okazaki and Yamaguchi 2011). The Global Superior Energy Performance Partnership (GSEP) is now following many of the activities of APP. GSEP is working to accelerate energy-efficiency improvements in industrial and large building sectors. Other examples of the global sectoral approach can be seen in the marine and air transport sectors, i.e. in the International Maritime Organization and International Civil Aviation Organization (Yamaguchi 2012). The UNFCCC framework is important because it covers almost all countries, but multiple frameworks including the bottom-up approach for specific sectors will also contribute to effective emissions reductions.

6 The proposal of Japanese experts: Revisiting climate sensitivity

As described in Section 1, the challenges to achieving the 2°C target are enormous, if not impossible, and imply that current emissions levels need to be reduced by 40–70% by 2050 (IPCC 2014). The Paris agreement, based on each country's pledge – including that of the US, China, EU, Japan, and so on – will never be enough for this purpose.

It is noteworthy, however, that there is implicit evidence (Rogelj et al. 2012, IPCC 2014, Schaeffer et al. 2015) that the 40-70% reduction suggested in AR5 was based on the assumption that a best estimate or median value of climate sensitivity was 3°C (the same value as AR4), even though the likely range of climate sensitivity was lowered to 1.5–4.5°C in AR5 (from 2–4.5°C in AR4) and experts could not agree on any value of best estimate in AR5 (it was 3°C in AR4). Recent observation-based studies on climate change, however, tend to show lower climate sensitivity and best estimates (IPCC 2013, Otto et al. 2013, Lewis and Curry 2014).

Figure 2 Consistency of individual country's INDCs and the path to the 2°C target



Notes: The figure shows estimated emission pathways toward 2050 by the DNE21+ model (a global model with 54 disaggregated regions and countries that seeks cost-effective measures on emission reductions) couple with the MAGICC climate model. The grey dotted line shows the emissions pathway under current policies, the light blue line shows the emissions pathway that limits the temperature increase below 2°C over the 21st century under a climate sensitivity of 2.5°C, which corresponds to the scenario of a slight temporal overshoot of 580ppm CO_2eq. concentration. Temperature is expected to stabilise below 2°C in the long run. The dark blue line shows the emissions pathway that limits the temperature increase to below 2°C over the 21st century under a climate sensitivity of 3°C, which corresponds to the scenario under which the concentration stays below 500ppmCO_2eq. up to 2100. Temperature is expected to stabilise below 2°C even under a climate sensitivity of 3°C. The red line shows emissions until 2030 based on the assumption that individual country's INDCs (Canada, China, EU, Japan, Mexico, Norway, Russia, South Korea, Switzerland and US) known at the end of June will be implemented. In all scenarios, we assumed China's emissions in 2030 to be 16.7 $GtCO_2$eq. based on CO_2/GDP improvement ratio of 65% and annual GDP growth ratio of 6.2%. The US pledge covers only until 2025 and comprises two targets, i.e. 26% and 28% emissions reduction relative to 2005. We assumed here that the 28% emissions reduction will be implemented by 2025, thereafter with a linear interpolation to 80% reduction in 2050.

Source: Research Institute of Innovative Technology for the Earth.

What will happen if the best estimate is less than 3°C? What we found with the RITE DNE21+ and the simple climate change model, called Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC), is that once the best estimate is selected (for example, 2.5°C), the 2°C target will be within reach with the pledge-based Paris agreement (see Figure 2), so the agreement will become workable and feasible. Under this situation, we propose revisiting climate sensitivity and its best estimate to reduce uncertainty in decision-making by global leaders. We also argue that we should decouple the 2°C target and the 40–70% reduction. Sticking to the 2°C target and the 40–70% global emissions reduction by 2050 based on 3°C climate sensitivity without reviewing them would lead to a weak strong target that might collapse. We need a strong weak target that may be implemented as a second best policy to a strong strong target. And for this purpose, the promotion of technology innovations and diffusion will be the ultimate solution. This is the background to the initiation of ICEF.

References

Akimoto, K., F. Sano, T. Homma, J. Oda, M. Nagashima and M. Kii (2010), "Estimates of GHG emission reduction potential by country, sector, and cost", *Energy Policy* 38: 3384-3393.

Akimoto, K. (2012), "Potential for Energy Efficiency Improvement and Barriers", in M. Yamaguchi (ed.), *Climate Change Mitigation, A Balanced Approach to Climate Change*, London: Springer, pp. 161-177.

Aldy, J. E. and W. A. Pizer (2015), "Comparing emission mitigation pledges: Metrics and institutions", Chapter 12 in this volume.

Collier, P. (2015), "Curbing carbon without curbing development", Chapter 29 in this volume.

IPCC (2013), *Climate Change 2013: The Physical Science Basis* (see IPCC (2013a) in the introduction to this book for the report's complete reference).

IPCC (2014a), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's complete reference).

Lewis, N. and J. A. Curry (2014), "The implications for climate sensitivity of AR5 forcing and heat uptake estimates", *Climate Dynamics* 45(3-4): 1009-1023.

Nagashima, M., T. Honma, F. Sano, K. Akimoto, J. Oda, T. Tomoda and K. Wada (2015), "Assessment of U.S. restrictions on public financing for new coal-fired power plants overseas and proposed regulation", *Proceedings of the 31st Conference on Energy, Economy, and Environment*, Osaka: Japan Society of Energy and Resources, pp. 595-598 (in Japanese).

Oda, J., K. Akimoto, T. Tomoda, M. Nagashima, K. Wada and F. Sano (2012), "International comparison of energy efficiency in power, steel and cement industries", *Energy Policy* 44: 118-129.

Okazaki, T. and M. Yamaguchi (2011), "Accelerating the transfer and diffusion of energy saving technologies, steel sector experience – Lessons Learned", *Energy Policy* 39: 1296-1304.

Otto, A., F. E. L. Otto, O. Boucher, J. Church, G. Hegerl et al. (2013), "Energy budget constraints on climate response", *Nature Geoscience* 6: 415–416.

Purvis, N. (2009), "Blueprint for a transatlantic climate partnership", Climate & Energy Paper Series 09, The German Marshall Fund of the United States.

Rogelj, J., M. Meinshausen and R. Knutti (2012), "Global warming under old and new scenarios using IPCC climate sensitivity range estimates", *Nature Climate Change* 2: 248–253.

Schaeffer, M., L. Goharc, E. Krieglerd, J. Lowec, K. Riahie and D. van Vuuren (2015), "Mid- and long-term climate projections for fragmented and delayed-action scenarios", *Technological Forecasting and Social Change* 90: 257–268.

Tokushige, K., K. Akimoto, J. Oda and T. Homma (2015), "Analysis on Emission Reduction Efforts of GHG Emissions in Japan for the First Commitment Period of the Kyoto Protocol", *Journal of Japan Society of Energy and Resources* 36(2) (in Japanese).

White House (2013), *The President's Climate Action Plan*, Washington, DC: Executive Office of the President, June.

White House (2014), *President Obama's Climate Action Plan – Progress Report*, Washington, DC: Executive Office of the President, June.

WTO (2015), "Trade Profiles", Washington, DC (available at http://stat.wto.org/CountryProfile/WSDBCountryPFReporter.aspx?Language=E, accessed 19 April 2015).

Yamaguchi, M. (2012), "Policies and Measures", in in M. Yamaguchi (ed.), *Climate Change Mitigation, A Balanced Approach to Climate Change*, London: Springer, pp. 129-159.

Yang, A. and Y. Cui (2012), "Global coal risk assessment: Data analysis and market research", WRI Working Paper, World Resources Institute, Washington, DC.

About the authors

Mitsutsune Yamaguchi is an environmental economist and special advisor at the Research Institute of Innovative Technology for the Earth (RITE). Previously a Professor at Keio University and a Visiting Professor at the University of Tokyo until March 31, 2015. He was a member of several governmental committees on climate change, is presently vice chair of the Joint Working Party on Trade and Environment, Organization for Economic Co-operation and Development (OECD), and has also contributed as a lead author in IPCC Working Group III for the third, fourth, and fifth assessment reports. He has written many books and articles including *Climate Change Mitigation, A Balanced Approach to Climate Change* (Springer, 2012), of which he was editor and a co-author. He also frequently writes articles to leading Japanese newspapers on climate change.

Keigo Akimoto is the Group Leader of the Systems Analysis Group, Research Institute of Innovative Technology for the Earth (RITE). He was a guest Professor at the Graduate School of Arts and Sciences, the University of Tokyo in FY2010-14 and a Lead Author in IPCC Working Group III for the Fifth Assessment Report. He is a member of several advisory bodies on energy and environmental policy for the Japanese government, including the Strategic Policy Committee of Advisory Committee for Natural Resources and Energy, the Global Environment Subcommittee of the Industrial Structure Council, and the Climate Change Impact Assessment Subcommittee of the Central Environment Council. He is also an associate member of the Science Council of Japan. He holds a PhD.

9 A view from Europe

Roger Guesnerie
Collège de France and Paris School of Economics

This chapter starts with an overview of the climate actions implemented in Europe as a response to the Kyoto Protocol, organised around the creation of the EU Emissions Trading Scheme. The discussion stresses the problems faced by the newly created carbon market and explains its disappointing outcome. The chapter then recalls the political and legal background of the initial European choice for an industry-limited market and briefly presents the intellectual debate on the relative merits of a 'carbon market' and a 'carbon tax' as a regional climate policy. The European story illustrates some of the general difficulties behind the implementation of an ideal global climate treaty. The discussion then evokes the solution by economic considerations alone, a kind of 'super-Kyoto' whose implementation would require the action of a powerful benevolent world planner. With utilitarian objectives, such a solution would go together with a strongly redistributive allocation of national quotas. This 'grande rivière' ('big river') is unfortunately utopian. What are the 'petits ruisseaux' ('small streams') that can be launched as partial substitutes? In between, can we expect 'petites rivières' in the form of climate clubs to emerge? The chapter concludes with a discussion emphasising the underlying difficulties, in particular (i) providing compensation and incentives to developing countries; (ii) making trade and environment policies compatible; and (iii) facing the possible occurrence of the 'green paradox', a reflection of the complex interactions between the markets for fossil fuels and climate policies.

The European Union's climate policy: Some key aspects explained

Under the provisions of the Kyoto Protocol, the European Union as a whole was committed to reducing its emissions by 8% by 2012, compared with 1990. Following a redefinition of member states' objectives, negotiated to be legally binding, a common policy was introduced.

This policy has several strands. On the one hand, the directives focused on 2020 and proposed targets relating to the role of renewable energy sources in the energy mix – 20% to be specific – and to improving energy efficiency. On the other hand, and this was the most dramatic innovation, a market for emissions allowances was established: the European Union Emissions Trading System, commonly known by its abbreviation, EU ETS. This trading system encompasses 11,000 industrial plants and power stations across 27 countries. It covers around 50% of the EU's CO_2 emissions[1] and is the world's largest carbon credits mechanism.

EU ETS: Past and future

Following a pilot phase (Phase 1) launched in 2005, the mechanism entered into force. This was Phase 2, which coincided with the 2008–2012 commitment period of the Kyoto Protocol. A total allowance is divided between member states, who allocate their national allowances according to common criteria based on previous emissions and sector-specific facilities.

In Phase 2, allowances were, for the most part, allocated for free; a small proportion (5% in 2012) was sold via auction. Last but not least, the companies involved can also seek carbon credits from the Kyoto Protocol project mechanisms (such as, for example, the Clean Development Mechanisms, or CDMs).

Phase 3,[2] which will run from 2013 to 2020, introduces or will introduce a series of modifications, the main elements of which are outlined here. First, the process of

1 And 40% of its greenhouse gas emissions.
2 This is part of the approach to reduce emissions by 20% by the end of the period.

auctioning off allowances will be significantly expanded, but in principle adjusted for different sectors depending on their exposure to the risk of 'carbon leakage'. Then, the total allowance at the European level is set to be linearly reduced each year. Finally, allowances may be placed in reserve or withdrawn, depending on the trends observed, particularly with regard to the economic situation.

This is a brief overview of the mechanism and planned developments, which take account of an experience which has been, to say the least, disappointing. Price trends on the market are, in this regard, illuminating. After reaching €30 per tonne of CO_2 at the beginning of the preliminary phase, prices inevitably fell to zero by the end of the phase. More significant changes were seen in Phase 2. Starting at €15 per tonne of CO_2 at the beginning of Phase 2, the price began to collapse from March 2011, often falling below €5 per tonne. This is not at all surprising if we consider the huge number of allowances, in millions of tonnes, held by companies in 2012: 2,049 million tonnes in free allocations and around 100 million tonnes auctioned off, to which must be added the Kyoto credits (almost 500 million tonnes), which greatly exceed verified emissions (1,867 million tonnes) (Gloagen and Alberola 2013).[3] It is therefore primarily the option of transferring allowances between periods that supports a positive price. Of course, what can be seen here must be termed a serious failure of the trading system – the incentive effect of a CO_2 price of €4 per tonne in terms of implementing significant 'decarbonisation' measures is close to zero. Indeed, existing studies suggest that the reduction in CO_2 emissions within the EU ETS area (which were down 12% during the period 2008–2012) could be explained firstly (up to 30%) by the post-crisis economic context (Gloagen and Alberola 2013), and secondly (50–60%) by the positive effects of the increased use of renewables and progress in energy efficiency.

How can this poor performance be explained? First of all, it is worth looking at certain aspects of the design of the trading system; here, the link established with the Kyoto Protocol project mechanisms. The link, no doubt already problematic in the initial Kyoto mechanism (which saw the establishment of a trading system between states), is even more questionable in the system that actually resulted. Control over the total number of allowances in circulation, a key element of the rationale behind the trading

3 Moreover, the gap has grown since 2008, and is likely to be 1,742 million tonnes over the period.

system if the manuals are to be believed, is becoming more uncertain. This is only part of the story; we must, of course, add the fact that allowances were allocated too generously and without taking account of the economic climate. And this is before we consider the unknowns surrounding the future of the quantities allocated on a longer-term basis, bringing even greater uncertainties with regard to prices.

The changes introduced in Phase 3, which have been briefly presented, seek to respond to these challenges, but without necessarily inspiring optimism. The issue is that in a market which is complex but limited to a subset of emitters, the problems of governance are more difficult to manage than it might seem, and this despite the introduction of an extremely unwieldy administrative structure which is also – there is no point trying to hide it – particularly opaque from the point of view of external observers.[4]

Why does the trading system exist? A look back at the beginning

Given this experience, it is worth revisiting the choice that was made to establish a trading system.

Why a trading system rather than a carbon tax? The issue is considered here at the country level, or at the level of a group of associated countries. The analysis does not prejudge the relative merits of a trading system and a tax at the global level, a largely independent issue to which I will return shortly.

A carbon tax has and would have had, at the European level, obvious advantages. First of all, it encompasses all stakeholders, households and companies. The amount of the tax and its evolution over time can be made public, with a credibility which reflects the credibility, assumed to be good, of the authority which is implementing it. Last but not least, this option would guarantee a form of equalisation between countries of the efforts made, somewhat of a blind spot in the current policy,[5] which lacks clarity on both the procedures for the national allocation of allowances and the variations between the national policies which complement that allocation.

4 One example of this opaqueness is the allocation of allowances between sites and between countries.
5 Also the subject of a communications effort which has, to put it mildly, been poor.

Given the fact that all or the majority of allowances were allocated for free, the system is and has been popular with companies, and it is true that a system of differentiated exemption thresholds within the framework of a carbon tax, which would be able to mimic the effects on corporate profits of partly or completely free allowances, is difficult to implement. One point for the trading system, even if the completely free nature of allowances initially goes far beyond what economic expertise would advocate (see Guesnerie et al. 2012).

It is also worth noting that all else being equal, and in particular when the carbon tax and the trading system price are equal, the effects on the relative competitiveness of industries are identical. In both cases, the argument for putting in place border adjustment measures has the same force and raises problems which, while not identical, are not materially different.

To sum up, by its universal nature and apparently superior capacity to establish and better coordinate the price expectations of agents, a carbon tax could appear to be the solution, despite the probable preference of companies. I am one of those who believe this to be the case: at both the national and the regional level, a carbon tax solution is better than a market solution, even if it may be part of the broader framework of the Kyoto trading system (see also Cooper 2008, Gollier and Tirole 2015).

The reason why Europe adopted the trading system had nothing to do with an analysis of the relative merits of the two solutions, however. It reflects a legal provision (which ignores the close relationship that economic analysis ascribes to the trading system and the tax) whereby creating an EU-wide tax requires unanimity, while setting up a trading system can be done by majority. The choice was dictated by legal feasibility, but also indirectly reflects political feasibility. As we have noted, since the allowances are partly free, the trading system is strongly preferred by companies – and therefore by industrial lobby groups. And a carbon tax which affects consumers incites a great deal more hostility from the public than a trading system whose effect on prices is less direct and probably less noticeable in terms of redistribution. The fate of the French carbon tax is illuminating in this regard, and it can be assumed that there was fairly widespread resistance to a carbon tax approach in the various EU member states.

If we follow my argument, then, the creation of the EU ETS can be seen as the implementation of a second-best or even third-best solution, if we highlight the fact that it has been much more difficult than expected to get the system to operate effectively. This implementation reflects the favourable political context at the time that it was introduced, and the resilience of the system – when it is clear that many countries have only limited enthusiasm for implementing a climate policy – is worth noting.[6]

Climate policy around the world

A great river – a utopian ideal?

The EU ETS is what one might call a 'small stream' contributing to the fight against climate change. Will the existing small streams, along with those which will be developed in the future, feed into a 'great river' able to support a climate policy which can meet the challenges we are facing?

At this point, it is worth revisiting the idea of what an ideal 'great river' would look like, including the requirements for economic effectiveness as well as for a degree of distributive justice between participating nations.

The objective here is to control emissions, i.e. quantities, and economic expertise advocates charting a path for global emissions levels over the long term, say 30 years, which are compatible with the IPCC analysis on limiting the temperature increase to 2°C.[7] To achieve this, economic expertise strongly suggests implementing a 'cap and trade' system: the global target for year *n* takes the form of a global allowance, broken down into allowances for each participant. The approach is therefore in line with that of the Kyoto Protocol, but with full participation (see also the chapters by Stavins and Sterner and Gunnar in this book).

All that remains is to define the procedures for this super Kyoto by allocating allowances to all countries. Let us allocate them from the point of view of a benevolent planner

6 It is probably worth examining the reasons for this resilience and the part played by the interpersonal skills and activism of the Commission – and perhaps also the opaqueness of the system!

7 A path which may be contingent on the gradual emergence of information.

who is sufficiently powerful to be able to impose these national allowances. It would make sense, in utilitarian logic, to set identical per capita allowances for all countries;[8] countries whose per capita emissions were less than the global average would be the sellers within the trading system and therefore overall beneficiaries, while countries with emissions above the global average would be the buyers. Everyone would see their efforts governed each period by the same global carbon price. Of course, this particular approach of equalising per capita allowances is up for discussion, but it is clearly a logical way of spreading the costs of climate change from a utilitarian standpoint.

Although I have previously advocated for a carbon tax, the solution recommended here is a global market rather than a global carbon tax, which could result in very unpredictable regulation of quantities, if only because of the uncertainties associated with the 'green paradox'. There is no contradiction; again, this 'super-Kyoto' market would establish a carbon price through the trading between states. And this price would serve as a reference for a regional or national carbon tax, which, if one accepts the argument made previously, could – indeed *should* – be laid on top of a global trading system to take over and support it at the regional or national level.

Note that such a system would not be the answer to all problems, far from it, and the voluntary nature of quantities leaves it open to uncertainty regarding the carbon price. The equalisation of spot prices does not establish the desired coordination of expectations regarding the future scenario. The reason for this, of course, is that the scenario is contingent on how quickly new technologies emerge, but also remains subject to the vagaries of the 'green paradox', created by the uncertainties of the policy's effects on the fossil fuel market, and particularly on the development of the income they generate.

Small streams...

So, having taken every possible care in my choice of words, this is what a very successful 'great river' might look like. While everything points to the fact that this would be

8 This would apply all the way along the path. It should be noted that the proposal that Sterner and I made (Guesnerie and Sterner 2009a,b), regarding endorsing an ambitious objective for 2050 today by including a reference to equal per capita emissions rights in 2050, did not receive an encouraging response.

desirable, it is clearly entirely utopian, since the allocation of equal allowances for all countries would be rejected by the most powerful nations. Having described this river, can we say more about the 'small streams' that currently exist and will emerge in the future?

- First of all, why not link the existing small streams (see the chapter by Stavins in this book), specifically the EU ETS, with the Chinese market currently being created and a modest North American market which has been set up between some American states and Canada, and thus make not a great river, but certainly a bigger stream? However, even if we forget some of the shifts in the European market, objections immediately come to mind: the complexities arising from specific[9] and potentially contradictory considerations cannot easily be superimposed, and how can the risk of a race to the bottom among the member systems be avoided?
- Another idea: Why not use the global reference of per capita emissions not to allocate allowances, but to calculate the contributions of each country with above-average emissions to a green fund of one kind or another, which would provide aid to poor countries? This is the option preferred by the Climate Economics Chair at Paris Dauphine University (Perthuis and Jouvet 2015), and if it were accepted, it would amount to the implementation of a sort of global carbon tax at a low rate. The low rates are evidently a factor in making the concept acceptable, and if accepted, could be the beginning of a virtuous circle – a sort of prelude to a global carbon tax (see also the chapter by Hourcade in this book).
- Why not also come to an agreement today on the targets for 2050, and the allocation procedures?[10] Such an agreement would not be terribly binding in one sense, but it would be likely to anchor current discussions on what a desirable long-term future would look like.

9 As is happening with the assessment of the risk of leakage in Europe (see the chapter by Fischer in this book).
10 See note at the bottom of page 11, which refers to the Guesnerie-Stener proposal, which is along these lines.

What about small rivers?

To conclude, it is important to highlight the limits of an ever-increasing number of small streams. There are certainly some useful initiatives here, but in all likelihood, they leave us quite a long way from the approach strongly advocated by economic expertise: the progressive promotion of a single global carbon price.

Going beyond coordinated small streams, some small rivers could of course begin to emerge. The creation of climate coalitions involving several countries or regions adopting some kind of shared climate policy would fit into this category. So let us finish by talking about climate coalitions, their potential weaknesses, and the probable inevitability of a link between trade and the environment.

Both the cost and the effectiveness of a climate policy that is unilateral or still limited to one or more virtuous coalitions are open to debate. In the case of cost, this is due to the risks of carbon leakage: minor risks to the competitiveness of the economy when the carbon price within the virtuous coalition remains within the ranges reached by the EU ETS, and probably significant risks outside these ranges. Effectiveness is affected if, as a result of the green paradox and the difficulties of market regulation, results do not match expectations.

Seeking to link trade and the environment is not in itself a protectionist step, even though it may support such temptations (Guesnerie and Stern 2012, de Melo 2013).[11] Thus, border adjustment mechanisms, which are difficult to set up properly, constitute either a legitimate response or a legitimate and credible threat from a virtuous coalition establishing a meaningful price for carbon among its members. Specifically, this means the coalition restoring a certain accuracy to prices within its economic area. That Europe has not explored and raised this option in international negotiations is no doubt explained by the failure of the EU ETS to establish meaningful prices, but also illustrates the weakness of the EU in moving beyond its prejudices and realising its potential for diplomatic influence.

11 See Guesnerie and Stern (2012) and Melo (2013).

Environmental protection through trade is good for the coalition in the sense that, in principle, it increases its stability. But it in no way increases the appeal of the coalition in question. To increase the appeal of the coalition to nations outside it, it is necessary to introduce a punitive dimension, but not border adjustment! In any case, this is the argument recently put forward by Nordhaus (2015),[12] which shows that the implementation of a measure that is much tougher than border adjustment – in other words, an undifferentiated tax on imports from members outside the coalition – would create, if this tax were high enough, the stable conditions for a system of climate coalitions. The argument and numerical simulations underlying the study are complex. But the sanction for the 'stowaway' escaping the virtuous coalition is clear: a loss of external revenue that can only be avoided by joining the coalition. This is not about restoring accurate prices within the coalition, as a border adjustment would do, but about sanctioning, through restrictions on trade not linked to the carbon content of the products traded, those who do not join the coalition. This study merits consideration. In the absence of the benevolent dictator sought above, adherence to a climate policy would involve retaliatory measures with an impact beyond the scope of the climate policy. There is a certain naivety in being surprised by this, even if there are questions regarding the plausibility of the emergence, should it be necessary, of such a confrontational policy, the benefits of which would be long term. And I will conclude on this point, which is moving from economic analysis to 'realpolitik', a subject which clearly deserves another contribution!

References

Barrett, S. (1994), "Strategic Environmental Policy and International Trade", *Journal of Public Economics* 54: 325-338.

Barrett, S. (1997), "The Strategy of Trade Sanctions in International Environmental Agreements", *Resource and Energy Economics* 19: 345-61, 1997.

Cooper, R. N. (2008), *The Case for Charges on Greenhouse Gas Emissions*, The Harvard Project on International Climate Agreements.

12 Following an argument reminiscent of that previously presented by Barrett (1994, 1997).

de Perthuis, C. and L.-A. and Jouvet (2015), "Les voies d'un accord climatique ambitieux en 2015", Opinions et débats, Institut Louis Bachelier.

de Melo, J. (2013), "Le Commerce dans une stratégie de développement axée sur la 'croissance verte' : problèmes et enjeux", *Revue d'économie du développement* 2: 25–58.

Fischer, C. (2015), "*Options for avoiding carbon leakage*", Chapter 21 in this book.

Gloagen O. and E. Alberola (2013), "Plus d'1 milliard de tonnes de CO_2 évitées depuis 2005 en Europe: 50 % du fait des politiques énergie-climat et 50 % du contexte économique", *Point Climat* No. 32, CDC Climat recherche.

Gollier, C. and J. Tirole (2015), "Negotiating Effective Institutions Against Climate Change", mimeo, Toulouse School of Economics.

Guesnerie R., F. Henriet and J. P. Nicolai (2012), "Trois questions épineuses à l'arrière-plan des politiques climatiques", *Annales d'Economie et Statistique*, Special Edition.

Guesnerie, R. and N. Stern (2012), "Deux économistes face aux enjeux climatiques", in *Savoirs et Débats Économiques*, Paris: Editions le Pommier.

Guesnerie, R. and T. Sterner (2009), "Big advantage of discussing 2050", *Financial Times*, 9 November.

Guesnerie, R. and T. Sterner (2009), "Fixons à 2050 la réduction de 50% des émissions de CO_2", *Le Monde,* 20 November.

Hourcade, J.-C. (2015), "The case for carbon-based monetary instruments", Chapter 34 in this book.

Nordhaus, W. (2015), "Climate Clubs: Overcoming Free Riding in International Climate Policy", In *American Economic Review*, 105(4), 1–32.

Stavins, R. N. (2015), "Linkage of regional, national, and sub-national policies in a future international climate agreement", Chapter 20 in this book.

Sterner, T. and G. Köhlin (2015), "Pricing carbon: The challenges", Chapter 18 in this book.

About the author

Roger Guesnerie is the former holder of the *Théorie économique et organisation sociale* chair at Collège de France, and president of the Paris School of Economics. He has taught in many places in France (EHESS) and elsewhere (for example, at the London School of Economics). His intellectual interests range from public economics to general equilibrium, from the theory of mechanisms to expectational coordination. He has been involved in six books on climate policies, including a 2003 report to the French prime minister, a 2005 MIT Press book co-edited with Henry Tulkens, and a 2012 general audience piece written with Nicholas Stern. Roger Guesnerie has been a member of the editorial board of some influential journals (in particular, he was co-editor of *Econometrica* from 1984 to 1989). He has served as president of several societies including the European Economic Association in 199 and, the Econometric Society in 1996. He was awarded the Médaille d'Argent of the CNRS in 1993 and is an Honorary Foreign Member of the American Economic Association since 1997, and a member of the American Academy of Arts and Sciences since 2000.

10 A view from the United States

Matthew J. Kotchen
Yale University

The US plays an important role in international negotiations on climate change. Fortunately, the role of the US has evolved from that of laggard to leader. Having reduced emissions significantly in recent years, the US is promising substantially more and encouraging other countries to do the same as part of the next international agreement. In this chapter, I provide a high-level view on the state of climate-change affairs from the US perspective. My aim is to briefly cover selected topics that help explain progress, opportunities, and challenges for the US. The topics include public opinion and domestic politics; trends in domestic emissions and policy; the US's Intended Nationally Determined Contribution (INDC) and the importance of matching ambition; climate finance; and expectations for success in Paris.

The US plays an important role in international negotiations within the United Nations Framework Convention on Climate Change (UNFCCC). Representing the world's largest economy as measured in unadjusted GDP, and the largest historical emitter of greenhouse gases, buy-in from US is critical for a workable and effective climate regime. Fortunately, the role of the US has evolved from that of laggard to leader. Having reduced emissions significantly in recent years, the US is promising substantially more and encouraging other countries to do the same as part of the next international agreement.

In this chapter, I provide a high-level view on the state of climate-change affairs from the US perspective. While other chapters in this eBook cover specific topics in detail, my aim here is to briefly cover selected topics that help explain progress made by the US as well as opportunities and challenges facing the country. The topics include public opinion and domestic politics; trends in domestic emissions and policy; the US's

Intended Nationally Determined Contribution (INDC) and the importance of matching ambition; climate finance; and expectations for success in Paris.

1 Public opinion and domestic politics

A view from the US must begin with observations about American public opinion. This is important not only because the US is a representative democracy, but also because of sharp differences between the two major political parties, the Democrats and Republicans. The differences shape the current dynamic between the executive and legislative branches of the US government, as well as the approaches being undertaken to address climate change both domestically and internationally.

A recent poll found that about two-thirds of American registered voters think that global warming is happening, support laws to increase renewable energy and energy efficiency, support setting emission limits on coal-fired power plants, and think the US should reduce greenhouse gas emissions regardless of what other countries do (Leiserowitz et al. 2014). Although climate 'sceptics' or 'deniers' often capture media attention, the majority of Americans believe that climate change is real and warrants political action.

Beneath the majority view, however, is political polarisation. According to the same poll, 81% of Democrats are 'worried' about global warming, compared to only 30% of Republicans. Some 69% of Democrats think global warming is caused by human activities, whereas only 31% of Republicans think the same. When it comes to support for political action, 60% of Democrats say the federal government should be doing more to protect people from global warming, while the comparable number is 21% for Republicans. Among self-identified conservative Republicans, the view is even quite different: 42% think the federal government should be doing even less than it is now.

President Obama has identified climate change as a top priority for the remainder of his term in office, and his Democratic administration is taking the lead on a range of domestic and international initiatives. At the same time, the Republican-controlled Congress, including both the Senate and the House of Representatives, does not support the initiatives and, in many cases, is aggressively seeking to prevent the agenda from advancing. This dynamic has shaped the particular ways that climate policy has progressed in the US, and the political landscape appears unlikely to change in the near future. Current electoral forecasts are for the Democrats and the Republicans to maintain control of the White House and Congress, respectively.

2 US emission trends and domestic policy

As part of the 2009 Conference of the Parties to the UNFCCC in Copenhagen, the US pledged to cut its CO_2 and other GHG emissions to 17% below 2005 levels by 2020. How are things progressing towards that goal?

2.1 Emission trends

Energy-related CO_2 emissions, which comprise the vast majority of all emissions in the US, are the lowest they have been for 20 years. Actual emissions in 2013 were 10% below 2005 levels (EIA 2015a). This reduction is more than half way towards the 2020 commitment and, importantly, it occurred over a period when energy-related CO_2 emissions worldwide have increased by 20% (EIA 2015b).

One reason for the significant reduction in US emissions since 2005 is the Great Recession that began to take hold in 2008. This was the most significant economic downturn since the 1930s, and forecasts predict the US economy will not return to potential levels for years to come. A clear consequence has been lower emissions. One estimate attributes about half of the emissions reduction through 2012 to the recession (CEA 2013). Unfortunately, while helping to achieve emission goals in the short term, lower economic activity is not a strategy for lower emissions in the future.

Another important factor has been a lowering of the carbon content of energy, primarily due to the increased supply of domestic natural gas. The technological combination of horizontal drilling and high-volume hydraulic fracturing has significantly increased the amount of economically recoverable natural gas in the US. Most of the gas has been used for electricity production, crowding out production from more carbon-intensive coal-fired power plants. This shift is responsible for about 28% of the US emission reductions since 2005 (CEA 2013). Also playing an increasingly important role are non-hydro renewable sources of energy for power generation. The US now produces 7% of its electricity from non-hydro renewables, compared to just 2% in 2005 (CEA 2015).

A third factor contributing to lower CO_2 emissions in the US is economy-wide energy efficiency. One measure of efficiency is energy intensity, which captures the amount of energy used to produce a dollar's worth of GDP. For decades, US energy intensity has decreased by more the 1.5% per year, and this alone accounts for an estimated 8% of the emissions reductions between 2005 and 2012 (CEA 2013). While market forces are a critical factor affecting energy efficiency, as well as the carbon content of energy, government programmes also play an important role.

2.2 Major domestic policy

In June 2013, President Obama announced his Climate Action Plan. Among the Plan's broad range of initiatives, two major policies are designed to reduce emissions in the transportation and electricity sectors. The federal government finalised national standards to double the fuel economy of light duty cars and trucks by 2025, and the rules are expected to reduce total CO_2 emissions over this period by the equivalent of one full year of current US emissions. The just realised final version of the Clean Power Plan calls for a reduction in emissions of 32% below 2005 levels by 2030 (see also Burtraw 2015). This target would imply a further reduction of 20% beyond what has already occurred since 2005.

Most aspects of the Climate Action Plan are taking place under the executive authority of the president and therefore do not require Congressional authorisation. While this has been – and will continue to be – politically controversial, it means that climate policy in the US is being pushed along further than the Republican-led Congress would itself support. Unfortunately, it also raises questions about whether the policies will withstand legal challenges, changes in political leadership, or both. Not only does the uncertainty make planning for future compliance more difficult, it also undermines the confidence that other countries have in US climate commitments.

Not all significant climate policy in the US takes place at the federal level; there is a wide range of policies taking place at the state, regional, and local levels. The most prominent example is California's state-wide goal of reducing emissions to 1990 levels by 2020. At the regional level, nine northeastern states participate in a cap-and-trade programme to reduce emissions known at the Regional Greenhouse Gas Initiative (RGGI). Together, California and the RGGI states account for more than half of the US economy. Additionally, many other states and municipalities have policies and programmes in place that are achieving real emission reductions and serving as policy 'laboratories' for future expansion and refinement.

3 The US's INDC and matching ambition

Most countries are in the process of submitting and refining their climate action commitments to cover the post-2020 period. These plans are the official INDCs that will form the basis of the UNFCCC agreement in Paris. The US made its submission on 31 March 2015.

The overarching US commitment is to reduce economy-wide GHG emissions to 26-28% below 2005 levels by 2025. Meeting this commitment will require a 9-11 percentage point reduction beyond the Copenhagen commitment to 2020 (see also Aldy and Pizer 2015). It also represents a significant reduction from business as usual (BAU), which accounts for what would otherwise be increasing emissions until 2025. From one BAU forecast, the US commitment is to reduce emissions by between 18% and 25% from 2014 levels by 2025 (C2ES 2015). At this stage of the process, the US commitment is generally perceived as representing a reasonably high level of ambition.

It remains to be seen how the US commitment compares to those of other key countries. Many of the most important submissions are still outstanding and reliable comparisons will require careful analysis, which takes time. Yet the outcome of this analysis will be critical to ensure a meaningful agreement in Paris – one with broad participation, substantive commitments, and sufficient matching ambition for all countries to follow through.

Indeed, the best way for other countries to allay concerns about whether US climate commitments will withstand domestic political pressures is to submit and maintain equally ambitious INDCs. Over time, the greatest challenge to advancing an ambitious climate agenda in the US will not be domestic politics, for this is changing along with the majority of public opinion. Instead, as the realities of climate change become ever more certain, the greater concern in the US will be that other countries – especially the large and growing developing countries – will not seek to reduce their own emissions. Without commitments from these countries, it will be difficult to defend a climate agenda in the US that does little to bend the curve of worldwide emissions, yet has adverse consequences for US jobs and competitiveness in a global economy.

4 Climate finance

Climate finance is as an increasingly important aspect of UNFCCC negotiations. Developed countries have made ambitious commitments, and there is a significant need for resources to help developing countries implement mitigation strategies and adapt to inevitable climate changes. One channel of finance that has become a focal point is the Green Climate Fund (GCF). Established in 2009 as part of the Copenhagen Accord, the GCF is open for business with initial pledges totalling more than $10 billion.

President Obama pledged $3 billion from the US. As the first instalment, his administration has requested $500 million for the GCF in this year's budget cycle, but the appropriation requires Congressional authorisation. Many countries are looking closely to see if the US will deliver on this commitment. Developing countries in particular are focused on the GCF, viewing robust contributions as somewhat of a *quid pro quo* for submitting plans to cut their own emissions.

At the time of this writing, the Obama administration is pushing hard to obtain GCF funding, and Congress is threatening to not provide it. While the near-term prospects are uncertain, and could quite possibly fall short this year, it would be unfortunate if the Paris agreement were to falter as a result. The US budget process is notoriously unpredictable year-to-year, and the world's emission targets in the post-2020 period should not hinge on this outcome.

Other countries should nonetheless have reasonably high confidence in US contributions to the GCF over time. Beyond short-term political flashpoints, both Republicans and Democrats have long recognised the value and impact of climate-related assistance to poor countries. It was under two Republican presidents – George H.W. Bush and George W. Bush – that the US helped create the Global Environmental Facility (GEF) and the Climate Investment Funds (CIFs). The GCF is the intended extension, and followers of the process may recall that it took a couple years for US appropriations to begin for the CIFs.

Although not taking centre stage in UNFCCC negotiations, other areas of climate-related finance in need of reform and international coordination are the phasing out of fossil-fuel subsidies and of public financing for coal projects overseas. The International Monetary Fund estimates perverse fossil fuel subsidies to equal 6.5% of global GDP (Coady et al. 2015), and global public assistance for coal has averaged about $9 billion per year since 2007 (Bast et al. 2015). While US-led efforts in these areas have focused on the G20 and across multilateral and bilateral assistance channels, greater integration into the UNFCCC process would be a positive development.

5 Success in Paris

The Paris agreement will not provide a great fix to the world's growing problem of climate change – not even close. The bottom-up approach of basing the agreement on INDCs is certain to fall short of setting sufficiently high global ambition. This is a straightforward and predictable implication of economic incentives on the part of countries voluntarily providing a global public good. So how should we define a successful outcome in Paris?

From the US perspective, there are two key elements. The first is that all major emitting countries, regardless of whether they are developed or developing, submit reasonably ambitious INDCs. The 'common but differentiated responsibility' distinction between developed and developing countries that has defined the UNFCCC process for decades must give way to a more inclusive approach whereby all countries – not just developed countries – seek to reduce emissions. An agreement that does not include emission reductions from the large and fast-growing developing countries simply does not match the future reality of the problem. The recent bilateral announcement between the US and China represents significant progress, and a successful outcome in Paris would be to have other developing countries set similar goals.

The second key element for broad success in Paris is to explicitly recognise the agreement as the beginning of a process, rather than something to be completed so that climate change can fall off the international agenda. The agreement must establish clear pathways towards transparency and regular reporting of emissions, because accurate information is critical to evaluate progress and fairness. And in addition to post-2020 goals, the agreement must also find ways to keep up pre-2020 ambition – the next four years are an important window in which significant progress should be made.

References

Aldy, J. and W. Pizer (2015) "Comparing emission pledges: Metrics and Institutions", chapter 12 in this volume.

Bast, E., S. Godinot, S. Kretzmann, and J. Schmidt (2015), *Under the Rug: How Governments and International Institutions are Hiding Billions in Support of the Coal Industry,* Washington, DC: Natural Resource Defense Council.

Burtaw, D. (2015), "The regulatory approach in US climate mitigation policy", Chapter 17 in this volume.

Center for Climate and Energy Solutions (C2ES) (2015), "Achieving the United States' Intended nationally Determined Contribution", Policy Brief, Arlington, VA.

Coady, D., I Parry, L. Sears and B. Shang (2015), "How Large Are Global Energy Subsidies?", IMF Working Paper No. 15/105, Washington, DC.

Council of Economic Advisors (CEA) (2013), *Economic Report of the President*, Washington, DC: United States Government Printing Office.

Council of Economic Advisors (CEA) (2015), *Economic Report of the President,* Washington, DC: United States Government Printing Office.

Energy Information Administration (EIA) (2015a), *Annual Energy Outlook 2015, with Projections to 2040*, Washington, DC: Office of Integrated and International Energy Analysis, US Department of Energy.

Energy Information Administration (EIA) (2015b), *International Energy Statistics*, Washington, DC: Office of Integrated and International Energy Analysis, US Department of Energy.

Leiserowitz, A., E. Maibach, C. Roser-Renouf, G. Feinberg and S. Rosenthal (2014), *Politics & Global Warming, Spring 2014*, New Haven, CT: Yale Project on Climate Change Communication.

About the author

Matthew Kotchen is Professor of Economics at Yale University and a Research Associate at the National Bureau of Economic Research (NBER). His research interests lie at the intersection of environmental and public economics and policy. Kotchen recently served as Deputy Assistant Secretary for Environment and Energy at the U.S. Department of the Treasury in Washington, DC. While there, he worked on President Obama's Climate Action Plan and represented the United States on the governing boards of the Climate Investment Funds, the Global Environmental Facility, and the Green Climate Fund, in addition to the Treasury Department in UN climate negotiations and energy and environment finance efforts in the G20. Kotchen has also served on the Science Advisory Board of the U.S. Environmental Protection Agency and as the visiting chief economist at the Environmental Defense Fund (EDF).

PART III

Architecture and Governance

11 Legally binding versus non-legally binding instruments

Daniel Bodansky
Arizona State University

Although it now appears settled that the Paris agreement will be a treaty within the definition of the Vienna Convention on the Law of Treaties, debate continues over which provisions of the agreement should be legally binding. The legal character of the Paris agreement and its constituent parts may matter for several reasons, even in the absence of any enforcement mechanisms. Formulating an agreement in legally binding terms signals stronger commitment, both by the executive that accepts the agreement and by the wider body politic, particularly if domestic acceptance requires legislative approval. It can have domestic legal ramifications, to the extent that treaties prompt legislative implementation or can be applied by national courts. And it can serve as a stronger basis for domestic and international mobilisation. But, despite much empirical work over the past two decades, it has proved difficult to assess the strength of these factors in promoting effectiveness, both absolutely and relative to other elements of treaty design, such as an agreement's precision and its mechanisms for transparency and accountability. On the one hand, states exhibit a strong belief that the legal character of an agreement matters. On the other hand, some political agreements, such as the 1975 Helsinki Accords, arguably have had a greater influence on state behaviour than their legal counterparts. As a result, confident assertions, one way or the other, on the degree to which the legally binding nature of the Paris agreement does or does not matter seem unwarranted.

Discussions of the legally binding character of the Paris outcome often mix together five related but distinct issues: (1) the legal form of the Paris agreement; (2) the legally obligatory character of its particular elements; (3) whether its provisions are sufficiently precise as to constrain states; (4) whether it can be applied judicially; and (5) whether it can be enforced. It now appears likely that the Paris agreement will take the form of a treaty. But it remains uncertain which provisions of the agreement will create legal obligations, how precise the agreement will be, and what mechanisms it will establish to promote accountability and compliance.

The 2013 Warsaw decision suggests that states' nationally determined contributions (NDCs) on mitigation will be a central element of the Paris outcome, but was expressly without prejudice to the legal character of these contributions. Will states have a legal obligation to implement and/or achieve their NDCs, or will NDCs represent non-legally binding aims or intentions, rather than obligations? Similarly, will the Paris agreement establish new financial obligations? And how much does the legally binding character of these provisions matter? These are among the central issues in the Paris negotiations.

1 Legal form of the Paris agreement

The 2011 Durban Platform for Enhanced Action calls for the development of 'a protocol, another legal instrument, or an agreed outcome with legal force under the Convention applicable to all parties'. Although this formulation was deliberately vague, the negotiations reflect growing agreement that 'an agreed outcome with legal force' means a legally binding instrument under international law – that is, a treaty.

The Vienna Convention on the Law of Treaties (VCLT) defines a treaty as 'an international agreement concluded between states in written form and governed by international law'

(VCLT article 2(a)).[1] Treaties can be referred to by many terms, including 'agreements', 'conventions', 'protocols', 'charters', 'accords', and 'amendments'. According to the VCLT, whether an agreement constitutes a treaty does not depend on its title, but on whether the parties intended the instrument to be governed by international law (Aust 2007). Although in some cases this may be ambiguous, treaties can usually be distinguished from non-legally binding instruments by the inclusion of 'final clauses', addressing issues such as how states express their consent to be bound (for example, through ratification or accession) and the requirements for entry into force – provisions that would not make sense in an instrument not intended to be legal in character.[2]

Could a decision by the Conference of the Parties (COP) satisfy the Durban Mandate? Arguably not. In general, decisions by international institutions such as the COP are not legally binding unless their governing instrument so provides.[3] The UN Charter provides a simple example. Article 25 of the Charter provides that member states *shall* carry out decisions of the Security Council, so this provision makes Security Council decisions legally binding. But otherwise, decisions by UN organs are not binding on the member states. Similarly, a COP decision could be legally binding if there is a 'hook' in the UNFCCC that gives it legal force. For example, Article 4.1 of the UNFCCC requires parties to use for their greenhouse gas inventories 'comparable methodologies to be agreed upon by the COP'. But, otherwise, COP decisions are not legally binding, so a COP decision, by itself, would not satisfy the Durban Platform's mandate that the Paris outcome have legal force (Bodansky and Rajamani 2015), and any element of the

1 In contrast, 'treaty' has a narrower meaning in US domestic law, referring to international agreements adopted with the advice and consent of the Senate, pursuant to Article II of the Constitution. As a result, only a subset of 'treaties' in the international sense are 'treaties' within the meaning of the US Constitution. Whether the Paris agreement would require advice and consent by the US Senate in order for the US to participate is uncertain and will depend, in part, on what the agreement provides. To the extent that it is procedural in character, could be implemented on the basis of existing US law, and is aimed at implementing or elaborating the provisions of the UN Framework Convention on Climate Change, then arguably the president could join the Paris agreement based on his existing legal authority (see generally Bodansky 2015).

2 For non-legally binding agreements, the functional equivalent of an entry-into-force provision is a provision specifying when the agreement 'comes into effect'.

3 Brunnée reaches a different conclusion, namely, that a larger set of COP decisions should be considered binding, because she adopts a broader definition of 'bindingness' than suggested here (Brunnée 2002).

Paris outcome that is intended to be legally binding would need to be either contained in, or provided for by, the Paris agreement.

2 Mandatory character of particular provisions

Under the principle of *pacta sunt servanda* ('agreements must be kept'), treaties are binding on the parties and must be performed by them in good faith (VCLT article 26). But this does not mean that every provision of a treaty creates a legal obligation, the breach of which entails non-compliance. Although they are sometimes confused, the issue of an instrument's legal form is distinct from the issue of whether particular provisions create legal obligations. The former requires examining the instrument as a whole, and depends on whether the instrument is in writing and is intended to be governed by international law, while the latter depends on the language of the particular provision in question – for example, whether it is phrased as a 'shall' or a 'should'.

Treaties often contain a mix of mandatory and non-mandatory elements. For example, Article 4.1 of the UNFCCC establishes legal obligations, because it specifies what parties 'shall' do to address climate change. By contrast, Article 4.2 formulates the target for Annex I parties to return emissions to 1990 levels by the year 2000 as a non-binding 'aim', rather than as a legal commitment.

Similarly, the Paris agreement might contain a mix of mandatory and hortatory provisions relating to parties' nationally determined contributions and other issues. For example, it might include commitments that parties maintain, report on, and update their NDCs throughout the lifetime of the agreement, but make the achievement of NDCs only hortatory. The choice regarding NDC-related obligations is therefore not simply whether to have legally binding NDCs or not. Rather, the question is what specific obligations, if any, parties will have with respect to their NDCs – and, in particular, whether these obligations will be purely procedural or also substantive in character.

3 Distinguishing the concept of legally binding from other dimensions of bindingness

What is the import of saying that the Paris agreement is a legal instrument or that one of its provisions is legally binding? It is difficult, if not impossible, to answer this question in a non-circular way. Ultimately, legal bindingness reflects a state of mind – most importantly of officials who apply and interpret the law (judges, executive branch officials, and so forth), but also to some degree of the larger community that the law purports to govern. It depends on what the British philosopher HLA Hart referred to as their 'internal point of view', a sense that a rule constitutes a legal obligation and that compliance is therefore required rather than merely optional (Hart 1994).

The concept of 'legally binding' is distinct from several other dimensions of 'bindingness' (Goldstein et al. 2001, Bodansky 2009, Stavins et al. 2014). First, it differs from whether an instrument is *justiciable* – that is, whether the instrument can be applied by courts or other tribunals. In general, courts can apply only legal instruments, so justiciability depends on legal form. But the converse is not the case – the legally binding character of an instrument does not depend on whether there is any court or tribunal with jurisdiction to apply it.

Second, the concept of 'legally binding' is distinct from that of *enforcement*. Enforcement typically involves the application of sanctions to induce compliance. As with justiciability, enforcement is not a necessary condition for an instrument to be legally binding. If an instrument is created through a recognised lawmaking process, then it is legally binding, whether or not there are any specific sanctions for violations. Conversely, enforcement does not depend on legal form, since non-legal norms can also be enforced through the application of sanctions.[4]

Third, the legal form of an agreement is distinct from its *precision*. Of course, the more precise a norm, the more it constrains behaviour. But legally binding instruments can be

4 For example, US law provides for the imposition of trade sanctions against states that 'diminish the effectiveness' of an international conservation program, whether or not a state has committed any legal violation (Pelly Amendment, 22 USC 1978).

very vague, while non-legal instruments can be quite precise. So the constraining force of precision is different from that of law.

In domestic legal systems, the elements of legal form, judicial application, and enforcement often go together. But this is much less common internationally. Many, if not most, international legal agreements provide no mechanisms for judicial application and little enforcement. So it is important to distinguish the different dimensions of bindingness.

Although the issue of legal form is binary – the Paris agreement either will or will not be a legal instrument, and its particular provisions either will or will not be legally binding (Raustiala 2005) – the Paris agreement could be more or less binding along other dimensions. For example, it could be more or less precise, and establish weaker or stronger mechanisms to promote accountability and compliance.

4 Does the legally binding character of a rule matter and, if so, how?

Will the Paris agreement be more effective in addressing climate change if it is a legal rather than a political instrument, and if parties' NDCs are legally binding obligations rather than non-binding aims? How much does the legal form of the Paris outcome matter? Opinions on these questions differ widely.[5]

The effectiveness of an international regime is a function of three factors: (1) the ambition of its provisions; (2) the level of participation by states; and (3) the degree to which states comply (Barrett 2003). Those who argue for the importance of a legally binding outcome in Paris focus primarily on compliance. But the legally binding character of the Paris agreement and its constituent elements could also affect ambition and participation, potentially in negative ways. So even if legal bindingness promotes compliance, as proponents argue, it may not increase effectiveness if its positive effects on compliance are outweighed by negative effects on participation and/or ambition.

5 On the effectiveness of international law, compare Downs et al. (1996) with Simmons (2009).

In theory, the legal character of a norm might promote compliance in a number of ways, even in the absence of judicial application or enforcement (Abbott and Snidal 2002). First, treaties must be formally ratified by states, usually with the approval of the legislature. So acceptance of a treaty generally signals greater domestic buy-in and commitment than acceptance of a political agreement, which typically can be done by the executive acting alone.

Second, the internal sense of legal obligation discussed earlier, if sincerely felt, means that legal commitments exert a greater 'compliance pull' than political commitments, independent of any enforcement.

Third, to the extent that states take legal commitments more seriously than political commitments, this not only makes them more likely to self-comply; it causes them to judge non-compliance by other states more harshly. As a result, states risk greater costs to their reputation and to their relations with other states if they violate a treaty commitment than a political commitment, making non-compliance less attractive.

Fourth, legally binding agreements tend to have greater effects on domestic politics than political agreements, through their influence on bureaucratic routines and by helping to mobilize and empower domestic advocates.

Finally, legal obligations are at least capable of being applied by courts. So if legalised dispute settlement is available, either in an international tribunal or a state's domestic courts, then the legal character of a norm would be a necessary condition of using these procedures.

Perhaps the best evidence that states take legal commitments more seriously than political commitments is that they are more careful in negotiating and accepting them – and, in many states, acceptance of treaties requires special procedures, such as legislative approval. This caution would be irrational if legal bindingness didn't matter. The fact that treaties are more difficult to negotiate and to approve than non-legal instruments suggests that states view them as imposing a greater constraint on their behaviour.

But while there are good reasons to believe that legal form enhances compliance, other factors are also important. As elaborated by Wiener (2015) in his contribution to this eBook, transparency and accountability mechanisms make it more likely that poor performance will be detected and criticised, thereby raising the reputational costs for the state concerned, regardless of whether a norm is legally binding. Like legal commitment, transparency and accountability mechanisms can also help mobilise and empower domestic supporters of an agreement. In addition, the precision of an instrument can enhance effectiveness, both because precise norms exert greater normative guidance and because violations are more apparent.

As a result of these factors, non-legal instruments can significantly affect behavior (Victor et al. 1998, Shelton 2000). Indeed, the 1975 Helsinki Declaration[6] has been one of the most successful human rights instruments, despite its explicitly non-legal nature, because of its regular review conferences, which provided domestic advocates with a basis for mobilisation and which focused international scrutiny on the Soviet bloc's human rights performance.

Similarly, with respect to ambition, the legal character of an agreement can cut both ways. On the one hand, it may make states willing to assume more ambitious commitments, by giving them greater confidence that their actions will be reciprocated by others. On the other hand, it may also have a negative effect on ambition, if states are more concerned about locking themselves into potentially costly commitments than about non-compliance by other states.

Finally, since states are cautious about entering into legal agreements (or have special requirements for ratification that raise additional hurdles), making an instrument legally binding may reduce participation. The US declined to participate in the Kyoto Protocol, in part, because of the legally binding nature of Kyoto's emission targets and the impossibility of getting Senate consent to ratification. Similarly, far fewer countries, arguably, would have participated in the Copenhagen Accord, by putting forward emissions pledges, if the Accord had been a legally binding instrument that made countries' pledges legally binding.

6 Conference on Security and Cooperation in Europe, Final Act (1 August 1975), Article 10 in *International Legal Materials* 14: 1292.

How do these countervailing factors play out? Thus far, it has been next to impossible to answer this question empirically. To do so, one would need to hold all other factors constant, and vary only the legal form of an agreement. Despite significant efforts over the last two decades to determine the significance of legal bindingness internationally, we still do not have any definitive answers (Stavins et al. 2014).

5 Conclusion

To satisfy the Durban Platform's requirement that the Paris outcome have legal force, the Paris agreement must constitute a treaty within the definition of the Vienna Convention on the Law of Treaties; a COP decision would not suffice. But this does not mean that every provision of the Paris agreement must create a legal obligation or that parties' NDCs in particular must be legally binding. The Paris agreement could contain a mix of mandatory and non-mandatory provisions relating to parties' mitigation contributions, as well as to the other elements of the Durban Platform, including adaptation and finance.

One cannot definitively say how much the legally binding character of the Paris agreement matters. Making the agreement legally binding may provide a greater signal of commitment and greater assurance of compliance. But transparency, accountability, and precision can also make a significant difference, and legal bindingness can be a double-edged sword if it leads states not to participate or to make less ambitious commitments. Thus, the issue of legal form, though important, should not be fetishised as a goal of the Paris conference.

References

Abbott, K. and D. Snidal (2000), "Hard and Soft Law in International Governance", International Organization 54(3): 421-456.

Aust, A. (2007), *Modern Treaty Law and Practice*, 2nd edition, Oxford: Oxford University Press.

Barrett, S. (2003*), Environment and Statecraft: The Strategy of Environmental Treaty-Making*, Oxford: Oxford University Press.

Bodansky, D. (2009), *The Art and Craft of International Environmental Law*, Cambridge: Harvard University Press.

Bodansky, D. (2015), *Legal Options for U.S. Acceptance of a New Climate Change Agreement*, Arlington, VA: Center for Climate and Energy Solutions.

Bodansky, D. and L. Rajamani (2015), *Key Legal Issues in the 2015 Climate Negotiations*, Arlington, VA: Center for Climate and Energy Solutions.

Brunnée, J. (2002), "COPing with Consent: Law-Making under Multilateral Environmental Agreements", *Leiden Journal of International Law* 15(1): 1-52.

Downs, G., D. Rocke and P. Barsoom (1996), "Is the Good News about Compliance Good News about Cooperation?", *International Organization* 50(3): 379-406.

Goldstein, J., M. Kahler, R. Keohane and A.-M. Slaughter (eds) (2001), *Legalization and World Politics*, Cambridge, MA: MIT Press.

Hart, H. L. A. (1994), *The Concept of Law*, 2nd edition, Oxford: Oxford University Press.

Raustiala, K. (2005), "Form and Substance in International Agreements", *American Journal of International Law* 99: 581-614.

Shelton, D. (ed.) (2000), *Commitment and Compliance; The Role of Non-Binding Norms in International Law*, Oxford: Oxford University Press.

Simmons, B. (2009), *Mobilizing for Human Rights: International Law in Domestic Politics*, New York: Cambridge University Press.

Stavins, R., J. Zou et al. (2014), International Cooperation: Agreements and Instruments, in *Climate Change 2014: Mitigation of Climate Change* (see IPCC 2014b) in the introduction to this volume for the reports complete reference).

Victor, D., K. Raustiala and E. Skolnikoff (eds) (1998), *The Implementation and Effectiveness of International Environmental Law*, Cambridge, MA: MIT Press.

Wiener, J. (2015), "Towards an effective system of monitoring, reporting and verification", Chapter 13 in this volume.

About the author

Daniel Bodansky is Foundation Professor at the Sandra Day O'Connor College of Law, Arizona State University. He served as Climate Change Coordinator at the US Department of State from 1999-2001, and is the author of *The Art and Craft of International Law* and co-editor of the *Oxford Handbook of International Environmental Law*.

12 Comparing emission mitigation pledges: Metrics and institutions

Joseph E. Aldy and William A. Pizer
Harvard Kennedy School; Duke University

A key element in the emerging international architecture will be practical mechanisms to compare domestic efforts to mitigate global climate change. How do countries decide whether and to what degree pledges by their peers – often expressed in different forms that stymie obvious apples-to-apples comparison – are sufficient to justify their own actions now and more ambitious actions in the future? We describe a number of desirable features of metrics that might be used for ex ante comparisons of proposed pledges and ex post assessments of subsequent actions delivering on those pledges. Such metrics should be comprehensive, measurable, and universal. In practice, however, no single metric has all these features. We suggest using a collection of metrics to characterise and compare mitigation efforts, akin to employing a suite of economic statistics to illustrate the health of the macroeconomy. We illustrate the application of a suite of metrics to several countries' mitigation pledges (their intended nationally determined contributions in the UN climate talks). In the pledge and review model emerging in the climate change negotiations, participation, compliance, and ambition can be enhanced if this collection of metrics can illustrate comparable actions among peers, both prospectively and retrospectively. The latter, in particular, highlights the need for a well-functioning policy surveillance regime.

1 Introduction

Countries will pledge to mitigate their greenhouse gas emissions as part of the negotiations leading up to the Paris climate change talks in December 2015. These pledges will take on many different forms: targets versus 1990 or 2005 base year emissions, percentage improvements in the ratio of carbon dioxide to GDP, percentage abatement versus a ‘no-policy’ reference (or ‘business-as-usual’) case, renewable power goals, energy efficiency goals, afforestation goals, and more. Understanding the comparability of the pledged mitigation efforts will play a critical role in the negotiating process.

Why? To build confidence among countries, there will need to be a common understanding of how pledges expressed in different forms stack up against one another. Similar efforts among similar countries would likely be seen as a ‘fair’ deal, likely a necessary condition for countries both to live up to their pledges now and to increase ambition in the future (Ostrom 1998, Barrett 2003, Cazorla and Toman 2003). Comparable mitigation effort costs across countries also could represent a relatively cost-effective agreement and help level the playing field internationally for energy-intensive industries (e.g. Aldy et al. 2010). This interest in comparability of effort is emerging in domestic politics, both from environmental advocates who believe that such assessments can enable a ratcheting up of ambition as well as business leaders concerned about the potential adverse competitiveness impacts of climate change policy.

Comparing efforts requires metrics. Yet official agreement on specific metrics and a comprehensive policy surveillance mechanism is a tall order. To help inform the difficult task ahead, we have developed a set of three basic design principles and illustrate how an array of metrics might satisfy them. Because no single metric does well in meeting all the principles, we recommend a portfolio approach that assesses countries’ estimated emission levels, emission abatement, carbon and energy price effects, and costs of implementation.

It is worth noting that we emphasise the role of metrics as a *facilitative* mechanism. Metrics are presented without any attempt to emphasise what countries *should* do. A clean, non-judgemental presentation of information, we believe, will encourage and facilitate reciprocity and stronger action. In contrast, a long literature across an array of disciplines has attempted to prescribe what countries should do based on ethical principles and a long-term objective (e.g. Groenenberg et al. 2004, Michaelowa et al. 2005, den Elzen et al. 2006, Höhne et al. 2006, Gupta 2007, Hof and den Elzen 2010, Bosetti and Frankel 2012).

2 History of comparability in international climate negotiations

The concept of comparable effort has evolved over the past several decades in international climate change negotiations. The 1992 UN Framework Convention on Climate Change and the 1997 Kyoto Protocol set emission targets for developed countries and established the first and most enduring notion of comparability: emissions levels relative to a 1990 base year. By defining quantitative emissions limits this way, particularly in the Kyoto Protocol, negotiators effectively defined effort as the percentage reductions in emissions relative to 1990. This turned out to be a simplistic and potentially misleading approach that fails to distinguish between purposeful reductions and those achieved by chance. For example, Russia's emissions have remained well below 1990 levels since the Kyoto Conference due to the state of its economy, not a broad and effective emission mitigation programme.

The term 'comparability of effort' first emerged explicitly in the text of the 2007 Bali Action Plan, which noted that the concept should guide consideration of developed countries' emission mitigation efforts. At the 2009 Copenhagen Conference, the EU and Japan each announced domestic emission targets that included an unconditional pledge plus a further, more ambitious component conditioned on whether other developed countries committed to 'comparable' reductions. At the same time, there was no concrete definition of what 'comparable' meant to the EU and Japan. Moreover, different countries undoubtedly held different perspectives on how to measure and compare effort – and whether to also include the pledges by the fast-growing emerging economies, such as China and India. To promote the transparency of these mitigation pledges and facilitate a better understanding of effort, the Copenhagen Accord and the 2010 Cancun Agreements called for 'international consultations and analysis' and 'measurement, reporting, and verification' – review mechanisms comprised of reporting, technical analysis, and a period of consultation with other parties (see Wiener 2015 for further discussion of measurement, reporting, and verification).

The emerging international climate architecture reflected in decisions at the 2014 Lima climate talks further advanced the concept of pledge and review, building on the Copenhagen model. A number of countries – including the US, the EU, and Russia – tabled their mitigation pledges, referred to as 'Intended Nationally Determined

Contributions' (INDCs) in the negotiations, by the initial 31 March 2015 deadline, and more are expected to do so over the course of 2015. Through this pledge process, the Lima Call for Climate Action notes that countries may submit additional information, including data, analysis, methods, and descriptions of implementation policies that may promote the transparency and credibility of countries' INDCs.

This evolution illustrates how economics can inform the implementation of the comparability of mitigation efforts concept. In the 2009 Copenhagen Accord and in what is expected for Paris, countries' emission mitigation pledges take on different forms. A negotiator can no longer do a simple accounting like the one required in the 1997 Kyoto talks. Instead, economic data and analysis will be necessary to determine the credibility of countries' pledges.

3 Principles for choosing comparability metrics

We identify three principles to help inform the selection of metrics to use in comparing nations' mitigation efforts (see also Aldy and Pizer 2015).

- **Comprehensiveness**. An ideal metric should be comprehensive, characterising the entire effort actively undertaken by a country to achieve its mitigation commitment. Such a metric would clearly reflect all climate-related policies and measures – and exclude non-policy drivers of climate outcomes. It should take on similar values for countries undertaking similar mitigation efforts.
- **Measurability and replicability**. A metric should be measurable and replicable. The ability to replicate a given metric without subjective assumptions, using available public information, enhances the credibility of review. An emphasis on observable characteristics of effort, such as emissions, energy and carbon prices, and/or use of particular zero-carbon technologies, also creates an incentive for countries to undertake actions that can be measured this way. This further facilitates transparency.
- **Universality**. Metrics should be universal. Given the global nature of the climate change challenge, metrics should be constructed for and applicable to as broad a set of countries as possible.

In practice, there will be tradeoffs among principles in identifying and constructing the metrics. For example, changes in emission levels over time may be measurable and universally available in all countries, but this measure may not comprehensively represent mitigation effort. Mitigation cost may be a more comprehensive measure of effort, but is not easily measured.

4 Comparability metrics: Emissions, prices, and costs

Mitigation efforts can be measured many different ways, and the nations of the world are far from agreeing on a single way to do so. But the strengths and weaknesses of popular metrics begin to emerge when we examine how they stack up against our basic principles. These metrics fall into three general categories: those that focus on emissions, prices, and costs. Emissions (and other physical measures) are typically the outcomes that matter for the environment. Prices on carbon and energy taxes reflect the economic incentives created by government policies to reduce emissions and energy use. Cost metrics measure useful economic resources diverted away from current consumption and non-climate investment and toward abatement.

4.1 Emissions and related metrics

We noted that an early comparability metric was emissions relative to 1990 levels, as specified in the Kyoto Protocol. More recently, countries including the US and Japan have focused on emissions relative to 2005 levels. Ultimately, choices like this come down to each country's interest in achieving a more favourable baseline. And, as we saw in the Russian example, changes in emissions over time may have nothing to do with effort. One popular approach to dealing with the particular influence of economic activity is to focus on emission intensity, or tonnes of CO_2 per GDP. Prior to the 2009 Copenhagen talks, China and India each proposed emission goals structured as percentage reductions in the ratio of emissions to GDP (as did the Bush administration in 2001). Such metrics can ensure that a country is not penalised as a climate laggard simply because of faster economic growth, nor is it rewarded simply because of economic decline.

Unfortunately, emissions intensity as a measure of mitigation effort is confounded by several issues. Growing countries tend to experience a decline in emission intensity owing to technology improvements and changing economic structures rather than purposeful mitigation effort. It is difficult to know what level of intensity improvement represents effort versus growth effects. Also, faster growing countries typically experience a faster decline (Aldy 2004, Newell and Pizer 2008). This makes it difficult to compare countries growing at different rates. It also means that countries growing faster or slower than expected will find it easier or harder, respectively, to meet a target. One could instead compare levels of emission intensity rather than trends, but this involves the problematic conversion of local currencies into a single currency.

In recent years, regulators in some developing countries have become more interested in emission goals specified as percentage reductions from a forecast level in a future year. While more comprehensive than other emission metrics in theory, in practice, calculating the emission forecasts requires subjective judgements. If the forecast comes from the government setting the goal, there is an obvious incentive to make the forecast high in order to make the target seem more ambitious than it truly is. Even if the forecast is unbiased, comparing a goal to forecast emissions is only more comprehensive in a *prospective* analysis. Retrospectively, comparing observed emissions to a forecast can still confuse mitigation effort with other non-mitigation events that affect emissions. A comprehensive retrospective metric would compare observed emissions to an analysis of what emissions would have been absent mitigation policies; in essence, a retrospective forecast.

4.2 Carbon and energy prices

An observed carbon price bears a direct connection to effort, as it measures the economic incentive to reduce emissions created by a country's mitigation policies; it also reflects marginal cost. Comparing carbon prices across countries measures the degree to which a country is undertaking more or less expensive per-tonne mitigation efforts. Since countries implement domestic carbon taxes and tradable permit markets in their local currencies, comparisons will require the use of (and raise questions of the appropriate) currency exchange rates (similar to comparisons of emissions intensity). Moreover, carbon prices will not reflect mitigation efforts associated with non-price policies – such as efficiency standards and renewable mandates – and most carbon prices are not applied to all of a country's emissions. A country also may undermine the effectiveness of the carbon price by adjusting taxes downwards for firms covered by the carbon price, through so-called fiscal cushioning.

Alternatively, one could consider implicit (or 'effective') carbon prices that estimate the average cost of abatement associated with a specific climate policy or collection of policies. Such implicit prices have the advantage of potentially being applied to a broader set of policies, but the disadvantage of not being directly observed. Instead, they are produced by model simulations. Implicit prices also do not reflect actual impacts on energy prices, which is often the focus of those concerned about economic competitiveness as well as a necessary incentive for improving end-use energy efficiency.

This leads us to consider energy prices directly. Energy prices are transparent and measurable with high frequency. Energy prices permit a net assessment of all price-based policies (including carbon pricing) and thus can mitigate concerns that a country is engaging in fiscal cushioning and speak directly to competitiveness concerns and incentives for end-use efficiency. This would again fail to capture effects from non-price regulations and be a poor measure of effort for countries with significant non-price policies, including the US (see Burtraw 2015 for further discussion of US greenhouse gas regulations).

4.3 Economic costs

Ultimately, concern about the costs of combating climate change represents one of the most, if not the most, significant impediments to serious action by countries around the world. Costs are also closely aligned with most economists' notions of effort. A metric to compare effort based on costs – expressed as a share of national income or per capita – could examine whether comparable countries bear comparable costs from their actions. A metric based on the cost of actual policies would have the potential disadvantage of rewarding costly but ineffective policies. A complementary metric could examine the cost of achieving the same emission outcome but using the least costly policy (see McKibbin et al. 2011 for an illustration of this approach). This would highlight the potential advantages of some policies (that reduce more emissions with lower mitigation costs) over others. Estimating costs, however, requires economic assumptions and detailed modelling frameworks for evaluating economic changes in specific sectors and national economies.

4.4 Synthesis of metrics

No single metric scores well against all the principles. Table 1 illustrates the challenges for each type of metric in satisfying our three design principles. Those easily measured – emissions levels and intensity compared to historic levels – do not discriminate between effort and happenstance. Prices provide an observable snapshot for certain policies but not others. Emission abatement and abatement costs probably best represent effort but require subjective assumptions and modelling to estimate. Credible differences in opinion over assumptions will produce different results, complicating any comparison and potentially undermining confidence in the transparency and review regime. The necessary modelling tools are also quite limited outside of the largest developed and developing countries.

With these considerations in mind, it is easy to see why we recommend a portfolio of metrics, and why considerable work remains to construct the more comprehensive measures of abatement and cost. Such an approach would mirror how analysts describe the health of the macroeconomy with a suite of economic statistics that includes GDP, the unemployment rate, the inflation rate, and interest rates.

Table 1 Synthesis of principles and metrics for comparability of effort

	Principle		
Metric	Comprehensive	Measurable and replicable	Universal
Emission levels	No – a poor estimate of effort because it conflates natural trends	Yes – public domain data for energy and fossil CO_2 available	Yes for fossil CO_2 data, which exist for all countries; additional work needed for all GHGs
Emission intensities	Better than emission levels as it controls for economic trends, but a noisy signal	Yes – public domain data for energy and fossil CO_2 available	Yes for fossil CO_2/GDP; additional work needed for GHG/GDP
Emission abatement	Yes – most comprehensive among emission-related metrics	Challenging – requires modelling tools / subjective choices to determine counterfactuals	No – few modelling platforms evaluate more than 10 countries
Carbon prices	No – captures effort per tonne, but says little about quantity of tonnes or aggregate effort	Explicit – yes; implicit – requires detailed analyses	No, given few explicit CO_2 pricing policies; modelling tools necessary for implicit CO2 prices
Energy prices and taxes	No – inadequate for non-energy emissions; fails to account for non-market regulatory instruments	Yes, but unclear how to aggregate	Yes, but requires more detailed data collection than currently in public domain
Abatement costs	Yes – best measure of effort	Challenging – requires modelling tools/subjective choices to determine counterfactuals and to model costs	No – few modelling platforms to comprehensively evaluate more than 10 countries

5 The review of pledges on the road to Paris and beyond

Analyses that compare climate change pledges and actions across countries are increasingly relevant as we transition to unilateral pledges of domestic action and policy within international negotiations. The emerging architecture calls for countries to state what they intend to do, form views about the adequacy of each other's efforts, and react accordingly as they implement policies and make further pledges in the future.

No single metric comprehensively measures effort, is easily measured, and is universally available for all countries. Moreover, each country will prefer to emphasise measures that improve their own appearance. This makes it unlikely that an official metric will emerge. Instead, countries will advertise and utilise the metrics they prefer. Analysis is necessary to translate among metrics, particularly harder to measure metrics.

Compiling data and conducting this analysis of metrics will require a serious, transparent, and legitimate process (Aldy and Stavins 2012, Aldy 2014). In his contribution to this eBook, Wiener (2015) emphasises how provisions for such a process could be addressed in the UNFCCC negotiations. Whether or not such an official surveillance process emerges in Paris or thereafter, independent researchers can fill the gap in the meantime. An array of easily available metrics could be developed and data collected by existing international organisations to facilitate comparisons.

For example, we have drawn from the data the US (US Department of State 2014a,b) and the EU (European Union 2014a,b) recently published in their initial biennial reports to illustrate a set of metrics for their respective nationally determined contributions (Table 2). An initial assessment of comparability of effort could draw from these biennial reports, with a few caveats. First, independent assessments of the 'business as usual' (BAU) forecasts in the biennial reports would enhance the credibility of claims of emission reductions relative to BAU. Second, modelling is also required to estimate future prices and costs (for an example, see Aldy et al. 2015). Third, only a small set of developing countries have submitted biennial reports to date, requiring the use of other data sources and analyses for assessing and comparing the mitigation effort represented by their INDCs. A rigorous comparability of effort exercise would draw from multiple data sources and analyses conducted by a set of independent experts (Aldy 2014, Aldy and Pizer 2015).

Table 2 Metrics for the EU and US Intended Nationally Determined Contributions

	United States[1]	European Union[2]
Announced target	-26 to -28% relative to 2005 in 2025	-40% relative to 1990 in 2030
GHG emissions		
Target in tonnes (MMTCO$_2$e)	5252	3364
Relative to 1990 (%)	-17	-40
Relative to 2005 (%)	-27	-35
Relative to 2025 BAU (%)	-25	-9
Relative to 2030 BAU (%)	-25	-25
GHG/GDP[2]		
2015 kgCO$_2$e/US$ (2005)	0.45	0.35
Target 2025	0.28	0.25
Target 2030	0.25	0.20
Δ(GHG/GDP)		
2015-2025 (%/year)	-4.9	-3.4
2015-2030 (%/year)	-4.1	-3.7
Electricity price 2025	(requires modelling)	(requires modelling)
Gasoline/diesel fuel price 2025	(requires modelling)	(requires modelling)
Natural gas price 2025	(requires modelling)	(requires modelling)
Marginal abatement costs (US$/tCO$_2$e)	(requires modelling)	(requires modelling)
Mitigation costs per GDP (%)	(requires modelling)	(requires modelling)

Notes: To simplify presentation, we assume a -27% target in calculating US measures. The EU 2025 measures are based on a linear interpolation between the EU's 2020 target (-20%) and its 2030 target. EU GDP estimates are converted from 2005 euros to 2005 US dollars using the OECD's 2005 purchasing power at parity exchange rate of 0.857 euros/dollar (http://stats.oecd.org/Index.aspx?DataSetCode=PPPGDP). All other data used to construct the metrics are drawn from the first biennial reports by the EU and US to the UNFCCC (EU 2014a, 2014b; US 2014a, 2014b). Note reductions relative to forecasts use 'with existing measures' forecasts for both countries (Table 6(a) in the Common Tabular Format of the biennial reports).

Unofficial but independent expert analysis could further synthesise these data to estimate metrics that require forecasts and modelling. In turn, stakeholders and other users could provide feedback on the feasibility, integrity, and precision of available metrics and estimates. This enables further refinement and improved estimates going forward. In addition, the work on developing metrics for ex ante comparisons of effort can inform the data collection and analysis needs for ex post reviews. The retrospective review of pledges will be more informative and more effective if countries plan in advance for such reviews by implementing data collection and dissemination protocols. Given that Paris is just the beginning of an ongoing process of policy commitments, these refinements and improvements can ultimately feed into greater confidence and stronger ambition among all countries.

References

Aldy, J. E. (2004), "Saving the planet cost-effectively: the role of economic analysis in climate change mitigation policy", in R. Lutter and J.F. Shogren (eds), *Painting the White House Green: Rationalizing Environmental Policy Inside the Executive Office of the President*, Washington, DC: Resources for the Future Press: 89-118.

Aldy, J. E. (2014), "The crucial role of policy surveillance in international climate policy", *Climatic Change* 126(3-4): 279-292.

Aldy, J. E. and W. A. Pizer (2015), "Alternative metrics for comparing domestic climate change mitigation efforts and the emerging international climate policy architecture", *Review of Environmental Economics and Policy*, forthcoming.

Aldy, J. E. and R. N. Stavins (2012), "Climate negotiators create an opportunity for scholars", *Science* 337: 1043-1044.

Aldy, J. E., A. J. Krupnick, R. G. Newell, I. W. H. Parry and W. A. Pizer (2010), "Designing climate mitigation policy", *Journal of Economic Literature* 48(4): 903-34.

Aldy, J. E., W. A. Pizer and K. Akimoto (2015), "Comparing emissions mitigation efforts across countries", RFF Discussion Paper No. 15-32, Resources for the Future, Washington, DC.

Barrett, S. (2003), *Environment and statecraft: the strategy of environmental treaty-making*, Oxford: Oxford University Press.

Bosetti, V. and J. Frankel (2012), "Politically feasible emission targets to attain 460ppm CO_2 concentrations", *Review of Environmental Economics and Policy* 6(1): 86-109.

Burtraw, D. (2015), "The regulatory approach in US climate mitigation policy", Chapter 17 in this volume.

Cazorla, M. and M. Toman (2001), "International equity and climate change policy", in *Climate Change Economics and Policy: An RFF Anthology*, Washington, DC: Resources for the Future Press.

den Elzen, M. G. J., M. Berk, P. Lucas, P. Criqui and A. Kitous (2006), "Multi-stage: a rule-based evolution of future commitments under the climate change convention", *International Environmental Agreements: Politics, Law and Economics* 6: 1-28.

European Union (2014a), Sixth national communication and first biennial report from the European Union under the UN Framework Convention on Climate Change.

European Union (2014b), Biennial report common tabular format submission workbook, 1 March.

Groenenberg, H., K. Blok and J. van der Sluijs (2004), "Global triptych: a bottom-up approach for the differentiation of commitments under the climate convention", *Climate Policy* 4(2): 153-175.

Gupta, J. (2007), "Beyond graduation and deepening: toward cosmopolitan scholarship", in J. E. Aldy and R. N. Stavins (eds), *Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World*, Cambridge, UK: Cambridge University Press: 116-130.

Hof, A. F. and M. G. J. den Elzen (2010), "The effect of different historical emissions datasets on emission targets of the sectoral mitigation approach triptych", *Climate Policy* 10(6): 684-704.

Höhne, N., M. den Elzen and M. Weiss (2006), "Common but differentiated convergence (CDC): a new conceptual approach to long-term climate policy", *Climate Policy* 6(2): 181-199.

McKibbin, W. J., A. C. Morris and P. J. Wilcoxen (2011), "Comparing climate commitments: a model-based analysis of the Copenhagen Accord", *Climate Change Economics* 2(2): 79-103.

Michaelowa, Axel, Sonja Butzengeiger, and Martina Jung (2005), "Graduation and deepening: an ambitious post-2012 climate policy scenario", *International Environmental Agreements: Politics, Law and Economics* 5: 25-46.

Newell, R. G. and W. A. Pizer (2008), "Indexed regulation", *Journal of Environmental Economics and Management* 56(3): 221-233.

Ostrom, E. (1998), "A behavioral approach to the rational choice theory of collective action: presidential address", *American Political Science Review* 92(1): 1-22.

US Department of State (2014a), The first biennial report of the United States of America under the UN Framework Convention on Climate Change.

US Department of State (2014b), Biennial report common tabular format submission workbook, 17 March.

Wiener, J. (2015), "Towards an effective system of monitoring, reporting and verification", Chapter 13 in this volume.

About the authors

Joseph Aldy is an Associate Professor of Public Policy at the Harvard Kennedy School, a Visiting Fellow at Resources for the Future, a Faculty Research Fellow at the National Bureau of Economic Research, and a Senior Adviser at the Center for Strategic and International Studies. His research focuses on climate change policy, energy policy, and mortality risk valuation. He also serves as the Faculty Chair of the Mossavar-Rahmani Center for Business and Government Regulatory Policy Program. In 2009-2010, he served as the Special Assistant to the President for Energy and Environment at the White House. Aldy previously served as a Fellow at Resources for the Future, Co-Director of the Harvard Project on International Climate Agreements, Co-Director of the International Energy Workshop, and worked on the staff of the President's Council of Economic Advisers. He earned his doctorate in economics from Harvard University and MEM and bachelor degrees from Duke University.

William Pizer is Professor at the Sanford School and Faculty Fellow at the Nicholas Institute, both at Duke University, University Fellow at Resources for the Future, Research Associate at the NBER, and Non-Resident Fellow at the Center for Global Development. From 2008 until 2011, he was Deputy Assistant Secretary for Environment and Energy at the U.S. Department of the Treasury, overseeing Treasury's role in the domestic and international environment and energy agenda of the United States. Prior to that, he was a researcher at Resources for the Future for more than a decade. He served as Senior Economist at the President's Council of Economic Advisers from 2001-2002. He has written more than thirty peer-reviewed publications, books, and articles, and holds a PhD and MA in economics from Harvard University and BS in physics from the University of North Carolina at Chapel Hill.

13 Towards an effective system of monitoring, reporting, and verification

Jonathan B. Wiener[1]
Duke University

Information is essential to assessing policies, but information may also be costly. This chapter discusses information systems for monitoring, reporting and verification (MRV) of climate change policy. It enumerates six essential roles for MRV: (1) assessing the performance of national policies, (2) comparing across national efforts (and thereby bolstering credibility and mutual confidence to reduce free riding), (3) assessing aggregate international action towards global goals, (4) evaluating alternative policy instrument designs, (5) facilitating cross-national linking, and (6) enabling adaptive learning. The diversity of national pledges now emerging in the international climate regime only heightens the need for MRV. The chapter argues that even if national policies are diverse and targeted, MRV should cover a broad scope of policies and outcomes to ensure comprehensive impact assessment, while keeping costs low to ensure net benefits, to attract participation, and to avoid discouraging ambition.

1 Introduction

Information is essential to good policy (Mackaay 1982). We need to know whether policies are making a difference, how much, and in what ways compared to relevant alternatives. Successful environmental policy, in particular, depends on good information about the extent of problems and about the relative performance of

1 I am grateful for discussions with Joe Aldy, Valentin Bellassen, Scott Barrett, Dan Bodansky, Jim de Melo, Billy Pizer, Igor Shishlov, and others; and for research assistance by Stephen Youngblood.

alternative policy measures (Esty 2004). Information can enhance policy performance and public accountability. Around the world, countries are increasingly adopting systems to monitor and evaluate information for both prospective policy assessment and retrospective policy evaluation (Wiener 2013).

Information can itself be used as a policy instrument, when rules mandate information disclosure by governments or businesses in order to foster accountability through public awareness of actions and outcomes, and to motivate actors to ensure their compliance and enhance their ambition. As Jeremy Bentham posited, 'the more strictly we are watched, the better we behave' (Bentham 1796). Careful empirical studies show that well-designed information disclosure policies can spur actors facing disclosure (and concerned about their reputations) to make even greater reductions in pollution than required by direct regulation (Bennear and Olmstead 2008).

At the same time, however, information can be costly, both in the direct expenses for its production (hence the calls to relieve administrative burden, reduce paperwork, and cut red tape), and in the inhibitions that disclosure may impinge on autonomy and decision making (hence the calls to shield privacy and deliberation) (Schauer 2011). There can be tradeoffs among the benefits and costs of expanded information requirements. The cost of information can distort choices when some actors have more information than others (Stiglitz 2000), and too little information can impede choices and the evaluation of policy measures. But excessive information disclosure can also be undesirable, overwhelming and confusing decision makers (Ben-Shahar and Schneider 2014).

Optimal information policy seeks to reconcile these tradeoffs (Mackaay 1982: 110, Ogus 1992: 116). It does so by designing reporting protocols and selecting metrics that are accurate and comprehensive, by generating useful indicators, and by targeting audiences who can use them well, yet without imposing excessive costs, encouraging evasion, or overloading recipients with too much information (Weil et al. 2006, Ben-Shahar and Schneider 2014).

Further, if the costs of information are borne by private actors or by countries while the benefits of information are widely shared, then information itself – like climate protection – will have the character of a public good, with incentives for actors (firms or national governments) to underinvest in providing such goods while free riding on others' provision (Barrett 2003). If this is significant, then information can require some form of collective action, such as an international agreement to collect, share and check – i.e. to monitor, report and verify.

2 Challenges facing information for climate change policy

For climate change policy, good information policy is more crucial than ever. A well-designed system of monitoring, reporting and verification (MRV) will be essential to the success of the evolving international climate regime (Aldy 2014, Bellassen and Stephan 2015). To succeed, a system of MRV will need to be designed in a way that enhances the benefits and reduces the costs of this information.

After two decades, the 1992 United Nations Framework Convention on Climate Change (UNFCCC) is entering a new phase. The 1997 Kyoto Protocol to the UNFCCC had sought agreement on quantitative emissions limitation targets, applicable to 'Annex I countries' (generally, although not all, wealthier countries), leaving to each country the choice of measures to achieve its national target; but Kyoto provided no quantitative targets for 'Non-Annex I countries' (generally, although not all, lower-income countries). Some key Annex I countries did not join Kyoto's targets (e.g. the US, at the time the world's largest national emitter and now the second largest), and some key Non-Annex I countries soon became much larger emitters (e.g. China, now the world's largest national emitter).

The IPCC reports that Annex I countries, as a group, actually met their aggregate targets in both the UNFCCC (reducing their aggregate emissions below 1990 levels by 2000 – partly due to the economic downturn in former Soviet countries) and in the Kyoto Protocol (reducing their aggregate emissions more than 5.2% below 1990 levels by 2012) (Stavins et al. 2014, Section 13.13.1.1, pp. 59-60). But these emissions reductions by the group of Annex I countries under the UNFCCC and Kyoto Protocol did not succeed in reducing *global* emissions, because rapid increases in emissions from Non-Annex I countries (major developing countries) drove overall growth in global emissions over the past two decades (Stavins et al. 2014, Section 13.13.1.1, p. 60).

After important talks since 2009 in Copenhagen, Cancun, Durban, and Lima, negotiations in Paris in December 2015 will seek to launch a new phase of the UNFCCC for the year 2020 and beyond. This new regime is calling on each country to propose its own 'Intended Nationally Determined Contribution' (INDC), to be melded into a global effort and reviewed (and updated) over time. As under Kyoto, countries may choose their own sets of measures to reduce their emissions of various greenhouse gases (GHGs) in various economic sectors – such as energy and electricity, transportation, agriculture, and forests – and using various policy instruments – such as technical standards, performance standards, taxes, allowance trading markets (both within and across countries), reducing subsidies, and adaptation measures, among others. But unlike Kyoto, the INDC approach now enables countries to aim their actions at, and report their results against, differing baselines, differing targets, and differing time periods. Also unlike the targets under Kyoto, the call to adopt INDCs now applies to all countries. The regime of INDCs is expected to enable each country to choose its own level of ambition according to its national circumstances, and to offer financial assistance from wealthier to poorer countries.

The flexibility for each country to design its own INDC may attract wider participation, which is important to address global emissions and global impacts effectively. (Incomplete participation would leave key sources of emissions unaddressed and may also lead to cross-country leakage of emitting activities, thus undermining the environmental effectiveness of the incomplete regime.) But the INDC approach may also invite free riding if countries pledge to do little more than they would have done anyway (Barrett 2003). Assessing and comparing efforts across these differing INDCs will be challenging (see the chapter by Aldy and Pizer in this book). Countries may formulate INDCs with differing scopes (e.g. gases, sectors), differing timing (e.g. base year, target year), differing targets (e.g. reductions below emissions in a past base year, reductions below a projection of future business as usual (BAU) emissions, or peak emissions to occur in a future year), and differing units of measurement (e.g. total emissions or emissions per unit of economic activity), all of which will complicate efforts to ascertain what these policies are pledging to achieve, what they actually achieve, how they compare with each other, and how they add up to yield global outcomes. Countries could potentially choose INDC metrics that are difficult to verify (such as reductions below BAU, which is a model projection), or that mask low ambition and free riding. Countries might adopt measures to limit emissions but also simultaneously adopt other domestic policies to subsidise their industries or otherwise 'cushion' the economic burden of the emissions limitation measures, thus undermining their actual emissions reductions in ways that may be difficult for outsiders to monitor and verify (Wiener 1999, coining the term 'fiscal cushioning', Rohling and Ohndorf 2012).

Many countries already have their own domestic MRV systems. Examples include the US GHG Reporting Rule and the reporting under the EU Emissions Trading System (Smith 2012). Countries might also act together in 'plurilateral' groups (Stewart, Wiener and Sands 1996, Stewart and Wiener 2003) or 'clubs' (Stewart et al. 2013, 2015, Nordhaus 2015, Keohane et al. 2015), requiring some form of MRV to document the collective actions of the group.

3 Key roles of MRV in climate policy

Any climate policy will need MRV to assess its effectiveness and impacts. The flexibility of the INDC process, and the diversity of the terms of potential INDCs and club initiatives, increase the need for, but also the challenges to, a well-designed system of MRV (Stewart et al. 2013: 384-391).

MRV of climate policies will be crucial for at least six roles, including:

a. *Measuring the actual performance of countries' implementation of their INDCs towards their own stated goals over time*. If a country or a club pledges to achieve something by a certain date, how will others know if that pledge has been accomplished? How will the country or club itself know what it has accomplished? What will the 'review' stage of 'pledge and review' actually examine? MRV is essential to tracking these results and ensuring policy accountability.

b. *Comparing efforts and results across countries*. Actors will want to know how well different jurisdictions are achieving their pledges compared to other jurisdictions. As Aldy (2014) and Aldy and Pizer (2014, 2015) detail, MRV is needed to produce and check the information from 'policy surveillance' to compare national or club efforts. This comparison may also encourage the level of ambition of each country or club – knowing what others are doing may build the confidence of each actor in the credibility of others' efforts, and thereby attract participation, compliance, and ambition (Barrett 2003).

c. *Comparing the performance of different policy designs and instruments*. Policies should be compared in terms of their efficacy (such as reducing GHG emissions), costs (direct industry compliance costs and broader social opportunity costs), and ancillary impacts (both co-benefits and countervailing harms in other environmental, social and economic outcomes) (Wiener 1995, Shindell 2015). For example, reducing emissions from deforestation may also affect biodiversity and local human populations; switching from coal to gas or nuclear may reduce CO2 emissions and also reduce other conventional air pollutants, yet also increase other risks; solar and wind energy may affect biodiversity; biofuel production may affect deforestation and food prices; and so on. This comparison of policy design and performance goes beyond comparing overall national efforts to examining at a more detailed scale the cost-effectiveness or cost-benefit evaluation of different policy options deployed within countries. Evaluating a comprehensive set of policy impacts follows from UNFCCC Article 4(1)(f), which calls for impact assessment of mitigation policies. Sharing this learning across countries can foster international diffusion of improved policy designs (Wiener 2013). Still, as Aldy and Pizer (2014, 2015) discuss, different methods for comparing differing national measures will involve different criteria, and no single comparison method will fully satisfy all criteria. Aldy (2014: 282) notes that there can be a choice between comparing efforts and comparing outcomes, each of which has its pros and cons. Ideally, MRV would cover both efforts and outcomes, in order to test the relationship of policy design to outcomes and thereby help states select the best policy designs for future use. Testing actual policy performance requires broad MRV covering both the specific policy and associated data on other variables that might also be influencing the outcomes that seemed to be due to the policy, such as other social trends and other public policies.

d. *Aggregating the sum of countries' progress towards global climate protection objectives*. For example, in order to assess how likely aggregate measures will be to limit global average surface warming to no more than 2°C above pre-industrial temperatures, or whatever other overall goal(s) may be selected, MRV will be needed to collect and check data for each jurisdiction and combine these data on a common metric.

e. *Facilitating cross-country connections*. For example:

- Linking of emissions trading markets across countries or clubs could employ MRV (using common metrics) to track trades and ensure that allowance transfers represent real emissions reductions that satisfy emissions limits in the buyer's jurisdiction (Stewart et al. 1996, Wiener 1999, Stewart et al. 2013, Bodansky et al. 2014, Keohane et al. 2015; see also the chapter by Stavins in this book). In the same way, common MRV can facilitate trading across the member states of a multi-state union – such as the EU or the US – or a plurilateral club. Common MRV coupled with recognition of allowances or credits from other states adhering to such common MRV can enable states to opt in to multi-state trading without formally agreeing to link their markets (as proposed by Monast et al. 2015, and facilitated by US EPA in its Clean Power Plan final rule issued in August 2015).
- An international carbon tax (or coordinated national carbon taxes) (see the chapter by Wang and Murisic in this book) would need MRV of emissions to ensure compliance with the tax, and to test its efficacy in reducing emissions. An emissions tax may be more susceptible than a quantity-based approach to fiscal cushioning in ways that are difficult to monitor and verify (Wiener 1999, Rohling and Ohndorf 2012). But the general point is that, whichever instrument is employed to limit emissions, MRV will need to include attention to other policies as well in order to assess the overall impact. Here, climate MRV may draw lessons from other efforts to assess overall fiscal policies, such as IMF assessments of macroeconomic stability.
- Matching international financial and technical assistance to where it is most needed or most effective will require MRV to measure the results of such assistance (Carraro and Massetti 2012).
- If countries adopt border trade adjustments that seek to treat the emissions embedded in imports in a way that is similar (non-discriminatory) to emissions from domestic production (such as a border carbon tax, or a border allowance requirement, on imports) (Nordhaus 2015, see also the chapter by Fischer in

this book), then MRV will be required to assess the emissions policies adopted by the source country of the imports (i.e. the exporting country) to calibrate the magnitude of the border trade adjustment in the importing country.

f. *Fostering adaptive updating of policies and MRV methods over time*. By measuring the actual performance of climate policies, MRV can enable retrospective and repeated performance evaluation, that is, evidence-based decision making that supports planned adaptive policy revision over time (McCray et al. 2010). Further, MRV methods are not static or exogenous; designing policies to reward dynamic advances in approaches to MRV (such as by setting default emissions factors but inviting sources to seek more abatement credit if they demonstrate more accurate MRV) can promote adaptive improvement over time in the MRV methods themselves (Wiener 1994, Aldy 2014: 281, 283, 289).

4 Improving MRV for climate policy

MRV has been addressed in past climate agreements, such as the national communications and emissions inventories under the UNFCCC. But this MRV system remains incomplete, with still patchy monitoring of different sources, sectors and gases, sporadic reporting by different sets of countries, and inconsistent verification by different types of auditors at different scales (national, firm, project site) with different payment contracts (Aldy 2014: 285-288, Bellassen and Stephan 2015). Data remain uncertain for some types of sources or countries, and marginal investment in MRV does not always correspond to the marginal value of information (or ‘materiality’, see Bellassen et al. 2015). At the same time, in some MRV protocols, the cost per tonne of emissions is already quite low, offering grounds for optimism that improved MRV can be implemented without undue cost (Bellassen and Stephan 2015, Bellassen et al. 2015).

Some past international agreements have developed effective MRV, such as for arms control and nuclear non-proliferation (Ausubel and Victor 1992). These regimes offer some lessons for climate policy. Arms control agreements call on states to regulate themselves (or their military forces), whereas international climate agreements call on states to regulate private subnational and transnational actors, which may make MRV more complicated for climate (Ausubel and Victor 1992). Further, the perceived high national benefits of arms control and non-proliferation have justified major investments in MRV, whereas the incentive to invest in MRV for shared global climate benefits may be weaker. On the other hand, climate MRV could be easier to the extent that emissions limitations policies can be monitored over years whereas arms control and non-proliferation accords require immediate or very rapid detection of non-compliance. To be sure, arms control and non-proliferation accords have not always succeeded, and indeed some such agreements have been rejected when their MRV systems failed to satisfy critics. For example, the Comprehensive Test Ban Treaty (CTBT) faced objections that underground testing might be difficult to monitor, and the 2015 nuclear non-proliferation accord with Iran faces acute debate over the likely efficacy of its MRV provisions, including limits on immediate inspections by the International Atomic Energy Agency (IAEA) (on this debate over MRV, see Welsh 2015).

Successful arms control and non-proliferation agreements have often relied on a combination of MRV strategies, including not only national reporting (which other parties may not find credible) but also on-site inspections (including unannounced in-country inspections by expert teams), visible indicators of non-compliance, and verification via remote sensing with 'national technical means' such as satellites (Ausubel and Victor 1992). Remote sensing by satellites (sometimes supplemented by telescopes or *in situ* sensors) can monitor changes in land use and forest cover (GFOI 2014). Remote sensing could also detect the status of key facilities and technologies, such as carbon capture and storage (CCS) projects, adaptation infrastructure, and geoengineering projects. But such remote sensing will still require on-site observers to verify actual changes, and even reporting the installation of specific technologies will still require corroboration to verify that the technology is operating and actually reducing emissions or damages (as illustrated in the recent scandal of VW diesel engines that were designed to limit emissions in the laboratory but then increase emissions on the road). Satellites will soon monitor GHG emissions fluxes from countries – NASA's Orbiting Carbon Observatory 2 (OCO-2), launched in July 2014, 'will be collecting space-based global measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize sources and sinks on regional scales' (NASA 2015), and its OCO-3 will be launched in late 2016.[2] Fisheries management agreements have also employed satellite and on-board 'vessel monitoring systems', both to track vessel movements and to monitor fish catches. Similarly, climate MRV can employ both satellite sensing and on-site inspections, with audits by neutral third parties (such as auditing firms, environmental non-profit organisations or intergovernmental organisations).

As discussed above, information has both benefits and costs. Seeking more accurate and comprehensive MRV may foster transparency, accountability and comparability. It may improve credibility and mutual confidence and thereby attract participation. It may enable assessment, aggregation, comparison, policy design evaluation, cross-country connections, and adaptive learning. But making MRV more accurate or comprehensive may also raise its cost. In some cases, broadening the scope is net beneficial – through expanding target benefits in reduced GHG emissions, promoting co-benefits in air quality, and avoiding perverse countervailing risks from other gases or substitute technologies (Wiener 1995, Shindell et al. 2012, Shindell 2015), as well as by achieving economies of scale in broader applications of the same MRV methods across more sources and transactions (Bellassen et al. 2015). But in other cases a broader scope may yield only minor gains in coverage at high cost – such as lowering the reporting threshold to cover small facilities (Bellassen et al. 2015: 324-325). Estimating emissions factors may be a lower-cost approach to small emitters (McAllister 2010). Costly MRV may not only yield smaller net benefits, but may also lead countries to evade reporting or to reduce the ambition of their pledges in anticipation of costly accountability.

The new climate regime can make progress by designing MRV provisions that collect needed and accurate data in ways that countries find acceptable and even attractive. Burdensome MRV may deter participation and ambition; low-cost but effective MRV may encourage participation and ambition. Design elements for low-cost but effective MRV might include, among others, international financial assistance for monitoring and reporting (Aldy 2014: 284, 290); regular national reporting using shared international MRV guidelines and reporting protocols; standardised BAU projections from joint expert modelling exercises; on-site inspections by joint expert teams; remote sensing of

2 See https://en.wikipedia.org/wiki/Orbiting_Carbon_Observatory.

sources, sinks and emissions fluxes (e.g. from energy emissions, transport emissions, process emissions, and land use change and forests/REDD+) (Esty 2004: 156, 177); and independent verification auditors, paid by neutral funds such as the UNFCCC, another UN body, the GEF, World Bank, or other MRV fund (not paid by the countries or actors being audited, because that may create a conflict of interest leading auditors to overstate achievements, as seen in securities market ratings agencies). Data about emissions and policy impacts should be translated even-handedly into comparable metrics of performance to facilitate comparison, aggregation, policy design evaluation, and adaptive updating. Learning about methods of MRV should be shared across countries, perhaps through neutral clearinghouses. Lower-income countries may need financial assistance to implement effective MRV, and higher-income countries may see such financing as mutually beneficial because better MRV can help reduce emissions globally, bolster confidence and reduce free riding, detect and avoid leakage, and facilitate linking.

The scope of MRV – what it measures and hence what data must be tracked – should be calibrated to maximise its net benefits. A more comprehensive scope gives a more complete impact assessment, but also requires more information and analysis; a more narrow scope reduces the information and analysis costs, but may also neglect or even encourage unintended consequences that undermine larger objectives (Wiener 1995). To be fully comprehensive (a criterion highlighted in UNFCCC Art. 3(3)), the scope of MRV should cover all relevant climate policies – not only the mitigation options selected in each INDC, but all GHGs in all sectors (including those targeted by the INDC as well as others not yet targeted but potentially still affecting the climate), sinks (such as forests/REDD+), co-benefits (such as air quality and public health, because they may motivate participation and ambition by all countries and notably by developing countries) (Shindell et al. 2012, Shindell 2015), countervailing risks (to avoid adverse side effects, see Wiener 1995, as indicated in UNFCCC Art. 4(1)(f)), and costs (to enable policy design comparisons). And it should cover all countries – even those not adopting (ambitious) INDCs – in order to monitor and prevent leakage of emissions from regulated to less regulated countries.

Fully comprehensive MRV should also cover other climate policies being undertaken beyond emissions limits, such as technology R&D, financing, adaptation, and geoengineering (solar radiation management, or SRM). Adaptation may be largely motivated by its local benefits, but international reporting on adaptation can share learning on best practices across jurisdictions, and can help match international adaptation funding to demonstrated results. Reporting on SRM research projects could be crucial to enabling international learning about the pros and cons of SRM options (Keith et al. 2010) and to preventing unwise deployment of risky SRM projects (Stavins et al. 2014, Section 13.4.4). Unlike emissions limits which confront incentives to free ride and avoid effort, SRM may conversely confront incentives to be a unilateral first mover; as a result, international cooperation may seek to restrain hasty SRM, and MRV of SRM may thus be more akin to MRV for arms control and non-proliferation (Stavins et al. 2014, Section 13.4.4; see also the chapter by Barrett and Moreno-Cruz in this book). Compared to MRV of emissions reductions, MRV of SRM geoengineering efforts may require greater emphasis on rapid real-time warnings through remote sensing, and verification through on-site inspections.

Where measurement is currently uncertain (as for some sectors, see Bellassen et al. 2015), that is not itself a reason to ignore or deny credit to emissions reduction efforts in those sectors. Rather, measurement uncertainty calls for adaptive policies that reward dynamic advances in MRV methods, such as by calibrating the degree of credit to the demonstrated accuracy of MRV, thereby creating an incentive for actors to improve MRV methods and reduce measurement uncertainties (Wiener 1994). In this sense, MRV is not static or exogenous, but rather endogenous: improvements in MRV methods depend on the incentives provided in climate policies.

5 Conclusion

The new climate regime is not a single treaty, but a complex of multiple agreements, INDCs, clubs, and transnational networks (Keohane and Victor 2011, Stewart et al. 2013, Stavins et al. 2014, Sections 13.3-13.4; see also the chapters by Keohane and Victor, and Stewart et al. in this book). Hence, comprehensive MRV should cover climate measures under not only the UNFCCC, but also other international agreements that bear on climate, such as GHG limits under the Montreal Protocol, the international aviation agreement (ICAO), and the network of low-carbon cities, among others (Stewart et al. 2013).

What we measure strongly shapes what we manage. The prospect of MRV (including its scope and cost) will have an important role in shaping the climate policies that countries adopt and implement. In turn, the system for MRV will be shaped by its benefits and costs, and by its ability to attract participation of key countries – for example, by keeping costs low, and by highlighting local co-benefits such as air quality and adaptation.

After COP21 in Paris, even if the climate policy regime is a complex of diverse and fragmented national commitments and institutions, it will be desirable to construct a comprehensive MRV system that embraces the multiple components and actors of the regime complex for climate. MRV itself is likely to be less costly than measures to limit emissions (especially if broadly applied to achieve economies of scale), and indeed can increase the net benefits of such measures. Investing in well-designed comprehensive MRV will likely be worth the costs, especially compared to adopting policy measures to limit emissions and realising only later that weak or absent MRV means that we know little about what those (costly) measures actually accomplished. A comprehensive MRV system would broadly cover all the gases, sectors and impacts noted above. Comprehensive MRV would promote the key functions of assessing and comparing national policies, aggregating global efforts, evaluating policy designs, facilitating linking, and promoting adaptive learning. To keep costs low and engage innovative public-private partnerships, components of this broad MRV system could be undertaken by different actors, such as intergovernmental organisations, national governments, auditing firms, university researchers, non-profit organisations, and private businesses. Designing MRV to cover co-benefits, countervailing risks, and adaptation, and to foster financing and allowance trading links, as noted above, could help shape socially desirable policies and offer added incentives for participation by low-income as well as wealthy countries. MRV of SRM geoengineering projects will be important for learning, and for restraining hasty deployment posing adverse side effects. Altogether, a comprehensive MRV system would provide the information essential to assessing and enhancing the success of the climate regime.

References

Aldy, J. E. (2014), "The crucial role of policy surveillance in international climate policy", *Climatic Change* 126: 279–292.

Aldy, J. E. and W. A. Pizer (2014), "Comparability of effort in international climate policy architecture", draft (December 31) (available at http://belfercenter.ksg.harvard.edu/files/dp62_aldy-pizer.pdf).

Aldy, J. E. and W. A. Pizer (2015) "Comparing emission mitigation pledges: Metrics and institutions", Chapter 12 in this book.

Ausubel, J. H. and D. G. Victor (1992), "Verification of international environmental agreements", *Annual Review of Energy and Environment* 17: 1-43.

Barrett, S. (2003), *Environment and Statecraft: The Strategy of Environmental Treaty-Making*, Oxford: Oxford University Press.

Barrett, S. and J. Moreno-Cruz (2015) "Geo-engineering", Chapter 25 in this book.

Bellassen, V. et al. (2015), "Monitoring, reporting and verifying emissions in the climate economy", *Nature Climate Change* 5: 319–328 (April).

Bellassen, V. and N. Stephan (eds) (2015), *Accounting for Carbon: Monitoring, Reporting and Verifying Emissions in the Climate Economy*, Cambridge: Cambridge University Press.

Bennear, L. S. and S. M. Olmstead (2008) "The impacts of the "right to know": information disclosure and the violation of drinking water standards", *Journal of Environmental Economics and Management* 56: 117–130.

Ben-Shahar, O. and C. E. Schneider (2014), *More Than You Wanted to Know: The Failure of Mandated Disclosure*, Princeton: Princeton University Press.

Bentham, J. (1796), "Farming defended", in M. Quinn (ed.), *Writings On The Poor Laws*, Vol. 1, Oxford: Oxford University Press (2001): 276, 277

Bodansky, D., S. Hoedl, G. Metcalf and R. Stavins (2014), "Facilitating Linkage of Heterogeneous Regional, National, and Sub-National Climate Policies through a Future International Agreement", Harvard Project on Climate Agreements (November).

Carraro, C. and E. Massetti (2012), "Beyond Copenhagen: A realistic climate policy in a fragmented world", *Climatic Change* 110: 523–542.

Esty, D. (2004), "Environmental protection in the information age", *NYU Law Review* 79: 115–211.

Fischer, C. (2015) "Options for avoiding carbon leakage", Chapter 21 in this book.

GFOI (2014), "Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative", Geneva: Group on Earth Observations.

Keith, D. W., E. Parson and M. G. Morgan (2010), "Research on global sun block needed now", *Nature* 463: 426–427.

Keohane, N., A. Petsonk and A. Hanafi (2015), "Toward a Club of Carbon Markets", Environmental Defense Fund, 20 April.

Keohane, R. O. and D. G. Victor (2011), "The regime complex for climate change", *Perspectives on Politics* 9: 7–23.

Keohane, R. O. and D. G. Victor (2015), "After the failure of top-down mandates: The role of experimental governance in climate change policy", Chapter 14 in this book.

Mackaay, E. (1982), *Economics of Information and Law*, Dordrecht: Springer.

McAllister, L. K. (2010), "The Enforcement Challenge of Cap-and-Trade Regulation", *Environmental Law* 40: 1195–2010.

McCray, L. E., K. A. Oye and A. C. Petersen (2010), "Planned adaptation in risk regulation", *Technological Forecasting & Social Change* 77: 951–959.

Monast, J., T. Profeta, J. Tarr and B. Murray (2015), "Enhancing Compliance Flexibility under the Clean Power Plan: A Common Elements Approach to Capturing Low-Cost

Emissions Reductions", Policy Brief 15-01, Nicholas Institute for Environmental Policy Solutions, Duke University.

NASA (2015), "Orbiting Carbon Observatory 2: Mission Overview", 30 July (available at http://www.nasa.gov/mission_pages/oco2/overview).

Nordhaus, W. (2015), "Climate Clubs: Overcoming Free-Riding in International Climate Policy", *American Economic Review* 105: 1339–70.

Ogus, A. I. (1992), "Information, Error Costs and Regulation", *International Review of Law & Economics* 12: 411–421.

Rohling, M. and M. Ohndorf (2012), "Prices versus Quantities with Fiscal Cushioning", *Resource & Energy Economics* 34: 169–187.

Schauer, F. (2011), "Transparency in three dimensions", *University of Illinois Law Review* 2011: 1339–1357.

Shindell, D. T. (2015), "The social cost of atmospheric release", *Climatic Change* 130: 313–326.

Shindell, D. T. et al. (2012), "Simultaneously mitigating near-term climate change and improving human health and food security", *Science* 335: 183–189.

Smith, B. (2012), "Transnational Carbon Trading Standards: Improving the Transparency and Coordination of Post-Kyoto Carbon Trading Markets", *Pace Environmental Law Review* 30(1): 325.

Stavins, R. N. (2015) "Linkage of regional, national, and sub-national policies in a future international climate agreement", Chapter 20 in this book.

Stavins, R., J. Zou et al. (2014), "International Cooperation: Agreements and Instruments", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Stewart, R. B., M. Oppenheimer and B. Rudyk (2013), "Building Blocks for Global Climate Protection", *Stanford Environmental Law Review* 32: 341–392.

Stewart, R. B., M. Oppenheimer and B. Rudyk (2015), "A building blocks strategy for global climate change", Chapter 15 in this book.

Stewart, R. B. and J. B. Wiener (2003), *Reconstructing Climate Policy: Beyond Kyoto*, Washington, DC: American Enterprise Institute Press.

Stewart, R. B., J. B. Wiener and P. Sands (1996), "Legal Issues Presented by a Pilot International Greenhouse Gas (GHG) Trading System", Geneva: United Nations Conference on Trade and Development.

Stiglitz, J. E. (2000), "The contributions of the economics of information to twentieth century economics", *Quarterly Journal of Economics* 115: 1441–1478.

Wang, X. and M. Murisic (2015) "Putting a price on carbon with a tax: Current state of play and prospects for future developments", Chapter 19 in this book.

Weil, D., A. Fung, M. Graham and E. Fagotto (2006), "The effectiveness of regulatory disclosure policies", *Journal of Policy Analysis and Management* 25: 155–181.

Welsh, T. (2015), "Monitoring Iran: A Hopeless Task?" US News and World Report, 24 July.

Wiener, J. B. (1994), "Solving the precautionary paradox: policy approaches to improve measurement of greenhouse gas sources and sinks", in J. Van Ham, L. J. H. M. Janssen and R. J. Swart (eds), *Non-CO_2 Greenhouse Gases: Why and How to Control*, Dordrecht: Springer: 527–532.

Wiener, J. B. (1995), "Protecting the Global Environment", in J. D. Graham and J. B. Wiener (eds), *Risk vs. Risk: Tradeoffs in Protecting Health and the Environment*, Cambridge, MA: Harvard University Press.

Wiener, J. B. (1999), "Global Environmental Regulation: Instrument Choice in Legal Context", *Yale Law Journal* 108: 677–800.

Wiener, J. B. (2013), "The Diffusion of Regulatory Oversight", in M. A. Livermore and R. L. Revesz (eds), *The Globalization of Cost-Benefit Analysis in Environmental Policy*, Oxford: Oxford University Press.

About the author

Jonathan Wiener is the Perkins Professor of Law, Environmental Policy and Public Policy at Duke University. He is also a University Fellow of Resources for the Future (RFF). He served as President of the Society for Risk Analysis (SRA) in 2008, and co-chair of the World Congress on Risk in 2012. He is a member of the scientific committee of the International Risk Governance Council (IRGC). He has been a visiting professor at Harvard, the University of Chicago, Univ. Paris-Dauphine, Univ. Paris-Ouest Nanterre, Sciences Po, and EHESS in Paris. He was a co-author of the IPCC, Fifth Assessment Report, Working Group III, chapter 13 on "International Cooperation" (2014). His publications include the books *Risk vs. Risk* (1995, with John Graham), *Reconstructing Climate Policy* (2003, with Richard Stewart), *The Reality of Precaution: Comparing Risk Regulation in the US and Europe* (2011, with others), and *Policy Shock* (forthcoming, with others). Before coming to Duke in 1994, he served at the US Department of Justice, Environment and Natural Resources Division (DOJ/ENRD); at the White House Office of Science and Technology Policy (OSTP); and at the White House Council of Economic Advisers (CEA); there he helped draft the IPCC 1st Assessment Report (1990), helped negotiate the Framework Convention on Climate Change (FCCC) (1990-92), and helped draft Executive Order 12,866 on regulatory review (1993). He was a law clerk to federal judges Stephen G. Breyer (1988-89) and Jack B. Weinstein (1987-88). He received his J.D. (1987) and A.B. (1984, Economics) from Harvard University.

14 After the failure of top-down mandates: The role of experimental governance in climate change policy

Robert O. Keohane and David G. Victor[1]
Princeton University; University of California at San Diego

The failure of the Kyoto process to generate an effective and integrated international regime reflects a lack of willingness of major states, in the presence of uncertainty, to make commitments to a demanding set of targets and timetables. In conjunction with strong conflicts of interest and fragmentation of power and capability, the result has been a decentralised 'regime complex for climate change' rather than an integrated international regime. Since 'top-down' approaches have failed, it is important to think about how more experimentalist, 'bottom-up' arrangements might work, by decomposing problems into smaller units that facilitate testing and learning. For such an approach to be effective for climate change issues, three tasks must be performed: (1) participants need to articulate their shared goals; (2) there must be significant costs to participants of inaction – a 'penalty default' that can induce cooperation where it is not spontaneously forthcoming; and (3) institutions to assess national pledges and help stitch them together must be developed. The most optimistic scenario for Paris is that it sets in motion a process that promotes learning and cooperation and that, over time, could have transformative impacts on the politics of climate cooperation.

The failure of the Kyoto process to generate an effective and integrated international regime has allowed for the emergence of what we have called 'the regime complex

1 We acknowledge discussions with Ottmar Edenhofer, Bryce Rudyk, Michael Oppenheimer, Richard Stewart and Charles Sabel. This chapter is based, in part, on Keohane (2015) and Sabel and Victor (2015).

for climate change' (Keohane and Victor 2011). We interpret the decentralised and partially overlapping regulatory efforts that now exist as reflecting strong conflicts of interest and fragmentation of power and capability. The issue now is whether there is a pathway forward that is both feasible and effective. Timetables and binding targets have not worked, attracting few countries outside of the EU; that is, 'top-down' approaches have failed. This is the theme of Section 1 of this chapter. In Section 2 we look at how 'bottom-up' might actually evolve in productive directions.

1 The top-down approach: Failure and poor prospects

It is now widely recognised that the Kyoto approach was a failure. The Framework Agreement on Climate Change – the 'UN F triple-C' agreement – made in 1992 contained few specifics and no meaningful commitments beyond the obligation to report. In the Berlin Mandate, agreed in 1995, rich countries agreed to exempt developing countries from obligations, without a clearly specified phase-out period. But the developing countries grew rapidly – China is by far the largest emitter today and emissions of other developing countries are growing fast (IPCC 2014). Developing countries have a strong and legitimate interest in ensuring that action on climate change will not condemn them to perpetual poverty by slowing rates of economic growth. But once given an entitlement to emit, countries classified as 'developing' were reluctant to give it up even as their growth, and emissions, rose. And rich countries – not just the US but also Australia, Canada, and eventually Japan – were unwilling to accept costly limits on their own emissions that would not solve the problem as long as developing countries' emissions were rising so fast. The EU was the one notable exception, and it went ahead with costly controls – largely driven by its own internal political needs. With all these diverging preferences, diplomatic deadlock resulted (Victor 2011, Hale et al. 2013).

In this context, it is easy to understand why Kyoto was more of a façade than a real scheme for policy coordination. It largely ratified what countries would have implemented anyway –except perhaps the US, which never joined. And it was steeped with accounting tricks that were abused as well. Particularly striking was the abuse of the Clean Development Mechanism (CDM), through which host governments sought certification of proposed credits for projects and dealt with verifiers who were dependent on the host governments for future business. Purchasers of the credits had few incentives to assure that projects were genuine, only that the credits were certified. Not surprisingly, some estimates indicate that many of the permits represented phony emissions reductions (Wara 2008). Indeed, the CDM even generated perverse incentives, reducing incentives for developing country governments to enact policies permanently reducing their emissions in favour of continuing overall high-emissions policies and then earning credits from projects that had inflated emissions baselines.

So Kyoto got it wrong in two ways: at the core of the regime, states did not have incentives to commit to ambitious targets, much less legally binding ones; and at the periphery, many of the characteristic dysfunctions of international organisations manifested themselves.

The current round of talks is premised on an arrangement that has been called 'pledge and review', although the exact names vary. Some call this approach to negotiating international commitments through pledges and smaller groups of commitments the 'building blocks' approach. Others refer to the scheme as building 'coalitions of the willing' (Falkner et al. 2010, Stewart et al. 2013). Today, formally, climate diplomacy calls these bottom-up pledges 'Intended Nationally Determined Contributions', or INDCs. In this pledge and review scheme, targets are not legally binding but once the pledges are made and accepted, states are expected to have incentives to fulfil them for reputational reasons. Indeed, this process has already begun to unfold, such as with the bilateral pledges announced by the US and China in November 2014. The US had an incentive to declare serious pledges of its own in order to induce China to do so as well – reciprocity is often important in world politics. But the incentives for this process to work remain weak. The Lima Declaration of December 2014 encouraged countries to submit targets by 31 March 2015. But when that deadline approached only a handful of parties – the US, the EU, and a few others – had actually bothered to submit pledges. The new planning goal for these pledges is early October 2015, leaving the Climate Change secretariat just a month to figure out what the totality of all the pledges implies for the overall health of the planet. The news is unlikely to be good; indeed, a growing number of studies are pointing to the reality that widely discussed goals of stopping global warming at 2°C is impractical, and the models used to study those scenarios are based on unrealistic technological and political assumptions (Fuss et al.

2014). Similarly, grand aspirations in Lima to develop strong review mechanisms that could monitor implementation and compliance with INDCs are, so far, leading to more disagreement than practical institution building.

Pledge and review can be seen in two ways. It can be seen cynically, merely as a euphemism for not changing policy in any substantial way. In this view, pledge and review essentially constitutes what Stephen D. Krasner calls 'organised hypocrisy' – pretending to take serious steps while actually proceeding with business as usual (Krasner 1999). On the ground, in Asia, trends are strongly toward more emissions. In India and Vietnam, there are scores of coal-fired power plants either under construction or in the serious planning stages. In India, for example, there are 381 gigawatts of coal-fired plants under construction or planned, which would more than triple current capacity of about 178 gigawatts, and in Vietnam the capacity of plants under construction or planned is over 48 gigawatts – a sixfold increase over current capacity. Over two-thirds of the new power plants under construction or planned in these countries will be coal-fired. The talk is all of limitations on emissions, but the reality is more emissions.[2]

Of course, the full story is a complex one. More economic growth means higher demand for electric power. But some countries are diversifying their power industries in ways that are slowing, if not stopping, the growth in emissions – in China, for example, a slower economy, aggressive energy efficiency, and support for new power sources including nuclear and renewables are leading to 'peak coal' in the next few years and most likely a peak in emissions over the next decade. That's better news than unfettered growth in emissions, but slower growth is still a far cry from the cuts of 50% or more from current levels that would be needed globally to stop warming.

But public cynicism may be counterproductive – sometimes, surprises occur. And in any case, hypocrisy is what Judith Shklar called an 'ordinary vice' (Shklar 1985), and not as bad as some other vices because at least it recognises virtue even if it does not observe it. The positive spin on pledge and review is that it could start a process of commitments, monitoring, persuasion, and imitation that could eventually generate

2 Research by Phillip Hannan based on data and methodology explained in Hannam et al. (forthcoming); see also IEA (2014).

some meaningful action on climate change. The Lima Declaration's vision for INDCs and review, for example, provides for the engagement of experts from civil society and the private sector, which some commentators argue could be used to facilitate 'bottom-up' arrangements to promote emissions reductions measures (Stewart et al. 2015a, 2015b). In any case, for the negotiators there is now little alternative to trying to make pledge and review work, since the mandatory targets and timetables approach is dead in the water.

If approached without illusions about likely breakthroughs, the Paris meeting can at least avoid a demoralising setback – it can avoid becoming a 'Copenhagen II'. Indeed, there is growing evidence that the French government hosts are organising themselves around exactly that mission – to avoid failure. But there is little reason to be optimistic. It seems likely that both pledge and review and attempts to foster 'bottom-up' arrangements without a binding overall agreement will have insufficient effects on this massive problem. We need to think more about these issues outside of the 'UN F Triple-C box'.

2 Towards an effective experimental governance of climate change

Climate change is marked by two intertwined sets of characteristics that make integrated, top-down bargaining all but impossible. The first set is political – the fragmentation of power and authority in the international system, and the corresponding absence of a hegemon to impose order on actors with sharply divergent interests. The second is cognitive – uncertainty about the feasibility of achieving policy outcomes, such as lower emissions, at acceptable costs. This uncertainty explains the inability of any country or firm that takes deep decarbonisation of emissions seriously to identify ex ante what behavioural, technological and regulatory commitments will actually prove most effective. This shroud of uncertainty about the actual burdens of various commitments exacerbates the bargaining problems; the bargaining problems in turn heighten the sense of uncertainty as key parties cannot anticipate – and must fear – how counterparts will react to the frustration of expectations (Young 1989a, 1989b). If it is unknown at the time of bargaining which commitments really can be fulfilled and how others will respond if some are not, bargaining among parties with sharply different interests will be highly complex and cautious to the point of paralysis. Risk-averse players will prefer deadlock to codifying ambitions that may prove too costly or simply unattainable (Abbott and Snidal 2000, Hafner-Burton et al. 2012).

Mindful of these difficulties in pursuing top-down bargaining, at best Paris will represent one step on a long road of efforts to build an effective bottom-up system. But pledge and review, although not a solution to the climate problem, *could* lead to a process of experimentation and momentum building. That is, it could help governments and other critical players determine what is feasible through coordination and it could establish some momentum in negotiations, so that countries not making serious efforts could be embarrassed as laggards. Countries willing to do more could learn how to connect and integrate their efforts into truly interdependent, deep cooperation. In an optimistic scenario, this process could, through a series of increasingly serious steps, move pledge and review to a more coordinated and effective effort in the long run.

Although such an outcome may not be likely, we see it as possible and we believe, therefore, that it is worthwhile to explore how such a positive process might unfold – and what would be necessary within and outside the UNFCCC process. Many conditions would need to be satisfied for this experimental and momentum-building process to work. There needs to be serious review, countries need to be willing to adjust their commitments in light of new information, and there need to be incentives for integration over time. Meeting these conditions is far from assured. Yet in the absence of any assured pathway to success, it is worthwhile to explore this experimental, momentum-building scenario.

The central insight of experimental governance (XG) is that seemingly impossible large problems can be decomposed into smaller units that facilitate testing and learning from experiments. Originally developed for understanding regulation and the provision of complex public goods, such as education, under uncertainty in the US and the EU (Sabel and Zeitlin 2008), XG has similar potential applications at the global level (De Búrca et al. 2014). XG emphasises that regulator and regulated, alike, rarely know what is feasible when they begin to tackle a problem under uncertainty; it prizes a diversity of efforts rather than monopoly. It identifies and continuously improves upon solutions that work – and pushes them to scale – while siphoning resources away from those that don't.

Applied to climate, XG suggests a focus on three tasks. First, participants need to articulate their shared goals in a way that implies specific initial actions, to be reviewed systematically with the expectation that they will be adjusted over time. Such an experimental process may make agreement on goals easier to secure because the actors know that specific steps toward achieving the target are subject to careful review, in which they will have a part. While the UNFCCC process has set some goals – such as articulated in Article 2 and with the goal of stopping warming at 1.5-2°C degrees – these goals have been either too abstract or unachievable to specify near-term actions.

Various groups of ground-level actors are then assigned responsibility for achieving pieces of the goal. They are authorised to search for and develop solutions as their experience suggests, but on the condition that they report results to the convening authority. The results are then compared through various forms of peer review so successes can be quickly identified and generalised if possible, failures rejected early on, and faltering efforts corrected in view of the advances of more promising ones. Where experience warrants, the goals themselves are revised – targets tightened, relaxed, or extended to new domains – and the revised goals are the starting point for the next round of local exploration. Over the next few years – perhaps as early as Paris – there will need to be a rethinking of the widely discussed goals of stopping global warming at 1.5 or 2°C (Victor and Kennel 2014). That process, bound to be highly controversial, would benefit from tangible ground-level knowledge about what countries can actually do to regulate emissions.

The second key task is to ensure that there are significant costs to participants of inaction. The engine that drives experimental governance is not a starry-eyed assumption that actors want solutions. Instead, XG relies on a ‘penalty default’ that can induce cooperation where it is not spontaneously forthcoming. A penalty default is a draconian sanction – exclusion from a valued market or denial of an indispensable permit or license – imposed for persistent violation of the regime’s norms. It is a form of enforcement that does not prescribe solutions – which may be impossible to agree on because states likely to be targeted will block them – but that forces the actors to cooperate unless they are willing to risk losing control of their joint fate. Under the shadow of a penalty default, experimental governance uses deliberation to help actors redefine their interests. Penalty defaults are thus at one and the same time information forcing and deliberation enhancing.

Other published work explores in more detail where penalty defaults may arise in the international system (De Búrca et al. 2014, Sabel and Victor 2015). Here we point just to the need for these penalties as an engine for cooperative efforts. Important sources of penalties in climate change will include the threat of trade sanctions and loss of markets, and, within countries, the threat of regulatory intervention that firms might forestall through actions of their own to self-regulate effectively.

There will be tremendous pressures in the multilateral context to avoid or disarm the mechanisms, such as trade sanctions, that could be used to threaten penalties that inspire experimentation and cooperation. Universal forums abhor unilateral and club actions. It will be important to resist efforts to outlaw penalties such as trade sanctions; a vague agreement at Paris would be preferable to one that eliminated the possibility of enacting such penalty defaults.

A third task is to develop the institutions that will be needed to assess national pledges and help stitch them together into more integrated and demanding international cooperation. A suite of agreed metrics will be necessary, as discussed in the contribution to this eBook by Aldy and Pizer (2015). Pledges should contain not just information about what countries aspire to do but also what has been tried, what worked, and what failed. Pledges could also be made conditional on others' actions and experimental, so they would signal to other countries what nations will try, not just what they will do. Introducing such an experimental orientation could lead to more constructive bargaining around joint gains as well as to more robust learning about what really works. Making productive use of these pledges will require institutionalised arrangements to ensure that reviews are serious so there is genuine monitoring of pledges and pressure to fulfil them (Victor et al. 1998).

An open question is exactly how the UN system would perform these monitoring and review functions. In the past the Climate Change secretariat has been assigned similar tasks, but it hasn't been given the authority needed for serious monitoring and review – an outcome that is hardly surprising since the UNFCCC operates under consensus rules and many members are wary of untested review mechanisms. The IPCC can't take on this role because it is not designed to make political judgements. All of these official UN institutions face the problem that their authority depends upon consensus and the very act of performing serious monitoring and review almost guarantees that some states will object. The best options probably lie outside the UN system, but are supportive of it. NGOs, supported by expert knowledge, could play a big role. Some countries could volunteer to have their national pledges scrutinised closely because they want to demonstrate how effective reviews actually work. These analyses would be reviewed in the peer-reviewed literature, after which IPCC could cite them.

3 Conclusion

The inability of nations to develop an integrated top-down climate regime is now widely accepted, and that new reality will be on full display at COP21 in Paris. The road to Paris is being paved with bottom-up efforts, most notably the scheme of national pledging organised around INDCs.

Whether this new strategy will be any better than the status quo – an anarchic outcome in which countries follow their self-interests and there is no real international collaboration –remains to be seen. Some of the pledges being made for Paris are encouraging, although we are sceptical that Paris will take the world very far, in itself, toward mitigating climate change. But the Paris meeting could set in motion a process that promotes learning and cooperation and that, over time, could have transformative impacts on the politics of climate cooperation. Whether that happens will hinge on whether the INDCs become more informative, whether countries that want cooperation can threaten penalties to those who don't, and whether new institutions are created that will review, assess and eventually help merge the INDCs into more collective efforts. Some of that can be done inside the UNFCCC box, but the hardest tasks – such as threatening sanctions and building effective review mechanisms – will require sympathetic efforts from the outside as well.

References

Abbott, K. and D. Snidal (2000), "Hard and soft law in international governance", *International Organization* 54(3): 421–456.

Aldy, J. and W. Pizer (2015), " Comparing emissions pledges: Metrics and institutions", Chapter 12 in this volume.

De Búrca, G., R. Keohane and C. Sabel (2014), "Global experimentalist governance", *British Journal of Political Science* 44(3): 477–486.

Falkner, R., H. Stephan and J. Vogler (2010), "International climate policy after Copenhagen: Towards a 'building blocks' approach", *Global Policy* 1(3): 252–262.

Fuss, S., J. Canadell, G. Peters, M. Tavoni, R. Andrew, P. Ciais, R. Jackson, C. Jones, F. Kraxner, N. Nakicenovic, C. Le Quéré, M. Raupach, A. Sharifi, P. Smith and Y. Yamagata (2014), "Betting on negative emissions", *Nature Climate Change* 4: 850–853.

Hafner-Burton, E., D. Victor and Y. Lupu (2012) "Political science research on international law: The state of the field", *American Journal of International Law* 106(1): 47–97.

Hale, T., D. Held and K. Young (2013), *Gridlock: Why Global Cooperation is Failing when We Need It Most*, Cambridge, UK: Polity.

Hannam, P., Z. Liao, S. Davis, and M. Oppenheimerm (forthcoming), "Developing country finance in a post-2020 global climate agreement", *Nature Climate Change*.

IEA (2014), *Medium-term Coal Market Report 2014: Market Analysis and Forecasts to 2019*, Paris: OECD/IEA.

IPCC (2014b), "Summary for Policymakers", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014d) in the introduction to this book for the report's full reference).

Keohane, R. and D. Victor (2011), "The regime complex for climate change", *Perspectives on Politics* 9(1): 7–23.

Keohane, R. (2015), “Beyond the UNFCCC: Rethinking the global politics of climate change”, C. Douglas Dillon Lecture, Chatham House, London, 11 May.

Krasner, S. (1999), *Sovereignty: Organized Hypocrisy*, Princeton, NJ: Princeton University Press.

Sabel, C. and J. Zeitlin (2008), “Learning from difference: The new architecture of experimentalist governance in the EU”, *European Law Journal* 14(3): 271–327.

Sabel, C. and D. Victor (2015), “Governing global problems under uncertainty: Making bottom-up climate policy work”, *Climatic Change*, forthcoming.

Shklar, J. (1985), *Ordinary Vices*, Cambridge, MA: Harvard University Press

Stewart, R., M. Oppenheimer and B. Rudyk (2013), “A new strategy for global climate protection”, *Climatic Change* 120(1): 1-12.

Stewart, R., M. Oppenheimer and B. Rudyk (2015a), “After Lima: Building blocks as a new way forward for global climate cooperation”, *Climatic Change* (forthcoming).

Stewart, R., M. Oppenheimer and B. Rudyk (2015b), “A building blocks strategy for climate change”, Chapter 15 in this volume.

Victor D., K. Raustiala, E. Skolnikoff (eds) (1998), *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*, Cambridge, MA: MIT Press.

Victor, D. (2011), *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet*, Cambridge, UK: Cambridge University Press.

Victor, D. and C. Kennel (2014), “Ditch the 2 °C warming goal”, *Nature* 514(7520): 30-31.

Wara, M. (2008). “Measuring the Clean Development Mechanism’s Performance and Potential”, *UCLA Law Review* 55: 1759.

Young, O. (1989a), *International Cooperation: Building Regimes for Natural Resources and the Environment*, Ithaca, NY: Cornell University Press.

Young, O. (1989b), "The politics of international regime formation: Managing natural resources and the environment", *International Organization* 43(3): 349–375.

About the authors

Robert Keohane is Professor of Public and International Affairs in the Woodrow Wilson School at Princeton University. He has served as Editor of *International Organization* and as President of the International Studies Association and the American Political Science Association. He is a member of the American Academy of Arts and Sciences, the American Academy of Political and Social Science, the American Philosophical Society, and the National Academy of Sciences; and he is a Corresponding Fellow of the British Academy. His publications include *Power and Interdependence* (with Joseph S. Nye, Jr., originally published in 1977), *After Hegemony: Cooperation and Discord in the World Political Economy* (1984), *Designing Social Inquiry* (with Gary King and Sidney Verba, 1994), and *Power and Governance in a Partially Globalized World* (2002). His recent work focuses on a variety of related topics, including multilateralism, climate change, and anti-Americanism.

David Victor is Professor at the School of Global Policy and Strategy at the University of California—San Diego. He leads the Laboratory on International Law and Regulation Laboratory, which studies why some international laws are highly effective and others founder. Prior to UC San Diego he served as director of the Program on Energy and Sustainable Development at Stanford University, where he was also a professor at Stanford Law School. He has also directed the science and technology programme at the Council on Foreign Relations (CFR) in New York, where he led the Council's task force on energy security. Victor's research has covered a wide array of topics related to international environmental regulation, energy markets, and international law. His books include *Global Warming Gridlock* (Cambridge University Press, May 2011), *Natural Gas and Geopolitics* (Cambridge University Press, July 2006), *The Collapse of the Kyoto Protocol and the Struggle to Slow Global Warming* (Princeton University Press, April 2001; second edition July 2004); and *Technological Innovation and Economic Performance* (Princeton University Press, January 2002).

15 A building blocks strategy for global climate change

Richard B. Stewart, Michael Oppenheimer and Bryce Rudyk
New York University; Princeton University; New York University

The likely future global climate regime, based on nationally determined, non-legally binding commitments, is not by itself likely to produce emissions reductions sufficient to prevent dangerous climate change. There is, however, already significant mitigation occurring outside the context of the UNFCCC that could potentially be scaled up to fill the gap. This chapter, expanding on earlier work, proposes a building block strategy that focuses on incubating and scaling up multilateral and multi-stakeholder initiatives in discrete sectors with mitigation potential. It outlines three paradigms – clubs, linkage and dominant actor – that provide a conceptual and institutional framework for mobilising non-climate interests of actors in order to generate associated climate benefits. Finally, it suggests that recent institutional developments in the UNFCCC could be used as a platform to launch and enhance these non-UNFCCC initiatives, compatible with the emerging UNFCCC strategy.

Introduction

Current UNFCCC negotiations signal a future global regime for climate action based primarily on voluntary (and likely not legally binding) commitments by individual countries. As this country-driven strategy cannot *by itself* ensure that individual country undertakings will in the aggregate achieve sufficient reductions to prevent dangerous climate change, complementary transnational strategies must be developed to fill the gap.

The building block strategy outlined in this chapter focuses on multilateral and multi-stakeholder initiatives around specific sectors of opportunity with high mitigation potential (Stewart et al. 2013a,b). These initiatives will enlist the enterprise and resources of public and private actors, including firms and NGOs, international organisations, and subnational jurisdictions, as well as states. The strategy relies on three distinct institutional paradigms – clubs, institutional linkages, and dominant market actors – to build such initiatives.

Recognising the highly uneven support among various public and private actors for climate mitigation, the building blocks strategy seeks to capitalise on an array of other incentives to initiate actions that will reduce emissions. These incentives include profits for businesses, enhanced economic development and energy security for developing and other countries, mission advancement for development funders, and avoiding competitive disadvantage (as a result of leakage) for firms in jurisdictions that have adopted mitigation regulations. Here we propose institutional structures to mobilise such incentives. In some cases, these initiatives could be supported by governmental or other actors committed to climate mitigation for its own sake, including specifically the UNFCCC.

The building block strategy avoids the problem of reaching agreement across a large group of countries as well as the risk entailed in national commitments to deep, economy-wide emission reductions. The strategy would produce multiple climate dividends: immediate emissions reduction through the deployment of the individual building block initiatives; significant learning about the costs of mitigation action and the characteristics of durable initiatives (Sabel et al. 2015), leading to more, and more effective, initiatives; and increased trust through demonstrating action and creating institutions that regularise interactions between public and private actors, which may lead to greater long-term ambition.

The building blocks strategy

In order to enhance existing action, foster new action, and complement the UNFCCC, the building blocks strategy embraces a variety of special-purpose initiatives in specific sectors that would:

1. Enlist a limited number of public and/or private actors;

2. Focus on sectors and opportunities with high mitigation potential;
3. Tap actor incentives other than a desire to promote climate mitigation;
4. Not necessarily be legally binding; and
5. Not necessarily be formally linked to the UNFCCC.

Smaller-scale initiatives avoid the problems involved in negotiating and implementing a comprehensive global treaty (Downs et al. 1998). It is often easier to reach agreement among a smaller number of participants both on substantive goals as well as critically important procedural issues like monitoring and other arrangements to ensure compliance (Barrett 2003). Mobilising a suite of specific, incremental undertakings also reduces the cost of initiative failure and permits institutional and policy experimentation and learning (Sabel et al. 2015).

The uneven support for mitigation across states and governments has stymied global agreement; intense support in some jurisdictions does not compensate for indifference or opposition in others. The building block strategy adapts to this situation by mobilising material incentives such as economic gains, increased adaptation capacity and health, economic development, energy security, and other benefits. At the same time, the strategy recognises that many actors – both public and private – are motivated at least in part by climate protection. It draws on these pockets of support, including in governments that are unwilling to commit to economy-wide emissions caps but are prepared to participate in more limited undertakings to reduce emissions.

To make broad progress on emission reductions, it is critical to engage directly the actors beyond national governments, including sub-national jurisdictions, firms, NGOs, and international regulatory bodies with missions other than climate, such as the Montreal Protocol, the International Civil Aviation Authority (ICAO), the International Maritime Organization, and the multilateral and regional development banks. These actors are not and cannot be parties to the UNFCCC and many are effectively fenced out of its deliberations and programmes. As much of the climate emissions, and therefore the resulting climate mitigation action, occur as a result of decisions by these actors, their participation is necessary (Heede 2013).

The building block strategy provides a clear path forward to both avoid a plethora of disaggregated and disparate initiatives, and incentivise those initiatives that produce positive climate co-benefits. It does this in two ways. First, we detail the club, linkage and dominant actor paradigms. These provide a systemic framework for a) analysing potential institutional and initiative opportunities, and b) identifying the incentives and actors that would be required to mobilise each initiative. The three paradigms involve somewhat different incentive structures and institutional logics, but each depends on opportunities to align non-climate incentives with activities that reduce emissions. Careful design is needed to target incentives that will tap actors' non-climate motivations and also produce positive climate outcomes. Second, we outline the essential role of institutional entrepreneurs and the prospect of building on elements of the UNFCCC (particularly the collaborative pre-2020 mitigation action process under Workstream 2) to more effectively and efficiently discover and implement building blocks initiatives.

Clubs

Recently, there has been much discussion of climate clubs to achieve emission reductions (Weischer et al 2012, Green et al. 2015, Nordhaus 2015, Victor 2015). The building block strategy focuses on incentivising clubs that produce a tangible 'club' good (e.g. new technology, pooled finance, pooled risk or common standards) that confers economic or other non-climate benefits such as reduced energy costs, energy security, or profitable R&D innovations. In order to prevent freeriding, these benefits are limited to members of the club who abide by its rules, which ensure that the club activities reduce emissions as well as provide benefits to members (Buchanan 1965). The incentives for participation, however, need not be uniform for all members (Hannam et al. 2015). Businesses or some developing countries may join a club in order to receive economic benefits limited to members, while other states and subnational jurisdictions may join and support the club activities in order to advance the global public good of climate protection that reduces emissions.

We see clubs being formed by industry, governmental authorities at different levels, NGOs, and international organisations, often in combination. Actual and potential examples include:

1. **Industry or industry-government clubs for research, development and deployment**. An example is the International Smart Grid Action Network (an arm

of the International Energy Agency), which aims to develop and deploy renewable transmission and smart grids across national borders.

2. **Green trade liberalisation clubs**. A group of countries is negotiating a general agreement on liberalised trade in green goods (Keohane et al. 2015).
3. **Standard-setting clubs**. Public-private expert bodies could form to harmonise technical standards to reduce transaction costs and increase the spread of technologies.
4. **Transnational supply chain regulatory clubs**. Following the example of the Forest Stewardship Council and its certification system and mark for sustainable timber, industry and NGOs could jointly develop performance standards and private certifying arrangements to leverage consumer demand for low GHG goods and services (Vandenbergh 2007).

Linkage

The linkage strategy leverages existing transnational organisations with missions other than climate protection through initiatives – undertaken by policy entrepreneurs within and outside of institutions – that further the organisation's basic mission while also achieving emission reductions. Strategic pockets of support within these organisations, along with flexibility in organisational mandates, may enable these policy entrepreneurs. This strategy economises by using existing organisations where entirely new institutions or programmes with explicit climate objects could not proceed. Like all building block strategies, each linkage initiative will be targeted to the interests of particular actors (in this case, those engaged in the existing organisation) and structured to produce net climate benefits.

Examples include:

1. **Extending the scope of existing environmental agreements to reduce emissions**. Discussions are already underway to extend the scope of the Montreal Protocol to include currently unregulated ozone-depleting substances (ODS) or ODS substitutes that are also GHGs.

2. **Adding an emissions reduction component to an existing non-environmental multilateral agreement**. For example, the ASEAN Agreement on Transboundary Haze capitalised on the ongoing relationships between the ASEAN countries to produce an environmental benefit. A similar strategy could be used to mobilise actions aimed at reducing emissions as a co-benefit.
3. **Preference of low-emission technologies in bilateral and multilateral development programmes**. A number of countries have prohibited their official development assistance from being used, except in very limited circumstances, to fund coal power generation.

Dominant market actors

The third strategy leverages the power of governmental regulators or firms with a dominant position in specific global or regional market sectors. Their dominant position enables them to promote GHG regulation throughout the sector in order to advance their interests. A regulatory jurisdiction with a major market share in goods or transportation services may thus be able to induce economic actors outside the jurisdiction to follow its rules in order to access its market or maintain scale economies in production. Relating to this phenomenon, there has been analysis of the 'California effect' (regarding Californian motor vehicle emission standards) and the 'Brussels effect' (regarding EU product regulations) (Bradford 2013). Regulating jurisdictions may actively pursue this strategy in order to protect their firms from competitive disadvantage. Dominant firms in industry may gain economic and strategic benefits by acting as first movers to adopt regulatory standards. Other firms can be induced through market pressures and network effects to follow the standards, which can be designed to enhance the dominant firm's position. The dominant firm may cooperate with government regulators to secure their adoption of the standards.

This strategy can advance climate protection when regulatory programmes that reduce GHG align with the incentives of dominant government or private market actors. Where dominant public or private actors enjoy sufficient economic, strategic, or other gains from acting as first movers with regulatory or market standards, they may act unilaterally with the goal of inducing others in a sector to follow suit. In some cases, dominant public and private actors may effectively collaborate by using the regulatory power of the public actors to propagate a standard that was set.

Examples of this strategy include:

1. **Product or performance standards.** A dominant firm or group of firms in a climate-beneficial technology, such as components for wind turbines or grid technologies, may adopt or promote government adoption of regulatory standards that will give it competitive advantage.
2. **Market entry condition.** The extension of the EU's Emissions Trading System for regulating domestic emissions to international airlines serving Europe has already been proposed, and spurred action at ICAO. A group of major maritime port jurisdictions could impose enhanced fuel efficiency standards as a condition for using the port.

Launching initiatives and linking the building blocks strategy to the UNFCCC

As illustrated above, we already see significant action based on each of the three building blocks strategies. But the existing initiatives have not appeared spontaneously. They have required both that the incentives of the actors are aligned, and also that one or more entrepreneurs ferret out opportunities for action, identify and convene appropriate actors, structure the parameters of the initiative including institutional/legal arrangements, and ultimately launch the initiative. The existing building blocks have been sparked by all manner of initiative entrepreneurs: oil firms in the Canadian Oil Sands Innovation Alliance (a technology sharing club); the International Renewable Energy Agency (IRENA) in the development of initiatives on renewables in Africa and the small islands; and even the United Nations Secretary-General's Climate Change Support Team in the development of multiple initiatives at the 2014 Climate Summit.

The uptake of opportunities by policy entrepreneurs within the initiatives can be enhanced by providing assistance in accessing information on opportunities in areas of high mitigation potential, locating potential actors, structuring initiatives, accessing technical and financial resources, and by providing a platform to gain visibility. The

UNFCCC itself has significant resources for such assistance: technical knowledge (e.g. on project implementation and monitoring through the Clean Development Mechanism and capacity-building know-how through the Durban Forum on Capacity Building); access to potential sources of finance (e.g. the Green Climate Fund, the Global Environment Facility and the Adaptation Fund); as well as the political participation of 196 countries and significant convening power to bring in non-state actors. Of particular interest as global support for building block initiatives are the institutions that are developing under the Workstream 2 pre-2020 mitigation ambition mandate – the Technical Expert Meetings (TEMs), high-level events, and the Non-state Actor Zone for Climate Action (NAZCA) portal.

Technical information: The TEMs. The TEMs have become a hub of discussion among state and non-state experts on mitigation opportunities as well as the co-benefits of action and the barriers to overcome them, and, where known, the strategies and resources needed. They not only provide an opportunity for initiative entrepreneurs to engage directly with experts, but also provide informational outputs (e.g. technical papers and an online menu of policy options) for continued learning.

Political and financial engagement: The annual high-level event on increased pre-2020 action. These new high-level events focusing on specific initiatives in areas of high mitigation potential are now held alongside the annual Conference of the Parties (COP); the first of these was held in Lima. They are designed to bring together high-level public and private actors to launch new initiatives and provide an opportunity for initiative proponents to attract new public and private participants, and tap the financial and other resources of the UNFCCC.

Visibility and continued engagement: The NAZCA portal. The portal – a UNFCCC website that recognises voluntary action by non-state actors – already includes a substantial number of the currently existing international cooperative initiatives. At present, the portal does not count the emissions reductions that are occurring as a result of the initiatives, either individually or in the aggregate. If the methodological and political considerations are overcome, a form of monitoring and reporting could be added to the NAZCA portal, which would give further and continued recognition and engagement of the initiatives of non-state actors, separate from the obligations of states to take action and report.

Mobilising action

There are significant opportunities for mobilising climate action through the building block strategies. This mobilisation is necessary to complement and support country mitigation programmes in achieving the overriding goal of ensuring that emissions peak and begin to decline in the near term. Capitalising on these opportunities will require concerted effort from public and private actors to participate in initiatives and act as initiative entrepreneurs. Also needed are support systems that assist entrepreneurs in creating new initiatives. While many see the UNFCCC as only focusing on the 'ends', particularly targets for national emissions reductions, the recent institutional developments that we outlined above have allowed for a new focus on the 'means' of developing climate action. While these new UNFCCC institutional developments provide some of the necessary components of acting as a support system for building block initiatives that would complement initiatives by national governments, they are not well linked, and there is no institutional focus on supporting initiatives from idea, to incubation, to launch. The UNFCCC does not have to be the only support system. There is much that NGOs, businesses, governments, research institutes and foundations can and should do to assist initiative entrepreneurs.

References

Barrett, S. (2003), *Environment and Statecraft the Strategy of Environmental Treaty-Making*, Oxford: Oxford University Press.

Bradford, A. (2013), "The Brussels Effect", *Northwestern University Law Review* 107(1).

Buchanan, J. (1965), "An Economic Theory of Clubs", *Economica* 32(125): 1-14.

Downs, G., D. Rocke and P. Barsoom (1998), "Managing the Evolution of Multilateralism", *International Organization* 52: 397-419.

Green, J., T. Sterner and G. Wagner (2014), "A balance of bottom-up and top-down in linking climate policies", *Nature Climate Change* 4: 1064–1067.

Hannam, P., V. Vasconcelos, S. Levin and J. Pacheco (2015), "Incomplete cooperation and co-benefits: Deepening climate cooperation with a proliferation of small agreements", *Climatic Change*, forthcoming.

Heede, R. (2013), "Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854-2010", *Climatic Change* 122(1-2): 229-241.

Keohane, N., A. Petsonk and A. Hanafi (2015), "Towards a Club of Carbon Markets", *Climatic Change*, forthcoming.

Nordhaus, W. (2015), "Climate Clubs: Overcoming Free-Riding in International Climate Policy", *American Economic Review* 105(4): 1339–1370.

Sabel, C. and D. Victor (2015), "Governing Global Problems under Uncertainty: Making Bottom-Up Climate Policy Work", *Climatic Chan*ge, forthcoming.

Stewart, R., M. Oppenheimer and B. Rudyk (2013), "Building Blocks for Global Climate Protection", *Stanford Environmental Law Review* 32(2): 341-392.

Stewart, R., M. Oppenheimer and B. Rudyk (2013), "A New Strategy for Global Climate Protection", *Climatic Change* 120: 1-12.

Vandenbergh, M. (2007), "The New Wal-Mart Effect: The Role of Private Contracting in Global Governance", *UCLA Law Review* 54: 913.

Victor, D. (2015), "The Case for Clubs", International Centre for Trade and Sustainable Development, Geneva.

Weischer, L., J. Morgan and M. Patel (2012), "Climate Clubs: Can Small Groups of Countries make a Big Difference in Addressing Climate Change?", *Review of European Community & International Environmental Law* 21(3): 177-192.

About the authors

Richard B. Stewart is University Professor and John E. Sexton Professor of Law at the New York University School of Law. A specialist in environmental, regulatory and administrative law, he has served as assistant attorney general in charge of the

Environment and Natural Resources Division of the US Department of Justice and Chairman of the Environmental Defense Fund, and was a faculty member at Harvard Law School. His current research projects include 'megaregional' international agreements on regulation, trade, and investment; using law to reform and secure justice in global governance; private and hybrid global regulation; innovative institutional strategies to reduce greenhouse gas emissions; and solving the challenge of nuclear waste. Stewart also works on global climate law initiatives, electricity sector reform, and environmental law reform projects in developing countries through the International Environmental Law Clinic and the Guarini Center on Environmental, Energy, and Land Use Law.

Michael Oppenheimer is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University and Director of Princeton's Program in Science, Technology and Environmental Policy (STEP). He joined the Princeton faculty in 2002 after more than two decades with the Environmental Defense Fund, where he served as chief scientist and headed the Climate and Air Program. Previously, he was Atomic and Molecular Astrophysicist at the Harvard-Smithsonian Center for Astrophysics. Oppenheimer is a long-time participant in the Intergovernmental Panel on Climate Change (IPCC), which won the Nobel Peace Prize in 2007, and a coordinating lead author on IPCC's Fifth Assessment. Oppenheimer coedits the journal *Climatic Change*. He serves on the US National Academies Board on Energy and Environmental Systems and the New York Panel on Climate Change, and is science advisor to the Environmental Defense Fund. His research focuses on the science and policy aspects of climate change and its impacts.

Bryce Rudyk is Adjunct Professor and Director, Climate Programs at the Guarini Center on Environmental, Energy and Land Use Law at the New York University School of Law. For 2014-2015, he is the Senior Legal Advisor to the Chair of the Alliance of Small Island States (AOSIS), the negotiating block for 44 countries in the UNFCCC negotiations. He joined NYU in 2009 after working in private law practice and lobbying. He teaches in international environmental law, global governance and climate change. His research focuses on global environmental institutions and climate change.

16 Climate change policies and the WTO: Greening the GATT, revisited

Petros C. Mavroidis and Jaime de Melo[1]
Columbia University; FERDI

The thrust of our argument in this chapter is that the present WTO 'negative contract' is a legal constraint that does not suffice to promote climate change-friendly policies, as WTO members do not have to adopt similar policies. Moreover, some of their policies might be judged inconsistent with the WTO, even if adopted in order to address externalities and distortions. To illustrate, we assume that Home, a WTO member, wishes to employ one of three instruments of different 'intensity' (labelling, domestic tax, and subsidy) to mitigate climate change. Can it do so while respecting its obligations under the WTO contract? Our response is affirmative when Home chooses the second option, and negative when it uses the first and the third options. The negative response is due to the bizarre manner in which the WTO Appellate Body, the highest court in the WTO infrastructure, has understood non-discrimination in the context of the Technical Barriers to Trade (TBT) Agreement, and the inertia/lack of foresight by trade delegates who did not extend the carve-out for 'green subsidies' that had been agreed in 1995 beyond 2000. Needed changes at the multilateral level require delegation of sovereignty to move towards a contract that would require positive steps from the WTO membership in order to avert climate change. As an immediate amendment, the reinsertion of the clause of non-actionable subsidies should be considered. Until greater delegation of sovereignty is accepted, the fight against climate change on the trade front will be substantially aided if the WTO were to embrace and accommodate clubs that have endorsed this objective.

1 For helpful discussions and comments, we are indebted to Scott Barrett, Jagdish Bhagwati, Carolyn Fischer, Henrik Horn, Damien J. Neven, and Luca Rubini. This is a shortened version of Mavroidis and de Melo (2015).

1 Introduction

Up until the launch of the Doha Round, the climate change and trade regimes evolved separately through stand-alone negotiations. Trade policy and the WTO enter the design of the upcoming climate regime architecture once one accepts that the first-best option of global carbon pricing is unachievable because of non-participation by a subset of countries. From a *Realpolitik* perspective, one must first understand how climate change policies fare under the current WTO mandate and ensuing legal discipline. The focus of the framers of the GATT was on tariff protection, leaving to members the freedom to design all domestic policies (including environmental) to their liking. Once a social preference had been revealed, it would apply in non-discriminatory terms, that is, without distinguishing between domestic and imported goods. Protection could take one form only (tariffs), and it became negotiable. This is why the GATT is often referred to as a 'negative integration' contract. As discussed in the working paper version of this chapter (Mavroidis and de Melo 2015), environmental policies have changed little from the GATT to the WTO.

Section 2 reviews how the three main instruments to address climate change mitigation objectives (labelling, taxes, and subsidies) fare under the current WTO regime. Section 3 discusses needed changes in the WTO, emphasising implementable improvements inspired by existing and former elements of the world trade architecture.

2 Instruments to deal with trade-related conflicts

Quantitative restrictions are illegal in the WTO. Hence, members cannot, in principle, block imports of products that pollute the environment unless they apply similar measures to domestic products. Again in principle, WTO members can also differentiate the customs treatment of imports depending on whether they fight climate change or not, but this is an instrument of limited effectiveness as tariffs are mostly bound and applied tariffs are, on average, in the range of 1-5%. Moreover, the Harmonized System (HS) that provides the basis for tariff classifications does not contain classifications that distinguish between goods based on whether they avert climate change or not. Classifications to this effect are thus 'national' (i.e. decided unilaterally), so that if a WTO members adds its own classification i.e. at the 8 and 8+ digit level, it is at the risk of a legal challenge (a potential complainant could argue that renewable and non-renewable energy are like products, and hence by imposing a lower customs duty on the former than that imposed on the latter, a WTO member would be violating the most-favoured-nation, or MFN, obligation). There is no case law that directly addresses this issue, but there is the risk of litigation.

Reversing a decision under US-Tuna (Mexico) in US-Shrimp, the Appellate Body (AB), the highest judicial organ of the WTO, held that unilateral policies are not illegal simply because they are unilateral. If they meet the relevant statutory criteria, then unilateral policies, including climate change policies, can perfectly well exist within the WTO regime. The Uruguay Round agreements reproduced the negative integration 'spirit' of the GATT. The WTO did strengthen the disciplines towards subsidies, making subsidies (i.e. every government intervention that confers benefits to specific recipients rather than to the public at large) either prohibited or 'actionable'. Only two categories of subsidies are prohibited – namely, export and local content subsidies – while a third category that included environmental subsidies was classified as 'non-actionable' over a five-year period up to 1 January 2000 (Art. 31 of the Agreement on Subsidies and Countervailing Measures, or SCM). All other subsidies are 'countervailable', e.g. either through unilateral (imposition of countervailing duties) or multilateral action (dispute before a Panel), whereby affected member states will impose a burden on the subsidising member equal to the benefit granted through the scheme. As the agreement on a non-actionable category was not renewed, a scheme that qualifies as a subsidy under the SCM Agreement is nowadays either a prohibited or an actionable subsidy. As a result, WTO members cannot subsidise producers in order to change their process and production methods (PPMs) to produce in a way that will avert climate change. They can, of course, always subsidise consumers. Political economy-related transaction costs often explain why similar measures do not see the light of day.

Against this background, three challenges facing the upcoming climate regime involve the WTO: first, a predictable time path for the price of carbon that would involve reforms of the subsidy code to handle the removal of fossil fuel subsidies and the application of subsidies at the international level to develop abatement technologies; second, border tax adjustments to tackle the different forms of carbon leakage, especially that related to the 'competitiveness channel' for energy-intensive, trade-exposed manufacturing (see the chapter by Fischer in this book); and third, labelling to distinguish PPMs that avert climate change from those that do not.

Acknowledging that climate change subsidies are no longer allowed, we consider three instruments to mitigate climate change.

2.1 Environmental labels

Home adopts a labelling scheme distinguishing between products that are not produced in manner that causes climate change and products that are. This is particularly important in the current climate negotiations, as the IPCC estimates that 38% of the reductions in CO_2 emissions to hit the 2°C target will have to come from the use of energy-efficient (EE) products (energy-saving products that minimise economy-wide energy consumption, and energy-efficient products in a performance-based sense). Along with minimum energy performance standards, comparative labelling to distinguish goods according to their PPMs is the most common policy instrument to promote EE.

Home then sets a ceiling on CO_2 emissions of cement clinkers (HS 252321), with products whose emissions exceed the ceiling not allowed to be sold lawfully sold in its market. Here it is irrelevant whether the PPM has been incorporated in the traded good or not. The Agreement on Technical Barriers to Trade (TBT) that applies to labelling schemes covers both incorporated inputs (termed 'physical characteristics') as well as non-incorporated PPMs. It is further irrelevant whether compliance with the scheme is mandatory for goods to be traded ('technical regulation') or not ('standard'). The substantive obligations are identical irrespective of the 'intensity' of the measure, and case law has anyway blurred this distinction.[2] Finally, note that this is a domestic, not a trade instrument so, prima facie, the test of likeness will not revolve around the Harmonized System (HS) classification of the product but, as discussed below, on consumers' reactions.

Foreign complains that the labelling scheme is unnecessary and discriminatory. The recent AB report on US-Tuna II (Mexico) reflects the current state of affairs. Labelling schemes must be *necessary* and applied in a non-discriminatory manner. The term

2 Mavroidis (2015) discusses this issue in detail.

"necessary" has been consistently interpreted to denote the least restrictive option to achieve an objective unilaterally set by the regulating state, which is not justiciable. In the example, if the regulating state cannot afford to subsidise, it could still use the tariff. In light of the above, it is hard to imagine how a labelling scheme cannot be judged necessary. As in US-Tuna II (Mexico), where a labelling scheme was found to be TBT-consistent on similar grounds, we expect the measure to pass muster in this respect. The costly part of the endeavour will be conformity assessment falling on exporters.

Assuming that Foreign cannot pass this first test, Foreign can still attack Home's measure and argue that it is discriminatory since, irrespective of emissions released, a widget is a widget is a widget. The problems for Home then come when reviewing the consistency of the measure with non-discrimination. In US-Tuna II (Mexico), the AB held that consumers would decide on likeness. If so, most likely they will be purchasing the cheaper of the two goods, i.e. the one with highest embodied CO_2 emissions. By not conditioning purchasing decisions on the volume of CO_2 emissions, the two goods will be judged 'like' goods. By treating two like goods in an unlike manner, Home will be violating its obligation to not discriminate. This is what the AB decided in US-Tuna II (Mexico).

Why not compare climate change-averting domestic to climate change-averting imported goods (i.e. labelling schemes in Home and Foreign)? In the Chile-Alcoholic Beverages case (and later in the EC-Asbestos case), the AB established that this comparison is not the right one. Case law has thus upheld that it is up to consumers to decide whether regulatory distinctions that create submarkets are legitimate or not. The measure cannot be saved through recourse to GATT Article XX, as consistent case law suggests that this defence is not available to violations of the TBT Agreement.

This is a deplorable state of affairs for climate change mitigation endeavours. Mavroidis (2013) explains why likeness should be a question of policy – not market-likeness (as perceived by consumers) in the TBT context. Governments will intervene only when they disagree with the behaviour of private agents; otherwise, why intervene in the first place? Similar statutes should thus pass the test of legality with flying colours. Alas, this is not what happens. In the end, the problem here is not major, since all that is required is a change in case law. Since the law as it stands does not prejudge the outcome at all, it leaves the question of establishing likeness in the hands of adjudicators.

2.2 Environmental taxes

Here we are dealing with a border measure, and the likeness test will revolve around the (inadequate) HS classification of the product. Horn and Mavroidis (2011) discuss this issue in substantial detail. Now, Home opts to adjust the level of taxation on the content of CO_2, such as a tax of \$10 per tonne of CO_2 released in the production of cement clinkers (HS 252321). Here we shift from the TBT Agreement to the GATT, since we are dealing with a tax collected at the border and the legal test is not identical, although consumers, yet again, are kings. If consumers prefer the more CO_2-intensive imported cement, the treatment will be judged 'less favourable' for imported goods, and hence GATT-inconsistent (in EC-Seals, the AB ruled that producers of seal bags could not market their bags in the EU market, whereas producers of other bags could). The treatment will be judged less favourable, since 'like' goods will be paying 'unlike' taxes.

Unlike what happens in the TBT labelling case, though, Home will be in a position to justify its measures under GATT Article XX(g). Clean air is an 'exhaustible natural resource' (US-Gasoline, AB), and the measure must simply 'relate to' its protection. This means that Home must demonstrate a rational connection between the tax differential and the protection of clean air, a rather easy-to-meet standard. CO_2 does pollute the air, and the less air is polluted, the cleaner it is. Tax disincentives to pollute 'relate to' the objective sought (the protection of clean air); hence, Home would prevail under the GATT.

Home could impose higher customs duties against polluting goods instead of adjusting domestic taxes at the border, as discussed by Fischer in her chapter in this book. But to do so, it would have to enter sub-classifications in the headings at the 10- or 12-digit level to distinguish the tariff treatment of goods made using renewable energy from those 'same' same goods when made using fossil fuels – a difficult exercise. The consistency of similar sub-classifications with the WTO is currently an open issue. Moreover, since tariffs are at an all-time low, the potential for 'meaningful' tariff advantages through similar schemes is limited.

2.3 Subsidies

Under the current WTO regime, 'green' subsidies are prohibited. The elimination of such subsidies signalled the end of the distinction between 'good' and 'bad' subsidies, thus defying economic logic that calls for the removal of market failures. Subsidies to consumers that are not specific are available, but they are accompanied by higher transaction costs than subsidies to producers (more transactions and higher verification costs). Moreover, even though there is no case so far, a complainant might be in position to show that, in spite of a subsidy having been paid to consumers, de facto, only a few companies have profited. In this case, a complainant could request withdrawal of the scheme. In the end, the limits to addressing climate change through subsidies are quickly understood when one takes on board the negative integration character of the WTO

3 Is the WTO a hindrance to environmental protection?

With foresight, Esty (1994) argued 20 years ago that the WTO was being negotiated without paying sufficient attention to environmental concerns. While some problems WTO members face when wishing to adopt measures to mitigate climate change can be dealt with by pre-empting the discretion of WTO 'courts' (e.g. labelling), most derive from the overall attitude of the WTO legal regime towards global public goods. The framers of the WTO focused on improving a series of pre-existing agreements and did not consider the need to internalise the growing transnational externalities. A few scattered initiatives, like the ongoing negotiation of environmental goods, are a step in the right direction, but are insufficient. A total recall – call it a WTO 2.0 – that would not *allow* but would *oblige* WTO members to adopt a different attitude towards protecting and serving public goods, and give priority to this objective when and if conflicts with trade obligations arise, is what is needed. Consider, then, implementable reforms at the multilateral and plurilateral levels.

3.1 Reforms at the multilateral level

Two improvements are necessary. Monitoring of subsidies for fossil fuels is the starting point. Collins-Williams and Wolfe (2010) have adequately explained why WTO members are disincentivised from providing information about their subsidies, since supply of similar information is self-incriminating. Note, though, that as Aldy (2015) explains in detail, the G20 Fossils Subsidies Agreement call for external review is a step forward. Hence, this is an area where the wishes of the G20 and the reality at the WTO are in conflict. Here, the WTO (the common agent) could be mandated by members to play a more active role in marshalling evidence worldwide on similar subsidies. Second, the provision on non-actionable subsidies needs to be re-inserted in the WTO, and this time improved so as to correspond to whatever is needed to fight climate change. Those who fear that the frontier between green policies and 'blue' industrial policies is more of a line in the sand than a distinction set in stone will be comforted to know that local content subsidies are prohibited. Assuming effective monitoring of schemes along the lines discussed by Wiener in his chapter in this book, subsidisers will find it hard to help domestic producers sell their technology through subsidies allegedly aimed at averting climate change.

Furthermore, assuming that a generic category of non-actionable subsidies has been re-introduced, the WTO legal regime could preempt the wrong exercise of discretion by Panels and the AB by including illustrations of the type of subsidies that should qualify as 'green', and therefore as non-actionable subsidies. For example, it could be spelled out that all subsidies paid to consumers to purchase renewable energy are non-actionable. The WTO membership could go further and, inspired by practice, exonerate other types of subsidies as well. Indeed, in the same way that it has been possible to include an indicative list of schemes that qualify as export subsidies in the SCM Agreement, the WTO membership should be in a position to agree on a list of schemes that should qualify as non-actionable.

3.2 Reforms at the plurilateral level

Plurilateral agreements that bind a subset of the WTO membership – assuming authorisation by the plenum – is another route to address the climate mitigation objective. The ongoing negotiation on environmental goods, where a subset of the WTO membership is willing to reduce tariffs on goods that address climate change-related concerns, will eventually take the form of a plurilateral agreement. Hoekman and Mavroidis (2015) and de Melo and Vijil (2015) both forcefully argue why this avenue should be encouraged in the future functioning of the WTO. Mentioning six tasks that have eluded multilateral negotiations, Victor (2015) also advocates the 'climate club' approach.[3]

Climate clubs should not be viewed as attempts to curb multilateralism. Both critical mass and plurilateral agreements share one feature in common: they keep the umbilical cord to the WTO intact, as MFN is observed in the former case, while accessions are open to non-original members in the latter. A combination of the two could be of particular interest in the fight against climate change. WTO members could agree, for example, that a certain threshold of world production of energy-intensive goods are particularly harmful towards the environment and incite climate change. Assume, for example, that cement production, which accounts for 5-7% of global CO2 emissions, has been singled out. Signatories to a critical mass plurilateral agreement could agree to the staged reduction of CO2 emissions. They could further agree that, before the agreement has entered into force, WTO members representing, say, 80% of world cement production will have ratified it.

Punishing non-participants is not envisioned in the critical mass and plurilateral approaches discussed above. Nordhaus (2015) explains and shows how a set of climate amendments to international law that would "explicitly allow for uniform tariffs on non-participants within the confines of a climate treaty… [and] prohibit retaliation against countries who will invoke the mechanism" could entice participation by non-members (p. 1349). He then shows that the use of 'carbon duties' is an effective sanction to prevent leakage only, but that uniform tariffs on imports are more effective in preventing free-riding. This penalty turns out to be reasonably well targeted and it is also incentive-compatible (it imposes costs on the defectors and confers benefits to the

3 The tasks best-suited for being addressed in a climate club include enticing reluctant countries to participate using carrots and sticks, designing smart border measures, crafting conditional commitments, crafting and demonstrating technology strategies and tackling easier problems like short-lived climate pollutants.

punisher). In conclusion, the huge benefits of belonging to the WTO in terms of MFN access could be made an effective enticement for participation.

Nordhaus does not go into the details of the legal amendments required. The problem is that under the current negative integration contract, countries cannot be told to adopt climate-mitigation policies, and nor can a club of countries raise their bound tariffs – even in a non-discriminatory manner – against non-members, since under a preferential trade arrangement (PTA) members are only allowed to reduce tariffs against outsiders. Moreover, as we have explained above, there is more promise in pushing outsiders to join the club through domestic taxes (which are unbound) than through customs tariff differentiations, the overall level of which is very low. And of course, the credibility of similar threats will depend on whether the WTO 'courts', in case of litigation, adopt our approach regarding the relevance of Article XX(g) of GATT. As discussed above, re-inserting Article 8 SCM might help, but it would have little effect in tackling the immensity of the problem, as the punisher is being punished while the free-rider benefits from abatement by club members.

A more promising approach would be for club members to adopt a regime of mutual recognition/equivalence (which is easier to do among club members who have relatively high within-group trust). Then, a coalition of the willing could agree on 'optimal' regulatory standards that should be followed and that would be implemented via conformity assessments.[4] In this case, outsiders would have to demonstrate that their production processes are equivalent to those prevailing among club members to profit from market access.

While it is unrealistic to expect that WTO members will have similar preferences in mitigating climate change, legislators need to ensure that both a defence by those willing to defend is provided through the WTO legal arsenal while at the same time, proactive behaviour is condoned. The former is the case indeed, as our discussion of border tax adjustments above shows. The latter remains to be seen under the current legal contract where members are reluctant to transfer sovereignty even when it is quite obvious that absent multilateral action, distortions will not be addressed. In this setting,

4 In Nordhaus' model, the tariff punishment is credible because it acts like an optimal tariff. Achieving credibility would be even harder for regulatory standards.

re-inserting Article 8 SCM and allowing 'coalitions of the willing' seems the most promising way to move forward. The GATT was not 'greened' and we have paid the price – one that the WTO, alas, cannot afford to pay anymore.

References

Aldy, J. (2015), "Policy Surveillance in the G-20 Fossil Subsidy Agreement: Lessons for Climate Policy", Belfer Center for Science and International Affairs Discussion Paper No. 15-70, Harvard University.

Collins-Williams, T. and R. Wolfe (2010), "Transparency as Trade Policy Tool: The WTO's Cloudy Windows", *The World Trade Review* 9(4): 551–581.

De Melo, J. and M. Vijil (2015), "The Critical Mass Approach to Achieve a Deal on Green Goods and Services: What is on the Table? How Much to Expect?", FERDI Working Paper No. P107, Cleremont-Ferrand, France (also forthcoming in Environment and Development Economics).

Esty, D. C. (1994), *Greening the GATT, Trade, Environment and the Future*, Washington, DC: Peterson Institute

Fischer, C. (2015), "Options for avoiding carbon leakage", Chapter XX in this volume.

Grossman, G. M., H. Horn and P. C. Mavroidis (2013), "Domestic Instruments", in H. Horn and P. C. Mavroidis (eds), *Legal and Economic Principles of World Trade Law*, New York: Cambridge University Press , pp. 205-345

Hoekman, B. M. and P. C. Mavroidis (2015), "Embracing Diversity: Plurilateral Agreements and the Trading System", *World Trade Review* 14(1): 101-116.

Horn, H. and P. C. Mavroidis (2011), "To B(TA) or Not to B(TA)? On the Legality and Desirability of Border Tax Adjustments from a Trade Perspective", *The World Economy* 34(11): 1911-1937.

Mavroidis, P. C. (2013), "Driftin' too far from shore – Why the test for compliance with the TBT Agreement developed by the WTO Appellate Body is wrong, and what should the AB have done instead", *The World Trade Review* 12(3): 509-531.

Mavroidis, P. C. (2015), *The Regulation of International Trade*, Cambridge, MA: MIT Press.

Mavroidis, P. C. and J. de Melo (2015), "Climate Change Policies and the WTO: From Negative to Positive Integration", forthcoming FERDI Working Paper, Clermont-Ferrand, France.

Nordhaus, W. (2015), "Climate Clubs: Overcoming Free Riding in International Climate Policy", *American Economic Review* 105(4): 1339-70

Victor, D. (2015), "The Case for Climate Clubs", E15 Initiative, ICSTD, Geneva.

Wiener, J. (2015), "Towards an effective system of monitoring, reporting, and verification", Chapter XX in this volume.

About the authors

Petros C. Mavroidis is Edwin B. Parker Professor of Law at Columbia Law School, and Professor of Law at the University of Neuchatel. He acted as chief reporter for the American Law Institute project on 'Principles of International Trade: the WTO'.

Jaime de Melo, emeritus professor at the University of Geneva, is Scientific Director at FERDI, an invited professor at the Johns Hopkins University Bologna Center, and a non-resident scholar at Brookings. He worked at USAID from 1972 to 1976, taught at Georgetown University from 1976-80 and at the University of Geneva from 1993-2012. From 1980 to 1993, he held various positions in the research Department at the World Bank. He serves on several editorial boards and was editor-in-chief of the *World Bank Economic Review*, 2005-2010.

PART IV

Policy Options

17 The regulatory approach in US climate mitigation policy

Dallas Burtraw
Resources for the Future

Climate policy in the United States stalled with the failure to pass comprehensive economy-wide cap and trade in 2010. Despite this setback, policy has continued to form, developing along a separate regulatory track that is on course to allow the US to achieve emissions reductions by 2020 approaching its pledge in Copenhagen. The current regulatory approach to climate policy is directed by the Environmental Protection Agency, which has the authority to regulate greenhouse gases at the national level under the Clean Air Act. This regulatory approach has so far separately targeted the transportation and power sectors, and additional regulations in other sectors are expected. The approach has technical foundations in policies previously implemented by state governments, which it extends through the introduction of national goals. The organic development of policy in the US has an apparent analogue in the international setting as sovereign nations independently prepare pledges and other activities in support of global climate outcomes. The cost of a regulatory approach is likely to be greater than a coordinated effort built on carbon pricing; however, the policy durability of regulation may be as great or greater. Perhaps more importantly, the regulatory approach has initiated a planning process in state capitals that may build a more robust foundation for future policy goals.

In 2009, with the support of a new president, the US House of Representatives passed comprehensive climate legislation including economy-wide cap and trade. Then, the winds of change shifted and the measure, which was never taken up in the US Senate, was left to expire. Cap and trade was declared politically dead. For over two years the president did not utter a word about the changing climate. Many observers thought that

President Obama's pledge in Copenhagen in 2009 to reduce US emissions by 17% from 2005 levels by 2020 was a forgotten promise.

However, out of view of the international community and most political observers, the Obama administration was pursuing a parallel strategy to address climate change through exercising the regulatory authority of the Environmental Protection Agency (EPA) under the Clean Air Act. This chapter summarises the key aspects of this regulatory approach and its expected accomplishments, and discusses its implications for economic efficiency and the prospects for enduring into the future.

1 Increasing the regulatory authority of the EPA

The EPA's authority to regulate greenhouse gases (GHGs) was established under the Clean Air Act and affirmed in a 2007 Supreme Court decision. The court's decision was precipitated by actions already taken by the states that were developing climate policies. The court decision triggered an agency investigation and formal finding of harm from GHG emissions in 2009. Under threat of private lawsuits (a special and unusual provision of the Clean Air Act), the EPA was obliged to move to mitigate that harm. The agency's first actions were finalised in January 2011 with new emissions standards for light duty vehicles and the inclusion of GHGs in the required emissions permitting for new construction of stationary sources. The vehicle standard initiated a 5% annual improvement in the miles per gallon measure of efficiency for new cars that has been extended through the middle of the next decade. The new mobile source standards are expected to contribute to a reduction in carbon dioxide (CO_2) emissions of about 4 percentage points toward the goal of a 17 percentage point reduction by 2020.[1] The preconstruction permitting requirement, which locked in the consideration of GHGs along with other air pollutants in air permitting, will not have much effect in

1 This estimate is based on the US Environmental Protection Agency estimates of turnover in the vehicle fleet. Other estimates in this paragraph and those describing the impact of the Clean Power Plan are based on the author's published research using a detailed simulation model of the power sector and a reduced form representation of the rest of the economy. As described in the chapter by Aldy and Pizer in this book, the comparison of mitigation efforts across nations raises many challenging issues including the validity of models used for that exercise.

the next decade because new construction occurs over a long time frame. The important effect of the permitting requirement will be felt in the long run.

In August 2015, as the centrepiece of this regulatory effort, the president finalised the Clean Power Plan, which aims to reduce emissions from existing power plants that are responsible for about 40% of the nation's CO_2 emissions and about one-third of total GHGs. The Clean Power Plan constitutes the biggest contribution to US emissions reduction efforts to date.

Together with recent changes in US fuel markets, these regulatory initiatives place the US on course to achieve or nearly achieve its Copenhagen pledge, at least with respect to emissions of CO_2. The expanded supply of natural gas and its substitution for coal in electricity generation already accounts for about 3-4 percentage points of the 17% pledge. This contribution might be interpreted as 'business as usual' and not credited to climate policy, but to some extent it results from other strengthened regulatory measures aimed at sulphur dioxide and nitrogen oxide emissions and new regulation of mercury and air toxics from coal power plants. Changes in the electricity sector also reflect extensive federal investments in energy efficiency programmes. Measures taken by state and local governments, including promotion of renewable and energy efficiency technologies, add 2-3 percentage points more. The 17% reduction in emissions that the US hopes to achieve would occur against a backdrop of nearly 30% growth in real terms between 2005 and 2020 in the US economy (CBO 2014).

2 The Clean Power Plan

Before consideration of the Clean Power Plan, measures put in place at all levels of government would achieve roughly 10 percentage points of reduction in emissions compared to 2005 levels. The Clean Power Plan as initially proposed in 2014 intended to add another 6 percentage points or more, placing the US very close to attaining the Copenhagen goal. The final version of the plan delayed full compliance from 2020 to 2022. It retains incentives for investments in renewable energy and energy efficiency beginning in 2020, but the new date will delay the incentive to shift generation from coal to natural gas that is also expected to contribute importantly to emission reduction. The net effect may be a set back with respect to the 2020 goals of the Copenhagen pledge. However, the final plan boosts the stringency of emissions reduction goals over the rest of that decade, compared to the proposed plan.

Burtraw and Woerman (2013) estimate that altogether the regulatory measures taken under the authority of the Clean Air Act, if fully implemented, will result in domestic emissions reductions that are greater than would have been achieved under the comprehensive cap-and-trade proposal that failed to pass Congress. The cap-and-trade proposal embodied an emissions reduction target equal to the Copenhagen pledge, but it allowed for international offsets as a means to meet the target, which would have substituted for domestic emissions reductions. The regulatory measures taken under the authority of the Clean Air Act do not provide a role for international offsets, so emissions reductions are achieved all within the US economy.

To an international audience of policymakers and economists, the structure of the Clean Power Plan is noteworthy because the process it inaugurates mirrors one that is taking shape in international negotiations. As in the US, the international dialogue has moved from the design of a coordinated system to the evolution of an organic one that builds on measures that are taken by sovereign jurisdictions. Individual nations will declare independent nationally determined contributions to mitigating emissions. By analogy, under the Clean Power Plan the US states have responsibility for planning, implementing and enforcing strategies to reduce emissions. The Plan prescribes state-specific emissions rate goals and alternative mass-based equivalents (emissions caps), and states may decide which approach to take. While the state-level goals are federally determined, which solves one aspect of the coordination problem, the policy options available to the states are unconstrained. Each state must choose whether to comply with an emissions rate or emissions cap goal, and submit a plan that demonstrates policies that will achieve the EPA's goal for that state. This presents a substantial coordination challenge, especially among states that operate in the same power market. While this coordination challenge will surely exist within the development of international climate policy, leakage of electricity generation and investment under the Clean Power Plan is potentially much more immediate and sizable than what might be observed internationally in the movement of industrial production (Bushnell et al. 2014, Burtraw et al. 2015).

Also the goals among the states are differentiated, as occurs internationally among nations. The goals are based on a national emissions rate target for coal-fired units and another for natural gas combined cycle units, and are calculated on the basis of the resource mix in a given state, including the opportunity to substitute away from fossil fuels to nonemitting generation. Energy efficiency is given credit under a rate-based approach and contributes directly to compliance under an emissions cap. The technical opportunities vary according to the fuel mix, generation fleet, and resource availability among states, just as technical opportunities vary among nations.

3 The triumph of law and engineering: Assimilating a key economic idea

What is missing in the Clean Power Plan compared to the approach that would be taken by most economists in designing a climate policy is cost-effectiveness – that is, explicit attention to equating the marginal costs of emissions reductions measures throughout the sector and the entire economy. In this sense, the Clean Power Plan is a triumph of law and engineering over economics – law because it is implemented subject to the requirements and constraints of the Clean Air Act, and engineering because the relevant portion of the Act is based on a demonstration of technical opportunity. Because the demonstrated options take into account regional variation, there is some rough alignment of marginal cost, but the Plan does not make cost effectiveness a centrepiece.

However, the EPA has preserved perhaps an even higher order principle from environmental economics — the opportunity for flexible compliance. States can choose to use a tradable emissions rate approach (emissions rate averaging) to achieve compliance, or they can adopt a mass-based equivalent. States can choose from a complete menu of policy approaches to achieve these goals, including cap and trade or emissions taxes, or they can convene a resource planning exercise that is familiar in many states where electricity generation is still regulated.

The flexibility under the Clean Power Plan is of central importance because it gives the regulated entities the tools to negotiate to a cost-effective outcome. Such an outcome is not built in, but it is available and it is likely to be pursued within and among many groups of states. In this sense, the Clean Power Plan differs from traditional prescriptive approaches to regulation and it embodies an important lesson from several decades of economic thinking.

It is also noteworthy that the Clean Power Plan empowers and reinforces the actions of first movers in climate policy among states and local governments. Often these first movers have taken actions that demonstrate the technical opportunities that are the basis for the regional goals. Ten US states have existing cap-and-trade programmes. Twenty-nine states have renewable technology support policies and about 25 have funded energy efficiency policies.[2] This bottom-up leadership has been central to the development of national policy because the accomplishments at the state level are encapsulated in the EPA's findings of technical possibility that underpin the regulation. Paradoxically, comprehensive policies may eliminate the incentive for bottom-up leadership. For example, because cap-and-trade programmes establish a specific tradable quantity of emissions, they have the unanticipated characteristic of imposing not only an emissions ceiling but also an emissions floor (Burtraw and Shobe 2009). With the quantity of emissions established at the national level, measures taken by subnational governments such as energy efficiency measures that overlap an emissions trading program result in 100% leakage (Goulder and Stavins 2011). This characteristic undermines initiatives that might be taken by regulatory agencies, subnational governments or individuals – the type of decentralised initiatives that form the technical foundation for the current regulation.[3]

4 Process and public participation

In contrast to a comprehensive policy that might undermine the contribution of subnational and individual efforts, the Clean Power Plan has launched a substantial process of public participation through planning activities in every state capital that must

2 www.dsireusa.org (accessed August 14, 2015).

3 This is not the necessary outcome when governments introduce a price on carbon and simultaneously promote complementary policies to direct technological development. For example, a tax on carbon will maintain its signal for innovation even as other measures promote directed incentives for technological development. The same outcome is achieved in a cap-and-trade programe if there is a price floor in place. All three North American cap-and-trade programmes (California, Quebec and RGGI) have a price floor.

include interactions with the public. This emphasis on process is a strategy borrowed from the states, and appears to mirror international developments. Keohane and Victor (2013) suggest that for a global climate policy regime to succeed, it is likely to require the learning and coalition-building that is achieved through an incremental process. The public engagement through the Clean Power Plan is unprecedented and deliberate. The outcome of such a process is certainly not guaranteed to be efficient. Conceivably, though, it may help build a decentralised public consensus for action on climate that would not be inherent in national-level comprehensive legislation, and certainly was not part of the debate around cap and trade in the US six years ago.

If fully implemented, the Clean Power Plan will position the US to achieve its Copenhagen pledge with respect to CO_2 emissions. After 2020 it will also yield additional emissions reductions that will contribute to the nation's pledge going into the Paris negotiations for reductions of 26-28% by 2025. But achieving comparable reductions in all greenhouse gases or fully realising the 2025 target will require additional regulations (Hausker et al. 2015). The next ones are expected to be regulation of emissions from heavy-duty trucks, regulation of methane emissions associated with the natural gas industry (including gas extraction and transportation), and regulation of emissions from aircrafts. Others will include regulation of industrial gases. These measures could achieve the Copenhagen pledge and go beyond it. It is not yet clear that policy options using existing regulatory authorities have been identified that will achieve the 2025 target. However, the US is much closer to these targets than many thought possible just a couple of years ago.

5 Efficiency and durability of the regulatory approach

The efficiency of the regulatory approach is difficult to gauge. The cost of vehicle standards depends on the value of fuel savings, which varies directly with the price of gasoline. In the electricity sector, the cost of the Clean Power Plan depends on the ability of states to plan or negotiate to a cost-effective outcome. If they do so, modelling indicates the marginal cost of emissions reductions would be around $20 per tonne of CO_2 reduced (in 2010 US dollars) (Burtraw et al. 2014). If they fail, the marginal costs will vary by a great deal around the country. In the future, the Clean Air Act will require the propagation of new regulations across additional sectors. The marginal abatement costs introduced in other sectors might be calibrated with those introduced under the Clean Power Plan and with the government's estimate of the social cost of carbon (Interagency Working Group 2015). This would give cost effectiveness a prominent if not central role in policy design, thereby achieving most of the efficiency that would be associated with a comprehensive carbon price.

How durable will the regulatory approach be? The US Clean Air Act is a venerable institution that is credited with significant improvements in the nation's air quality, and there is a legal requirement that it address climate change in the future. Hence, the Clean Power Plan is unlikely to be politically overturned even if there were a sweeping shift in election outcomes. More likely, a new administration that opposed the Plan would slow the development of new regulations and starve the budget of the regulatory agency, which could erode the short-run effectiveness of US climate policy significantly. The regulatory effort is already facing legal challenges aplenty, potentially affecting its reach in the power sector, but not stopping it.

Importantly, the requirements of the Clean Air Act to regulate and the specific proposal of the Clean Power Plan have unalterably changed the investment climate in the US electricity sector, whatever the status of the Plan may be going forward. A seemingly irreversible major outcome is the lack of new investment in coal generation capacity and the declining role for coal. Generation from existing coal nonetheless remains significant and it is the major focus of the Clean Power Plan. The authority of the Clean Power Plan to regulate these emissions sources is likely to survive.

Whether a legislated carbon price would accelerate or slow the decarbonisation of the US economy compared to the regulatory approach depends primarily on its price level, although another consideration is the salience of the policy for decision makers. A legislative mandate aimed directly at climate-related goals could be more forceful and comprehensive than the regulatory authority implied by the Clean Air Act. A legislative approach would be entirely politically determined, and only indirectly influenced by technical and economic feasibility. Through legislation, the Congress has unconstrained latitude to implement a direct emissions cap or carbon fee. In contrast, the design and stringency of regulation is indirectly influenced by political considerations, but it is directly based on findings of technical and economic feasibility. If political dynamics are not aligned to promote a robust carbon price, the regulatory process will continue to move forward, at perhaps a slow, but steady pace.

Some observers have offered that comprehensive carbon pricing could be adopted in exchange for removing the potentially inefficient role of current regulation. Congress has the authority to preempt the development of further federal regulations and even some at the state level, which might be possible politically if it were coupled with comprehensive federal policy. Whether this would achieve the most robust carbon policy, the most stringent or the most efficient is uncertain. Innovation must play an important role in addressing climate policy; prices and regulation have different potency in this regard in different sectors and over different time frames.

Whether a regulatory or a legislative approach would be more stringent or enduring is entirely uncertain. Technology-based policies may be less fickle than politically based ones. It is certainly true that a legislative approach could be simpler and more coherent. However, if that approach were coupled with preemption of regulatory authorities it would likely ignite internecine political warfare. An outcome that seems politically achievable and that economists might hope for is the introduction of a comprehensive policy that leaves in place but mostly eclipses the steady but slow-moving regulatory authority that has formed the basis of US emissions reductions to date.

References

Aldy, J. and W. Pizer (2015), "Comparing emission mitigation pledges: Metrics and institutions", Chapter 12 in this book.

Bushnell, J. B., S. P. Holland, J. E. Hughes and C. R. Knittel (2014), "Strategic Policy Choice in State-Level Regulation: The EPA's Clean Power Plan", University of California Energy Institute Working Paper No. 255.

Burtraw, D. and W. Shobe (2009), "State and Local Climate Policy under a National Emissions Floor", RFF Discussion Paper 09-54, Washington, DC.

Burtraw, D. and M. Woerman (2013), "Economic Ideas for a Complex Climate Policy Regime", *Energy Economics* 40: S24-S31.

Burtraw, D., J. Linn, K. Palmer and A. Paul (2014), "The Costs and Consequences of Clean Air Act Regulation of CO2 from Power Plants", *American Economic Review: Papers & Proceedings* 104(4): 557-562.

Burtraw, D., K. Palmer, S. Pan and A. Paul (2015), "A Proximate Mirror: Greenhouse Gas Rules and Strategic Behavior under the US Clean Air Act", *Environment and Resource Economics* 62(2): 217-241.

Congressional Budget Office (2014), *The Budget and Economic Outlook: 2014-2024*, Washington, DC: Congress of the United States.

Goulder, L. H. and R. N. Stavins (2011), "Challenges from State-Federal Interactions in US Climate Change Policy", *American Economic Review: Papers & Proceedings* 101(3): 253-257.

Hausker, K., K. Meek, R. Gasper, N. Aden and M. Obeiter (2015), "Delivering on the US Climate Commitment: A 10-Point Plan Toward a Low-Carbon Future", Working Paper, World Resources Institute, Washington, DC.

Interagency Working Group (2015), "Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866", revision to May 2013 document, Interagency Working Group on Social Cost of Carbon, United States Government.

Keohane, R. O. and D. G. Victor (2013), "The Transnational Politics of Energy", *Daedalus* 142(1): 97-109.

About the author

Dallas Burtraw is the Darius Gaskins Senior Fellow at Resources for the Future. Burtraw has worked to create more efficient and politically rational control of air pollution from the electricity sector and has written extensively on electricity industry deregulation and environmental outcomes. He has particular interest in the spectrum of incentive-based approaches leading to formal environmental prices. Burtraw recently estimated the distributional effects of carbon pricing in the U.S. His research also assesses the costs and benefits of regulation. He has evaluated opportunities for efficiency improvements in the electric power sector from greenhouse gas regulations under the Clean Air Act. He has studied the role for policy interactions including subnational efforts within a federalist system and provided technical guidance in the design of the subnational cap-and-trade programs in the US. Burtraw holds a PhD in Economics and a Master's degree in Public Policy from the University of Michigan.

18 Pricing carbon: The challenges

Thomas Sterner and Gunnar Köhlin[1]
University of Gothenburg

In this chapter we provide examples of how carbon taxes can be very efficient in reducing fossil fuel consumption and resulting emissions, focusing on the Swedish experience that shows a significant decoupling of carbon emissions from GDP growth. But only a few countries have seriously implemented carbon taxation. This leads us to discuss political challenges of carbon taxes such as strong lobbying by fossil fuel stakeholders; opposition from the public because of the price impacts of a tax; transparency as to the effects on winners and losers; and the perception that taxes reduce welfare and increase unemployment. The chapter then reviews some of the policy responses to these challenges that share some ambitions and features of carbon taxes but are perhaps easier to implement. These include the removal of fossil fuel subsidies; sectoral carbon taxes such as fuel taxes; cap and trade, exemplified by the EU Emissions Trading System, and regulation; and, finally, the promotion of renewable energy sources exemplified by the German Energiewende. The chapter is concluded with a discussion on lessons learnt and some implications for the international negotiations and the COP in Paris.

1 Introduction

The climate problem can seem, paradoxically, quite simple. There are a series of activities that generate externalities and these should be priced according to the polluter-pays-principle. This could be done through taxes or cap and trade (CAT). There are confounding and complicating aspects such as non-carbon gases and emissions from land use and forestry, but at its core, the problem is simple. Yet there has been

1 Thanks to Amie Svärd and Susanna Olai for excellent research assistance and to the editors and reviewers for insightful comments.

little progress to date in halting the carbon emission rate. Part of the reason is due to politics – some policies are unpopular and therefore policymakers might prefer to deny the underlying problem or procrastinate. There are also powerful fossil fuel lobbies in many countries that influence politics in a very direct way. At the international level, unilateral action is slow and negotiations have several times come to a standstill when burden-sharing and fairness aspects are discussed. Against this background it is instructive to review the experiences hitherto. In this chapter we will briefly review the experiences of carbon taxation at the sectoral and national level, cap and trade in the European Union, and the *Energiewende* in Germany.

2 Carbon tax

A tax on carbon is the most cost-efficient policy in order to reduce carbon emissions according to economists. It is generally more efficient than direct regulation of technology, products, and behaviour, as it affects consumption and production levels as well as technologies, it covers all industries and production and provides dynamic incentives for innovation and further emissions reductions. In addition, the tax revenue can be used to facilitate the transition toward renewable energy, cover administrative and implementation costs, or lower taxes on labour. A tax also continuously encourages industry to reduce emissions in comparison with CAT that only incentivise industry to reduce their emissions to the point of the cap. Furthermore, a tax is easy to incorporate in the existing administration, unlike a cap and trade programme that requires new administrative machinery.

Carbon taxes have existed internationally for 25 years. Finland was the first country to implement a carbon tax in 1990 and the rest of the Nordic countries followed in the early 1990s. Despite the positive aspects of carbon taxes, only a handful of countries beside the Nordic countries have implemented a general tax on carbon of at least US$10/$tCO_2$ to date: the UK, Ireland, Switzerland, and the province of British Columbia in Canada (World Bank 2014). In Sweden, the carbon tax is roughly US$130/$tCO_2$ as of April 2015. The tax is significantly higher than any other carbon tax or CAT permit price across the globe, and it appears to have been very effective in the sectors where it applies. It applies in particular to transport, where gasoline and diesel are taxed strictly in proportion to carbon emissions, but also to commercial use and residential heating as well as partially to industry.[2]

In Sweden and the rest of EU28, buildings contribute to a large part of carbon emissions since almost 40% of final energy consumption comes from buildings (28% residential buildings and 12% non-residential buildings) (European Commission 2014). More than half of all buildings in Sweden are heated by district heating, which in itself is very efficient compared to individual heating of each building. In the last few decades the district heating system has been greatly expanded and a good deal of fuel switching has occurred. Fossil fuels have been phased out and today it relies almost solely on waste and renewable energy sources – thanks to the carbon tax implemented in 1991. The share of oil used for heating decreased in the 1980s to reduce exposure to oil price shocks, but at that time oil was mainly replaced by coal and natural gas. It was not until the carbon tax was introduced that biofuels became the main source of energy for district heating and emissions dropped. Since 1980, output has almost doubled in the district heating sector while carbon emissions have decreased by 75% (Svensk Fjärrvärme 2015). The latest decrease in emissions came in 2003 after the implementation of the Tradable Renewable Electricity Certificates scheme.[3] Together with the carbon tax and building regulations, this scheme has reduced average energy usage in buildings in Sweden significantly.

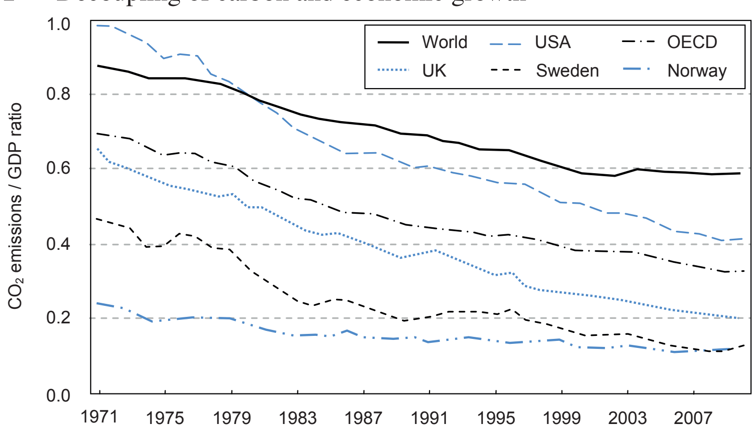
The likelihood that a carbon tax will be the only instrument in place on a global scale looks minuscule. As discussed in Chapter 15 of the latest (fifth) IPCC Assessment

2 Industry pays reduced (but still high by international standards) carbon tax rates but also has exemptions and major industries participate in the EU ETS instead of paying taxes in order to avoid double taxation.

3 The Tradable Renewable Electricity Certificate scheme was introduced in Sweden in 2003. For every MWh of renewable electricity generated, producers obtain a certificate from the state. These are then sold in an open market, where the market determines the price. Certificates therefore represent extra revenue for renewable energy producers. Buyers, mainly electricity suppliers, have quota obligations to purchase certificates. Renewable energy that qualifies under the scheme includes wind power, certain hydropower, certain biofuels, solar energy, geothermal energy, wave energy and peat in CHP plants. New generation plants qualify for 15 years, and quota levels are defined until 2035. In 2012, Sweden and Norway created a joint electricity certificate market with a common target of increasing renewable electricity production by 26.4 TWh between 2012 and 2020. The two countries contribute with 50% of financing each, however the market will decide where and when new production will occur. Since its inception, the Swedish-Norwegian certificate system has already contributed with 10.3 TWh of new renewable production capacity (Swedish Energy Agency 2015).

Report, countries normally rely on a combination of several instruments with different targets simultaneously, as exemplified by the experience of the Swedish building sector, described above. Therefore, it is difficult to assess the efficiency and environmental impact of carbon taxes. In Sweden, between 1990 and 2007, there was a decline in CO_2 emissions by 9% while the country's economy experienced a growth of 51%. There was a strong decoupling of CO_2 emissions and economic growth and the carbon intensity of GDP was reduced by 40% (Johansson 2000, Hammar et al. 2013). However, it is important to note that these figures reflect only emissions from production within countries. Products manufactured abroad and consumed in Sweden are not taken into account. Looking at emissions domestically, the Swedish carbon tax has so far proven to be both cost effective and efficient in achieving the commitment in the Kyoto Protocol. Greenhouse gas emissions have decreased by 22% since 1990, and the next domestic goal is to decrease emissions by 40% from 1990 to 2020 (Naturvårdsverket 2015). As Figure 1 shows, there is a clear trend over the last 40 years of decreasing CO_2 emissions per unit of GDP. Sweden's emissions per unit of GDP are about one-third of the world average.

Figure 1 Decoupling of carbon and economic growth



Source: IEA (2012).

3 Political challenges with carbon tax

In the 1990s, the EU tried to implement a tax but failed for several reasons. Ministers of finance are notoriously unwilling to compromise on taxes and give up their prerogative on tax issues to supra-national authorities. Taxes are viewed as a national concern and central for domestic economic policy. Another reason was the reluctance of letting the EU decide on yet another area of policy, moving the decision-making power from the national to the European level. But let us not forget that, in the 1990s, climate change was not the burning issue it is today, which made it hard to implement effective policy that would substantially reduce carbon emissions. This has led many to the unsubstantiated conclusion that carbon taxes do not work and are impossible to implement.

Globally there are even more reasons why countries have failed to implement carbon taxes: (i) strong lobbying by fossil fuel stakeholders; (ii) opposition from the public because a tax will raise prices; (iii) transparency as to the effects on winners and losers compared to the much less visible cost of regulations (Brännlund and Persson 2010); (iv) a perception that taxes reduce welfare and increase unemployment due to lower levels of consumption and production (Decker and Wohar 2007); and (v) possible institutional path dependencies that led to favouring cap and trade (Paterson 2012). In the absence of direct carbon pricing, countries have tried a number of other responses outlined below.

3.1 Response 1: Removal of fossil subsidies

Closely linked to taxes, but at the other end of the green fiscal reform scale, is the major issue of removing energy subsidies. Not only do energy subsidies damage the environment in various ways, they also discourage investment in renewable energy and energy efficiency, and impose a large fiscal burden (Coady et al. 2015). Subsidies need to be financed and this usually happens by increasing public debt or taxes on labour or goods. Subsidies also crowd out essential public spending on, for example, health and education. Some view energy subsidies as a way of providing support for low-income households, but subsidies are a highly inefficient way to support disadvantaged groups since the rich capture most of the benefits (Sterner 2011). Of course, there are political challenges in compensating the losers of a subsidy removal reform, but that discussion is beyond the scope of this chapter. Either way the current low oil prices provide a unique opportunity to shed such subsidies (Fay et al. 2015).

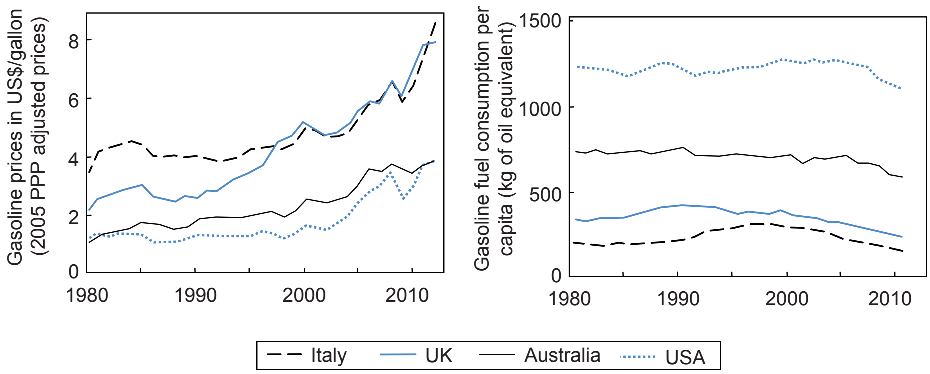
3.2 Response 2: Fuel taxation

Instead of a carbon tax, a closely related policy instrument that also has a major impact on carbon emissions is excise taxes on goods that have a high fossil carbon content. The prime example is a fossil fuel tax. A fuel tax is essentially a tax on carbon in the transport sector – a tax that is sometimes easier to implement than a carbon tax. As a result, there are more taxes on fuel than carbon around the world and, consequently, more studies and evidence of the performance of fuel taxes. Studies conclude that fuel has low price elasticity in the short run of somewhere between -0.1 and -0.25. This means that if the price of fuel increases by 1%, consumption would decrease by between 0.1% and 0.25% during the first year of implementation. This low effect is probably due to slow-moving structures such as habits, infrastructure, or technology. However, in the long run, surveys have shown the price elasticity of fuel to be about -0.7 on average (Graham and Glaister 2002, Goodwin et al. 2004).

In Europe and Japan, fuel taxes have reduced CO_2 emissions by more than 50%. According to various studies, fuel taxation is the policy that most likely has had the greatest impact on global carbon emissions (Sterner 2007). Fuel taxes not only impact total consumption by changing individual behaviour (e.g. driving fewer miles), they also create incentives for companies to invent fuel saving technology and greener cars. In Figure 2 we see how fuel prices affect demand in two high fuel-price countries (Italy and the UK) and two low fuel-price countries (the US and Australia). The two extremes are Italy and the US, with Italy having a fuel price three times that of the US. The US, on the other hand has a per capita consumption more than four times that of Italy.[4]

4 Per capita consumption is of course not *only* affected by prices, but prices *are* important (Sterner 2011).

Figure 2 Gasoline prices and gasoline fuel consumption per capita in four countries



A commonly used argument against fuel taxes is that they are regressive, that those who are poor pay a larger share of their disposable income on fuel and taxes. Sterner (2011) has empirically shown that this is not generally the case – in many developing and low-income countries, fuel taxes are *progressive* and a valuable source of revenue for the state. The progressivity depends on location, the design of the policy, and the type of fuels covered. In Europe, the distributional effects are basically neutral while studies in the US do actually display some regressivity (Metcalf 1999, Hassett et al. 2009). However, if the US government would take action and recycle the revenue from fuel taxation back to consumers, fuel taxation could be made progressive (West and Williams 2012, Sterner and Morris 2013).

3.3 Response 3: Cap and trade, and regulation.

In contrast to a tax, cap and trade (CAT) regulates the quantities of emissions, not the price – an advantage for a regulator who really wants to be assured of a given decline in emissions. The idea is that permits to emit CO_2 are created and allocated to industries, giving them the right to emit CO_2. They need a permit for every ton of CO_2 they emit. If they reduce their emissions they can sell their excess permits, while they would have to buy permits if their emissions are above the quantity of permits they own. Permits in a CAT programme are allocated either by auction, free allocation, or a mix of both approaches. With an auction, the government raises revenue just as with a tax, while there is clearly no revenue raised with free allocation. In the latter case the decision-maker must however decide on a mechanism for the free allocation. One of these is benchmarking that is roughly in proportion to output, and another is grandfathering based on historical emission levels. Each comes with some advantages and disadvantages.

The EU Emissions Trading Scheme (ETS) is the world's largest carbon CAT programme, covering roughly 45% of the EU's total GHG emissions (European Commission 2013). Estimates of the emission reductions achieved by the first (2005-2007) and second (2008-2012) phases of the programme, calculated relative to forecasts of emissions, have in general been modest (Ellerman et al. 2010, Anderson and Di Maria 2010, Georgiev 2011). In a recent paper, Bel and Joseph (2015) conclude that the main driver of decreasing emissions was the Global Crisis in 2008/2009 rather than the EU ETS. The effectiveness of the EU ETS is often considered to be compromised due to a lenient allocation of permits in the first two phases. It seems to have been politically difficult to put in place a tight cap on the programme. However, in its third phase the cap will be reduced by 1.74% annually. Hence we know that emissions will fall relative to historical levels. Currently, permit prices are still low – though those who defend CAT say that this is due largely to ancillary policies and external conditions.

Unfortunately, carbon CAT programmes have not been the success story many had hoped for. The caps have been set too high, and as a consequence the prices of permits have been too low to achieve sufficient reductions. One reason for this is heavy lobbying from the industry. Industry has also lobbied for grandfathering (IPCC 2014). Burtraw and Palmer (2008) calculate that if as little as 6% of the pollution permits in electricity generation are grandfathered and the rest are sold by auction, industry profits would be maintained. Allocating more than about 10% for free leads to windfall profits. CAT has been found to be regressive to a certain degree, but, at least in richer countries, poor people generally have their cost offset by social welfare programmes (Blonz et al. 2012).

Politicians are worried that a tight cap will hurt their industries. If they were to agree to a tight cap and the economy would boom, the big concern is that this would lead to rocket-high prices of permits. Such concerns lead to over-allocation because companies and politicians want to avoid very high prices. Many politicians do not trust CAT to work or they are concerned about agreeing on a cap that is too tight. Instead (or in addition), they implement other types of regulation such as renewable energy certificates to complement the policy and this in turn contributes to the low permit prices. Hence, unlike carbon taxes that can be complemented with other policies, CAT schemes cannot easily be complemented in this way.

In the US, attempts to introduce CAT have succeeded in some states, notably California, but at the federal level they have so far failed. The US is currently turning instead to fairly large-scale implementation of simple regulation in various areas related to climate change emissions.

An interesting and important question is how different national instruments such as cap and trade or carbon taxes will operate within international agreements. Up till today, most negotiations have focused on quantitative allocations or undertakings by different countries. This might be realised through a linking, for instance, of cap and trade schemes. The issues involved are however far from straightforward. It is difficult to link schemes without a full agreement on future targets (which is the most contentious part of the international negotiations).[5] There are therefore alternative suggestions about structuring international negotiations around agreed minimum prices (Nordhaus 2015, Weitzman 2014).

3.4 Response 4: Promoting renewable energy

Progress on effective policy instruments and on international treaties is thus in general poor. Both taxes and CAT are strongly resisted. Becoming carbon neutral is not only about reducing our carbon emissions. It is also (and perhaps more importantly) about creating new energy infrastructure made up of renewables such as solar, wind, and hydro.[6] Up till today, renewables have needed government support to be a viable option for households and industry, but the price gap between fossil and renewable energy is

5 See Green et al. (2014) or Stavins (2015) for different views of the pros and cons of linking CATs across jurisdictions.

6 See the chapter by Toman in this book for a more elaborate review of approaches to increase the use of renewables.

decreasing very quickly.[7] We believe this is a vital issue to discuss in combination with taxes because of the dynamic effect of relative prices between renewable energy and fossil fuels. When renewable energy becomes cheaper than fossil fuels the market takes over the transition. Since the price gap is now small, this can be induced by carbon taxes or subsidies on renewables – or a combination of both.

The political power in subsidising renewable energy in order to close the gap between fossils and renewables has been well demonstrated by Germany. For at least 15 years,[8] Germany has pursued energy transition (*Energiewende*), an initiative to facilitate the transition from nuclear- and coal-powered energy generation to renewable sources within the next four decades. Targets include reducing GHG emissions by 80-95% compared with 1990, increasing energy efficiency to reduce usage by 50%, and increasing the share of renewable sources in energy consumption to 80%. The transition focuses mainly on increasing solar and wind power as these sources are the most cost-efficient renewable technologies to date (Agora Energiwende 2013). Between 2000 and 2014, the share of renewable energy consumption increased from 6% to 27% (BDEW 2014).

So far, even though the use of renewables has increased dramatically, carbon emissions per kWh have not dropped very much. This is because Germany is trying to reduce carbon emissions and phase out nuclear power by 2022 simultaneously (Agora Energiwende 2014). A positive externality from the Energiewende is a lower cost of renewables for the rest of the world through know-how and technological innovation. However, the initial levels of the feed-in tariff implemented in 2000 guaranteed 20 years of fixed and very high prices for solar and wind producers, and people rushed to install solar panels and expand wind farms. This caused the desired expansion in

7 According to Bloomberg New Energy Finance (2014), the average global cost of solar PV electricity has fallen by more than 50% in the past five years, while the cost of wind power has fallen by about 15% in the same time period. The cost of electricity generation from coal and natural gas has not changed significantly during this period. The estimated global cost of electricity generation from wind power is close to that of coal power, while the cost of natural gas generation is still lower than both wind power and coal. The cost of solar PV electricity is currently roughly twice as that of natural gas. However, that will change if the trend of rapidly falling system costs continues. Note that electricity generation costs vary widely locally.

8 The *Erneuerbare-Energien-Gesetz* (Renewable Energy Sources Act or EEG) was adopted in 2000.

supply of electricity, but the subsidy became more expensive as supply increased. The tariffs have been lowered considerably but the cost (shared amongst all households) is still quite substantial. Early investors were able to guarantee a very good return on their investment.

The *Energiewende* technology policies have been very successful in increasing supply and bringing down the price of renewables. This has shifted the balance of power among lobbies, weakening the fossil lobby and strengthening the green lobbies and thereby making other policies such as carbon taxes more likely. There are, however, difficulties when transitioning to renewable energy sources at a national level – solar and wind are intermittent, and energy in general is expensive to store. These are challenges that a renewable energy system has to address and this is going to require considerable modifications of the traditional utility business model, including incentives for storage, transmission, and time-of-day pricing to help steer demand.

4 Lesson learned – now what?

When carbon taxes felt politically out of reach, policymakers decided to opt for cap and trade – to set a quantity of emissions rather than a price. What we have learned, however, is that it is as difficult to negotiate a quantity as it is a price. With a quantity it is more apparent who are the 'winners' and 'losers' in a negotiation. Previous negotiations have come to a standstill because of distribution and fairness aspects. In the global context, large countries such as India will benefit if quantities are allocated on a per capita basis, whereas countries with large historical emissions such as the US will benefit from grandfathering.

To facilitate the negotiation process in Paris, there are, as mentioned above, academics who argue that the focus should shift towards prices rather than quantities. A variety of reasons are mentioned, for instance to make the treaty and its implementation more incentive compatible (Nordhaus 2015) or because it is easier to negotiate just one number rather than a quantity (Weitzman 2014). When discussing quantities, it is not apparent what the related cost would be for industry, while a price is, in this sense, more transparent. It is possible that the future regime and negotiations will include many instruments (possibly for different parts of the climate change complex – different sectors, gases, etc). The aim of the negotiations might include not only quantitative commitments but also a price floor – or possibly a tax per tonne of carbon. Countries will then be free to opt for just the minimum level or – a higher level as in the case of Sweden – to raise the bar and encourage consumers to become energy efficient and industry to invest in research and development of new technology. The price floor would increase the global efficiency of carbon mitigation and reduce the risk of leakage and pollution havens, while at the same time the market would receive a clear signal to invest in renewable energy technology and emission abatement.

References

Agora Energiwende (2013), "12 Insights on Germany's *Energiewende*: A Discussion Paper Exploring Key Challenges for the Power Sector", Berlin.

Agora Energiwende (2014), "Benefits of Energy Efficiency on the German Power Sector", Final report of a study conducted by Prognos AG and IAEW, Berlin, pp. 65-69.

Anderson, B. and C. Di Maria (2010), "Abatement and allocation in the pilot phase of the EU ETS", *Environmental and Resource Economics* 48: 83–103.

Bel, G. and S. Joseph (2015), "Emission abatement: Untangling the impacts of the EU ETS and the economic crisis", *Energy Economics* 49: 531–533.

Bloomberg (2014), New Energy Finance database (accessed November 2014).

Blonz J., D. Burtraw and M. Walls (2012), "Social safety nets and US climate policy costs", *Climate Policy* 12: 474 – 490.

Brännlund R. and L. Persson (2010), "Tax or No Tax? Preferences for Climate Policy Attributes", Center for Environmental and Resource Economics (CERE), Umeå, Sweden.

Bundesverband der Energie- und Wasserwirtschaft (BDEW) (2014), "Stromerzeugung nach Energieträgern 1990 – 2014" ["Electricity generation by energy source 1990 - 2014"], Berlin.

Burtraw B. and K Palmer (2008), "Compensation Rules for Climate Policy in the Electricity Sector", *Journal of Policy Analysis and Management* 27(4): 819-847

Coady, D., I. Parry, L. Sears and B. Shang (2015), "How large are global energy subsidies?", IMF Working Paper WP15/105, Washington, DC.

Decker, C.S. and M.E. Wohar (2007), "Determinants of state diesel fuel excise tax rates: the political economy of fuel taxation in the United States", *The Annals of Regional Science* 41: 171–188.

Ellerman, A. D., F. J. Convery and C. De Perthuis (2010), *Pricing Carbon: The European Union Emissions Trading Scheme*, Cambridge, UK: Cambridge University Press.

European Commission (2013), "The EU Emission Trading System (EU ETS)", Brussels.

European Comission (2014), "Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy", Communication from the Commission to the European Parliament and the Council, Brussels.

Fay, M., S. Hallegatte, A. Vogt-Schilb, J. Rozenberg, U. Narloch, and T. Kerr. (2015), *Decarbonizing Development: Three Steps to a Zero-Carbon Future*, Washington, DC: World Bank.

Georgiev, A., M. Alessi, C. Egenhofer and N. Fujiwara (2011), "The EU Emission Trading System and Climate Policy Towards 2050", Center for European Policy Studies, Brussels

Goodwin, P., J. Dargay and M. Hanly (2004), "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review", *Transport Reviews* 24: 275–292.

Graham, D.J. and S. Glaister (2002), "The demand for automobile fuel: A survey of elasticities", *Journal of Transport Economics and Policy* 36(1): 1–25.

Green, J., T Sterner and G Wagner (2014), "A balance of 'bottom-up' and 'top-down' in linking climate policies", *Nature Climate Change* 4: 1064–1067.

Hammar, H., T. Sterner and S. Akerfeldt (2013), ”Sweden’s CO2 tax and taxation reform experiences”, in R. Genevey, R. K. Pachauri and L. Tubiana (eds.), *Reducing Inequalities: A Sustainable Development Challenge*, New Delhi: The Energy and Resources Institute.

Hassett K.A., A. Mathur and G. Metcalf (2009), “The Incidence of a U. S. Carbon Tax: A Lifetime and Regional Analysis”, *The Energy Journal* 30: 155–178.

International Energy Agency (IEA) (2012), *CO_2 Emissions from Fuel Combustion* (2012 Edition), Paris.

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report’s complete reference).

Johansson, B. (2000), “The Carbon Tax in Sweden”, in *Innovation and the Environment*, Paris: OECD Publishing, pp. 85–94.

Metcalf, G. E. (1999), “A Distributional Analysis of Green Tax Reforms”, *National Tax Journal* 52(4): 655–682.

Morris, D. F. and T. Sterner (2013), “Defying Conventional Wisdom: Distributional Impacts of Fuel Taxes”, Mistra Indigo Policy Paper.

Naturvårdsverket (2015), *Miljömålen. Årlig uppföljning av Sveriges miljökvalitetsmål och etappmål 2015*, Stockholm: Swedish Environmental Protection Agency.

Nordhaus, W. (2015), “Climate Clubs: Designing a Mechanism to Overcome Free-riding in International Climate Policy”, background paper for the Presidential Address to the American Economic Association.

Paterson, M. (2012), “Who and what are carbon markets for? Politics and the development of climate policy”, *Climate Policy* 12: 82–97.

Stavins, R. N. (2015) “Linkage of regional, national, and sub-national policies in a future international climate agreement”, Chapter 20 in this volume.

Sterner, T. (2007), “Fuel taxes: An important instrument for climate policy”, *Energy Policy* 35: 3194–3202.

Sterner, T. (2011), *Fuel Taxes and the Poor: The Distributional Effects of Gasoline Taxation and Their Implications for Climate Policy*, Washington, DC: RFF Press.

Svensk Fjärrvärme (2015), *Tillförd energy utveckling 1980-2012*, Stockholm.

Swedish Energy Agency (2015), “En svensk-norsk elcertifikatsmarknad - Årsrapport för 2014”, Eskilstuna, Sweden.

Toman, M. (2015), “International cooperation in advancing energy technologies for deep decarbonisation”, Chapter 22 in this volume.

Weitzman, M. (2014), “Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?”, *Journal of the Association of Environmental and Resource Economists* 1(1): 29–49.

West, S.E. and R.C. Williams III. (2012), “Estimates from a Consumer Demand System: Implications for the Incidence of Environmental Taxes”, in T. Sterner (ed.), *Fuel Taxes and the Poor: The Distributional Effects of Gasoline Taxation and Their Implications for Climate Policy*, Abingdon, UK: RFF Press, pp. 78–105.

World Bank (2014), *State and Trends of Carbon Pricing 2014*, Washington, DC: World Bank.

About the authors

Thomas Sterner is a Professor of Environmental Economics whose work is focused on the design of policy instruments to deal with resource and environmental problems. He has built up the Unit for Environmental Economics in Gothenburg to a leading European centre for environmental economics that gives a unique PhD programme in climate economics with students from developing countries. Sterner has published more than a dozen books and a hundred articles in refereed journals, mainly on environmental policy instruments with applications to energy, climate, industry, transport economics and resource management in developing countries. Sterner is the recipient of the Myrdal Prize, past president for the European Association of Environmental and Resource Economists and Associate Editor of *Environmental and Resource Economics*. He is also a Fellow and researcher at Resources for the Future, The Beijer Institute and Statistics Norway. With Gunnar Köhlin, he has founded the Environment for Development Initiative, a global network of environmental economics centres. During 2012 and 2013 he served as Visiting Chief Economist of the Environmental Defense Fund in New York. He has recently been elected as a guest professor at the Collège de France for 2015-16.

Gunnar Köhlin is an Associate Professor of Environmental Economics and the Director of the Environment for Development Initiative, a global network of environmental economics centres. As co-founder of the Environmental Economics Unit, he has now spent 25 years working with applications of environmental economics in developing countries including the development of a dedicated PhD programme in environmental and development economics. Köhlin has published more than 20 peer-reviewed papers and he is the editor of the Routledge book series *Environment for Development*. His research interests focus on natural resources in developing countries. Methodologically he has a focus on non-market valuation techniques, household production models and broad reviews of existing literature. Currently, his research is focusing on sustainable natural resource management in Africa, particularly institutions to foster greater cooperation in management.

19 Taxing carbon: Current state of play and prospects for future developments

Xueman Wang and Maja Murisic[1]
World Bank

Pricing carbon is emerging as an essential element for achieving global mitigation targets, providing a necessary signal for investments in low-carbon and resilient growth. Depending on each country's different circumstances and development priorities, various instruments (such as domestic emissions trading schemes or carbon taxes) can be used to price carbon and efficiently and reduce emissions in a cost-effective manner.

In 2015, about 40 national and over 20 sub-national jurisdictions are putting a price on carbon, representing almost a quarter of global GHG emissions, with the value of existing carbon taxes around the world being estimated at US$14 billion. Despite successful experiences and lessons that have been generated over the years of carbon tax implementation, the challenges that countries face when designing and implementing carbon taxes are not to be underestimated.

That said, the progress countries have shown so far is indisputable. With a uniform global carbon price being difficult to envisage in the near future, these on-the-ground efforts to use market forces to curb emissions are critical for any global mitigation efforts, potentially paving the way for the emergence of an international coordination mechanism for carbon pricing.

1 The findings, interpretations and conclusions expressed herein are those of the authors and do not necessarily reflect the view of the World Bank Group, the Partnership for Market Readiness or the governments they represent. The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgement on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

1 National context: A key driver behind countries' choice of carbon-pricing instruments

1.1 A wide variety of carbon-pricing instruments

Closing the gap between the 2°C target and our current climate trajectory requires a set of pragmatic policy and competitiveness solutions that support national development goals, while lowering carbon emissions. With the 2015 deadline for a global climate deal drawing nearer, policymakers around the world have been increasingly looking at carbon pricing to meet the challenge of achieving global mitigation targets, while providing a necessary signal for investments in low-carbon and resilient growth.

1.2 National political economy matters

Depending on their different circumstances and development priorities, countries opt for various instruments to price carbon efficiently and reduce emissions cost effectively. Considerations behind countries' choices of a carbon-pricing instrument can be of a political, economic, institutional, or social nature, to name a few. In some cases, it is easier to introduce one instrument as opposed to another. Moreover, specific design features can reduce opposition to the instrument of choice without jeopardising environmental effectiveness.

South Africa is a case in point. With a majority of the country's GHG emissions coming from the energy sector and the oligopolistic nature of the energy market which is dominated by a few companies, a carbon tax was an evident choice. Simply put, the lack of energy industry players would likely reduce the efficiency gains that would normally result from an emissions trading scheme (ETS). Moreover, several studies modelling the broad macroeconomic impact of a carbon tax for South Africa have indicated that the tax could be an important instrument for achieving the country's mitigation objectives at a reasonable cost to the economy, especially if coupled with one or more revenue recycling options (World Bank 2015).

China, on the other hand, has opted for a market-based instrument. With the support of the World Bank's Partnership for Market Readiness (PMR), the national government is intensifying its preparation for the design of a national ETS, which is expected to be launched in 2017. The ETS will cover major industry and power sectors, which are the major drivers for GHG emissions. A national ETS is expected to play a critical role in using market means to reduce emissions at scale but in a cost effective way.

1.3 Carbon tax versus ETS: Not so different?

While the choice between an ETS and carbon tax is mainly driven by political economy considerations, the similarities between the two approaches are greater than the differences. Moreover, the design details are more important than the choice of instrument itself. For instance, many emissions trading schemes demonstrate a trend of including 'hybrid' elements, such as price floors or market stability reserves. To this end, the UK's carbon price floor (CPF) is in fact a tax on fossil fuels used to generate electricity. Some tax schemes also include similar 'hybrid' elements, such as carbon offset schemes. South Africa is again a good example of such an approach, currently exploring how offsets could complement its carbon tax and serve as a flexibility mechanism that would enable industry to deliver least-cost mitigation and therefore lower its tax liability. In order to ensure the effective implementation of both a carbon tax and a complementary offset mechanism – and ultimately facilitate transition towards a low-carbon economy – design features need to be well thought through. In the case of South Africa, the carbon offset eligibility criteria include South African-based credits only.

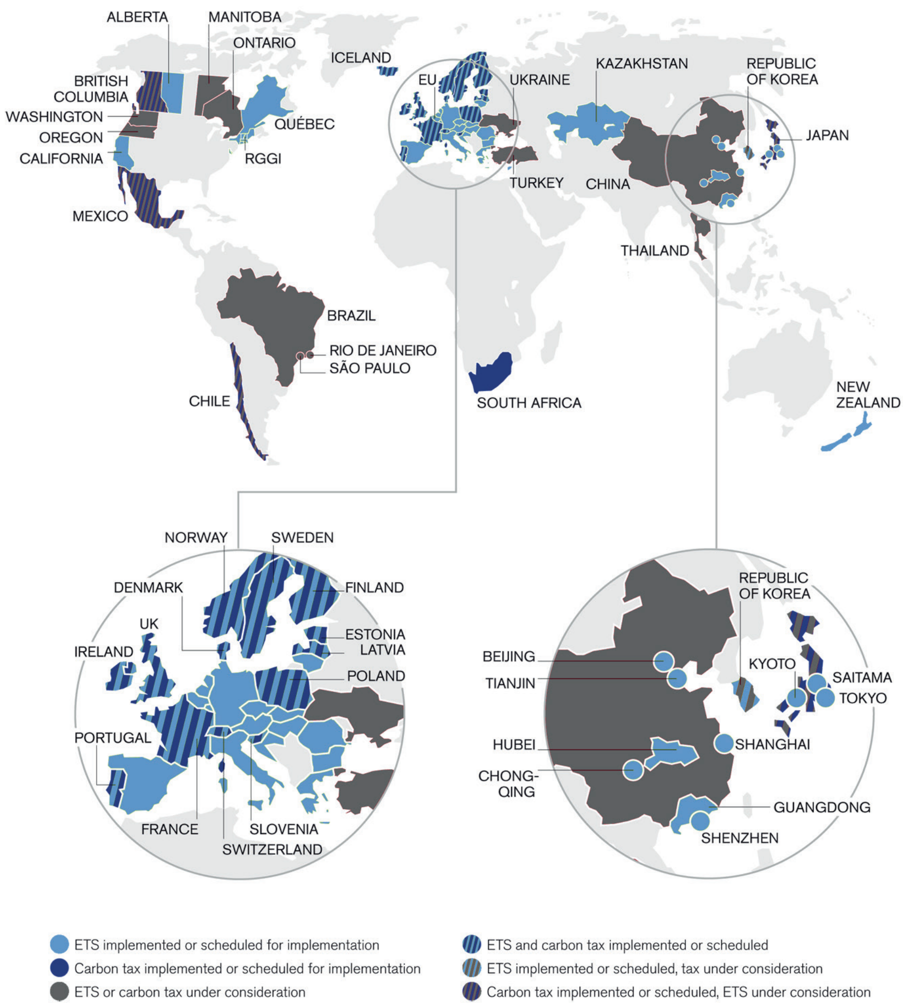
2 Carbon tax around the world: Overview and recent developments

2.1 Carbon tax at a glance

A carbon tax refers to a tax directly linked to the level of CO_2 emissions, often expressed as a value per tonne CO_2 equivalent (per tCO_2e). Carbon taxes provide certainty in regard to the marginal cost faced by emitters per tCO_2e, but do not guarantee a maximum level of emission reductions, unlike an ETS.[2]

2 Based on OECD (2013).

Figure 1 Summary map of existing, emerging, and potential regional, national and subnational carbon pricing



Source: World Bank (2015b).

Carbon taxes can be implemented as ‘upstream taxes’ (on the carbon content of fuels), ‘downstream’ taxes (on emitters), or some combination of the two. In all cases, the main policy issues concern determining the tax base, the tax rate, the use of revenues, compensation mechanisms for industries and households, if any, and coordination and interaction with other policies.

2.2 Overview of existing and emerging carbon taxes

Today, about 40 national and over 20 sub-national jurisdictions, representing almost a quarter of global GHG emissions, are putting a price on carbon (see Figure 1 and the Appendix) (World Bank 2015b). These carbon-pricing instruments cover about half of the emissions in these jurisdictions, which translates into approximately 7 $GtCO_2e$, or about 12% of annual global GHG emissions (World Bank 2015b). The value of global ETSs as of 1 April 2015 is about US$34 billion, while the existing carbon taxes around the world are estimated to be valued at $14 billion (World Bank 2015b).

2.3 Carbon tax experience in developed countries and jurisdictions

Carbon taxes were first adopted in Europe in the early 1990s and were often introduced alongside another carbon-pricing instrument, such as an energy tax (see also the contribution by Sterner and Köhlin to this book). While the experience with direct carbon tax implementation is relatively new, a number of important lessons can be drawn, as illustrated by the examples of Norway, Sweden, and British Columbia.

Norway introduced its carbon tax in 1991, which covers all consumption of mineral oil, gasoline and natural gas. It is, therefore, estimated that approximately 50% of the country's total GHG emissions are covered by the carbon tax. Emissions not covered by the carbon tax are included in Norway's emissions trading scheme (ETS), which was linked to the European ETS in 2008. Depending on the fuel type and usage, the tax rate varies between 25–419 krone/tCO_2 (US$4–69/$tCO_2$) (Kossoy et al 2014).

Sweden introduced its carbon tax in 1991, mainly as part of the energy sector reform. The major sectors included in Sweden's carbon tax system are natural gas, gasoline, coal, light and heavy fuel oil, liquefied petroleum gas (LPG), and home heating oil. While households and services are fully covered by the carbon tax, non-ETS industry and agriculture are partially exempted. Over the years carbon tax exemptions have increased for installations under the EU ETS, as opposed to directly providing exemptions to all GHG emissions covered under the EU ETS. The tax rate is 1,076 krone/tCO2 (US$168/$tCO_2$), as of January 2014 (Kossoy et al 2014).

British Columbia introduced a carbon tax in 2008, applicable to the purchase or use of fuels within the province. The main objective of the tax is to encourage low-carbon development without increasing the overall tax burden. For this reason, British Columbia's carbon tax is revenue neutral, which means that all the funds generated by the tax are returned to the citizens through reductions in other taxes, such as in personal and corporate income tax and tax credits. After seven years of implementation, British Columbia's carbon tax has been generally supported by the public, and has achieved significant environmental impacts without compromising economic development (Kossoy et al 2014). For instance, from 2008 to 2011, British Columbia reduced its GHG emissions per capita from sources subject to the carbon tax by a total of 10%, while the rest of Canada only reduced their emissions from the same source types by 1% over the same period (Elgie and McClay 2013).

2.4 Carbon taxes in emerging economies

Emerging economies are taking action, too. Recent noteworthy developments include passage of carbon tax legislation in Chile in 2014, further refinements to the design of a carbon tax in South Africa, and implementation of a carbon tax in Mexico.

Chile, as part of a major tax reform, is introducing a carbon tax that will regulate CO_2 emissions, as well as local pollutants, produced by fixed sources used for thermal power generation. The carbon tax is expected to enter into force in 2017 and is envisioned to be designed as a tax on emissions from boilers and turbines with a thermal input equal or greater than 50MW (Kossoy et al. 2014). With an additional analysis to examine the impact of proposed carbon tax in the works, initial assessments suggest that approximately 50% of energy in the country will be taxed. While further analytical work is needed, it is clear that carbon tax design and implementation will carry a number of challenges – including technological changes in the energy sector and the implications on international competitiveness, to name a few.

South Africa is working on a carbon tax scheme, which could be launched in 2016 if the Parliament adopts the legislation. The proposed rate is set at RND120 (US$11.20) per tonne of CO_2e, with a yearly increase of 10% until 2019/2020. However, the 'effective' rate is much lower – between US$1 and US$4 due to a relatively high tax threshold and ‘exemptions’ (World Bank 2015a). The tax is envisioned to be a fuel input tax, based on the carbon content of the fuel used, and will cover all stationary direct GHG emissions from both fuel combustion and non-energy industrial process emissions, amounting to approximately 80% of the total GHG emissions. The carbon tax and accompanying tax incentives, such as an energy-efficiency tax incentive, are expected to provide appropriate price signals to help shift the economy towards a low-carbon and sustainable growth path. A complementary offset scheme is also proposed, though its parameters have yet to be finalised. The offset scheme aims to provide flexibility to taxpayers, leading to a lowering of their tax liability, as well as to incentivise mitigation in sectors not directly covered by the tax (World Bank 2015a).

Mexico’s carbon tax on fossil fuel import and sales by manufacturers, producers and importers, which came into effect in 2014, covers approximately 40% of the country’s total GHG emissions. Depending on the type of fuel, the tax rate is \$10–50 pesos/tCO_2 (US\$1–4/tCO_2). Mexico’s carbon tax is not a tax on the carbon content of fuels, but rather on the additional amount of emissions that would be generated if fossil fuels were used instead of natural gas. Therefore, natural gas is not subject to the carbon tax. The tax also allows for the use of offsets. Companies may choose to comply with their commitments by buying offset credits from domestic Clean Development Mechanism (CDM) projects – equivalent to the market value of the credits at the time of paying the tax – therefore promoting the growth of mitigation projects in Mexico and the creation of a domestic carbon market (World Bank 2015a).

3 Carbon tax design and implementation: Key lessons

3.1 The case for a carbon tax

While a carbon tax (unlike the ETS) does not guarantee the maximum level of emission reductions, this economic instrument can be used to achieve a cost-effective reduction in emissions.

First, since a carbon tax puts a price on each tonne of GHG emitted, it sends a price signal that gradually causes a market response across the entire economy, creating a strong incentive for emitters to shift to less GHG-intensive ways of production and ultimately resulting in reduced emissions.

Second, a carbon tax can also raise substantial amounts of government revenue, which can be recycled towards low-carbon development investments, reductions in other taxes, or funding of other government programmes and policies. Chile is a case in point – its carbon tax is expected to increase revenues for funding the national education reform.

Moreover, carbon taxes can further improve national welfare through various co-benefits, such as improvements in health or a reduction in local pollution.

Last but not least, by reducing GHG emissions that are driving global warming, national carbon taxes also have global benefits.

3.2 Common challenges to carbon tax implementation

Despite these advantages, the many challenges that countries face when designing and implementing a carbon tax are not to be underestimated.

First, it is often argued that carbon taxes tend to have a disproportionate impact on low-income households. In reality, there are different mechanisms and policies that are targeted at protecting low-income individuals and families, and the experience of British Columbia's carbon tax attests to this. Its revenue recycling mechanism, which includes various tax cuts and credits for low-income households to offset their carbon tax liabilities, is a good example how this challenge could be overcome (see also the contribution by Sterner and Köhlin in this book).

Second, many political challenges could arise from issues around carbon leakage, i.e. if the introduction of a carbon tax in one jurisdiction leads to a relocation of economic activity to jurisdictions where carbon taxes are not in place – a matter of concern especially for industrial competitiveness (see the contribution by Fischer in this book.). Despite the importance that these issues have been given in policy debates around the world, a number of approaches can help mitigate the risks of carbon leakage – ranging from measures that are integrated into the design of a carbon tax, such as tax exemptions and credits, to those that exist alongside a carbon tax, such as financial and institutional support for emission reductions investments, energy efficiency improvements, and so on.

Moreover, careful management and coordination of a carbon tax with other existing or planned policies is critical in order to avoid overlapping and uncoordinated efforts. Good practice demonstrates that, when designing a carbon tax, countries typically look across the entire portfolio of policy measures that put a price on carbon and assess their cost-effectiveness, as well as consistency with other climate policies. Engaging in policy-mapping exercises in this regard ensures that new policies align with the existing ones and contribute to countries' overall efforts to achieve medium- and long-term mitigation objectives.

Finally, countries often face significant practical challenges during carbon tax implementation (in particular, 'downstream' taxes) in regard to data on current and projected emissions, technical infrastructure for monitoring reporting and verification (MRV) of emissions (see also the contribution by Weiner to this book) or legal rules and procedures for implementation, to name a few. What is important to stress is that improving carbon-pricing readiness in terms of technical and institutional capacity sets a foundation for the implementation of a forthcoming carbon-pricing instrument. Regardless of whether a country ultimately implements a carbon-pricing instrument, building and improving such readiness is a no-regrets measure, which has cross-cutting benefits that support domestic climate change policies and low emissions development.

4 Looking ahead: Options for global carbon pricing

4.1 Carbon tax: A domestic policy with a global reach

As noted in the case of countries and jurisdictions with long-standing experience of carbon tax implementation, a carbon tax promises a number of national co-benefits – from encouraging low-carbon alternatives and shifts in technology to raising revenues and ultimately leading to a socially efficient outcome. Additional to these benefits, of course, is a contribution to global efforts to curb emissions.

Despite facing many challenges when designing and implementing carbon taxes and other carbon-pricing instruments, the progress that countries have made so far is indisputable. These on-the-ground efforts to use market forces to curb emissions will be critical for any global mitigation efforts.

4.2 Coordinated efforts are key to achieving global mitigation targets

Paris is hardly an end goal, but it is surely an important milestone. For the global climate regime to be successful, the Paris agreement must reinforce our collective ambition and provide a clear pathway to net zero GHG emissions before the end of the century. Equally important for the agreement will be to draw on individual country contributions and include comparable mitigation targets from major economies. Since it is difficult to envisage a globally uniformed carbon price in the near future, an international coordination mechanism may be necessary to enhance a dialogue across different jurisdictions, to promote transparency in the process of price setting, as well to overcome some of the perpetual challenges – such as issues around carbon leakage – that countries face when putting a price on carbon.

That being said, it is encouraging to see that a number of bottom-up initiatives for fostering the international cooperation on carbon pricing have already taken root. For example, the World Bank's Partnership for Market Readiness (PMR),[3] established in 2011, brings together the world's major economies that are pursuing various carbon pricing instruments, including those that are preparing to implement a carbon tax. As an illustration, the PMR supports efforts by Chile and South Africa to design and implement their respective carbon taxes, including looking at the issues around the use of offset mechanisms, exploring interactions between the carbon tax and other existing polices and measures, building technical foundations for the tax implementation, and so on.

Through the PMR platform and other relevant initiatives on the subject matter, policymakers share valuable knowledge on technical and policy challenges faced during

3 PMR Participants are: Brazil, Chile, China, Colombia, Costa Rica, India, Indonesia, Jordan, Mexico, Morocco, Peru, South Africa, Thailand, Turkey, Tunisia, Ukraine, Vietnam, Kazakhstan, Australia, Denmark, the European Commission, Finland, Germany, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the UK and the US. For more information about the PMR and its participants, see https://www.thepmr.org

the design and implementation of carbon tax and other carbon-pricing instruments. By facilitating efforts to establish common standards for GHG mitigation and supporting pricing schemes to become more open and transparent, it is not inconceivable that the international coordination mechanism on carbon pricing could emerge from such bottom-up initiatives, ultimately helping us get on a path to zero net emissions before the end of the century.

References

Elgie, S. and McClay, J. (2013), *BC's Carbon Tax Shift after Five Years: Results. An Environmental (and Economic) Success Story*, Ottawa: Sustainable Prosperity.

Fischer, C. (2015), "Options for avoiding carbon leakage", Chapter 21 in this book.

Kossoy, A., K. Oppermann, A. Platonova-Oquab, S. Suphachalasai, N. Höhne et al. (2014), *State and Trends of Carbon Pricing 2014*, Washington, DC: World Bank.

OECD (2013), "Climate and Carbon: Aligning Prices and Policies", OECD Environment Policy Papers No. 1 Paris.

Stavins, R. (2015) "Linkage of regional, national and sub-national policies in a future International climate agreement", Chapter 20 in this book.

Sterner, T. and G. Köhlin (2015), "Pricing carbon: The challenges", Chapter 18 in this book.

World Bank (2015a), "South Africa Market Readiness Proposal (MRP)", Partnership for Market Readiness, Washington, DC.

World Bank (2015b), *Carbon Pricing Watch 2015*, Washington, DC (available at https://openknowledge.worldbank.org/handle/10986/21986).

About the authors

Xueman Wang is the team leader for the World Bank's Partnership for Market Readiness (PMR). Before joining the World Bank, she served at the United Nations Environment Programme's Convention on Biological Diversity in Montreal, Canada, where she worked on the Biosafety Protocol and trade and environment. Xueman has also worked at the United Nations Climate Change Secretariat in Bonn, Germany, where she was responsible for negotiations of the Kyoto Protocol and its compliance regime, as well as the Treaty and Law Department of the Ministry of Foreign Affairs of China, as one of chief negotiators for the Climate Change Convention and other environmental treaties. Xueman earned Master of Laws degrees at Wu Han University in China and the Fletcher School of Law and Diplomacy of Tufts University.

Maja Murisic works for the World Bank's Partnership for Market Readiness (PMR). Since she joined the World Bank in 2010, Maja has been working on a number of technical assistance programs in the areas of low emission development, energy efficiency and climate resilience, mostly in Europe and Central Asia Region. Maja holds a Master's degree in International Relations and Economics from the Johns Hopkins University's School of Advanced International Studies (SAIS) and a Bachelor's degree in International Relations from the University of Belgrade.

Appendix: Overview of carbon taxes around the world

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
1	British Columbia	Sub-national	2008	The carbon tax applies to the purchase or use of fuels within the province. The carbon tax is revenue neutral; all funds generated by the tax are returned to citizens through reductions in other taxes.	CA$30 per tCO_2e (2012)
2	Chile	National	2014	Chile's carbon tax is part of legislation enacted in 2014. The carbon tax is expected to enter into force in 2017 (currently it is being debated in the Senate) and is envisioned to be designed as a tax on emissions from boilers and turbines with a thermal input equal or greater than 50 thermal megawatts (MWt).	US$5 per tCO_2e (2018)
3	Costa Rica	National	1997	In 1997, Costa Rica enacted a tax on carbon pollution, set at 3.5% of the market value of fossil fuels. The revenue generated by the tax goes toward the Payment for Environmental Services (PES) programme, which offers incentives to property owners to practice sustainable development and forest conservation.	3.5% tax on hydrocarbon fossil fuels
4	Denmark	National	1992	The Danish carbon tax covers all consumption of fossil fuels (natural gas, oil, and coal), with partial exemption and refund provisions for sectors covered by the EU ETS, energy-intensive processes, exported goods, fuels in refineries and many transport-related activities. Fuels used for electricity production are also not taxed by the carbon tax, but instead a tax on electricity production applies.	US$31 per tCO_2e (2014)
5	Finland	National	1990	While originally based only on carbon content, Finland's carbon tax was subsequently changed to a combination carbon/energy tax. It initially covered only heat and electricity production but was later expanded to cover transportation and heating fuels.	€35 per tCO_2e (2013)
6	France	National	2014	In December 2013 the French parliament approved a domestic consumption tax on energy products based on the content of CO_2 on fossil fuel consumption not covered by the EU ETS. A carbon tax was introduced from 1 April 2014 on the use of gas, heavy fuel oil, and coal, increasing to €14.5/tCO_2 in 2015 and €22/tCO_2 in 2016. From 2015 onwards the carbon tax will be extended to transport fuels and heating oil.	€7 per tCO_2e (2014)

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
7	Iceland	National	2010	All importers and importers of liquid fossil fuels (gas and diesel oils, petrol, aircraft and jet fuels and fuel oils) are liable for the carbon tax regardless of whether it is for retail or personal use. A carbon tax for liquid fossil fuels is paid to the treasury, with (since 2011) the rates reflecting a carbon price equivalent to 75% of the current price in the EU ETS scheme.	US$10 per tCO_2e (2014)
8	Ireland	National	2010	The carbon tax is limited to those sectors outside of the EU ETS, as well as excluding most emissions from farming. Instead, the tax applies to petrol, heavy oil, auto-diesel, kerosene, liquid petroleum gas (LPG), fuel oil, natural gas, coal and peat, as well as aviation gasoline.	€20 per tCO_2e (2013)
9	Japan	National	2012	Japan's Tax for Climate Change Mitigation covers the use of all fossil fuels such as oil, natural gas, and coal, depending on their CO_2emissions. In particular, by using a CO_2 emission factor for each sector, the tax rate per unit quantity is set so that each tax burden is equal to US$2/$tCO_2$ (as of April 2014).	US$2 per tCO_2e (2014)
10	Mexico	National	2012	Mexico's carbon tax covers fossil fuel sales and imports by manufacturers, producers, and importers. It is not a tax on the full carbon content of fuels, but rather on the additional amount of emissions that would be generated if the fossil fuel were used instead of natural gas. Natural gas therefore is not subject to the carbon tax, though it could be in the future. The tax rate is capped at 3% of the sales price of the fuel. Companies liable to pay the tax may choose to pay the carbon tax with credits from CDM projects developed in Mexico, equivalent to the value of the credits at the time of paying the tax.	10-50 pesos per tCO_2e (2014)* * Depending on fuel type
11	Norway	National	1991	About 55% of Norway's CO2 emissions are effectively taxed. Emissions not covered by a carbon tax are included in the country's ETS, which was linked to the European ETS in 2008.	US$4-69 per tCO_2e (2014)* *Depending on fossil fuel type and usage

	Country/ jurisdiction	Type	Year adopted	Overview/coverage	Tax rate
12	South Africa	National	2016	South Africa plans to introduce a carbon tax at RND120 per tonne of CO_2e, with annual increases starting in January 2016. The tax is envisioned to be a fuel input tax based on the carbon content of the fuel and cover all stationary direct GHG emissions from both fuel combustion and non-energy industrial process emissions, amounting to approximately 80% of the total GHG emissions.	RND120/tCO_2e (Proposed tax rate for 2016)* *Tax is proposed to increase by 10% per year until end-2019
13	Sweden	National	1991	Sweden's carbon tax was predominantly introduced as part of energy sector reform, with the major taxed sectors including natural gas, gasoline, coal, light and heavy fuel oil, liquefied petroleum gas (LPG), and home heating oil. Over the years, carbon tax exemptions have increased for installations under the EU ETS, with the most recent increase in exemption starting from 2014 for district heating plants participating in the EU ETS.	US$168 per t$CO_2$e (2014)
14	Switzerland	National	2008	Switzerland's carbon tax covers all fossil fuels, unless they are used for energy. Swiss companies can be exempt from the tax if they participate in the country's ETS.	US$68 per t$CO_2$e (2014)
15	United Kingdom	National	2013	The UK's carbon price floor (CPF) is a tax on fossil fuels used to generate electricity. It came into effect in April 2013 and changed the previously existing Climate Change Levy (CCL) regime, by applying carbon price support (CPS) rates of CCL to gas, solid fuels, and liquefied petroleum gas (LPG) used in electricity generation.	US$15.75 per t$CO_2$e (2014)

Source: http://www.worldbank.org/content/dam/Worldbank/document/SDN/background-note_carbon-tax.pdf.

20 Linkage of regional, national, and sub-national policies in a future international climate agreement

Robert N. Stavins[1]
Harvard University

As international negotiations proceed towards COP21 in Paris in December 2015, a hybrid policy architecture is emerging under the 2011 Durban Platform for Enhanced Action, in which all countries will participate under a common legal framework. This hybrid architecture for the Paris agreement will likely feature bottom-up elements in the form of a pledge-and-review system of Intended Nationally Determined Contributions (INDCs) plus top-down elements, such as for monitoring, reporting, and verification. The INDCs will feature a broad range of targets (in keeping with the UNFCCC principle of common but differentiated responsibilities and respective capabilities) and a diverse set of national policies and actions intended to achieve those targets. Cap-and-trade has emerged as one preferred policy instrument for reducing emissions of greenhouse gases (GHGs) in much of the industrialised world, as well as within key parts of the developing world. This includes Europe, the US, China, Canada, New Zealand, and Korea. Because linkage – unilateral or bilateral recognition of allowances – can reduce compliance costs and improve market liquidity, there is considerable interest in linking cap-and-trade systems. Beyond this, many jurisdictions will propose or adopt other types of climate policies, including carbon taxes, performance standards, and technology standards. With varying degrees of difficulty, such heterogeneous policy

1 This chapter draws upon previous co-authored work, including Bodansky et al. (2014), and Ranson and Stavins (2015), but the author is responsible for any errors and all opinions expressed here.

instruments can also be linked across borders. This chapter reviews the key benefits and concerns associated with various types of linkages, and examines the role that linkage may play in the 2015 Paris agreement.

1 Introduction

The Kyoto Protocol, negotiated in 1997, has entered what is probably its final commitment period of 2013-2020, covering only a small fraction – 14% – of global GHG emissions. It is scheduled to be replaced by a new international agreement featuring a new policy architecture. In 2011, at the Seventeenth Conference of the Parties (COP17) of the United Nations Framework Convention on Climate Change (UNFCCC), the nations of the world adopted the Durban Platform for Enhanced Action, in which they agreed to develop a 'protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties' for adoption at COP21 in December 2015 in Paris (UNFCCC 2012).

It now appears likely that the Paris agreement will feature a hybrid climate policy architecture, combining top-down elements, such as for monitoring, reporting, and verification, with bottom-up elements, including 'Intended Nationally Determined Contributions' (INDCs) from each participating country describing what it intends to do to reduce emissions, starting in 2020, based on its national circumstances (Bodansky and Diringer 2014).

For such a system to be cost effective – and thus more likely to achieve significant global emissions reductions – a key feature will be linkages among regional, national, and sub-national climate policies, where 'linkage' refers to the formal recognition by a GHG mitigation programme in one jurisdiction (a regional, national, or sub-national government) of emission reductions undertaken in another jurisdiction for purposes of complying with the first jurisdiction's mitigation programme. How can the 2015 Paris agreement facilitate such linkage?

2 Diverse forms of linkage

Policy instruments in different political jurisdictions can be linked through mutual recognition and crediting for compliance. This can be between two cap-and-trade systems, between two tax systems, between cap-and-trade and tax systems, between either of those and non-market regulatory systems, or among regulatory systems (Metcalf and Weisbach 2012). Linkage can be direct or indirect, and bilateral or multilateral.

Direct linkage occurs when an agreement is reached between two systems to accept allowances (or credits) from the other jurisdiction for purposes of compliance. This can occur on a one-for-one basis – for example in the case of cap-and-trade linkage – where an allowance from one jurisdiction is accepted in place of an allowance for the same amount of emissions in another jurisdiction (Ranson and Stavins 2013, 2015), or a trading ratio (exchange rate) can apply to allowance transfers between the two systems. Direct linkage can be bilateral (two-way), where both systems accept allowances from the other system for compliance, or unilateral (Ranson and Stavins 2013).

Indirect linkage occurs when two systems do not accept allowances from each other, but both accept allowances (or credits) from a common third party (Ranson and Stavins 2013). For example, by accepting credits (or allowances) from a common source (jurisdiction), two cap-and-trade allowance markets influence the common offset market, and in turn both influence allowance prices (and compliance costs) in each other's markets.

Cap-and-trade programmes provide the most obvious example of linkage, but it is highly unlikely that all or even most countries will employ national cap-and-trade instruments as their means of reducing GHG emissions under the Paris agreement. Other possible instruments include carbon taxes or fees, emission reduction credits (ERCs), and traditional regulatory approaches.[2] Hence, it is important to consider options for linking different types of policy instruments (Hahn and Stavins 1999, Metcalf and Weisbach 2012).

2 See the chapters in this book by Sterner and Köhlin (2015) and Burtraw (2015).

For example, firms that are subject to a carbon tax could be allowed to pay taxes at a higher level than they owe based on their emissions, and sell certified 'Emission Tax Payment Credits' (ETPCs) to firms that are operating under a cap-and-trade system. Within the cap-and-trade region, firms could use ETPCs just as they would the equivalent quantity of allowances for purposes of compliance. Conversely, firms under the cap-and-trade system could sell allowances to firms required to pay a carbon tax, allowing the purchasing firm to lower its tax obligation by the amount of allowances it submits for retirement. Likewise, either a carbon tax or a cap-and-trade system could be linked with policies that provide subsidies for emissions reductions, which could be traded like ERCs to be used in place of allowances to comply with a cap-and-trade programme, or as ETPCs for compliance with a carbon tax (Metcalf and Weisbach 2012).[3]

Market-based mechanisms (taxes, targeted subsidies, and cap-and-trade) could – in principle – be linked with a conventional, performance-based regulatory system. If the regulation is in the form of a quantity standard (for example, tons of carbon-dioxide-equivalent (CO_2-e) emissions reduction), firms could buy allowances or ETPCs from another market to meet the required quantity of reduction, or to achieve reductions in excess of the regulatory minimum and then sell additional reductions as ERCs (Metcalf and Weisbach 2012).[4]

3 Potential merits

Because linkage allows for voluntary exchanges across systems, it facilitates cost-effectiveness, that is, achievement of the lowest-cost emissions reductions across the set of linked systems, minimising both the costs for individual jurisdictions as well as the overall cost of meeting a collective cap. Also, by increasing the number of allowance buyers and/or sellers across linked cap-and-trade systems, linkage tends to increase market liquidity (Ranson and Stavins 2015). And to the degree that linkage reduces

3 For example, Mexico's carbon tax allows the use of offset credits from projects under the Kyoto Protocol's Clean Development Mechanism (CDM) in lieu of tax payments (ICAP 2014).

4 Technology standards present a much greater challenge, because it is difficult to verify the additionality of emissions reductions from meeting or exceeding a technology standard.

carbon price differentials across countries or regions, it also reduces the potential for competitive distortions caused by leakage, that is, incentives for emissions-generating sources or activities to move to jurisdictions with less stringent climate policies.

Moreover, by expanding the scope and size of the market for carbon allowances, linkage can mitigate allowance price shocks caused by unexpected shocks (Burtraw et al. 2013), and thereby reduce price volatility, although in the process, linkage also can transmit price volatility from one jurisdiction to another. Finally, linkage can reduce the market power of individual market participants, provided that the same entity is not a significant allowance buyer or seller in both jurisdictions (Wiener 1999, Metcalf and Weisbach 2012).

Turing to potential political advantages, one possible political motivation for linkage is the ability of a country to demonstrate global leadership. For example, the European Commission indicated that linking the European Union's Emissions Trading System (EU ETS) with other cap-and-trade systems 'offers several potential benefits, including… supporting global cooperation on climate change' (European Commission 2014). The prospect of linkage may allow nations to exert greater diplomatic influence on unlinked, free-riding nations, encouraging them to take action on climate change. This is related to the notion of 'climate clubs' as an approach to international cooperation (Nordhaus 2015).[5]

Likewise, international linkage agreements can offer domestic political benefits, as leaders can point to linkage as a sign of 'momentum' for increasing participation in systems similar to (or at least compatible with) their domestic climate policies. There can be administrative benefits from linking that come from sharing knowledge about the design and operation of a policy instrument. For example, Quebec may benefit from

5 A frequently proposed mechanism to make benefits exclusive to the members of a climate club has been a set of national border adjustments (tariffs in countries with carbon taxes and/or import allowance requirements in countries with cap-and-trade systems); Nordhaus (2015) follows this approach. In this chapter, I emphasise fundamentally less coercive approaches to international cooperation, but in both forms of cooperation, the use of market-based policy instruments and international linkage are key.

its linkage with the larger Californian cap-and-trade system.[6] Also, linkage may reduce administrative costs through the sharing of such costs and the avoidance of duplicative services.

Political support for linkage may also come from the capture of greater local co-benefits, such as reductions of emissions of correlated pollutants (Flachsland et al. 2009). If one jurisdiction has a lower GHG price than another before linkage, linkage may provide a market for additional emissions reductions in the low-price jurisdiction that yields additional co-benefits to that jurisdiction. Conversely, a high-price jurisdiction may resist linking with a low-price system because linkage could mean fewer domestic emissions reductions, with the loss of related co-benefits. This concern was raised during debates in California regarding whether to link with Quebec's cap-and-trade system.

4 Potential problems

First, linkage has the potential to improve the cost-effectiveness of a pair of linked policies only if there is sufficient environmental integrity in both systems with respect to their monitoring, reporting, and verification requirements (Ranson and Stavins 2015). If one jurisdiction in a linked pair or large set of linked jurisdictions lacks the capacity or motivation to track emissions and emission allowances accurately, these loopholes will be exploited throughout the system, damaging the cost-effectiveness of the full set of linked policies. This can create significant barriers to linkage between nations with different levels of environmental and financial management (Metcalf and Weisbach 2012).

Linkage can undermine environmental integrity. For example, linkage can result in double counting if transfers between countries are not properly accounted for and if, as a result, the same emissions reduction is counted towards compliance in more than one national system. Of course, guarding against such errors is one of the roles for the top-down elements of the Paris policy architecture, as I discuss later.

6 For details about the California-Quebec and other existing linkages, the reader is referred to Bodansky et al. (2014) and Ranson and Stavins (2015).

Strategic behaviour could also produce adverse economic consequences in a set of linked systems (Helm 2003). In particular, if countries anticipate the possibility of future linkages, they may behave strategically when establishing their national targets. And even if a linkage is established, it may not be executed in terms of actual trades if transaction costs inhibit trading.

Turning to potential political problems of linkage, it is important to recognise that whereas linkage has the potential to improve aggregate cost-effectiveness across jurisdictions, it can also have significant distributional implications between and within jurisdictions (Ranson and Stavins 2015). Firms that were allowance buyers (firms with high abatement costs) in the jurisdiction with the higher pre-link allowance price will be better off as a result of the allowance price changes brought about by linking, as will allowance sellers (firms with low abatement costs) in the jurisdiction with the lower pre-link allowance price. Conversely, allowance sellers in the jurisdiction with the higher pre-link allowance price and allowance buyers in the jurisdiction with the lower pre-link allowance price will be hurt by the allowance price change that results from the link. For the jurisdiction that faces higher prices post-linkage, this means greater transfers from buyers to sellers (Newell et al. 2013).

An increase in the volume of trades (as a result of linkage) may also have distributional implications and attendant political consequences, depending on the relative influence of buyers and sellers in the jurisdiction (Ranson and Stavins 2015). Within jurisdictions, the potential also exists for elites in developing countries to capture allowances from domestic cap-and-trade systems and sell them into linked markets to the detriment of the local economy (Somanathan 2010).

In some cases, jurisdictions that have established emissions-reduction policies may be motivated, at least in part, by a political desire to provide incentives for long-term investment in domestic abatement activities. If a system with a high allowance price links with a system with a lower allowance price, the firms in the system with higher abatement costs will have less incentive to find innovative ways to reduce their emissions, since they can opt instead to purchase allowances at the new lower price. The result may be less technological innovation than expected under the emissions policy pre-linkage.

Finally, linkage presents the political challenge of ceding some degree of national (or other jurisdictional) autonomy. Before two jurisdictions link, they may need to agree on how to reconcile design features that they have separately established for their respective systems (Ranson and Stavins 2013). As those design features may represent a compromise between competing stakeholder interests within a country, any changes could pose political hurdles.

5 Linkage under the 2015 Paris agreement

Specific elements of a future international policy architecture under the 2015 agreement could help facilitate the growth and operation of a robust system of international linkages among regional, national, and sub-national policies. On the other hand, other potential elements of a new agreement could get in the way of effective, bottom-up linkage.

5.1 Elements that would inhibit effective linkage

One design element that would have the effect of inhibiting international linkage would be overly prescriptive or restrictive rules on allowable trading across linked systems. A clear example would be a requirement (or even a preference) for domestic actions to achieve national commitments. Such a 'supplementarity principle' can render cross-border linkage difficult or impossible, and thereby drive up compliance costs, decrease international ambition, and reduce the feasibility of reaching an agreement.

For example, several provisions of the Kyoto Protocol suggest that internal emissions abatement should take precedence over compliance through the Protocol's flexibility mechanisms (International Emissions Trading, Joint Implementation, and the CDM), but the precise meaning of this principle of supplementarity has been debated since the adoption of the Protocol.

A second issue is the confusion that can arise from competing and conflicting objectives and rules between the UNFCCC and regional or national policies. The potential for conflicting rules relates to a broader issue about how national or regional carbon mitigation systems become recognised as valid for the purposes of meeting international commitments under the Paris agreement. There are two possible approaches – approval and transparency – through which reductions under domestic systems might become eligible for counting in the UNFCCC context (Marcu 2014). The former would require explicit COP approval of domestic systems, while the latter would involve the development of model rules through COP negotiations.

A third area of potential concern stems from a lack of clarity (or even confusion) over objectives. For example, adding a 'sustainable development condition' to CDM projects can create confusion in markets. This in turn undermines trading across systems, an essential role of linkage. Finally, rules that restrict which countries can link (for example, allowing linkage only among Annex I countries), or that make it difficult for countries to join the category of countries that can link, would inhibit effective linkage.

5.2 Elements that could facilitate effective linkage

If linkage is to play a significant role in executing a hybrid international policy architecture, several categories of design elements merit consideration for inclusion in the Paris agreement, either directly or by establishing a process for subsequent international negotiations.

Effective linkage requires common definitions of key terms, particularly with respect to the units that are used for compliance purposes. This will be especially important for links between heterogeneous systems, such as between a carbon tax and a cap-and-trade system. A model rule for linkage could be particularly helpful in this area. Registries and tracking are necessary with linked systems, whether the links bring together a homogeneous or heterogeneous set of policies.

Indeed, a key role for the top-down part of a hybrid architecture that allows for international linkage of national policy instruments will be tracking, reporting, and recording allowance unit transactions. A centralised institution could maintain the accounts of parties that hold allowances, record transfers of allowances between account holders, and annually reconcile allowances and verified emissions. Some form of international compliance unit would contribute to more effective and efficient registry operation and would help avoid double-counting problems.

International compliance units would make the functioning of an international transaction log more straightforward and reduce the administrative burden of reconciling international registries with national registries. There is also a possible role for the UNFCCC to provide centralised registry services for countries that lack the capacity to develop national registries on their own. Finally, there may be economies of scale in regionalising registries for certain developing countries under the auspices of the UNFCCC or some other multilateral institution (for example, the World Bank or a regional development bank).

More broadly, any system, with or without linkage, will require monitoring, verification, and reporting of emissions (Weiner 2015). Likewise, compliance and enforcement mechanisms are of generic need in any effective agreement.

The interaction of linked systems with cost-containment elements (banking, borrowing, offsets, and price-stabilisation mechanisms) raises particular issues in the context of linkage, because in some cases these mechanisms automatically propagate from one linked system to another. Common rules for approving and measuring offsets may be important, and – more broadly – a tiered system of offset categories could be helpful, with jurisdictions choosing their own 'exchange rates' for each category.

Finally, market oversight and monitoring, together with various safeguards against market manipulation such as by large holders of allowances who may be able to exercise market power, may increase confidence in the system. In some cases, national and international institutions may already exist, or need only relatively minor additional capacity, to provide these functions.

6 Conclusion

The 2015 Paris agreement will likely be a critical step in the ongoing international process to reduce global GHG emissions. Whether the agreement is judged to be sufficiently ambitious remains to be seen. In general, greater ambition is more easily realised when costs are low. Linkage — between and among market and non-market systems for reducing GHG emissions — can be an important element in lowering costs.

If linkage is to play a significant role, then several categories of design elements merit serious consideration for inclusion in the Paris agreement. However, including detailed linkage rules in the core Paris agreement is not desirable as this could make it difficult for rules to evolve in light of experience. Instead, minimum standards to ensure environmental integrity should be elaborated in COP decisions – for example, the COP could establish minimum requirements for national measuring, reporting and verification (MRV), registries, and crediting mechanisms. In terms of linkage, the function of the core Paris agreement might be confined to articulating general principles relating to environmental integrity, while also authorising the COP or another organisation to develop more detailed rules.

Ultimately, the most valuable outcome of the Paris agreement regarding linkage might simply be the inclusion of an explicit statement that parties may transfer portions of their INDCs to other parties and that these transferred units may be used by the transferees to meet INDCs. Such a statement would help provide certainty both to governments and private market participants and is likely a necessary condition for widespread linkage to occur. Such a minimalist approach will allow diverse forms of linkage to arise among what will inevitably be heterogeneous INDCs, thereby advancing the dual objectives of cost-effectiveness and environmental integrity in the international climate policy regime.

References

Bodansky, D. and E. Diringer (2014), "Building Flexibility and Ambition into a 2015 Climate Agreement", Arlington, VA: Center for Climate and Energy Solutions.

Bodansky, D., S. Hoedl, G. E. Metcalf and R. N. Stavins (2014), "Facilitating Linkage of Heterogeneous Regional, National, and Sub-National Climate Policies through a Future International Agreement," Discussion Paper, Harvard Project on Climate Agreements, Belfer Center for Science and International Affairs, Harvard Kennedy School.

Burtraw, D. (2015), "The regulatory approach in US climate mitigation policy", Chapter 17 in this book.

Burtraw, D., K. L. Palmer, C. Munnings, P. Weber and M. Woerman (2013), "Linking by Degrees: Incremental Alignment of Cap-and-Trade Markets", Discussion Paper No. 13-04, Resources for the Future, Washington, D.C.:

European Commission (2014), "International Carbon Market", available at http://ec.europa.eu/clima/policies/ets/linking/index_en.htm (accessed 16 October 2014).

Flachsland, C., R. Marschinski and O. Edenhofer (2009), "To Link or Not to Link: Benefits and Disadvantages of Linking Cap-and-Trade Systems", *Climate Policy* 9: 358-372.

Hahn, R. W. and R. N. Stavins (1999), *What Has the Kyoto Protocol Wrought? The Real Architecture of International Tradeable Permit Markets*, Washington, DC: AEI Press.

Helm, C. (2003), "International Emissions Trading with Endogenous Allowance Choices", *Journal of Public Economics* 87(12): 2737–2747.

International Carbon Action Partnership (ICAP) (2014), "Mexico Announces ETS Plans and Introduces a Carbon Tax", ICAP Newsletter No. 2, June.

Marcu, A. (2014), *The Role of Market Mechanisms in a Post-2020 Climate Change Agreement*, Special Report No. 87, Brussels: Centre for European Policy Studies.

Metcalf, G. and D. Weisbach (2012), "Linking Policies When Tastes Differ: Global Climate Policy in a Heterogeneous World", *Review of Environmental Economics and Policy* 6(1): 110-128.

Newell, R., W. Pizer and D. Raimi (2013), "Carbon Markets 15 Years after Kyoto: Lessons Learned, New Challenges", *Journal of Economic Perspectives* 27: 123–146.

Nordhaus, W. (2015), "Climate Clubs: Overcoming Free-Riding in International Climate Policy", *American Economic Review* 105(4): 1339-1370.

Ranson, M. and R. N. Stavins (2013), "Post-Durban Climate Policy Architecture Based on Linkage of Cap-and-Trade Systems", *The Chicago Journal of International Law* 13(2): 403-438.

Ranson, M. and R. N. Stavins (2015), "Linkage of Greenhouse Gas Emissions Trading Systems: Learning from Experience", *Climate Policy*, 4 February.

Somanathan, E (2010), "What Do We Expect from an International Climate Agreement? A Perspective from a Low-Income Country", in J. E. Aldy and R. N. Stavins (eds), *Post-Kyoto International Climate Policy: Implementing Architectures for Agreement*, Cambridge, UK: Cambridge University Press: 599-617.

Sterner, T. and G. Köhlin (2015), "Pricing carbon: The challenges", Chapter 18 in this book.

UNFCCC (2012), "Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011", FCCC/CP/2011/9/Add.1, p. 2, Decision 1/CP.17, "Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action", 15 March. .

Wiener, J. B. (1999), "Global Environmental Regulation: Instrument Choice in Legal Context", *Yale Law Journal* 108: 677-800.

About the author

Robert Stavins is the Albert Pratt Professor of Business and Government, Harvard Kennedy School; Director of the Harvard Environmental Economics Program; and Director of the Harvard Project on Climate Agreements. He is a University Fellow at Resources for the Future; a Research Associate of the National Bureau of Economic Research; an elected Fellow of the Association of Environmental and Resource Economics; a Member of the Board of Directors, Resources for the Future; and an Editor of the *Journal of Wine Economics*. He was Chairman of the Environmental Economics Advisory Board, US Environmental Protection Agency. He was a Lead Author of the Second and Third Assessment Reports of the Intergovernmental Panel on Climate Change; and Coordinating Lead Author of the Fifth Assessment Report. His research has examined diverse areas of environmental economics and policy, and appeared in more than a hundred articles in academic journals and popular periodicals, plus a dozen books. He holds a B.A. in philosophy from Northwestern University, an MS in agricultural economics from Cornell, and a PhD in economics from Harvard.

21 Options for avoiding carbon leakage

Carolyn Fischer
Resources for the Future

Carbon leakage – the increase in foreign emissions that results as a consequence of domestic actions to reduce emissions – is of particular concern for countries seeking to put a substantial price on carbon ahead of their trading partners. While energy market reactions to changes in global fossil fuel demand are difficult to avoid, absent a global price on carbon, some options are available to address leakage associated with changes in competitiveness of energy-intensive, trade-exposed industries. This chapter discusses the main legal and economic trade-offs regarding the use of exemptions, output-based rebating, border carbon adjustment, and sectoral agreements. The potential for clean technology policies to address the energy market channel is also considered.

Ultimately, unilateral policies have only unilateral options for addressing carbon leakage, resulting in weak carbon prices, a reluctance to go first and, for those willing to forge ahead, an excessive reliance on regulatory options that in the long run are much more costly means of reducing emissions than carbon pricing. Recognising those costs, if enough major economies could agree on a coordinated approach to carbon pricing that spreads coverage broadly enough, carbon leakage would become less important an issue. Furthermore, a multilateral approach to anti-leakage measures can better ensure they are in harmony with other international agreements. If anti-leakage measures can support enough adherence to ambitious emissions reduction programmes, they can contribute to their own obsolescence.

1 Introduction

Carbon leakage is a chief concern for governments seeking to implement ambitious emissions reduction policies – particularly those that place high prices on carbon – ahead of similar actions on the part of their major trading partners. 'Emissions leakage' is generally defined as the increase in foreign emissions that results as a consequence of domestic actions to reduce emissions. Since greenhouse gases (GHGs) are global pollutants, emissions leakage in the case of carbon is a particular concern, as it directly undermines the benefits of the domestic emissions reductions.

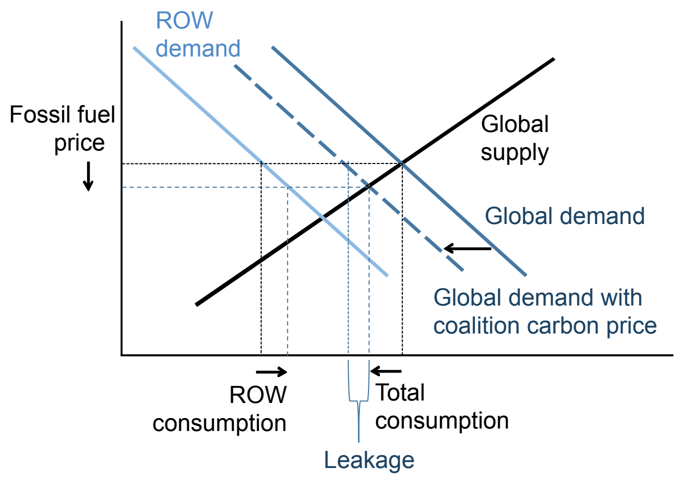
Carbon leakage from economy-wide carbon pricing policies in major economies is centrally estimated by global trade models to range between 5% and 30%.[1] Higher rates are associated with smaller coalitions, higher carbon prices, more substitution through trade, and stronger energy market responses. Sector-specific carbon leakage rates can be much higher, as well – as much as three to five times the economy-wide leakage rate.[2]

Carbon leakage occurs through multiple channels. The largest one, as indicated by the modelling literature, is the *energy market channel*. The idea is that if a major economy on its own withdraws a lot of demand for fossil fuels, the global prices for those fuels become depressed. As a consequence of cheaper prices, other countries consume more fossil fuels and their economies become more carbon intensive.

Figure 1 illustrates this form of carbon leakage with global supply and demand curves for fossil fuels. If a coalition of countries adopts carbon pricing, their demand (and thus global demand) for fossil fuels shifts inward. If the price did not change, the quantity that suppliers offer would exceed the quantity demanded at that price; thus, the price falls to find a new market equilibrium. However, since demand in the rest of the world (ROW) has not changed, they consume more at the new lower price. Therefore, the net reduction in global consumption is less than the reduction in coalition consumption.

1 Readers interested in more detail can see an Energy Modeling Forum exercise on carbon leakage and border carbon adjustments (EMF 29), published as a Special Issue of *Energy Economics* (Böhringer et al. 2012).
2 Fischer and Fox (2012).

Figure 1 Carbon leakage from demand and supply responses in energy markets



The reasoning is the same as many explanations for the drop in oil prices and their consequences over the past year: growth in worldwide demand has been lower than expected, and now lower gasoline prices are encouraging more sales of SUVs, which have higher fuel consumption rates. Importantly, the energy market channel operates via any changes in demand for fossil fuels, whether due to carbon pricing or regulation and energy efficiency.

The channel for carbon leakage that causes the greatest concern for policymakers, however, is the *'competitiveness' channel*. This channel relates to policies – like carbon pricing – that pass on higher energy costs to energy-intensive, trade-exposed (EITE) industries, making manufacturing in carbon-pricing countries less competitive. This causes economic activity, market share, and, in the longer run, investments in those sectors to shift abroad to jurisdictions with lower energy costs. Modelling results indicate that one-quarter to one-half of carbon leakage occurs through competitiveness effects. This channel is somewhat narrower than the energy market channel, as it primarily affects specific industrial sectors that represent a small share of the economy,[3] but they have outsized effects on emissions leakage, and may also wield outsized political influence.

3 In the case of the US, industries with energy expenditures in excess of 5% of the value of their output account for only one-tenth of the value of US manufacturing output and less than 2% of US GDP (Fischer et al. 2014).

A third channel, the *induced innovation channel*, has the potential to create negative leakage in the long term. If carbon mitigation policies induce innovation in clean energy technologies, lowering their costs globally, all countries will find them more attractive. Greater adoption of clean technologies in countries with low or no carbon prices will help displace fossil fuels and further reduce global emissions. On the other hand, countries with low carbon prices that become more competitive in energy-intensive sectors may see their technical change directed towards energy-using technologies, exacerbating carbon leakage. Thus far, this innovation channel has been theorised (e.g. Gerlagh and Kuik 2014) but empirical evidence of its scope is lacking.

1.1 Carbon pricing and carbon leakage

Understanding these different channels informs how we evaluate the options for addressing carbon leakage. Clearly, the best option for reducing emissions while addressing all channels of leakage would be to have harmonised carbon prices worldwide. Of course, this is not a likely outcome of the current framework for INDCs, although such commitments would certainly not be precluded. Several prominent economists are advocating for forming a club of major economies with minimum carbon prices (see, for example, Nordhaus 2015, Gollier and Tirole 2015, Weitzman 2013).

The challenge is that options for dealing with carbon leakage unilaterally are more limited. One, unfortunately, is simply to set lower carbon prices – that creates less pressure for leakage, but also less incentive for emissions reductions. Arguably, we observe a fair amount of this behaviour. Currently, about 12% or less of global CO_2 emissions is subject to a carbon price (World Bank 2015). With the exception of some carbon taxes in Scandinavian countries, current prices are well below \$40 – the US Environmental Protection Agency's central estimate of the global social cost of carbon (SCC) – and all of the largest systems have prices below \$15 (see also the contribution by Wang and Murisic in this book).[4]

One reason for individual jurisdictions to contribute too little to the global public good of climate mitigation is the free-rider effect: most of the benefits accrue to other

4 Prices as of 1 April 2015: California \$13, EU ETS \$8, RGGI \$6, Japan carbon tax \$2, Chinese provincial pilot ETS \$5-8. (World Bank 2015).

jurisdictions, and those benefits can be enjoyed whether or not one contributes oneself. These types of incentives create challenges for an international climate agreement. However, many climate negotiators may take issue with the idea that their countries are seeking to free ride on the efforts of others. Indeed, many feel an ethical responsibility to contribute significant emissions reduction programmes, but not by using significant carbon prices when their trade partners are not facing similar policies. The US is an example – in its regulatory policy evaluations, it uses a global SCC, not a domestic (self-interested) SCC as one would expect of a free-rider. However, its main contributions involve regulatory standards for power plant emissions and vehicles, but not carbon pricing (see the chapter by Burtraw in this book). Thus, while free-riding would weaken intentions to take action, the fear of carbon leakage weakens the actions of the well-intentioned, thereby exacerbating the challenge of a strong international agreement on emissions mitigation.

Still, there are some other options that countries or clubs of countries might take to address carbon leakage unilaterally. Most of the commonly proposed options are only suited for addressing competitiveness-related leakage.

2 Addressing the competitiveness channel

Mitigating the leakage associated with the competitiveness channel has the additional benefit of addressing the competitiveness concerns that often create barriers to putting a price on carbon. Indeed, if carbon pricing is not possible in a domestic context in the absence of dealing with competitiveness-related leakage, then these measures can be argued to have a much bigger impact on global emissions reductions than just the leakage avoided. However, one must tread carefully, as competitiveness concerns are related to international trade, and trade-related measures are governed by disciplines agreed to in the WTO, as explained by Mavroidis and de Melo in their chapter in this book. Moreover, many of the EITE industries of concern are already experiencing dislocation and pressures through changes in international trade patterns, so it can be difficult to distinguish motivations for dealing with emissions leakage from baser motivations to protect domestic industries. Hence, it is important to consider these options in tandem with the potential constraints imposed by international trade law.

Firms face two kinds of cost increases from emissions-reduction policies. One is higher production costs associated with reducing emissions – that is, the changes in techniques or equipment that require less energy, emissions, or emissions-intensive inputs. These costs occur whether the changes are being directed by regulation or by price incentives. A second cost increase is associated only with carbon-pricing mechanisms, which require firms to pay for their embodied emissions (that is, the emissions remaining after reduction efforts, associated with their production), either by paying a carbon tax or by surrendering valuable emissions allowances. Generally, it is only these embodied carbon costs that can be addressed in a straightforward and transparent manner, in accordance with other legal obligations.

Anti-leakage policies for the competitiveness channel focus directly on the EITE sectors. In all cases, some determination of eligibility must be made. In order to buttress an argument that the measures are being undertaken for the purposes of avoiding leakage, the criteria for eligibility must be clearly related to leakage potential – that is, involving a combination of carbon-intensiveness of manufacturing and trade exposure. At that point, there are three main options for addressing leakage among identified EITE sectors: exemption from carbon pricing, output-based rebating, and border carbon adjustments.

2.1 Exemptions

A straightforward option is to exempt qualified EITE industries from the broader GHG reduction policy, in whole or in part. For example, in Sweden, industrial consumers pay no energy tax and only 50% of the general carbon tax; in Germany, heavy industry is exempt from the surcharges for renewable energy and EITE sectors can request exemptions from most energy taxes. While potentially simple from an administrative point of view, exemptions tend to be a highly inefficient means of addressing emissions leakage. By differentiating carbon prices among industries, some cost-effective options for reducing emissions will be left untapped, which will either limit overall reductions or leave a greater burden on the remaining non-exempt industries. As a result, exemptions would likely increase the total cost of achieving a given emissions target, unless leakage effects are very strong (and the alternative would be weakening the carbon price for all). Furthermore, exemptions do not address indirect emissions; for example, certain sectors like aluminium may see larger competitiveness impacts from the pricing of carbon in electricity than from their direct emissions.[5]

Exemptions are not terribly likely to be seen as a trade-related measure, as the coverage of an emissions trading system or the designation of a carbon tax base is typically viewed as an intrinsic policy decision. However, in some interpretations, they could be viewed as subsidies.

2.2 Output-based rebating (OBR)

A second, common option is to use rebates to relieve some, or all, of the burden from the price on embodied carbon. The idea is to keep all energy-intensive industry under the carbon-pricing system, but to offer rebates for the EITE sectors in proportion to their output, based on a benchmark of sector-wide performance. For example, the EU chose a benchmark of the performance of the top 10% of firms (i.e. those with lowest emissions intensities) in a sector, while New Zealand uses up to 90% of average emissions intensity, based on recent historical data. Since more output generates more rebates, the rebate functions like a subsidy to output of EITE firms, signalling that emissions reductions should not be sought through reductions in output (since that would result in leakage). The advantage relative to exemptions is that OBR retains the carbon price incentive to reduce emissions intensity. However, it does come at a cost of muting the carbon price signal passed on to consumers, who then have less incentive to consume less energy-intensive products or find cleaner alternatives.

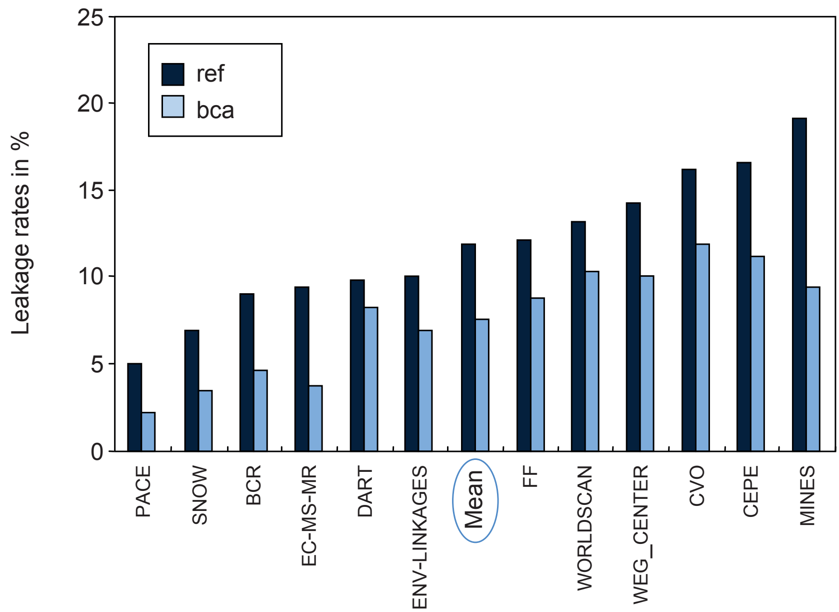
Preferential allocations or rebates to specific industries can, in theory, also be challenged as subsidies under trade rules. However, such a case has yet to be made in the WTO context, perhaps since to date such rebates have been implemented in domestic regulatory mechanisms (cap-and-trade programmes) with benchmarks that still imply some net tax burden on embodied emissions (Mavroidis and de Melo 2015).

5 Of the GHGs from global aluminium production unrelated to transport, electricity accounts for 62% of emissions, nearly twice that of direct process and thermal energy emissions (World Aluminium 2014).

2.3 Border carbon adjustment (BCA)

The third option is border carbon adjustment (BCA) of a domestic carbon price, which would levy charges on imports of EITE products to ensure that consumers pay the same price for embodied carbon, regardless of the origin. A recent Energy Modelling Forum modelling exercise on carbon leakage (summarised in Böhringer et al. 2012) found that BCA for EITE sectors for reduced carbon leakage from actions taken by OECD countries by one quarter to one half across most models (Figure 2).

Figure 2 Model estimates of leakage rates from OECD coalition carbon pricing (%)



Note: Vertical axis lists participating models by name. The dark blue bars represent simulated leakage rates in the reference scenario (OECD countries implementing emissions pricing to achieve global reductions equal to 20% of their baseline emissions). The light blue bars represent simulated leakage rates with the addition of BCA for EITE industries.

Source: Böhringer et al. (2012).

While theory and modelling tend to show that BCA is the most cost-effective option for addressing leakage, they also point to considerable tensions in design trade-offs. Furthermore, as an overtly trade-related measure, BCA is likely to raise disputes in trade circles, although a consensus has developed among international trade lawyers that they could be designed in accordance to WTO law. The key cases to be made are that the measure meets the WTO requirements for an Article XX exception – that is, it is essential and effective for reducing leakage – and that it conforms to the principle of common but differentiated responsibilities (CBDR) under international environmental law. Cosbey and Fischer (2014) and Cosbey et al. (2015) enumerate a full range of issues in designing a BCA regime that meets these goals, of which a few critical ones are highlighted here.

At its logical limit, if BCA were applied to all products, it would convert the carbon-pricing regime from one that taxes carbon arising from production to one that taxes carbon embodied in consumption (much like a value-added tax is a destination-based tax). While calling on consumers in developed countries to take responsibility for their carbon consumption sounds appealing, full BCA causes a strong shift in the terms of trade to the detriment of developing countries. For example, China's exports are eight times as carbon-intensive as those of the EU and three times those of the US (Atkinson et al. 2011). However, most of the avoided leakage benefits come from BCAs in the EITE sectors, and limiting the application of the measure to those sectors has less of a burden-shifting effect, supporting CBDR, as well as a stronger link to the legal motivations for an Article XX exception (Cosbey and Fischer 2014; Cosbey et al. 2015).

Another tension involves the use of the revenues collected at the border. Returning revenues to the exporting countries further mitigates the burden-shifting effects and can show good faith that the policy is being implemented for leakage rather than protectionist purposes. Another option conforming to these goals would be to earmark the revenues towards the financing of mitigation and adaptation activities in developing countries. On the other hand, larger burden-shifting effects make it more attractive for countries to be inside, rather than outside, the club of countries pricing carbon and imposing BCAs.

International legal obligations thus make it difficult to use BCAs to create leverage for getting other countries to take climate actions, although that would arguably have the greatest effect on limiting leakage. Some leading economists (e.g. Nordhaus 2015) have proposed using trade sanctions to enforce an agreement for high carbon prices among a club of countries; parties can always agree to a sanctions regime, but non-parties have not agreed to such measures. As a result, any sanctions against non-parties would need to meet the Article XX exception, which is likely to be limited to conforming BCAs. Unfortunately, for many countries, that may not be sufficient to ensure participation.

Some of the mundane practicalities of BCA are similar to OBR, requiring eligibility determinations for the products facing adjustment, and an exercise to calculate the embodied carbon emissions. The difference is that more accurate calculations would require foreign data, which is harder to obtain. Relying on domestic benchmarks is simpler and arguably less discriminatory (treating imported products the same as domestic counterparts), but gives blunter price signals to domestic consumers and foreign manufacturers. In addition, foreign carbon taxes paid should be taken into account, and any preferential treatment afforded domestic producers (such as rebates) must also be afforded imports. Again, a blunter instrument of exempting products from certain countries could recognise climate actions being taken, or least-developed status.

Overall, the design issues for this instrument are more complex and controversial; many experts think BCAs are likely still feasible (e.g. Cosbey et al. 2015, Mavroidis and de Melo 2015), though not all (e.g. Moore 2011, cited in Mathys and de Melo 2011). Many of the simplifications needed for administrative practicality and WTO compliance would mute some of the anti-leakage effects that one might achieve in theory with perfect information; however, the aforementioned alternatives to BCAs offer even blunter and weaker price signals for consumers. BCAs have some precedents: California has in effect BCA-like measures to discourage resource shuffling to out-of-state electricity generators. The latest carbon tax proposal in the US Senate includes a BCA. The failed attempt by the EU to include international aviation in the ETS offers a cautionary tale for BCA. A unilateral BCA measure will undoubtedly face resistance; to be accepted, BCA guidelines will have to arise out of some multilateral consensus.

2.4 Sectoral agreements

A final option for dealing with competitiveness-related leakage cannot be implemented unilaterally, but can achieve many of the goals. That would be to negotiate an agreement among major EITE trading partners for common actions to reduce emissions in those sectors. The actions may or may not be carbon pricing, but would alleviate competitiveness concerns and allow for greater emissions reductions in those sectors than simple exemptions from economy-wide carbon regulations.

3 Addressing the energy channel

While there are several options for addressing competitiveness-related leakage, there are few realistic unilateral options for addressing leakage related to global energy market adjustments. The available measures would have to either (1) raise global energy prices, or (2) lower clean energy prices.

3.1 Raising global energy prices

Raising global energy prices requires withdrawing more fossil fuel supplies than demand for them. For example, major energy producers could raise royalty payments, reduce their production subsidies, or simply commit to not extract unconventional resources. Few observers expect such commitments unilaterally.

Carbon capture and sequestration (CCS) presents another option. Incentivising or requiring the use of CCS as part of a domestic climate policy sustains demand for fossil fuels, avoiding leakage abroad, while ensuring reductions at home. However, CCS is still a relatively expensive mitigation option, and likely to remain so for the foreseeable future (see Tavoni 2015).

3.2 Lowering clean energy prices

Lowering the cost of clean energy technologies has the potential to offset the allure of cheaper fossil energy prices. However, these cost reductions must be global, and it must be noted that for the same emissions reductions, they must also be much bigger than if common carbon pricing were helping to make clean technologies competitive.

Technology policies are a popular option, particularly relative to carbon pricing; for example, over 50 countries have financial incentives or public procurement for renewable generation, and many more have feed-in tariffs or mandates.[6] The question is how well measures perform in lowering global costs. Toward this end, we may need to

6 See http://www.iea.org/policiesandmeasures/renewableenergy/ and http://www.map.ren21.net/ (accessed 1 June 2015).

distinguish between upstream incentives for manufacturers and downstream incentives for domestic deployment (see also Fischer et al. forthcoming).

Upstream measures encourage R&D and support domestic production of clean technologies. They shift out total supply, which lowers global technology prices, spurring additional deployment both at home and abroad and reducing leakage. They also benefit domestic producers at the expense of foreign ones, and may be constrained by WTO disciplines.

The effect of downstream measures depends on how global supply responds. In the short run, they shift out global demand for clean technology, which tends to bid up global equipment prices. Thus, expanded clean energy deployment at home can crowd out deployment abroad and exacerbate leakage. In the long run, however, strong learning-by-doing, complementary innovation, or scale effects may bend the global supply curve downward. In that case, both upstream and downstream policies – anything that increases clean energy scale – can lower global prices and crowd in cleaner technologies abroad. The potential for these effects is important to understand; recent work indicates that the global benefits of negative leakage from subsidies to manufacturing that lower the costs of clean technologies to all countries may be much larger than the trade-distorting effects of preferential upstream subsidies (Fischer 2015). As renewable energy subsidies are becoming contentious in the WTO, the time seems ripe for serious discussion about whether the Subsidies Code needs to make room for some clearly defined environmental exceptions to those disciplines, which are currently lacking (see the chapter by Mavroidis and de Melo in this book).

4 Conclusion

Addressing carbon leakage is a priority for supporting concerted action for mitigation, and in particular for supporting levels of carbon pricing that resembles the global social cost of carbon. In the current framework of countries individually contributing INDCs, convergence to multilateral carbon pricing will be a long time coming. With unilateral policy determinations, we are left with unilateral options for addressing carbon leakage, resulting in weak carbon prices, a reluctance to go first and, for those willing to forge ahead, an excessive reliance on regulatory options that in the long run are much more costly means of reducing emissions than carbon pricing.

Perhaps recognising those costs – not only the costs of climate change, but the costs of delayed action and the costs of second-best approaches to mitigation – enough major economies can agree on a coordinated approach to carbon pricing that spreads coverage broadly enough that carbon leakage becomes less important an issue. Furthermore, a multilateral approach to anti-leakage measures can better ensure they are in harmony with other international agreements. Ultimately, if anti-leakage measures can support enough adherence to ambitious emissions reduction programmes, they can contribute to their own obsolescence.

References

Atkinson, G., K. Hamilton, G. Ruta and D. van der Mensbrugghe (2011), "Trade in 'virtual carbon': Empirical results and implications for policy", *Global Environmental Change* 21(2): 563-574.

Böhringer, C., T. F. Rutherford, E. J. Balistreri and J. Weyant (2012), "Introduction to the EMF 29 special issue on the role of border carbon adjustment in unilateral climate policy", *Energy Economics* 34(S2): S95-S96.

Cosbey, A. and C. Fischer (2014), "International guidance for border carbon adjustments to address carbon leakage", in T. L. Cherry, J. Hovi, and D. McEvoy (eds), *Toward a New Climate Agreement: Conflict, Resolution and Governance*, London: Routledge, pp. 220–232.

Cosbey, A., S. Droege, C. Fischer and C. Munnings (2015), "The law and economics of developing guidance for implementing border carbon adjustments", Washington, DC: Resources for the Future and Geneva: International Institute for Sustainable Development.

Fischer, C. (2015), "Strategic subsidies for green goods", manuscript, Resources for the Future, Washington, DC.

Fischer, C. and A. K. Fox (2012), "Comparing Policies to Combat Emissions Leakage: Border Tax Adjustments versus Rebates", *Journal of Environmental Economics and Management* 64 (2): 199–216.

Fischer, C., M. Greaker, and K. E. Rosendahl (forthcoming), *Are Renewable Energy Subsidies in Need of Reform?*, in J. Strand (ed.), [Title to be determined], Cambridge, MA: MIT Press.

Fischer, C., D. Morgenstern and N. Richardson (2014), "Carbon Taxes and Energy Intensive Trade Exposed Industries: Impacts and Options", in I. Parry, A. Morris and R. Williams (eds), *Carbon Taxes and Fiscal Reform: Key Issues Facing US Policy Makers*, Washington, DC: IMF, Brookings Institution and RFF.

Gerlahg, R. and O. Kuik (2014), "Spill or leak? Carbon leakage with international technology spillovers: A CGE analysis", *Energy Economics* 45: 381-388

Gollier, C. and J. Tirole (2015), "Effective institutions against climate change", forthcoming in *Economics of Energy & Environmental Policy*.

Kossoy, A., G. Peszko, K. Oppermann, N. Prytz, A. Gilbert et al. (2015), "Carbon pricing watch 2015: an advance brief from the state and trends of carbon pricing 2015 report, to be released late 2015", *State and Trends of Carbon Pricing*, Washington, DC: World Bank Group.

Mathys, N, and J. de Melo (2011), "Political Economy Aspects of Climate Change Mitigation Efforts", *The World Economy* 34(11): 1938-1954.

Mavroidis, P. and J. de Melo (2015), "Climate change policies and the WTO: From negative to positive integration", Chapter 16 in this book.

Moore, M. O. (2011), "Implementing Carbon Tariffs: A Fool's Errand?", *The World Economy* 34(10): 1679-1702.

Nordhaus, W. (2015) "Climate Clubs: Overcoming Free-Riding in International Climate Policy", *American Economic Review* 105(4): 1339-70.

Tavoni, M. (2015), "Carbon capture and storage: Promise or delusion?", Chapter 24 in this book.

Wang, X. and M. Murisic (2015), "Taxing carbon: Current state of play and prospects for future developments", Chapter 19 in this book.

Weitzman, Martin (2013), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?" *Journal of the Association of Environmental and Resource Economists* 1(1/2): 29–49.

World Aluminum (2014), "Environmental Metrics Report Year 2010 Data: Final v1.1", International Aluminium Institute, London.

About the author

Carolyn Fischer is a Senior Fellow at Resources for the Future (RFF) and currently a Marie Skłodowska–Curie Fellow of the European Commission, visiting at FEEM. She is a fellow of the CESifo Research Network and a member of Environment Canada's Environmental Economics and Policy Research Network. Previously, she has been a visiting professor at Gothenburg University; a Dahrendorf Visiting Fellow at the London School of Economics; a UCE3 Senior Fellow at the University of California Santa Barbara; and a fellow at the Center for Advanced Study of the Norwegian Academy of Science and Letters. She has taught at Johns Hopkins University, consulted for the World Bank Group, and was a staff economist for the Council of Economic Advisers. She joined RFF in 1997, after earning her PhD in economics from the University of Michigan at Ann Arbor. She has served on the board of directors of the Association of Environmental and Resource Economists, and currently serves on the editorial board of *REEP* and the *International Review of Environmental and Resource Economics*.

PART V

Technology Options

22 International cooperation in advancing energy technologies for deep decarbonisation

Michael Toman
World Bank

Climate change cannot be arrested without fundamental changes in the global energy system. Such a transformation will not be possible without major advances in a variety of low-carbon energy technologies. While carbon pricing can provide incentives for advancements in low-carbon energy technologies, more is needed to make deep cuts in global greenhouse gas (GHG) emissions in a cost-effective and politically feasible way. This is because the current state of the art for low-carbon technologies is such that they are significantly costlier than conventional fossil-based energy technologies if deployed at a larger scale. Bringing down the costs of low-carbon energy technologies will require substantial public sector investments not just in basic research, but also in pilot commercial-scale development of advanced energy technologies. Substantial gains in such efforts could be obtained from international agreement to coordinate national RD&D programmes for low-carbon energy and to share the fruits of discoveries. Such agreement promotes the provision of a public good versus negotiating over sharing the cost burden for curbing a global bad. International technology agreement can be complemented by coordinated efforts to raise international performance standards for energy efficiency and carbon intensity in key energy-using sectors.

The need for global energy system transformation

Global climate change cannot be arrested without fundamental changes in the global energy system. This can be seen from the following basic relationship explaining the influences the growth of greenhouse gas (GHG) emissions (the so-called Kaya identity):

[*% rate of change in global GHG emissions over time*] =

[*% rate of change in population*] +

[*% rate of change in income per capita*] +

[*% rate of change in energy utilised per unit of economic output (energy intensity)*] +

[*% rate of change in the embodied carbon per unit of energy utilised (carbon intensity)*]

The world's population will continue to grow over the remainder of the century, though the rate of growth will drop considerably over time. It is to be hoped that global average income per capita grows considerably over the coming decades, in order to sharply cut the percentage of individuals living in poverty and to achieve continued but more inclusive economic growth. Let us assume that population growth is about 1% per year over the next few decades, and that per capita income growth is about 3%.[1]

The growth in population and per capita income will be accompanied by considerable increases in energy use, in particular by the descendants of poor populations that today use little modern energy or even lack access to it altogether. Against these trends, energy efficiency is likely to continue to improve over time. However, annual rates of improvement in energy efficiency in the order of 4% would be needed to offset the growth in population and (hoped for) income growth. This is unrealistically high; 2% is a more realistic, albeit still ambitious figure. A rate of energy decarbonisation of 2% per year then would be needed to hold GHG emissions constant. In comparison, the global carbon intensity of energy use barely changed over the period 1990–2012 according to the IEA (2014, Figure 16), and the EIA's (2013) projection without major new policies internationally is for a decrease in carbon intensity of only 0.2% per year on average up to 2040.

These calculations illustrate only what would be needed to arrest growth in GHG emissions over the next few decades. In fact, global GHG emissions must not only peak fairly soon but also fall precipitously by the end of this century to limit the increase in the global average temperature to somewhere between 2°C and 3°C, a target range seen by many as needed to avoid unacceptably high risks from climate change. To

1 These are roughly the figures used in the Energy Information Administration's 2013 *International Energy Outlook* (EIA 2013).

accomplish this, the global energy system must be profoundly transformed into one that produces only a small fraction of the GHG emissions occurring today – even while average global income rises substantially from its current level. As shown in IPCC (2014a, Figure 7.16), low-carbon energy sources – renewables, nuclear, and fossil energy use with carbon capture and storage (CCS) – must increase from under 20% of total energy use to above 70% or even above 90% by 2100, depending on the stringency of the limit on temperature increase sought.

Such a transformation will not be possible without fundamental changes in energy technologies. The reason for this is that low-carbon energy technologies currently are not cost-competitive when implemented on a large scale. The lower 'energy density' of wind and solar resources per unit of capital expenditure, relative to conventional technologies, is one barrier (Kessides and Wade 2011). Even where direct costs of production are falling, as with solar photovoltaic (PV), the costs of large-scale PV use are increased by its intermittency and the challenges of coordinating such dispersed resources with the current power grid (Joskow 2011). While some very large hydroelectric resources remain to be developed, the number of economically attractive and environmentally manageable sites is inherently limited. Nuclear power remains dogged by cost overruns, public concerns, and the long time line that seems to be needed for 'next generation' reactors to become commercially available. 'Second-generation' biofuels that create fewer land-use tradeoffs and result in larger net carbon savings remain a number of years away (Cheng and Timilsina 2011). While plug-in vehicles are advancing quickly, they increase the pressure to decarbonise the power system.

All these potential pathways for decarbonisation of the energy system must bear fruit in terms of lower costs in order for dramatic decarbonisation to be economically manageable in practice. However, the ability to use carbon capture and storage appears to be especially urgent. Even some negative-emissions options are needed – in particular, growing biomass, which pulls CO_2 out of the atmosphere, and capturing the released CO_2 emissions when the biomass is burned to generate power. If CCS is not available in the portfolio of emissions mitigation options, the costs of constraining temperature increases are considerably larger (IPCC 2014b, Table SPM2). Yet, CCS remains an experimental technology, with very uncertain future prospects (see Tavoni 2015).

Challenges in achieving the transition

As it stands, the IPCC suggests that additional investments of around $150 billion per year may be needed to move forward on a path toward decarbonisation, as well as more than twice that amount for improvements in energy efficiency (IPCC 2014b, p. 27). The International Energy Agency has estimated that $44 trillion would be needed by 2050 in the effort to hold temperature change below 2°C (IEA, 2014), on top of the investments needed to meet growing energy demands.[2] Such added costs can limit the incentives for individual countries to launch programmes for energy decarbonisation, and exacerbate the debate over how the cost burden for drastically reducing global GHG emissions might be allocated.

Given that a profound change in the global energy system will be needed to reduce GHG emissions enough to stabilise the climate, and given that a high cost of decarbonisation acts as a serious barrier to unilateral and cooperative efforts to implement GHG-mitigating policies and measures, it stands to reason that technical progress in lowering the cost of decarbonisation needs to be a high priority. This is all the more important when one takes into account that the default for meeting rapidly growing energy demands in developing countries will include major increases in fossil energy, especially coal for electricity. Locking in high-carbon energy infrastructure only raises the opportunity cost of reducing emissions later, further deterring actions needed to stabilise the climate.

One way to stimulate such technical progress is by putting a price on GHG emissions. This creates powerful incentives for the development and diffusion of lower-cost, lower-carbon energy sources and technologies. With the development of such technologies, all GHG emitters can lower their costs of responding to policy (such as the need to buy allowances in the European Trading System (ETS) or to pay a carbon tax on residual emissions) by licensing the new technologies, and those who can provide cost-reducing GHG-mitigation technologies have a ready market in which they can recover their costs. Calel and Dechezleprêtre (forthcoming) show that carbon pricing in the ETS has

2 The IEA also estimates that fuel cost savings would be more than 2.5 times as large.

contributed to an increase in low-carbon innovation, though the effect is not that large given the relatively low carbon prices found in the ETS.

A key virtue of using carbon pricing to help induce development and diffusion of lower-carbon energy technologies is that it can foster competition among different approaches. Meanwhile, some of the cost disadvantages of large-scale low-carbon energy deployment will shrink through learning-by-doing as greater experience is gained with the operation of larger-scale solar photovoltaic and thermal power plants, different wind sites, and evolving technologies for growing and utilising biomass energy sources (as fuels and electricity feedstocks).

Beyond carbon pricing …

However, more will be needed to make deep cuts in global GHG emissions in a cost-effective and politically feasible way. There continues to be resistance in much of the world to setting carbon prices that are high enough to induce major energy technology transformations, despite mounting evidence of the threats posed by climate change. Moreover, some of the cost disadvantages of low-carbon energy systems may be persistent, requiring more fundamental advances in technology than might be induced through carbon pricing alone. These include the challenges of coordinating widely dispersed and intermittent renewable electricity sources for a stable power grid (and as part of that, the development of cost-competitive power storage technologies), and the development of a 'new generation' of nuclear power reactors that are cost-competitive and respond to public concerns about safety as well as nuclear proliferation. The technical challenges facing the development and widespread implementation of cost-competitive and publicly accepted CCS also are quite substantial. The more basic scientific research that seems necessary to overcome the cost barriers typically is undertaken on too small a scale, if at all, by the private sector, given both the risks from failure and the difficulties in appropriating economic benefits from a basic discovery.

...to disruptive innovation

The size and persistence of these sorts of challenges suggests that some 'disruptive' rather than just 'evolutionary' innovations in energy technologies will be needed to overcome them. While in principle such innovations could occur at any time and could come from a variety of sources, large and enduring increases in public sector R&D expenditures are likely needed in practice to raise the probability of achieving the necessary fundamental breakthroughs in low-carbon energy technology to an acceptable level. In addition, some public investment (or some other form of cost and risk sharing) will be needed in piloting commercial-scale applications of more fundamentally new technologies, in order to mitigate the economic risks of being an early mover with a new technology. For example, electricity grids that can successfully manage the integration of dispersed and intermittent resources are inherently large investments in technologies whose performance characteristics can only be fully understood once the technology has been scaled up. The same is true of large-scale CCS. Determining the economic performance of solar thermal technology on a large scale likely will require building a significant number of facilities using different specifications and operating conditions; yet each plant would cost some billions of dollars to build and would be likely deliver uneconomic power compared to alternatives while the technology is being refined.

The importance of international technology cooperation

The need for increased public sector R&D discussed above could be met by different governments funding a variety of different programmes, depending in part on their own comparative advantages (e.g. countries with high wind or solar potential, or geology favourable to CCS) as well as on their own reckonings of what technology paths may be more promising. There are, however, some significant limitations with this approach that point to the value of international cooperation in low-carbon RD&D.

One issue is the cost of greatly expanded national programmes for energy technology development. No one really knows how large these costs might be. According to figures from the IEA,[3] between 2005 and 2013, total energy-related RD&D in the OECD averaged about $15.3 billion per year. Of that amount, about 35% was for energy efficiency and renewable energy (in roughly equal parts), just under 30% was for nuclear, and only 15% was for fossil energy. On the other hand, the percentages for hydrogen and fuel cells and for storage technologies were only about 5% each. Funding for CCS is also minimal compared to its potential importance for decarbonisation in the medium to longer term.

As noted in IPCC (2014a, Section 7.12.4), energy R&D recently has been in the order of 5% of total R&D spending – less than half the level observed in 1980. With such a small share for total energy R&D, let alone low-carbon energy R&D, there are also concerns over the scope of international R&D for low-carbon energy. No one knows which of many possible technology pathways might be successful in lowering costs as well as emissions. Because of this, it would be highly desirable to pursue a number of them simultaneously, rather than picking a few 'winners' early on. However, many pathways can only be adequately explored through very substantial expenditures on both R&D and commercial-scale piloting, as noted above. Keeping open a range of options for technology development and diffusion, while very desirable, is costly.

At a time of limited fiscal space for many OECD and other countries, a significant absolute increase in RD&D spending for low-carbon energy will be challenging with or without international cooperation. Another difficulty, however, is the analogue of the problem with private R&D spending falling below the socially desirable level because of inherent problems in establishing adequate incentives for knowledge creation. Because fundamental knowledge coming from expanded public-sector R&D typically would not be possible to patent (though new devices based on that knowledge could be), a portion of the benefits of any R&D increase undertaken by a particular country will 'leak away' to others who can make use of the resulting knowledge without sharing in the costs. Yet, technology development and transfer to developing countries will be essential for a successful global climate regime (see Coninck et al. 2015). Understandably, individual governments considering major increases in low-carbon energy R&D programmes will

3 See http://www.oecd-ilibrary.org/energy/data/iea-energy-technology-r-d-statistics/rd-d-budget_data-00488-en.

be motivated by the benefits they can secure, not the benefits for the world as a whole. Moreover, the economic and political costs of unsuccessful programmes can create a bias in favour of pursuing technology options that appear more likely to succeed or easier to implement – even though success in decarbonisation may arise from what are seen today as 'fringe' possibilities. This may be easier to manage when one considers a global portfolio of R&D in which activities are coordinated and costs are at least implicitly shared for a range of options.

These points highlight the potential benefit from focusing substantial attention in upcoming international climate cooperation efforts on ways to greatly expand and coordinate global RD&D activity in low-carbon energy. Agreements on coordinating research programmes to share the costs of such RD&D investing, and on arranging for broad access to successes from the R&D, add to the global public good. This compares favourably with the politics of negotiation over allocating the cost of mitigating emissions (a global public bad) through negotiating over national emissions targets.[4]

That is not to say that arriving at an international agreement for low-carbon energy technology development would be easy. There would still need to be tough discussions over funding level commitments, the means for assuring that those commitments are carried out, and rights of participants to access discoveries coming from the programme. The details of programme administration would matter greatly. Trade barriers that limit the movement of international foreign-made green technologies today would remain an issue. Nevertheless, the promise of this approach suggests that it should receive much greater emphasis in international climate policy discussions.

4 Even with 'Intended Nationally Determined Contributions' (INDCs) for mitigating global GHG emissions, which are figuring prominently in the run-up to the Paris COP, there is still room to debate whether any one country's INDC is in some sense 'adequate'. Moreover, there is reason to believe that negotiations over INDCs will have to overcome the same basic challenge to international climate agreements that has been pointed out by numerous authors, namely, the fact that among many countries coming from diverse circumstances but with a common incentive to do less while hoping others will do more, the only feasible agreements may have limited impacts on the trajectory of global GHG emissions. The nature of this challenge is thoroughly reviewed in the various essays in Aldy and Stavins (2010).

A Global Apollo Programme?

The recent call by a number of prominent authors (including Lord Stern) for a 'Global Apollo Programme to Tackle Climate Change' (King et al. 2015) draws welcome attention to the need for expanding international RD&D for GHG mitigation, including low-carbon energy technologies.[5] The proposed programme calls for increased spending starting at $15 billion per year, or about 0.02% of global GDP, rising thereafter with growth in global income. Compared to the figures on recent energy RD&D expenditures presented above, this would represent somewhat more than double the recent levels of expenditure for non-fossil energy. However, it is an order of magnitude smaller than the amounts that the IPCC and IEA have suggested for effecting a low-carbon transition. Thus, the extent to which the proposed expenditures would lower the costs of new investments in low-carbon energy is open to question. The extent to which the expenditures would bring down the cost of low-carbon energy enough to stimulate earlier retirement of existing fossil energy production capacity is even more uncertain (Evans 2015).

On the other hand, is the international community prepared to spend something close to 0.02% of global GDP per year for some time on public and private RD&D in order to effect a deep and rapid reduction in GHG emissions? Only time and increased efforts to expand global RD&D cooperation will tell.

Complementary measures: Coordination of technology standards

A useful complement to creating a programme for internationally coordinated technology development for low-carbon energy would be international agreements on various performance standards for energy-using technologies, which could help spur demand for existing and new technologies (Barrett and Toman 2010). Even with current technologies, it could be possible to stimulate demand for more energy-efficient energy-using technologies and lower their cost of production through internationally

5 The analogy with the programme for successfully landing people on the moon is somewhat flawed, though, since it does not fully capture the diversity of technology initiatives needed to successfully accomplish drastic reductions in GHGs.

coordinated performance standards. The result could be significant reductions in emissions at relatively manageable costs (though the costs of energy efficiency programmes continue to be debated), and without the serious political economy challenges of carbon pricing.

More ambitious measures for stimulating new technology demand could involve international agreements on sector-specific carbon-intensity performance standards. For example, countries could agree that their national electricity systems would achieve targets for GHG emissions per unit of output by specified dates. Such agreements would obviously involve different costs for different countries, depending on the nature of the agreements. However, agreements over performance standards may be easier to negotiate than carbon-reduction targets per se, in that the performance standards can be framed in terms of technology modernisation and opportunities to compete internationally in the provision and utilisation of modern technologies. The ambition of any such agreements would depend on how countries perceive the prospects for declining costs of decarbonisation over time, in particular through shared efforts to reduce the cost of low-carbon energy technologies. They would not necessarily be a substitute for coordinated international carbon pricing, but they could play a valuable role en route to such coordination.

References

Aldy, J. E. and R. N. Stavins (eds) (2010), *Post-Kyoto international climate policy: Implementing architectures for agreement*, Cambridge, UK: Cambridge University Press.

Barrett, S. and M. A. Toman (2010), "Contrasting future paths for an evolving global climate regime", *Global Policy* 1(1): 64-74.

Calel, R. and A. Dechezleprêtre (forthcoming), "Environmental policy and directed technological change: Evidence from the European carbon market", *Review of Economics and Statistics,* in press.

Cheng, J. J. and G. R. Timilsina (2011), "Status and barriers of advanced biofuel technologies: A review", *Renewable Energy* 36(12): 3541-3549.

de Coninck, H, S. Bhasin and G. Blanco (2015), "Meaningful technology development and transfer: a condition for involving developing countries into a viable climate regime", Chapter 31 in this volume.

Energy Information Administration (EIA) (2013), *International Energy Outlook 2013*, Washington, DC.

Evans, S. (2015), "Climate change 'Apollo programme' raises both hope and questions", *The Carbon Brief*, 2 June (available at http://www.carbonbrief.org/blog/2015/06/analysis-climate-change-apollo-programme-raises-both-hope-and-questions/).

IPCC (2014a), *Climate Change 2014: Mitigation of Climate Change*, (see Introduction to this volume for the report's complete reference.

IPCC (2014b), "Summary for Policymakers", in IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this volume for the report's complete reference).

International Energy Agency (IEA) (2014), "CO_2 Emissions from fuel combustion: Highlights", Paris: OECD/IEA.

Joskow, P. L. (2011), "Comparing the costs of intermittent and dispatchable electricity generating technologies", *American Economic Review* 101(3): 238-241.

Kessides, I. N. and D. C. Wade (2011), "Deriving an improved dynamic EROI to provide better information for energy planners", *Sustainability* 3(12): 2339-2357.

King, D., J. Browne, R. Layard, G. O'Donnell, M. Rees, N. Stern, A. Turner (2015), *A Global Apollo Programme to Combat Climate Change*, London: Centre for Economic Performance (available at http://cep.lse.ac.uk/pubs/download/special/Global_Apollo_Programme_Report.pdf).

Tavoni, M. (2015), Carbon capture and storage: Promise or delusion?", Chapter 24 in this volume.

About the author

Michael Toman is a Lead Economist in the Development Research Group at the World Bank and Manager of the Energy and Environment Team. His current research interests include the energy-poverty nexus, mechanisms for achieving environmentally sustainable growth including greenhouse gas mitigation, and electricity sector restructuring. Prior to joining the World Bank, he held senior analytical and management positions at RAND Corporation, the Inter-American Development Bank, and Resources for the Future. He served as Senior Economist at the President's Council of Economic Advisers from 1994-1996. Mike received his PhD in Economics from the University of Rochester.

23 The role of renewables in the pathway towards decarbonisation

Valentina Bosetti
Bocconi University and FEEM

Renewable energy technologies represent an important low-carbon alternative to hydrocarbons in all applications, from transport to electricity generation and heating. In the shorter term, developments that lower the costs of renewable energy will help lower the cost of decarbonisation efforts. In the longer term, renewables could represent the main source of energy for a zero-carbon planet. Renewables can also bring about a whole set of important ancillary benefits, such as reductions in local pollution and increased access to energy. For all these reasons, policies that lower the barriers to adopting renewable energy and that spur innovation should play a key role in a future international climate agreement.

Introduction

Renewables represent the broad category of energy flows occurring in the natural environment that can be captured for use up to their rate of replenishment. Renewables include hydropower (although typically excluded from the group of 'new' renewables), wind and solar energy, tidal and wave energy, ocean and geothermal energy, and biomass energy (IPCC, 2011). Renewables are a key energy option for decarbonisation, but their use as a substitute for fossil fuel energy can also result in important co-benefits, such as improvements in 'energy security' by diversifying the set of energy sources, reductions in local pollution, the alleviation of energy poverty, and more broadly the promotion of 'green growth'. As renewables offer a variety of sources of energy, they are geographically distributed more widely than hydrocarbons. Thus, in principle, renewable energy provides new possibilities for development in most regions in the world.

In the short term, a shift towards renewables and improvements in these technologies have the potential to lower the cost of transitioning out of fossil fuels, thus making it more attractive for countries to adopt more ambitious INDCs. In the longer term, renewables provide the main technological means for reducing global emissions to zero, and so can help shape the ambition for setting long-term global temperature targets.

For all these reasons, policies related to renewables (either easing their adoption, lowering integration barriers, or promoting innovation in the next generation of technologies) should play a key role in future international climate negotiations.

This chapter provides an introduction to renewable energy technologies, describing their future technical potential (Section 1); reviewing their key role in addressing the GHG-mitigation challenge (Section 2); and, finally, discussing in Section 3 the main bottlenecks to the large-scale penetration of these technologies and the policies needed to help overcome these bottlenecks.

It is important to keep in mind that, following a period that has seen an unprecedented drop in the cost of new renewables (and solar modules in particular), a generalised trend change in the regulatory environment of several countries might result in a slowdown of future investments (IEA, 2014). As a result, renewables might run the risk of falling short of the levels required by deep decarbonisation scenarios. As argued here, international climate negotiations could counteract this trend by providing the predictable and long-term signals that will be needed to secure a sustained growth in these technologies.

1 Renewables today and their technical potential

In 2013, renewables represented about 22% of total electricity generation, with hydropower producing the lion's share, and roughly 13% of the world's total primary energy supply, the vast majority of which came from biomass alone. The deployment of renewables power capacity is expected to rise globally to 2550 GW in 2020 (a growth of 50%), with more than half of this new capacity expected to be installed in non-

OECD countries. The International Energy Agency projects that, thanks to this growth, by 2020 power supplied by renewables will grow from 22% to 25%. A further 50% growth by 2030 is shown in the projections presented in Table 1.

Table 1 Global installed capacity of renewables in 2000, 2010 and 2014, and projections for 2030 (GW)

Renewable technology	2000		2010		2014		2030 (IEA projections)	
Hydropower	781.73	(92.8%)	1027.60	(76.2%)	1172.00	(64.1%)	1670.00	(41.4%)
Wind energy	17.33	(2.1%)	196.33	(14.6%)	369.60	(20.2%)	1173.00	(29.1%)
Solar energy	1.23	(0.1%)	40.05	(3.0%)	179.64	(9.8%)	900.00	(22.3%)
Bioenergy	33.72	(4.0%)	72.54	(5.4%)	94.53	(5.2%)	245.00	(6.1%)
Geothermal energy	8.32	(1.0%)	10.98	(0.8%)	12.41	(0.7%)	42.00	(1.0%)
Tidal, wave, ocean energy	0.27	(0.0%)	0.27	(0.0%)	0.53	(0.0%)	6.00	(0.1%)

Notes: Relative share in parentheses.
Source: IRENA (http://resourceirena.irena.org/); 2030 projections from IEA (2015).

Table 1 gives estimates and projections for the cumulated installed capacity of different renewables technologies for various years. Wind and solar capacity have grown most rapidly, in response to the large reductions in the costs of solar PV modules, which fell by a half in several countries over the period. Most of this cost reduction was due to innovative changes in the production structure developed by Chinese manufacturers.

Roughly 50% of renewable installed capacity is currently located in the top five countries in terms of renewables deployment: China, the US, Brazil, Germany and Canada. However, most of the future instalment is expected to be concentrated in developing countries, where energy demand will grow the most in the next decades.

Underlying the projected numbers for 2030 presented in Table 1 is the assumption of an increase in investments in renewable energy technologies in the power sector from US$270 billion in 2014 to $400 billion in 2030, resulting in a more than threefold increase in the installed capacity for both wind and solar. Notwithstanding the current growth trend in renewables investments, renewables are projected to face a transition period in response to a change in the policy regime of most countries (IEA, 2014). Although it might be affected by international climate negotiations, new generation, capacity additions and investment in renewable power are all expected to level off through 2020. As far as biofuels are concerned, production and consumption in the US, the EU and Brazil are now slowing down after a period of very rapid expansion, mainly due to changes in policies in reaction to the peak in land demand and general equilibrium implications on crop prices that previous policies have caused. To meet the IEA's projections for 2030, a change in this recent policy trend would be required.

Renewable energy technologies can potentially cover the full spectrum of human energy needs; they can be used to produce electricity and heat, and provide energy for transportation. The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation concluded that the aggregated global technical potential for renewables as a whole is significantly higher than global energy demands although there is great uncertainty regarding assumptions on land use availability that have to account for issues like biodiversity, food security, water limitation, and soil degradation (IPCC 2011).[1]

2 The projected role of renewables in a decarbonised future

Simulations from global energy economy models suggest that renewables are fundamental both in the short to medium term as well as in the second half of the century (Clarke et al. 2014).

Those renewables options that are largely confined to the electricity sector (e.g. wind and solar) and to heat generation are projected to be especially important in the first part of the century. Each option contributes to keeping mitigation costs down and to facilitating decarbonisation by enriching the portfolio of technological alternatives and allowing a diversification of energy sources. In the short term, coupling renewables penetration with gas power generation is seen as the most promising solution, which would help maintain the flexibility of the power system.

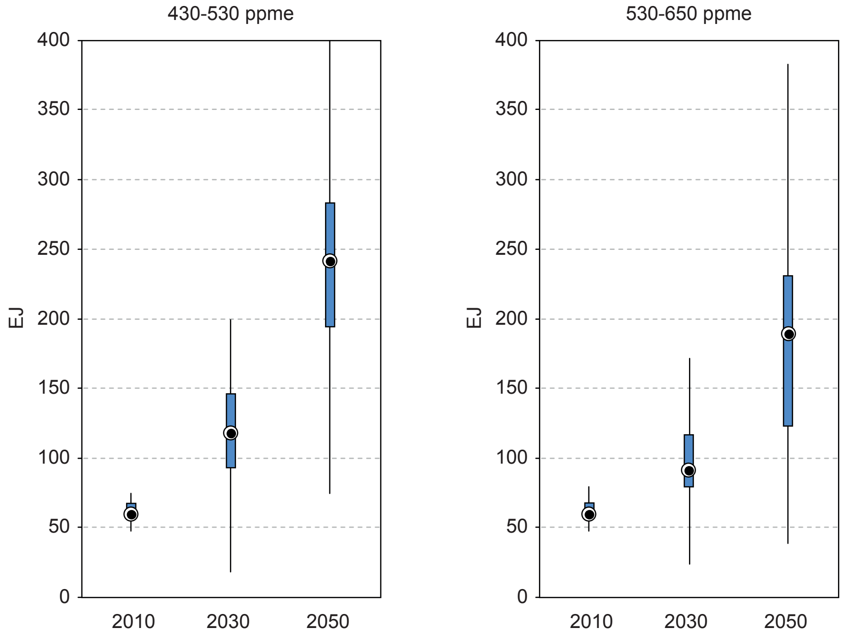
1 The complexity of such intricate interactions scales up the uncertainty surrounding the potential deployment levels of biomass for energy, which is estimated to be in the range of 100 to 300 EJ by 2050 (for the sake of comparison, 112 EJ is the primary energy consumption of North America in 2012 was 112 EJ).

Wind and solar technologies might have a less critical role in the longer run. Around 2050 and beyond, the effort to keep the average global temperature in line with a 2°C or 2.5°C target is such that 'negative emissions' technologies in moderating mitigation costs (Krey et al., 2013). Indeed, in the longer term, the technological option of combining biomass generated power with carbon capture and storage (CCS) gains a prominent role as it allows for the production of carbon-neutral power while, at the same time, generating 'negative' emissions. The idea is to generate power using carbon-neutral sustainable biomass and then capture CO2 at the plant level and store it underground in geological sites (see the chapters in this book by Tavoni and Barrett and Moreno-Cruz). Most projections that do not incorporate such a technological option either report costs of decarbonisation that are at the higher end of the scale, or fail to find a combination of technologies that would deliver stringent climate targets (i.e. scenarios leading to about 450 ppm CO2eq) (Azar et al., 2006; van Vliet et al., 2009, 2012; Krey et al., 2013).

Figure 1 summarises projections of renewables primary energy from multiple integrated assessment model (IAM) simulations for two representative future years (2030 and 2050) under two climate scenario classes (the left-hand panel reports the range of model results for 430-530 ppme, approximately in line with a 2°C temperature target, while the right-hand panel reports results for 530-650 ppme, or approximately 3°C).

Notwithstanding the huge uncertainties that characterise this range of IAM results, including over breakthroughs in renewables technologies, the average required expansion by mid-century in the more stringent climate scenarios (left-hand panel) is projected to be a threefold increase relative to today's levels. *This would represent a level of primary energy supplied by renewables in 2050 that is roughly half of today's total primary energy* (and a third for the more moderate climate stabilisation scenarios).

Figure 1 Model-based projections of primary energy from renewables



Notes: Average of estimates from integrated assessment models (IAMs). In each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, and the whiskers extend to the most extreme data points not considered outliers (corresponding to 99% if the data are normally distributed). Primary energy is the energy contained in raw fuels. Note that today's total primary energy global consumption (including fossils and nuclear) is 567 EJ, projected to grow to 612 and 643, by 2020 and 2030, respectively (IEA 2015).

Source: Author's elaboration of the IPCC AR5 Working Group III database (https://secure.iiasa.ac.at/web-apps/ene/AR5DB).

3 Limits to actual deployment

Below I review the uncertainties that could prevent the deployments of renewables.

Costs evolution

The major bottleneck slowing down the materialisation of the huge technical potential of renewables is, first and foremost, related to their transformation cost relative to the incumbent, fossil-fuelled technologies.[2] Although costs of both solar and wind power

2 Hydropower is the most mature of the renewables technologies and the only one for which costs are competitive. However, most of the hydropower potential, except for in Latin America and Africa, is already tapped and most projections are pessimistic with regards to the possible growth in the role of hydropower.

have decreased substantially in the last five years, grid parity[3] is still some way off, especially if fossil fuel prices were to remain low. Indeed notwithstanding regional variabilities due to resource availability, besides hydropower, it is only onshore wind that may be competitive with coal or gas power production. While in the case of wind technologies, the main source of cost reduction might come from improvements in assemblage and material costs as well as learning effects, solar, biomass-based and ocean technologies might still foresee drastic cost reductions due to major technological breakthroughs.

Three main (and not mutually exclusive) strategies could make renewables more competitive. The first is mainly based on directly funding public research and development (R&D) programmes or incentivising private R&D efforts in renewables technologies. The second is a set of strategies based on demand-side promotion schemes. Public policies directed to renewables deployment that include standards, energy certificates and feed-in tariffs not only promote the adoption of renewables, but also play a critical role in spurring additional innovation in these technologies (Johnstone et al., 2010). The third strategy would be to directly price carbon emissions, thus penalising the competitive, incumbent technology and again spurring adoption of and innovation in renewable technology. Though the debate over the relative merits of these strategies is far from being settled, it is increasingly evident that a combination of the three will likely be required. In addition, a key to success will be the adoption of a long-term policy strategy that will secure the commitment to the required investments.

Multiple recent studies have collected expert assessments of the probabilistic evolution of the cost of carbon-free technologies in response to R&D efforts – the first of the three strategies – by means of structured protocols and interviews (so-called 'expert elicitations'). These studies gather the probabilistic distributions of future costs of renewables technologies and how these distributions might be affected by R&D investments (Baker et al. 2008, 2009, Anadón et al. 2012; Bosetti et al. 2012, Fiorese et al. 2013, 2014).[4]

3 Grid parity occurs when an alternative energy source can generate power at a levelised cost of electricity (LCoE) that is less than or equal to the price of purchasing power from the electricity grid. The term is most commonly used when discussing renewable energy sources, notably solar power and wind power (en.wikipedia.org/wiki/Grid_parity).

4 Tidal and wave energy, ocean and geothermal energy technologies have not yet been covered by expert elicitation surveys.

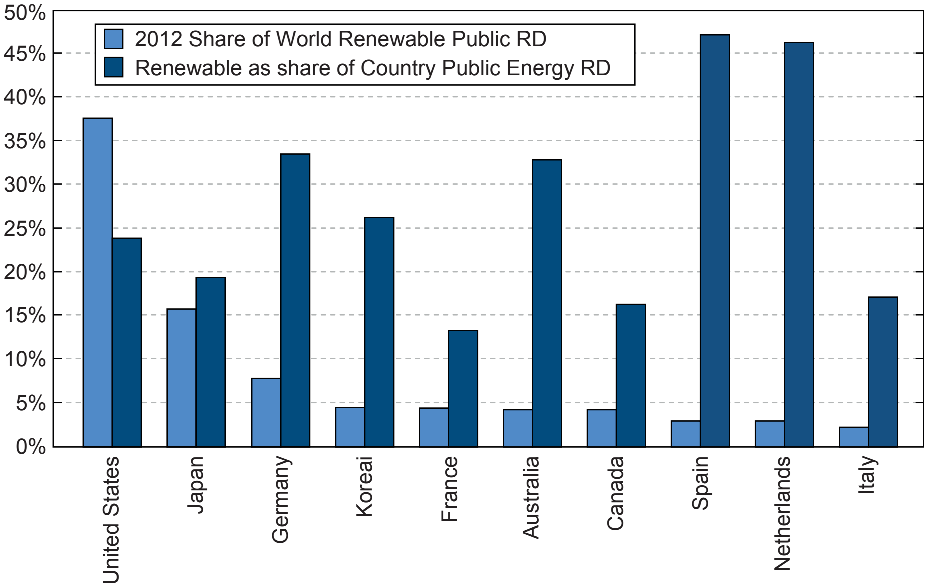
A summary of these studies (Bosetti et al. 2015) reports that overall renewable technologies costs are projected to decrease in the coming 15 years, and that experts expect these costs to be responsive to current levels of public R&D efforts. These elicitations also support the notion that R&D investments will often not reduce the uncertainty surrounding costs; rather, uncertainty is likely to stay the same or increase with larger investment in R&D as the range of technological possibilities expands (Bosetti et al. 2015). Solar PV technologies are to have the largest relative cost reductions, both under current public R&D funding as well as under increased R&D funding. Notwithstanding this expected trend, all reported median values for 2030 costs (and, in most cases, 10th percentile values) imply levelised costs of electricity still higher than coal- or gas-generated power (reported medians of solar PV LCoE cluster around $0.1 per kWh, in 2010 US dollars).

Elicitations for biofuels and biopower for 2030 also suggest that to become competitive with their fossil-fuelled competitors, public R&D efforts in renewables in OECD countries (see Figure 2) might not be enough, and policies that either internalise the external costs of carbon emissions or that work as demand-side promotion schemes will be necessary.

To get a sense of the magnitude of these investments, the dark blue bars in Figure 2 show each country's public contribution to renewables R&D as a share of its total public energy R&D (including fossils and nuclear). Contribution to R&D of renewables remains within the range of 13-20% for most countries, except for a few outliers (Australia, Germany, the Netherlands, Spain).

If we look at the private side of R&D investment, the Bloomberg New Energy Finance databases report, for the period 2004-2011, an average corporate R&D investment in renewables of around $3.5 billion, with solar receiving the largest share (around 60%) and wind following at just under 20% (Frankfurt School-UNEP Centre/BNEF, 2014). To put this number into perspective, in 2011 the R&D expenditure by Exxon Mobil alone was more than $1 billion. In addition, the energy sector is traditionally one of the sectors with the lowest levels of R&D expenditure as a ratio of net sales (less than 1%, while, for example, the R&D expenditure level in the drugs and medicine sector is in the order of 10%).

Figure 2 Share of renewables in public R&D expenditures of selected OECD countries, 2013



Source: Author's calculation from OECD Energy R&D dataset (2013 data).

Looking at patenting activities (see Popp et al., 2011), an indicator of the output of innovation, the US, Japan and Germany again emerge as the most innovative countries in renewables technologies.

On the second set of policy instruments (demand-side promotion schemes), evidence from multiple countries is becoming available. Supported by long-term policy frameworks, renewable investments have increased from multiple financing sources. Energy markets, in particular futures markets for electricity, span forward only a few years, whereas renewables are capital-intensive investments with a life-time of 20-30 years. This market failure, together with the lock-in of fossil fuels, has been the main motivation for these demand-side promotion schemes (Edenhofer et al., 2013) which have been fundamental for the adoption of solar PV and wind throughout Europe and that this has, in turn, been critical for the decrease in the cost of these technologies.

Several factors have contributed to the declining trend in demand-side promotion schemes throughout the developed world. In the case of biofuels, it is mainly related to the realisation of failures in the original policy schemes. In the EU and Japan, uncertainties remain over the evolution of the renewable policy framework, the feed-in tariffs schemes, and the prospected investments towards grid integration across countries. In the US, the EPA regulation on existing power plant emissions could help support renewables going forward, although renewable portfolio standards are debated in several states (see the chapter by Burtraw in this book).

In developing countries, most policy frameworks have traditionally emphasised electrification. Starting from Brazil and China (two major markets for renewables today), as well as India, policies to promote renewables adoption and to cope with barriers to their use have been increasingly important in accelerating deployment and attracting investment to this sector, while in Africa electrification remains a huge challenge (see the chapter by Mekkonen in this book).

System integration

Even if recent developments in the evolution of renewables costs were to be replicated in the near future, a second, major obstacle is becoming increasingly important – system integration. In the face of stable and growing demand, renewables are an energy source that is unpredictable and highly variable over timescales that might range from seconds to years (IPCC, 2011). System integration issues are important barriers to deployment and they will require investment in innovation (most notably, for storage technologies), investment in new infrastructures, and institutional changes to account for required changes in the energy markets. The larger the share of renewables in the system, the more pressing these issues will become.

In order to meet power demand at each moment in time, either complementary technologies supporting enough flexibility in dispatch or energy storage systems are required. Gas power plants, with their flexibility, are the best complement to increases in the share of renewables in the grid, at least in the short term. For storage technologies, the most prominently discussed technologies are either based on pumping water or air pressure, or on large batteries, including networks of smaller batteries, such as those employed in electric drive vehicles. Finally, renewables could also be better managed by using demand-side response practices.

Lack of predictability and lack of flexibility can also put pressure on energy markets, which are currently based on marginal cost pricing; hence, large penetration of renewables could lead to low and even negative pricing, which in turn could lead to reductions in overall sectorial investments (Edenhofer et al., 2013).

Environmental issues

Other environmental and social issues should be kept in the picture when designing policy that implies penetration of renewables technologies on a massive scale. This is particularly critical in the case of large-scale penetration of biomass usage, both for power production and for biofuels. Indeed, diffusion of energy crops exerts pressure on other land uses, ranging from food crops to forestry, and, in principle, threatens biodiversity. Land use is also one of the major potential issues associated with large-scale deployment of solar technologies (together with the issue of toxic waste and lifecycle GHGs emissions for solar), but it is overall much less of a concern than in the case of biomass.

The modest potential for hydroelectric energy still available, hydroelectric development will play only a minor role in the future of renewables.

Environmental risks from ocean energy technologies appear to be relatively low, although the technology is too immature for any definitive evaluation. Finally, in the case of wind, the environmental footprint of the technology is relatively low.

4 The way forward

Even though renewables will become more competitive, their future development is still closely linked to public policies aimed at stimulating innovation, actual deployment and carbon pricing. In particular, long-term and stable policy frameworks and market signals will be crucial for large-scale deployment of renewables. This is in contrast to the uncertainty recently affecting the renewables regulatory environment (in particular, in the EU, Japan and the US). This general trend in the policy environment could be reversed by an international climate agreement that establishes a long-term global commitment to internalising the costs of carbon emissions or that includes some form of commitment to renewables deployment.

Indeed, any international climate agreement implying a mid- to long-term commitment to fossil fuel emissions mitigation and an appropriate carbon price would help to provide this signal. In addition, policies and technologies aimed at increasing power system flexibility will be particularly important. In the longer term, policies fostering innovation and key technological breakthroughs in storage technologies, third generation PV, algae-based biodiesel or third generation biofuels, as well as other technologies still far from any commercial application, will play a more important role.

As discussed by Toman in his chapter in this book, an international agreement with the objective of coordinating national R&D programmes for renewables and sharing the resulting knowledge (for example, with special patent rights for open knowledge or facilitated licensing) could represent an important step forward in dealing with these longer-term innovation issues. This would be particularly relevant for high-risk technologies with large potential but that are still far from any commercial implementation.

However, as we have discussed, most experts believe that innovation policies alone would fall short in delivering the required price cuts in the short to medium term. Rather, demand-side promotion schemes could play a crucial role, as well as policies favouring international transfer of technologies. Since in the coming decades the largest share of the global energy demand growth will be located within fast-growing developing countries, technological transfers will play a key role. Indeed, notwithstanding China and Brazil, most of today's renewables installed capacity and know-how is located in developed countries. Similarly, the largest share of investments in R&D, as well as the largest effort in terms of complementary policies to spur the diffusion of renewables has, so far, mainly taken place in the developed world. As discussed in detail by de Coninck et al. in their chapter in this book, agreements and policies promoting the transfer of technology and know-how to developing countries will therefore be extremely valuable in the deployment of renewables.

In addition, as discussed by Buchner and Wilkinson in their chapter, specific programmes designed to reduce the risk-return ratio of renewables investments and explicitly targeting developing countries, whereby risk is shared with public (national or international) institutions, could nurture a thriving market for renewables in developing countries.

References

Anadón, L. D., V. Bosetti, M. Bunn, M. Catenacci and A. Lee (2012), "Expert Judgments about RD&D and the Future of Nuclear Energy", *Environmental Science & Technology* 46(21): 11497–504.

Azar, C., K. Lindgren, E. Larson and K. Möllersten (2006), "Carbon Capture and Storage From Fossil Fuels and Biomass – Costs and Potential Role in Stabilizing the Atmosphere", *Climatic Change* 74 (1-3): 47–79.

Baker, E. D., H. Chon and J. Keisler (2008), "Electricity from Biomass: Combining Economic Analysis with Expert Elicitations to Inform Climate Policy", Working Paper, University of Massachusetts, Amherst, MA.

Baker, E., H. Chon and J. Keisler (2009), "Advanced Solar R&D: Combining Economic Analysis with Expert Elicitations to Inform Climate Policy", *Energy Economics* 31: S37–S49.

Barrett, S. and J. Moreno-Cruz (2015), "The alternatives to unconstrained climate change: Emission reductions versus carbon and solar geoengineering", Chapter 25 in this book.

Bosetti, V., M. Catenacci, G. Fiorese and E. Verdolini (2012), "The Future Prospect of PV and CSP Solar Technologies: An Expert Elicitation Survey", *Energy Policy* 49: 308–317.

Bosetti, V. L. Diaz Anadon, E. Baker, L. Aleluia Reis and E. Verdolini (2015), "The Future of Energy Technologies: An Overview of Expert Elicitations", forthcoming OECD report, Paris.

Buchner, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional' finance", Chapter 33 in this book.

Burtraw, D. (2015) "The regulatory approach in US climate mitigation policy", Chapter 17 in this book.

Clarke, L., K. Jiang et al. (2014), "Assessing transformation pathways", Chapter 6 in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Edenhofer, O., L. Hirth, B. Knopf, M. Pahle, S. Schloemer et al. (2013), "On the Economics of Renewable Energy Sources", *Energy Economics* 40: S12–S23.

Fiorese, G., M. Catenacci, E. Verdolini and V. Bosetti (2013), "Advanced Biofuels: Future Perspectives from an Expert Elicitation Survey", *Energy Policy* 56: 293–311.

Fiorese, G., M. Catenacci, V. Bosetti and E. Verdolini (2014), "The Power of Biomass: Experts Disclose the Potential for Success of Bioenergy Technologies", *Energy Policy* 65: 94–114.

Frankfurt School-UNEP Centre/BNEF (2014), Global Trends in Renewable Energy Investment 2014 (available at http://www.unep.org/pdf/Green_energy_2013-Key_findings.pdf).

IEA (2014), *Medium-Term Renewable Energy Market Report*, Paris.

IEA (2015), *World Energy Outlook Special Report 2015: Energy and Climate Change*, Paris.

IPCC (2011), *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge, UK and New York: Cambridge University Press.

Johnstone, N., I. Haščič and D. Popp (2010), "Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts", *Environmental and Resource Economics* 45(1): 133–55.

Krey, V., G. Luderer, L. Clarke and E. Kriegler (2013), "Getting from Here to There – Energy Technology Transformation Pathways in the EMF27 Scenarios", *Climatic Change* 123(3-4): 369–82.

Mekkonen, A. (2015) "A view from Africa", Chapter 5 in this book.

Popp, D., I. Hascic and N. Medhi (2011), "Technology and the Diffusion of Renewable Energy", *Energy Economics* 33(4): 648–62.

Tavoni, M. (2015) "Carbon capture and storage: Promise or Delusion?", Chapter 24 in this book.

Toman, M. (2015) "International cooperation in advancing energy technologies for deep decarbonisation", Chapter 22 in this book.

van Vliet, J., M. den Elzen and D. van Vuuren (2009), "Meeting Radiative Forcing Targets under Delayed Participation", *Energy Economics* 31: S152–S162.

van Vliet, J., M. van den Berg, M. Schaeffer, D. P. van Vuuren, M. den Elzen et al. (2012), "Copenhagen Accord Pledges Imply Higher Costs for Staying below 2°C Warming", *Climatic Change* 113(2): 551–61.

Wang, X. and M. Murisic (2015) "Taxing carbon: Current state-of-play and prospects for future developments", Chapter 19 in this book.

About the author

Valentina Bosetti is Associate Professor at Bocconi University and a Research Fellow at the Foundation Eni Enrico Mattei, Milan. She has been visiting scholar at Princeton and Fellow at the Center for Advanced Studies in Behavioral Sciences at Stanford. She has been a lead author for the Fifth Assessment Report of the IPCC. She has several publications on technical change in energy technologies, integrated assessment modeling and climate change policy. She has been awarded two European research grants.

24 Carbon capture and storage: Promise or delusion?

Massimo Tavoni
Fondazione Eni Enrico Mattei (FEEM) and Politecnico di Milano

Fossil fuels currently dominate the global energy mix, and there is no indication of a significant reversal of this trend in the near future. The recent decline in oil prices, the revolution in extraction of gas and oil, and the abundance of global coal resources suggest that whatever strategy will be devised to deal with climate change, it will have to confront a large supply of competitive fossils. To this end, the possibility to sequester and store CO_2 geologically offers an important way to decouple fossil fuel use from greenhouse gas emissions. It could also provide incentives to engage fossil fuel producers in international climate action. CCS, if coupled with biological sources, also offers the potential to remove CO_2 from the atmosphere and is a technology that will be needed in the future if ambitious climate targets will need to be attained. Yet, the commercialisation of large-scale CCS plants has proven much more difficult and slower than originally envisioned. This chapter explores the importance of CCS for short- and long-term climate policies, drawing quantitative insights from the scenarios recently collected for the IPCC Fifth Assessment Report. It confronts the predictions of the models with the engineering assessment of the cost and performance of the technology, both in its current form and for different assumptions about technological progress in the foreseeable future. We conclude with a set of policy recommendations aimed at promoting the development of a large-scale and well functioning CCS programme.

1 Why CCS?

Carbon capture and storage (CCS) is a technology which allows capturing waste CO_2, transporting it to a storage site, and depositing it in such a way that it will not go into the atmosphere, for example in a geological or oceanic storage site. The key distinguishing feature of CCS is that it makes extraction and combustion of fossil fuel energy sources compatible with climate mitigation objectives. This is an important characteristic, because fossil fuels provide abundant sources of energy now and for the foreseeable future. As testified by the shale natural gas boom that occurred in the US in the past decade as well as in the recent drop in oil prices, fossil fuels remain extremely competitive. Although the estimates of fossil reserves and resources are highly uncertain, it is safe to say that the total fossil fuel reserves contain sufficient carbon, if released, to warm the planet well above any safety threshold (Rogner et al. 2012). This is particularly true for coal, which scores the highest among fossil fuels both in terms of reserves and carbon intensity.[1] Thus, CCS could effectively allow for the procrastinated use of fossil fuels while limiting – if not eliminating – their impact in terms of greenhouse gas emissions. Moreover, CCS can in principle be coupled with non-fossil energy sources, such as biomass, thereby possibly allowing CO_2 to be absorbed – rather than emitted – in the atmosphere. This would create a 'negative emission' technology, which could help remove some of the CO_2 that has already been or will be put into the atmosphere. Finally, by making emissions reduction strategies compatible – at least to a certain extent – with fossil fuels, CCS can have important repercussions on the climate negotiation process. In the remainder of this brief chapter, we explore the role of CCS for climate stabilisation, and discuss the current status of the technology and its role for climate and energy policy.

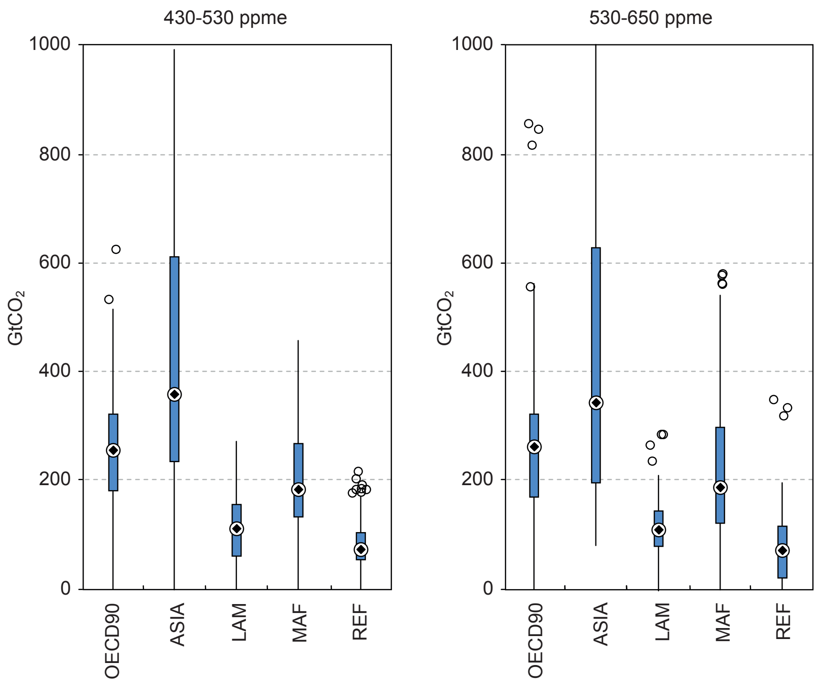
2 CCS and climate stabilisation

In order to provide information about the importance of CCS as a climate stabilisation strategy, let us look into the results of the scenarios recently produced for the Working Group III of the IPCC Fifth Assessment Report (see IPCC 2014, Chapter 6). These scenarios are generated by integrated energy economic models and describe possible realisations of the energy systems throughout the entire century, under different assumptions about climate policy. Figure 1 reports the total amount of CO2 that would need to be captured via CCS for different climate policy objectives, and five

1 For reference, the emission factors for electricity generated by coal is close to 1,000 grCO_2/kWh, with natural gas being around 600 grCO_2/kWh.

representative regions. These numbers represent the economically optimal CCS strategy in the context of the global transformation of the energy sector needed to achieve climate stabilisation roughly consistent with 2°C and 3°C temperature targets (left and right panels, respectively), as foreseen by integrated assessment models under a wide range of assumptions about policy implementation and alternative low carbon mitigation options. The figure illustrates the importance of CCS as an emission reduction strategy. Despite differences across regions, models, and policies, the average quantity of CO_2 captured and stored throughout the entire century is in the order of hundreds of $GtCO_2$. By comparison, current CO_2 emissions are in the order of 35 $GtCO_2$ per year. Summing up the regional contributions, the global sequestered CO_2 would exceed 1,000 GtCO2, an amount similar to the total carbon budget compatible with keeping temperature increase below 2°C.

Figure 1 Projections for cumulative CO_2 capture by region under two policy scenarios, 2010-2100.



Notes: LAM stands for Latin and Central America, MAF for Middle East and Africa, REF for Reforming Economies or Economies in Transition. Black dots are the medians, thick bars show the 25-75 percentiles, and thin bars extend to 99 percentile, outliers are shown as circles.

Source: Author's elaboration using the AR5 IPCC WGIII database.

The convenience of CCS under a climate policy regime is that it can be applied to different fossil sources, such as gas and coal, as well as to biological ones, as previously discussed. This flexibility makes CCS appealing for different levels of climate policy stringency, as shown in Figure 1. The capacity of biomass and CCS (commonly referred to as BECCS) to generate net negative emissions – at least in theory – by capturing the CO_2 stored in the biomass and sequestering it underground provides additional incentives in favour of CCS. Although the costs of BECCS and other negative emission technologies are currently above those of conventional mitigation technologies (e.g. above \$100 per tCO_2), models foresee a large role for CO_2 removal, especially during the second half of the century, when carbon prices will rise to sufficiently high levels. Despite its potential, it remains unclear whether BECCS can deliver the CO_2 absorption rates foreseen by economic optimisation models, when considering the technological and institutional limitations and the need to provide CO_2-neutral biomass. The uncertainties around the potential of negative emissions are therefore huge (Azar et al. 2013, Tavoni and Socolow 2013, Fuss et al. 2014).

These large uncertainties are also reflected in the wide range of the scenario results in Figure 1, which includes cases in which models have assumed that CCS would not be available, as shown by confidence interval bars including no CO_2 captured. Such analysis has further revealed that among all mitigation technologies, CCS is the one with the highest economic value – foregoing or banning CCS would lead to a significant increase (i.e. a doubling or more) in the economic costs of achieving a given climate stabilisation, especially for the most stringent mitigation scenarios (Tavoni et al. 2012, Kriegler et al. 2014: 27). Although a broad portfolio of low-carbon technologies is needed to achieve climate stabilisation, CCS stands out as one of the most important since it is the only one that would allow continued use of fossil energy sources.

3 Status of and prospects for the technology

The climate stabilisation scenarios call for a massive scaling up of CCS over the next several decades, a requirement that stands in stark contrast to the limited deployment of CCS observed in reality. At the time of writing, approximately 14 pilot CCS projects are operating, four of which are for enhanced oil recovery.[2] Several others have been announced, but an equally large number have been cancelled. One of the obvious reasons for this is the high capital costs of these technologies compared to conventional ones. For example, the US government's recent decision to pull the plug on the FutureGen project resides in the fact that, despite the $1 billion of federal money, investors remained wary of the economic viability of the carbon capture project. It is also due to the fact that cheap natural gas and the falling costs of renewable energy sources currently provide more economical solutions for reducing CO_2 emissions. In addition, public support for CCS remains a critical factor for its development – CCS involves infrastructure as well as storage sites, both of which require public acceptance. In Europe, adverse public acceptance has recently led to the cancellation of two CCS projects in the Netherlands and in Germany. Moreover, CCS alone would not eliminate other kinds of pollution coming from coal combustion, such as those responsible for local air quality. Last, but not least, if CO_2 were to leak from the reservoirs where it is stored, the benefits of CCS would be undone. Although current tests do not seem to indicate leakage to be a particularly critical issue, the long-term effects of storing CO_2 are not yet fully understood. Looking ahead, by 2020 the number of CCS projects in operation is expected to double, but this will mostly come from demonstration plants, with the aim of recovering oil (de Coninck and Benson 2014).

4 Policy issues and gaps

The gap between the currently observed rates of investment in low-carbon technologies and the actual levels needed for the transition towards a low-emission society is particularly significant in the case of CCS. Despite recent changes in the energy markets, coal and gas remain the dominant technologies in power generation (globally 40% and 23%, respectively), especially in the developing world (Steckel et al. 2015). As a result, developing a technology that is able to limit the CO_2 emitted by fossil fuel plants seems particularly valuable. In order for this to happen, several things would need to change at the policy level. First of all, the technology remains unproven at the

2 See http://sequestration.mit.edu/tools/projects/index_pilots.html.

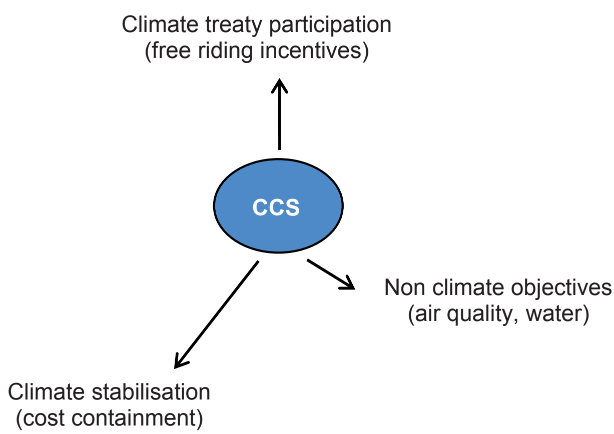
required scale. Several countries have embarked on or announced pilots, but more will be needed in order to test and demonstrate which among the different designs works best. Low natural gas prices now offer an additional and technologically easier way of testing whether CCS works, since this does not require the complicated gasification process needed for coal. Second, research and development is needed to close the cost gap between plants with and without CCS. Currently, the cost of CO_2 capture appears to be around \$100 per tCO_2, well above the carbon prices discussed in policy contexts. Expert elicitation studies indicate that R&D could reduce the additional CCS cost to a few cents per KWh by the year 2030, if incentives (see below) to innovate were in place (Baker et al. 2009). However, despite some considerable R&D investments in the recent past, CCS plants have not materialised as expected, highlighting the many enabling conditions that are needed to demonstrate CCS. These include climate policies that provide the appropriate economic incentives to sequester CO_2 – even if CCS develops further economically and technologically, it will always require a significant economic incentive in order to be viable and to compete with alternatives. Last but not least, several other enabling conditions will also need to be met at the same time in order for CCS to flourish: public and political support, trust of investors, and a transparent procedural justice (de Coninck and Benson 2014).

5 CCS in the context of climate negotiations

The barriers outlined above represent significant obstacles, which will not be easily overcome in the next few years. CCS might indeed never materialise at the scale foreseen by the scenarios depicted in Figure 1. In light of this uncertainty, to what extent should CCS be an important part of the current negotiation process? One thing we know now is that keeping the option open is vital for climate strategies. As shown in Figure 2, CCS represents one of the few levers that can be used to engage fossil fuel-rich countries in climate mitigation efforts, and to reduce the risks of carbon leakage via trade and intensified extraction of fossil fuels in anticipation of stringent climate legislation. The biggest challenge for international climate policy is to ensure participation and overcome free-riding incentives. If a climate coalition that reduces emissions is formed, non-participants have an economic incentive to increase fossil fuel consumption (see also the chapter by Fischer in this book). A possible way to overcome this conundrum, as recently highlighted by Harstad (2012), would be to buy fossil fuel deposits in the non-participating countries. However, this would require significant political capital and would have equity considerations (see the chapter by Collier in this book). CCS has the potential to achieve the same results and with higher chances of being successful. In order to do so, a technology agreement aiming at developing and commercialising CCS in all the major fossil fuel-rich countries (and especially countries rich in coal) could enrich the climate agreements, which as currently discussed are focused on the demand side of emissions quotas. Sufficient R&D investments aimed at reducing the currently high mitigation costs of CCS would be also needed in order to engage fossil-endowed countries and thus reduce the free-riding incentives.

Summing up, CCS would not provide significant benefits outside the climate ones. However, it remains an incredibly important option for climate policymakers, both in terms of providing incentives to participation in a broad climate treaty, as well as for ensuring climate stabilisation is attained at a minimum societal cost.

Figure 2 CCS and environmental policy goals, schematic representation



Note: The lengths of the arrows represent the potential benefit of CCS for three selected policy goals.

References

Azar, C., D. J. A. Johansson and N. Mattsson (2013), "Meeting Global Temperature Targets—the Role of Bioenergy with Carbon Capture and Storage", *Environmental Research Letters* 8(3): 034004.

Baker, E., H. Chon and J. Keisler (2009), "Carbon Capture and Storage: Combining Economic Analysis with Expert Elicitations to Inform Climate Policy", *Climatic Change* 96(3): 379–408.

Collier, P. (2015) "Curbing carbon without curbing development", Chapter 29 in this volume.

de Coninck, H. and S. M. Benson (2014), "Carbon Dioxide Capture and Storage: Issues and Prospects", *Annual Review of Environment and Resources* 39 (1): 243–70.

Fuss, S., J. G. Canadell, G. P. Peters, M. Tavoni, R. M. Andrew, P. Ciais, R. B. Jackson, et al. (2014), "Betting on Negative Emissions", *Nature Climate Change* 4(10): 850–53.

Harstad, B. (2012), "Buy Coal! A Case for Supply-Side Environmental Policy", *Journal of Political Economy* 120(1): 77–115.

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see (IPCC (2014b) in the introduction to this volume for the report's complete reference).

Kriegler, E., J. P. Weyant, G. J. Blanford, V. Krey, L. Clarke et al. (2014), "The Role of Technology for Achieving Climate Policy Objectives: Overview of the EMF 27 Study on Global Technology and Climate Policy Strategies", *Climatic Change* 123(3-4): 353–67.

Rogner, H.-H., R. F. Aguilera, C. Archer, R. Bertani, S. C. Bhattacharya et al. (2012), "Energy Resources and Potentials", in *Global Energy Assessment - Toward a Sustainable Future*, Cambridge, UK: Cambridge University Press and Laxenburg, Austria: International Institute for Applied Systems Analysis, pp. 423-512 (available at www.globalenergyassessment.org).

Steckel, J. C, O. Edenhofer and M. Jakob (2015), "Drivers for the Renaissance of Coal", *Proceedings of the National Academy of Sciences* 112(29): E3775–81.

Tavoni, M., E. De Cian, G. Luderer, J. Steckel and H. Waisman (2012), "The Value of Technology and of Its Evolution towards a Low Carbon Economy", *Climatic Change* 114(1): 39–57.

Tavoni, M. and R. Socolow (2013), "Modeling Meets Science and Technology: An Introduction to a Special Issue on Negative Emissions", *Climatic Change* 118(1): 1–14.

About the author

Massimo Tavoni is a 2014-15 Fellow at the Center for Advanced Studied in Behavioural Sciences (CASBS) at Stanford University, and Associate Professor at the Politecnico di Milano, Department of Management and Economics. He is also Deputy Director of the Climate Change programme at Fondazione Eni Enrico Mattei (FEEM). His research is on modeling climate change mitigation policies. He was is a Lead Author of the Fifth Assessment Report of the IPCC, the co-director of the International Energy Workshop and Deputy Editor at *Climatic Change*.

25 The alternatives to unconstrained climate change: Emission reductions versus carbon and solar geoengineering

Scott Barrett and Juan Moreno-Cruz
Columbia University; Georgia Institute of Technology

Having failed to limit emissions, negotiators began discussing adaptation about ten years ago. With the 2°C target likely to be crossed later this century, this chapter argues that it is now time to consider solar and carbon geoengineering as well. Carbon geoengineering offers the option of a true backstop and provides a ceiling to the costs of managing climate change. Solar geoengineering is a clear fall back, though it is unable to prevent all climate change impacts, and may have impacts of its own that cannot be foreseen. Both technologies are large engineering projects. Unlike emissions reductions, their use does not require large behavioral changes. However, solar geoengineering in particular poses problems for governance.

For centuries, humans have been extracting carbon from below the ground and ultimately dumping it into the atmosphere. The fraction of carbon emissions that is not captured by the terrestrial biosphere and the oceans accumulates in the atmosphere, some of it staying there for thousands of years. The fraction absorbed by the seas creates ocean acidification, causing corals to die. The amount absorbed by the terrestrial biosphere increases net primary productivity and changes the chemical composition of soils. The fraction accumulated in the atmosphere increases global temperatures and alters precipitation patterns, causing droughts and a rise in the sea level.

There are four ways in which the world can limit the negative impacts of climate change. First, we can *reduce the flow of emissions* – that is, we can reduce the amount of CO_2 we add to the atmosphere (relative to 'business as usual'). Second, we can reduce the consequences of climate change through *adaptation*. Third, we can reduce concentrations, or the stock of CO_2 in the atmosphere, by removing CO_2 directly from the atmosphere, a process we call *carbon geoengineering*. Finally, we can reduce temperatures by blocking some incoming solar radiation, a process we call *solar geoengineering*.

The primary focus of climate negotiations has always been on the first approach – reducing emissions. But because these efforts to limit emissions have failed, increasing attention has been given to the second approach – adaptation. Both approaches are on the agenda for COP 21 in Paris.

We believe that the continued failure to reduce emissions and the eventual ineffectiveness of some adaptation interventions will inevitably cause countries to consider the other two approaches. Indeed, both geoengineering approaches have already been taken up by the IPCC (2012) and have been the subject of numerous scientific inquiries, including investigations by the National Academies in the US (McNutt *et al*. 2015a, 2015b) and the Royal Society in the UK (Shepherd *et al*. 2009). As both approaches will also have profound effects worldwide, we believe that they will ultimately have to be considered by climate negotiators.

According to the latest IPCC assessment report (IPCC 2014), it will be very difficult to meet the agreed goal of limiting mean global temperature change to 2°C relative to pre-industrial levels in the long term without exceeding the concentration level likely to limit temperature change to this level for some period of time (a situation the IPCC describes as "overshooting"). Countries may come to tolerate an increase in temperature above this target level, but if efforts to limit emissions continue to falter, or the temperature change associated with these concentration levels turns out to be higher than expected, their attention may turn to using solar geoengineering to prevent the temperature from continuing to rise. The same IPCC report says that to meet the 2°C goal in the long term, with or without overshooting, CO_2 may need to be removed from the atmosphere. The report emphasises the option of 'bioenergy with carbon capture and storage', but the scale of this approach is limited.[1] As concentrations continue to increase, it may become necessary for countries also to contemplate deploying industrial techniques for removing CO_2 directly from the atmosphere.

In this chapter we focus on carbon and solar geoengineering and how they compare and interact with the mainstream option of reducing emissions so as to limit climate change. Since efforts to reduce emissions may continue to fall short, we also compare the two geoengineering approaches with the option of *unconstrained* climate change.

Comparison of the options

Emission reductions are the most conservative intervention to limit climate change. They simply involve not putting something into the atmosphere that isn't currently there.

To reduce emissions, countries must either prevent the CO_2 associated with fossil fuel combustion from entering the atmosphere – a process known as carbon capture and storage (CSS) – or they must reduce their consumption of fossil fuels. CSS is expected to be costly and may encounter local political resistance, due to concerns about the safety of CO_2 storage (Tavoni 2015). Fossil fuel consumption can be reduced at relatively little marginal cost initially, either by increasing the efficiency of energy use (conservation) or by switching to alternative energy sources like solar, wind, and nuclear power. However, to limit global mean temperature change, atmospheric concentrations must eventually be stabilised, meaning that fossil fuel consumption will have to cease entirely. Achievement of this goal will require a radical change in the global energy system. It will also be beset by free-riding problems, since it is very difficult to enforce an agreement to limit emissions. Finally, as the effort would affect production costs and

1 To be precise, the IPCC says, "[m]itigation scenarios reaching about 450 ppm CO_2eq in 2100 typically involve temporary overshoot of atmospheric concentrations, as do many scenarios reaching about 500 ppm to about 550 ppm CO_2eq in 2100. Depending on the level of overshoot, overshoot scenarios typically rely on the availability and widespread deployment of BECCS and afforestation in the second half of the century" (IPCC 2014: 12). A concentration level of 450 ppm CO_2eq will only have a 'likely' chance of limiting temperature change to 2°C, whereas a concentration level of 500 ppm CO_2eq with a temporary overshoot of 530 ppm CO_2eq before 2100 is 'about as likely as not' to keep temperature change below 2°C (IPCC 2014: 10).

fossil fuel prices in global markets, efforts to stabilise concentrations will be vulnerable to 'trade leakage' (Fischer 2015).

Carbon geoengineering methods aim to capture and remove CO_2 from ambient air. This approach reduces the concentration of CO_2 in the atmosphere *directly*. Like emissions reductions, carbon geoengineering affects the temperature very slowly; it is not a 'quick fix'. Compared to reducing emissions, carbon geoengineering will likely be very expensive. However, in contrast to emission reductions, carbon geoengineering technologies can be scaled up to limit atmospheric concentrations to virtually any level, making this approach the only true backstop technology for addressing climate change. Also unlike emission reductions, carbon geoengineering allows a single country or small 'coalition of the willing' to stabilise atmospheric concentrations unilaterally. Using this technology, achievement of a stabilisation target does not require large-scale international cooperation, and is less vulnerable to free riding than efforts to reduce emissions.[2] As it operates outside the international trade system, it is also protected from trade leakage.

Solar geoengineering methods aim to reflect a small fraction of incoming solar radiation back out into space, counteracting the effect on temperature of rising concentrations of greenhouse gases. Solar geoengineering can lower the global mean temperature quickly and at relatively little cost, but its effects on radiative forcing are different from those of the approaches that limit greenhouse gas concentrations. Solar geoengineering would also do nothing to limit ocean acidification. Solar geoengineering *is* a 'quick fix' for global mean temperature change, but is not a true fix for 'climate change' (Barrett et al. 2014). It might also have potentially damaging side effects. Like carbon geoengineering, solar geoengineering can be done unilaterally or by a coalition of the willing, and is not hampered by trade effects. Unlike carbon geoengineering, however, solar geoengineering is expected to be cheap to deploy.

2 The marginal cost of air capture will be approximately constant. So long as the global social cost of carbon exceeds the marginal cost of air capture, it will pay a subset of countries to fund air capture as a joint venture. This funding arrangement will be self-enforcing since, once enough countries drop out of the joint venture, the remaining countries will no longer have a collective incentive to fund air capture on their own, creating an incentive for countries not to drop out. In other words, countries need only *coordinate* financing of air capture.

Together, both of these geoengineering technologies provide a powerful frame for how we should think about climate policy and governance. Reducing emissions requires changing behaviour worldwide – a goal that, despite receiving unprecedented diplomatic attention, has so far seemed beyond our grasp. Unconstrained climate change is usually assumed to be the 'default' option, but as Table 1 shows, there are other options. The main thing that distinguishes solar and carbon geoengineering from emission reductions is that both approaches can be implemented as projects. In both cases, a decision has to be made to deploy them, and to pay for them, but no effort is needed to change behaviour or the global energy system.

The options shown in Table 1 are not mutually exclusive. The more we succeed in reducing emissions, the less carbon geoengineering will be required. The more we succeed in doing both of these things, the less tempting it will be to use solar geoengineering. At a fundamental level, all of these options are substitutes. They are, however, imperfect substitutes, as they operate on different stages of the carbon/climate cycle. From the perspective of reducing climate change risk, there is a case for deploying all of these technologies as part of a portfolio of options (Keith 2013, Moreno-Cruz and Keith 2013). For example, solar geoengineering could be used to limit temperature increases while some combination of emission reductions and carbon engineering is used to limit concentrations to a 'safe' level. Under this arrangement, solar geoengineering would be used to limit the risk from climate change, and the other interventions used to limit the risk from solar geoengineering.

Table 1 Comparison of the options for limiting climate change

Options	Objective	Costs	Risks	Unknowns	Collective action
Unconstrained climate change	Not an intended outcome, but a consequence of failure to limit emissions	Low	High	Many	Not achieved
Substantial emission reductions	Reduce the flow of CO_2 into the atmosphere.	High	Low	None	Difficult
Carbon geoengineering	Reduce the concentration of CO_2 in the atmosphere	Very high	Moderate	Few	Coalition of the willing
Solar geoengineering	Limit solar radiation reaching the lower atmosphere	Low	High	Many	Easy, apart from governance

The simple economics of carbon and solar geoengineering

Various methods have been proposed for removing CO_2 from the atmosphere. The one emphasised in the latest IPCC "Summary for Policymakers" report is land-based biomass capture and storage. This works like ordinary CSS at the power plant level, with the difference being that biomass is a renewable resource, and biomass growth takes CO_2 out of the atmosphere. If the CO_2 associated with burning the biomass is not captured, the CO_2 is essentially recycled from the trees into the air and back again. However, if the CO_2 emitted by burning the biomass is captured and stored, CO_2 will be removed from the atmosphere. This approach may prove useful, but it will inevitably be limited in scale. Other technologies have been considered, including ocean fertilization and increases in ocean alkalinity. However, these approaches are speculative, pose risks to the environment, or can only operate on a limited scale.

The most important carbon geoengineering technology is industrial air capture – a process by which a chemical sorbent such as an alkaline liquid is exposed to the air, removing CO_2. The process involves not only trapping the CO_2, but recycling the sorbent, and storing the captured CO_2. To be effective, the energy required to operate such 'machines' would need to be carbon-free, and this is one reason why the approach may prove expensive. Estimates of the cost vary from \$30/tCO_2 (Lackner and Sachs 2005) to over \$600/tCO_2 (Socolow *et al*. 2011).

Given current and future estimates for the social cost of carbon (calculated without regard to either form of geoengineering), if the costs of industrial air capture turn out to be as high as \$600/tCO_2, then the approach is unlikely to be used on any meaningful scale. If the cost turns out to be below \$200/tCO_2, then it might be deployed at scale this century. If air capture turns out to be as cheap as \$30/tCO_2, then this technology would be a ‘game changer’. This is because the global social cost of carbon is almost certainly already above this value. As the social cost of carbon for individual countries is currently well below \$30/tCO_2, no country is likely to deploy air capture machines unilaterally on a large scale any time soon. However, a coalition of countries would have an incentive to deploy this technology on a large scale. Of course, it would also be desirable for emissions to be reduced at a marginal cost below the marginal cost of air capture, but even if these emission reductions were not forthcoming, it would still pay to deploy air capture. Moreover, as the scale at which air capture can be deployed is independent of the emissions of the countries doing it, air capture by a ‘coalition of the willing’ could suffice to stabilise concentrations. Unfortunately, we don’t know the true value of the marginal cost of air capture; almost no research has gone into development of this technology. In our view, it is imperative that this situation be corrected. It is very important for the world to know the marginal cost of the only backstop technology for limiting climate change, as this value establishes a ceiling on the price of carbon.

Some solar geoengineering options, like the placement of reflective disks in space, are so technically challenging and expensive that they are almost certain never to be deployed. Other options, especially the injection of sulfate aerosols into the stratosphere, are so cheap that cost is likely to play almost no role in the decision to deploy them. A recent paper estimates that it would cost less than \$8 billion per year ‘to alter radiative forcing by an amount roughly equivalent to the growth of anticipated greenhouse forcing over the next half century’ (McClellan *et al.* 2012). This cost is so low that the economics of solar geoengineering appear truly ‘incredible’ (Barrett 2008). Indeed, it could easily pay a large number of countries to deploy solar geoengineering unilaterally.

The ‘cost’ that is likely to matter more concerns the risk of using this technology. Some risks, such as the possibility of added ozone depletion, are known (Crutzen 2006). Others are unknown. Research into this technology is sure to reveal more information about its effectiveness and the processes governing its functioning (Keith *et al.* 2010, Keith 2013). However, we won't know the full effect of deploying this technology at scale until we do it.

Geoengineering governance

Because the economics of solar geoengineering are so attractive, there has been concern that countries will be only too inclined to use this technology. In simple game theory terms, if anyone can use it, everyone can use it, and the country most likely to use it will be the one who desires the biggest change in the global mean temperature (Moreno-Cruz 2015, Weitzman 2015). That is, solar geoengineering introduces the possibility of 'free driving', a situation virtually opposite that of reducing emissions, which entails free riding. With free driving, policies are needed to rein in those who want to pursue climate engineering without consideration of the interests of the broader global community.

However, this assumes that countries have a *right* to use solar geoengineering as they please, and international law generally requires countries to take due regard of the effects of their actions on other countries. Moreover, other countries may be able to react to an attempt to deploy geoengineering unilaterally. They could deploy 'counter-solar-geoengineering', throwing particles into the stratosphere intended to warm rather than cool Earth, or releasing short-lived and powerful greenhouse gases like difluoromethane that would have a similar effect. More likely, they could use other measures such as trade sanctions or, possibly, the threat of military action. It is probably more realistic to assume that countries will need to negotiate the use of geoengineering. As matters now stand, however, there are no rules for whether, how, and when geoengineering can be deployed – or for which countries get to decide. The risk of not negotiating these issues, let alone settling them, is that countries may feel that they are free to act more or less without restraint.[3]

Carbon geoengineering can also be done unilaterally, but because of its likely high cost, this approach is unlikely to be attempted at scale by anything less than a substantial

3 Analyses of the governance of solar geoengineering are still fairly primitive; examples include Schelling (1996), Barrett (2008, 2014), Victor (2008), Ricke et al. (2013), Lloyd and Oppenheimer (2014) and Weitzman (2015).

coalition of countries. Moreover, this approach addresses the root cause of climate change, and so poses fewer risks than solar geoengineering. For both reasons, the governance of carbon geoengineering has not been a major concern. If this technology were deployed on a large scale, a decision would need to be made as to the desired level of atmospheric concentrations, but this is little different from the decision countries have already made to reduce their emissions so as to limit global mean temperature change. Countries would also need to agree how to share the substantial costs of carbon geoengineering. However, this is a relatively simple matter – countries frequently agree on cost-sharing arrangements for costly enterprises. For example, every three years, over 190 countries agree on how to fund the United Nations (Barrett 2007).

Conclusions

Just as the failure to limit emissions has brought adaptation onto the agenda of climate negotiations, so we believe the time has come for negotiators to consider the roles that solar and carbon geoengineering can play in addressing climate change.

If the 2°C goal were truly sacrosanct, then it seems unreasonable to ignore approaches that are capable of limiting temperature change directly or of limiting concentrations directly, especially as the IPCC's analysis suggests that even with a turnaround in the success of emission reduction efforts, overshooting of the 2°C goal is very likely. Should efforts to reduce emissions continue to fall short, the case for considering these alternative approaches will only increase over time.

The decision to use, or not to use, carbon and solar geoengineering will have consequences, and our view is that these consequences should be evaluated and the results of such analyses used to justify these decisions.

First, there should be collective funding of R&D into the costs and risks of carbon geoengineering. If the true cost of this approach is as high as \$600/tCO_2, then the approach can be disregarded this century. If the true cost turns out to be closer to \$30/tCO_2, however, then this technology will be a game changer.

Second, there should also be collective funding of R&D into the feasibility, effectiveness, and risks of solar geoengineering. At least as important, countries should begin to discuss governance of such research and of the possible future deployment of this technology (the distinction between research and deployment may not always be obvious). The risk of not doing this is that countries will feel that they are free to act more or less without restraint. A key focus should be on obtaining a consensus about these things, as excessively restrictive rules are likely to cause the countries that are most enthusiastic about geoengineering not to accept the rules but to strike out on their own.

References

Barrett, S. (2007), *Why Cooperate? The Incentive to Supply Global Public Goods*, Oxford: Oxford University Press.

Barrett, S. (2008), "The Incredible Economics of Geoengineering", *Environmental and Resource Economics* 39(1): 45-54.

Barrett, S. (2014), "Solar Geoengineering's Brave New World: Thoughts on the Governance of an Unprecedented Technology", *Review of Environmental Economics and Policy* 8(2): 249-269.

Barrett, S. et al. (2014), "Climate Engineering Reconsidered", *Nature Climate Change* 4: 527-529.

Crutzen, P. J. (2006), "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?", *Climatic Change* 77(3-4): 211-219.

Fischer, C. (2015), "Options for avoiding carbon leakage," Chapter 21 in this volume.

IPCC (2012), *Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Geoengineering* (see Introduction to this volume for the report's complete reference).

IPCC (2014b), "Summary for Policymakers", in IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014d) in the introduction to this volume for the report's complete reference).

Keith, D. W. (2013), *A Case for Climate Engineering*, Cambridge, MA: Boston Review Books.

Keith, D. W., E. Parsons and M. G. Morgan (2010) "Research on Global Sun Block Needed Now", *Nature* 463: 426-427.

Lackner, K. S. and J. D. Sachs (2005), "A Robust Strategy for Sustainable Energy", *Brookings Papers on Economic Activity* 2: 215-284.

Lloyd, I. D. and M. Oppenheimer (2014), "On the Design of an International Governance Framework for Geoengineering", *Global Environmental Politics* 14(2): 45-63.

McClellan, J., D. W. Keith and J. Apt. (2012), "Cost analysis of stratospheric albedo modification delivery systems", *Environmental Research Letters* 7(3) 034019.

McNutt, M.K. et al. (2015a), *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*, Washington, DC: National Academies Press.

McNutt, M.K. et al. (2015b), *Climate Intervention: Reflecting Sunlight to Cool Earth*, Washington, DC: National Academies Press.

Moreno-Cruz, J.B. and D.W. Keith "Climate Policy under Uncertainty: A Case for Geoengineering", *Climatic Change* 121(3): 431-444

Moreno-Cruz, J. B. "Mitigation and the Geoengineering Threat", *Resource and Energy Economics* 41: 248-263

Ricke, K. L., J. B. Moreno-Cruz and K. Caldeira (2013), "Strategic Incentives for Climate Geoengineering Coalitions to Exclude Broad Participation", *Environmental Research Letters* 8(1): 014021.

Schelling, T. C. (1996), "The Economic Diplomacy of Geoengineering", *Climatic Change* 33(3): 303-307.

Socolow, R. et al. (2011), *Direct Air Capture of CO_2 with Chemicals: A Technology Assessment for the APS Panel on Public Affairs*, Ridge, NY: American Physical Society (available at http://www.aps.org/policy/reports/assessments/upload/dac2011.pdf).

Shepherd J., K. Caldeira, J. Haigh, D. Keith, B., Launder, G. Mace, G. MacKerron, J. Pyle, S. Rayner, C. Redgwell and A. Watson (2009), *Geoengineering the Climate: Science, Governance and Uncertainty*, London: The Royal Academy.

Tavoni, M. (2015), "Carbon capture and storage: Promise or delusion?", Chapter 24 in this volume.

Victor, D. G. (2008), "On the Regulation of Geoengineering", *Oxford Review of Economic Policy* 24(2): 322-336.

Weitzman, M. L. (2015), "A Voting Architecture for the Governance of Free-Driver Externalities, with Application to Geoengineering", *The Scandinavian Journal of Economics* 117(4): 1049-1068.

About the authors

Scott Barrett is the Lenfest-Earth Institute Professor of Natural Resource Economics at Columbia University in New York City, with appointments in the School of International and Public Affairs and the Earth Institute. He taught previously at the Johns Hopkins University School of Advanced International Studies in Washington, DC and, before that, at the London Business School. He has also been a visiting scholar at Princeton, Yale, and Université de Paris 1 Panthéon-Sorbonne. He is the author of *Environment and Statecraft: The Strategy of Environmental Treaty-Making* and *Why Cooperate? The Incentive to Supply Global Public Goods*, both published by Oxford University Press. He received his PhD in Economics from the London School of Economics.

Juan Moreno-Cruz is an Assistant Professor in the School of Economics at the Georgia Institute of Technology. He has a PhD in Economics from the University of Calgary and a BSc and MSc in Electrical Engineering from the University of Los Andes, in Bogota, Colombia. Moreno-Cruz's research focuses on the role of technology in climate change and energy policy. Moreno-Cruz has investigated how solar geoengineering technologies affect the strategic interaction among nations, the intergenerational and interregional transfer of risk associated with these technologies, and the use of solar and carbon geoengineering as part of an optimal policy mix. His work is at the intersection between applied theory and public policy.

PART VI

Burden Sharing and Development

26 Poverty and climate change: Natural disasters, agricultural impacts and health shocks

Stephane Hallegatte, Mook Bangalore, Laura Bonzanigo, Marianne Fay, Tamaro Kane, Ulf Narloch, Julie Rozenberg, David Treguer and Adrien Vogt-Schilb
The World Bank Group

The international community aims to eradicate extreme poverty, and to do so in a sustainable manner. This chapter suggests that climate change poses a major obstacle to this challenge. Climate-related shocks and stresses – from natural disasters, to agricultural impacts and health shocks – already prevent households from escaping poverty. Poor people are disproportionally vulnerable to these shocks, because they are more exposed and lose more when affected. Climate change will worsen the situation, making it more difficult to eradicate poverty in a sustainable manner. Many policy options are available to help reduce poor people's risk and vulnerability, including building climate-smart infrastructure, providing universal health coverage, implementing social safety nets that can be scaled-up and rapidly targeted towards people affected by a shock, and facilitating migration. With regards to natural hazards, agricultural impacts and health shocks, climate change makes existing priorities more urgent. If addressed correctly, this urgency can turn into an opportunity to reduce both current poverty and future climate vulnerability, before most of the impacts of climate change materialise.

1 The impacts of climate change: Should we focus on poverty instead of GDP?

Estimates of the economic cost of climate change have always attracted interest and debate among policymakers and the public. These estimates, however, have mostly been framed in terms of the impact on country-level or global GDP, which does not capture the full impact of climate change on people's well-being.

One reason is that such estimates do not reflect distribution. The distribution of climate impacts – that is, which countries, regions and people are hit – will determine their effects on well-being. Three-quarters of global income belongs to North America, Europe, and East Asia; the other regions are economically much smaller, and in particular sub-Saharan Africa, which only generates 2% of global income (World Bank 2015). The location of impacts to GDP therefore matters.

Equally important is the fact that the impacts of climate change will be highly heterogeneous within countries. If the impacts mostly affect low-income people, the welfare consequences will be much larger than if the burden is borne by those with a higher income. Poor people have fewer resources to fall back on and lower adaptive capacity. And – because their assets and income represent such a small share of national wealth – poor people's losses, even if dramatic, are largely invisible in aggregate economic statistics.

Investigating the impact of climate change on poor people and on poverty requires a different approach, focused on people that play a minor role in aggregate economic figures and are often living within the margins of basic subsistence. Such an approach was behind a research programme on 'Poverty and climate change' at the World Bank, and this chapter is based on some of the programme's results (for a comprehensive presentation of the results, see Hallegatte et al. 2016). The research starts from the idea that poverty is not static, and poverty reduction is not a monotonic, one-way process. Over time, some people build assets and move out of poverty while others experience shocks and are pulled into poverty. What we call poverty reduction is the net result of these mechanisms. For instance, Krishna (2006) documents poverty dynamics in 36 communities in Andhra Pradesh, India, over 25 years. Each year, on average 14% of households escaped poverty while 12% of non-poor households became poor, so that, overall, poverty was reduced by 2% per year. These numbers show that a relatively small change in the flows in and out of poverty has a significant effect on overall poverty dynamics. For instance, increasing the flow into poverty by 10% is enough to halve the rate of poverty reduction.

Climate change can affect the flow of people into poverty. In the Andhra Pradesh sample, drought is a major factor – a household affected by drought in the past was 15 times more likely to fall into poverty (Krishna 2006). Droughts may also result in people falling into poverty traps as a result of asset losses. They often affect human capital, especially for children who may be pulled out of school or suffer permanent health consequences (Carter et al. 2007). Even just the risk of a drought can lead poor people to invest in low-risk but low-return activities, perpetuating poverty (Elbers et al. 2007). An impact of climate change on drought frequency and intensity could therefore hamper poverty reduction, with more people falling into and fewer people escaping poverty.

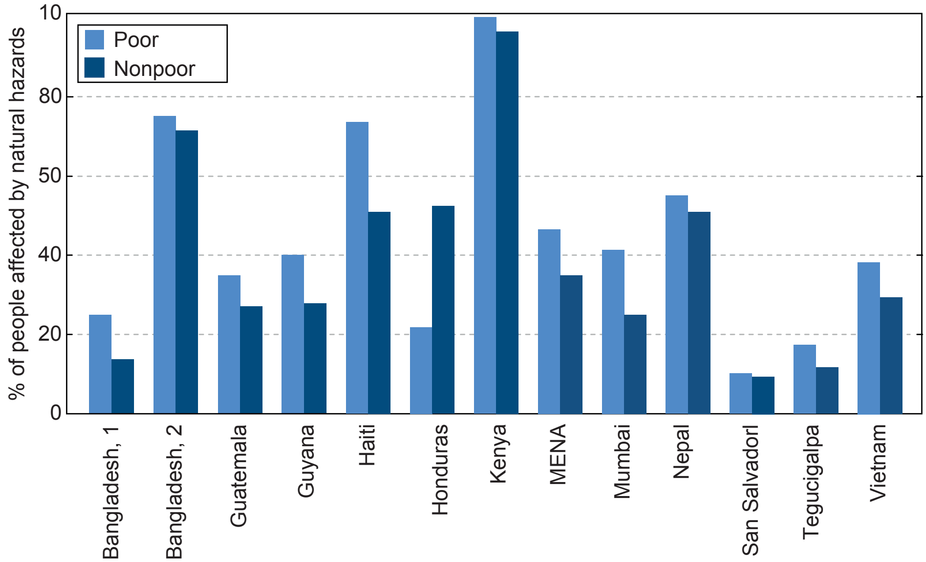
But droughts and natural hazards are not the only climate-sensitive factors to affect the flows in and out of poverty. Agricultural income and food prices matter, as do health shocks. The next sections investigate the following major channels through which climate change affects poverty dynamics: natural hazards, agriculture and health. Of course, many other factors play a role, but these three channels already have well-documented impacts on poor people and poverty reduction, and will be affected by future climate change.

2 Natural hazard impacts

In some regions, natural hazards such as floods, droughts, and extreme temperatures will increase in frequency or intensity as a result of climate change. The exposure, vulnerability, and lack of adaptive capacity of poor people puts them at particular risk.

Regarding exposure, it is often the case that poor people live in risky areas. A number of case studies have examined the exposure of poor and non-poor people to disaster risk, with most finding poor people to be more exposed (Figure 1). For instance, when large-scale floods hit the Shire River Basin in Malawi in January 2015, the areas with the highest exposure were also the poorest (Winsemius et al. 2015).

Figure 1 Several studies have examined the exposure of poor and non-poor people to natural hazards. All but one case reviewed find poor people are more exposed than non-poor people.

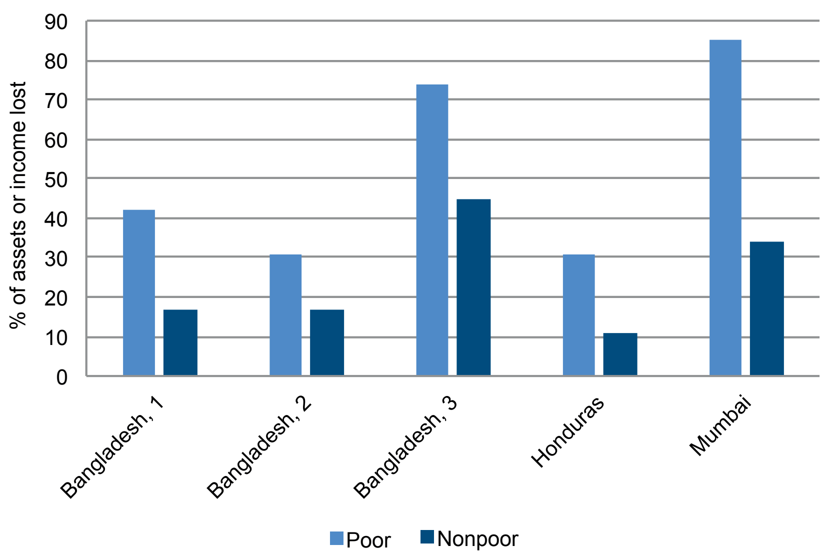


Note: MENA = Middle East and North Africa.
Source: Winsemius et al. (2015).

But the relationship between poverty and exposure to risk is not straightforward. Causality runs in both directions: poor people sometimes choose to settle in risky areas where land is available or affordable; and living in risky areas may make people poor when hazards destroy assets and livelihoods. But poor people are not always more exposed; for instance, flood-prone coastal or river areas benefit from low transport costs that attract firms and opportunities, and the wealthier populations in a country. In these cases, rich people may be the ones most exposed. In-depth analyses find no systematic overexposure of poor people to floods at the national level, although poor people are often the most exposed within a city or a region (Winsemius et al. 2015).

While not systematically more exposed, poor people are certainly more vulnerable when a disaster strikes and lose larger shares of their assets or income. This is because poor people hold a large fraction of assets in material and vulnerable form (rather than as financial savings in a bank), live in lower-quality housing (such as slums), and depend on lower-quality infrastructure (such as non-paved roads). In the small number of surveys that compare asset and income losses of poor and non-poor people after floods and storms, poor people are found to lose a larger share (Figure 2). With regards to droughts, the fact that poor people are more dependent on agricultural income makes them more vulnerable (see Section 3). In the future, these vulnerabilities will evolve as the share of people in agriculture changes and as differences between poor and non-poor people are reduced (for example, in terms of building quality and access to infrastructure).

Figure 2 Generally, poor people lose a larger percentage of assets or income after floods and storms.



Note: Each study has a different definition of 'poor' and 'non-poor' in their sample. Vulnerability depends on the type of hazard and context in which it occurs; even within the same country (Bangladesh), vulnerability measures vary greatly based on location and severity of flooding. The first three studies use percent of income loss as a metric, while the Honduras and Mumbai cases use asset loss.

Source: Based on Brouwer et al. (2007) for Bangladesh (1); del Ninno et al. (2001) for Bangladesh (2); Rabbani et al. (2013) for Bangladesh (3); Carter et al. (2007) for Honduras; and Patankar and Patwardhan (2014) for Mumbai.

In addition, poor people often have more limited access to social protection, a factor that makes them more vulnerable after disasters. A consistent finding across countries is that transfers (from social protection and labour markets) received are much lower for poor people (ASPIRE 2015). For example, in Colombia, the poorest 20% receive on average US$0.23 per person per day, while the richest 20% receive $4.60. Even after a disaster, ad hoc schemes to provide compensation have not targeted poor people, as evidenced by the 2005 Mumbai floods (Patankar 2015) and the 2011 Bangkok floods (Noy and Patel 2014). With less income coming from transfers and less savings, poor households are more dependent on their labour income for their consumption, making them more vulnerable to shocks and lost days of work (their inability to smooth consumption can even translate into avoidable health impacts, as discussed in Section 4).

It is therefore no surprise that natural disasters have a well-documented impact on poverty (Karim and Noy 2014). For example, at the municipal level in Mexico, Rodriguez-Oreggia et al. (2013) find that floods and droughts increased poverty by between 1.5% and 3.7% from 2000 to 2005. To compound these effects, disasters often result in reduced food consumption for children as well as interrupted schooling, with likely lifelong impacts such as stunting and reduced earning capacity (Alderman et al. 2006).

But looking only at the impact of actual disasters may underestimate the effect of risk on development and poverty. Ex ante, in the presence of uninsured weather risk, poor households engage in low-risk, low-return activities, perpetuating poverty. This ex ante effect, while much less visible, can dominate ex post impacts of disasters (Elbers et al. 2007). While progress has been made in recent years, many poor people remain uninsured and they exhibit lower financial inclusion than non-poor people (FINDEX 2015).

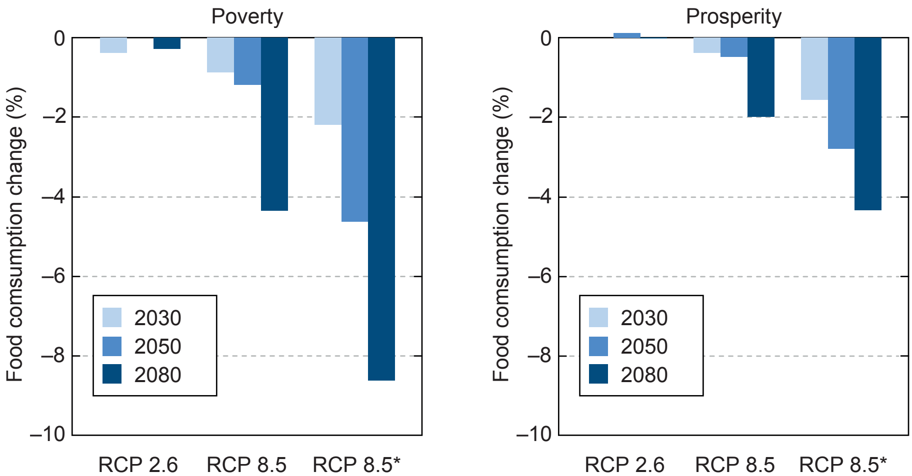
Climate change will worsen the frequency and intensity of natural disasters in some regions (IPCC 2014), but future impacts will depend not only on climate change, but also on the policies and actions implemented to manage risk. Land-use planning – especially in growing cities – is critical to ensure that new development is resilient and adapted to a changing climate (Hallegatte et al. 2013). Early warning systems, hard and ecosystem-based protection against floods, preservation of ground water, and improved building quality for poor people are all policies that can save lives and reduce asset losses. Providing options to poor households to save in financial institutions is critical to protect their savings. Social protection that can be scaled up after a disaster, and targeting instruments that are able to identify affected households and deliver aid in a timely fashion to those who need it can help avoid long-term, irreversible consequences and poverty traps (Pelham et al. 2011).

3 Agricultural impacts

Climate change will impact agricultural and land productivity, especially for major crops (wheat, rice and maize) in tropical and temperate regions, with higher emissions pathways worsening the impacts (Porter et al. 2014). Under the most optimistic climate scenario – and with CO_2 fertilization (an effect that suggests plants can improve photosynthesis and productivity with higher CO_2 concentrations) – crop yields may decrease globally by 2% by 2030; but if emissions continue unabated, the reduction could amount to 6% by 2050 and 14% by 2080. And without CO_2 fertilization, the impacts may be even more severe, with yields falling by 10% and 33% by 2030 and 2080, respectively (Havlík et al. 2015). But the global impacts will not be uniform across crops and regions. These impacts are also extremely uncertain – they depend on the extent to which CO_2 fertilization materialises, the availability of water, and the development of new varieties and techniques better suited to future climates.

Productivity impacts will be transmitted through markets, with very uncertain impacts on food prices; the IPCC suggests that global food prices may vary between -30% and +45% (Porter et al. 2014). Higher food prices would reduce consumption, but modelling exercises show the final effect will depend not only on the change in climate, but also on the socioeconomic context, including GDP growth and access to global food markets. Food security concerns are less in a world with fast economic growth and low poverty (a 'Prosperity' scenario) compared to a world with slow growth and high poverty (a 'Poverty' scenario). For instance, under RCP 8.5 (a high emissions scenario) without CO_2 fertilization, global losses in food consumption are estimated at 2.5% and 4% for 2050 and 2080 in the Prosperity scenario, while the figures are over 4% and 8% in the Poverty scenario (Figure 3).

Figure 3 Impact of climate change on food consumption for three climate scenarios, three time periods and two socioeconomic scenarios (Prosperity and Poverty)



Note: The climate scenarios are: RCP2.6, a low emission scenario; RCP8.5, a high emission scenario; and RCP8.5*, a high emission scenario without the (uncertain) effect of CO_2 fertilization. Impacts are much less severe under the Prosperity scenario.

Source: Havlík et al. (2015).

Any change in food consumption will be particularly severe for poor people, who spend a larger share of their budget on food (62% on average, compared to 44% for non-poor people; see Ivanic and Martin 2014). Poor people in urban areas often have higher shares than rural people, as the latter may produce some of their own food to cover their needs.

Increased food scarcity is likely to translate into more ‘food crises’ during which food prices rise rapidly, for instance due to weather- or pest-related reductions in production in a major producer country. As illustrated by the spike in 2008, such episodes have a major impact on poverty, and studies suggest that future increases will have significant impacts. In the absence of safety nets and economic adjustments, a number of countries – including Guatemala, India, Indonesia, Pakistan, Sri Lanka, Tajikistan and Yemen – could suffer from an increase in extreme poverty of 25 percentage points if faced with a 100% food price increase, with severe impacts in urban areas (Ivanic and Martin 2014).

But for food producers, an increase in food prices is not necessarily a bad outcome. The final impacts will depend on how changes in prices and in productivity balance (an increase in food prices due to reduced productivity does not automatically lead to increased revenues) and on how increased revenues are distributed among farm workers and landowners (Jacoby et al. 2014). Taking a comprehensive view of farm households (i.e. both their consumption and production), Hertel et al. (2010) argue that such households may benefit from climate impacts if the shock is widespread, farm-level demand for their production is inelastic (while the supply response is low), there are few sources of off-farm incomes, and food represents a relatively small share of expenditures.

In some areas, however, transformational change in the production sector will be required. For instance, in Uganda, coffee production is a central activity, employing more than 2 million people and contributing close to US$400 million to the national economy in 2012. But climate change will make growing coffee increasingly difficult in the next decades, making it necessary for the local economy to restructure around a different crop or sector (Jassogne et al. 2013). Going through such large-scale transformations is highly challenging; in the 1930s, the Dust Bowl eroded large sections of the Great Plains in the US (an area previously renowned for agriculture), and the impacts endured for decades (Hornbeck 2012).

Vulnerability to agricultural impacts will be shaped by the future of poverty and by future market structure and access. Evidence suggests that remote markets have higher price volatility (Ndiaye et al. 2015). Enhancing road infrastructure can strengthen links between rural markets and urban consumption centres, stabilising prices. And the share of their income that people spend on food will decrease as people escape poverty, making the consequences of higher food prices more manageable in the future (if poverty decreases as rapidly as expected, and if poverty reduction reaches the remote rural areas where it is largely absent at the moment) (Ravallion 2014).

4 Health impacts

Health shocks are the leading reason why households fall into poverty (Moser 2008). They affect households through many channels: the direct impact on well-being; the consequences of the death of a family member; loss of income when a family member cannot work; expenses from care and drugs, especially in the absence of health insurance; and time and resources spent on caregiving.

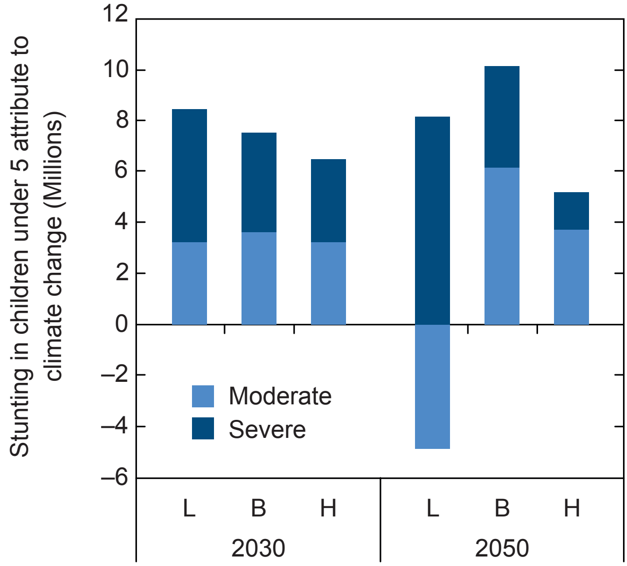
This is why the effect of climate change on health is particularly worrisome.

Impacts can occur through increased natural disasters, which have well-documented health effects. Disasters directly impact health through fatalities and casualties, particularly in low-income and lower-middle-income countries, which account for only a third of all disasters but more than 80% of all deaths (UNDP, UNICEF, OXFAM and GFDRR 2014). After a disaster, health conditions worsen when there is inadequate food, water and sanitation. The health effects also surge when affected poor households cannot smooth consumption – a drop in income often translates into reduced food intake, with potentially long-term effects on child development, affecting for example future strength, cognitive capacity and earning potential (Alderman et al. 2006).

As well as from disasters, health impacts also occur from environmental disruptions to crop productivity and food availability (Smith et al. 2014). One example is under-nutrition, which is not only influenced by crop productivity and food availability, but also by water quality and access to sanitation. Climate change is expected to increase stunting, with up to 10 million additional children stunted under a base case economic growth scenario in 2050 (Lloyd et al. 2011, Hales et al. 2014) (Figure 4). Some regions will be particularly affected, with cases of severe stunting possibly increasing by up to 23% in sub-Saharan Africa and 62% in South Asia (Lloyd et al. 2011). These trends are all the more alarming considering that moderate stunting increases the risk of death by 1.6 times and severe stunting by 4.1 times (Black et al. 2008).

Climate change will also change patterns of vector-, soil- and waterborne diseases, introducing them into new areas (Smith et al. 2014). The combined effects of temperature fluctuation, coastal salinity, humidity, heavy rainfall, flooding and drought can contribute to outbreaks of diseases such as schistosomiasis, cholera, malaria and diarrhoea (Cann et al. 2013, Hales et al. 2014).

Figure 4 Additional number of children aged under five years stunted due to climate change in 2030 and 2050 under low growth (L), base case (B) and high growth (H) socioeconomic scenarios.



Source: Hales et al. (2014).

All of these diseases affect poor people more than the rest of the population, and children more than adults. They also have an impact on income and economic growth. These micro-level impacts translate into lower macroeconomic growth; Gallup and Sachs (2001) find that countries with intensive malaria grew 1.3% slower than other countries in the period 1965-1990.

Estimates suggest that 3% of global diarrhoea cases can be attributed to climate change, and the frequency of malaria cases may increase by up to 10% by 2030 in some regions (WHO 2009). Higher temperatures are one reason for this: a study in Lima, Peru, found a 4% increase in hospital admissions for diarrhoea for each 1°C temperature increase during warmer months, and a 12% increase for every 1°C increase in cooler months (Checkley et al. 2000).

We can only begin to measure the global burden of disease from climate change, but observed patterns are worrisome. A recent synthesis of five key aspects – under-nutrition, malaria, diarrhoea, dengue and heat waves – estimates that under a base case socioeconomic scenario and a medium/high emissions scenario, approximately 250,000 additional deaths per year between 2030 and 2050 will be attributable to climate change (Hales et al. 2014).

But the future burden of disease will depend on development. Despite rising temperatures in the twentieth century, malaria rates dropped significantly. This is because socioeconomic trends – urbanisation, development, and improvements in health facilities – matter much more for controlling malaria than climate impacts (Gething et al. 2010). Development objectives such as achieving universal health coverage by 2030 could contribute greatly to adapting to climate change impacts on health. In fact, the recently released Lancet report on health and climate change declared that responding to climate change could be "the biggest global health opportunity of the 21st century" (Watts et al. 2015).

5 How can we achieve low-carbon resilient development?

While climate change impacts poverty, poverty reduction reduces vulnerability to climate impacts. The previous discussion highlights some of the benefits that development and poverty reduction can bring in terms of climate vulnerability. For instance, better social safety nets, improved access to financial institutions and insurance, and reduced inequality would mitigate the impact of disasters, and especially the irreversible impacts on children's health and education. Improved connection to markets – with better infrastructure and appropriate institutions – would protect consumers against large food supply shocks, and help farmers access the technologies and inputs they need to cope with a different climate. Basic services – for example, improved drinking water and sanitation and modern energy – can also help protect against some of the impacts of climate change, such as waterborne diseases and environmental degradation. And access to health care has been improving with development and growth in most countries, with the benefits being exemplified by reductions in child mortality and malaria.

Most importantly, development and climate mitigation need not be at odds with each other. Evidence suggests that raising basic living standards for the world's poorest will have a negligible impact on global emissions (Rao et al. 2014, Fay et al. 2015). Initiatives such as the UN's 'Sustainable Energy for All' can improve access to electricity and at the same time be compatible with a warming limit of 2°C (Rogelj et al. 2013). Making mitigation and poverty eradication compatible will require a sequenced approach where richer countries do more, special attention is given to the impacts of land-use-based mitigation on food production, and complementary policies (e.g. cash transfers) are introduced to protect poor people against negative side-effects of mitigation (Fay et al. 2015). In many cases, it will also require richer countries to support poorer countries to provide technologies and financing instruments.

The impacts of climate change will increase over time. There is therefore a window of opportunity to reduce poverty now and thereby reduce vulnerability tomorrow. Any climate agreement that aims to be workable and effective should have this goal of reducing vulnerability in mind, and be designed in a way that contributes to development and poverty eradication.

But not all development pathways reduce climate risks in the same way. Of course, low-carbon development mitigates climate change and reduces risks over the long term, benefiting everybody, particularly the poorest. In addition, resilient development would go further in reducing the impacts of climate change. But what does it entail? From our analysis, a few recommendations emerge:

- **Planning for a different (and uncertain) climate**. Many investment and policy decisions have long-term consequences. The effect of transport infrastructure on urban form and economic activity can be observed over long timeframes, sometimes even after the infrastructure has become obsolete (Bleakley and Lin 2010). Policies such as urbanisation plans, risk management strategies, and building codes can influence development for just as long. Therefore, to ensure development is adapted not only to present but also to future conditions, plans must consider the performance of investments and decisions in the short and long term.

  But doing so is challenged by deep uncertainty – we cannot predict future climate conditions precisely, we do not know which technologies will appear, and we are unsure about socioeconomic conditions and future preferences. There is a risk of locking development into dangerous pathways, for instance by urbanising impossible-to-protect flood plains or by specialising in agricultural production at risk of climate change. To avoid this, the planning process needs to investigate a large range of possible futures, and to make sure it does not create unacceptable risks when climate change and other trends are accounted for, especially if these changes differ from what is considered most likely today (Kalra et al. 2014). Such a robust approach leads to strategies that include safety buffers (e.g. adding safety margins around what areas are considered prone to flooding today), promoting flexibility (e.g. select solutions that can be adjusted over time as more information becomes available), and increasing diversification (e.g. developing the economic sectors that are less exposed to risk).

- **Improving access to healthcare**. Helping households manage health risks is already a priority, considering the role of these shocks in maintaining people in poverty. Climate change only makes this task more urgent and more important. Skilled health staff, with the right equipment and drugs, need to be available in all areas. But even if health care is available, the ability to afford health care is essential – about 100 million people fall into poverty each year due to having to pay for healthcare (WHO 2008). Increasing healthcare coverage and decreasing out-of-pocket expenses is a smart investment for development and poverty reduction, and would be an efficient tool to reduce climate change vulnerability. Doing so is possible at all income levels. For instance, Rwanda invested in a universal health coverage system after the 1994 genocide, with premature mortality rates falling precipitously, and life expectancy doubling (Binagwaho et al. 2014). Climate change does not dramatically change the challenges for the health sector, but emerging issues and diseases increase the importance of monitoring systems that can identify and respond quickly to new – and sometimes unexpected – emergencies.
- **Provision of well-targeted, scalable safety nets**. Safety nets can help manage weather shocks. During the 1999 drought in Ethiopia, the poorest 40% of the population lost almost three-quarters of their assets (Little et al. 2004). Today, Ethiopia's Productive Safety Net Program supports 7.6 million food-insecure people and builds community assets to counteract the effects of droughts. The programme has improved food security, access to social services, water supply, productivity, market access, and ecosystems (Hoddinott et al. 2013). Safety nets can also play a critical role in avoiding irreversible losses from under-nutrition,

but only if scaled-up and deployed quickly after shocks and targeted to the poorest and most vulnerable (Clarke and Hill 2013). In addition, the increasing impacts of natural disasters makes it essential for safety nets to be able to identify quickly those in need, and to scale-up and retarget support after a shock or disaster (Pelham et al. 2011).

Further, trends in climate conditions and risks mean that some places will become increasingly less suitable for development. As a result, temporary and permanent migration is an important risk-management tool, and can be an adaptation option. Independently of climate change, migration plays a key role in the ability of poor households to escape poverty by capturing opportunities for better jobs, higher pay, and improved access to services and education. Climate change may trigger more migration – for instance, if opportunities disappear because of climate impacts (for the example of coffee in Uganda, see Jassogne et al. 2013) – but may also impair migration, for example through increased conflict and exclusion (for an extended review, see Adger et al. 2014). Given the importance of mobility as an instrument for poverty reduction, it is critical that social protection does not lock people into places or occupations from which it will become harder for them to escape poverty. Portability of social protection (geographically and in terms of occupation) is therefore made even more important by a changing climate.

With regards to natural hazards, agricultural impacts and health shocks, climate change only makes existing priorities more urgent for many countries. If addressed correctly, this urgency can turn into an opportunity to reduce current poverty and future climate vulnerability simultaneously. Of particular importance are the high economic and health impacts that climate change could have on children. Without action to move towards low-carbon, resilient development now, we may lock ourselves into a future of increased intergenerational transmission of poverty.

References

Adger, W.N., J.M. Pulhin et al. (2014), “Human security”, in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report’s full reference).

Alderman, H., J. Hoddinott and B. Kinsey (2006), “Long term consequences of early childhood malnutrition”, *Oxford Economic Papers* 58(3): 450–474.

ASPIRE (2015), ASPIRE Database, World Bank, Washington, DC (http://datatopics.worldbank.org/aspire/).

Baez, J., L. Lucchetti, M. Salazar and M. Genoni (2014), “Gone with the Storm: Rainfall Shocks and Household Wellbeing in Guatemala”, World Bank Policy Research Working Paper, Washington, DC.

Binagwaho, A., P. E. Farmer, S. Nsanzimana, C. Karema, M. Gasana et al. (2014), “Rwanda 20 years on: investing in life”, *The Lancet* 384: 371–375.

Black, R. E., L. H. Allen, Z. A. Bhutta, L. E. Caulfield, M. de Onis et al. (2008), “Maternal and child undernutrition: global and regional exposures and health consequences”, *The Lancet* 371: 243–260.

Bleakley, H. and J. Lin (2010), “Portage: path dependence and increasing returns in US history”, NBER Working Paper No. 16314, Cambridge, MA.

Brouwer, R., S. Akter, L. Brander and E. Haque (2007), “Socioeconomic vulnerability and adaptation to environmental risk: a case study of climate change and flooding in Bangladesh”, *Risk Analysis* 27(2): 313–326.

Cann, K. F., D. R. Thomas, R. L. Salmon, A. P. Wyn-Jones and D. Kay (2013), “Extreme water-related weather events and waterborne disease”, *Epidemiology and Infection* 141(4): 671–686.

Carter, M. R., P. D. Little, T. Mogues and W. Negatu (2007), “Poverty Traps and Natural Disasters in Ethiopia and Honduras”, *World Development* 35(5): 835–856.

Checkley, W., L. D. Epstein, R. H. Gilman, D. Figueroa, R. I. Cama et al. (2000), “Effects of EI Niño and ambient temperature on hospital admissions for diarrhoeal diseases in Peruvian children”, *The Lancet* 355: 442–450.

Clarke, D. J. and R. V. Hill (2013), “Cost-Benefit Analysis of the African Risk Capacity Facility”, SSRN Scholarly Paper No. ID 2343159, Rochester, NY.

del Ninno, C., P. A. Dorosh, L. C. Smith and D. K. Roy (2001), “The 1998 Floods in Bangladesh Disaster Impacts, Household Coping Strategies, and Response”, Research Report No. 122, International Food Policy Research Institute, Washington, DC.

Elbers, C., J. W. Gunning and B. Kinsey (2007), “Growth and Risk: Methodology and Micro Evidence”, *World Bank Economic Review* 21: 1–20.

Fay, M., S. Hallegatte, A. Vogt-Schilb, J. Rozenberg, U. Narloch and T. Kerr (2015), *Decarbonizing Development: Three Steps to a Zero-Carbon Future*, Washington, DC: The World Bank.

FINDEX (2015), Global Financial Inclusion Database, World Bank (http://www.worldbank.org/en/programs/globalfindex).

Gallup, J. L. and J. D Sachs (2001), “The economic burden of malaria”, *American Journal of Tropical Medicine and Hygiene* 64(1-2 Suppl.): 85–96.

German Space Agency (2015), “January 2015 flood extent of Malawi Event”, Cologne.

Gething, P. W., D. L. Smith, A. P. Patil, A. J. Tatem, R. W. Snow and S. I. Hay (2010), “Climate change and the global malaria recession”, *Nature* 465: 342–345.

Hales, S., S. Kovats, S. Lloyd and D. Campbell-Lendrum (2014), *Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s*, Geneva: World Health Organization.

Hallegatte, S., C. Green, R. J. Nicholls and J. Corfee-Morlot (2013), “Future flood losses in major coastal cities”, *Nature Climate Change* 3: 802–806.

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb (2016), “Shock Waves - Managing the Impacts of Climate Change on Poverty”, Washington, DC: World Bank,

Havlík, P., H. Valin, M. Gusti, N. Forsell, M. Herrero et al. (2015), “Climate change impacts and mitigation in the developing world: Integrated assessment of agriculture and forestry sectors”, forthcoming in the World Bank Policy Research Working Paper series, Washington, DC.

Hertel, T. W., M. B. Burke and D. B. Lobell (2010), "The Poverty Implications of Climate-Induced Crop Yield Changes by 2030", *Global Environmental Change* 20(4): 577–85.

Hoddinott, J., J. Lind, G. Berhane, F. Flintan, S. Gidey et al. (2013), "Impact Evaluation of the PSNP and HAPB 2012", Institute for Development Studies, Brighton.

Hornbeck, R. (2012), "The Enduring Impact of the American Dust Bowl: Short- and Long-Run Adjustments to Environmental Catastrophe", *American Economic Review* 102: 1477–1507.

IPCC (2014) "Summary for Policymakers", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Ivanic, M. and W. Martin (2014), "Short- and Long-Run Impacts of Food Price Changes on Poverty", SSRN Scholarly Paper No. ID 2484229, Rochester, NY.

Jacoby, H.G., M. Rabassa and E. Skoufias (2014), "Distributional Implications of Climate Change in Rural India: A General Equilibrium Approach", *American Journal of Agricultural Economics* 97(4): 1135–1156.

Jassogne, L., P. Lderach and P. van Asten (2013), *The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains*, Oxford: Oxfam.

Kalra, N., S. Hallegatte, R. Lempert, C. Brown, A. Fozzard et al. (2014), "Agreeing on Robust Decisions: New Processes for Decision Making under Deep Uncertainty", World Bank Policy Research Working Paper, Washington, DC.

Karim, A. and I. Noy (2014), "Poverty and natural disasters: A meta-analysis", Victoria University of Wellington, School of Economics and Finance.

Krishna, A. (2006), "Pathways out of and into poverty in 36 villages of Andhra Pradesh, India", *World Development* 34(2): 324–404.

Little, P., P. Stone, T. Mogues, P. Castro and W. Negatu (2004), "'Churning' on the Margins: How the Poor Respond to Drought in South Wollo", BASIS Brief No. 21, University of Wisconsin- Madison.

Lloyd, S. J., R. S. Kovats and Z. Chalabi (2011), "Climate change, crop yields, and undernutrition: development of a model to quantify the impact of climate scenarios on child undernutrition", *Environmental Health Perspectives* 119: 1817–1823.

Moser, C. O. N. (2008), *Reducing Global Poverty: The Case for Asset Accumulation*, Washington, DC: Brookings Institution Press.

Ndiaye, M., E. d'Hôtel and L. C. Tristan (2015), "Maize price volatility: does market remoteness matter?", World Bank Policy Research Working Paper, Washington, DC.

Noy, I. and P. Patel (2014), "Floods and spillovers: Households after the 2011 great flood in Thailand", Working Paper Series No. 3609, Victoria University of Wellington, School of Economics and Finance.

Patankar, A. (2015), "The exposure, vulnerability and adaptive capacitiy of households to floods in Mumbai".

Patankar, A. and A. Patwardhan (2014), "Estimating the Uninsured Losses due to Extreme Weather Events and Implications for Informal Sector Vulnerability: A Case Study of Mumbai, India", accepted for publication in *Natural Hazards*.

Pelham, L., E. Clay and T. Braunholz (2011), "Natural disasters: what is the role for social safety nets?", Overseas Development Institute, London.

Porter, J.R., L. Xie et al. (2014), "Food security and food production systems", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Rabbani, G., S. H. Rahman and L. Faulkner (2013), "Impacts of Climatic Hazards on the Small Wetland Ecosystems (ponds): Evidence from Some Selected Areas of Coastal Bangladesh", *Sustainability* 5: 1510–1521.

Rao, N. D., K. Riahi and A. Grubler (2014), "Climate impacts of poverty eradication", *Nature Climate Change* 4: 749–751.

Ravallion, M. (2014), "Are the World's Poorest Being Left Behind?", NBER Working Paper No. 20791), Cambridge, MA.

Rodriguez-Oreggia, E., A. De La Fuente, R. De La Torre and H. A. Moreno (2013), "Natural Disasters, Human Development and Poverty at the Municipal Level in Mexico", *Journal of Development Studies* 49(3): 442–455.

Rogelj, J., D. L. McCollum and K. Riahi (2013), "The UN's 'Sustainable Energy for All' initiative is compatible with a warming limit of 2°C", *Nature Climate Change* 3: 545–551.

Smith, K.R., A. Woodward et al. (2014), "Human health: impacts, adaptation, and co-benefits", in IPCC (2014), *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, Cambridge, UK: Cambridge University Press (see the Introduction to this volume for the report's full reference).

UNDP, UNICEF, OXFAM and GFDRR (2014), "Disaster risk reduction makes development sustainable", conference paper, UN Development Programme.

UNOSAT (2015), "January 2015 flood extent of Malawi Event", United Nations Institute for Training and Research.

Watts, N., W. N. Adger, P. Agnolucci, J. Blackstock, P. Byass et al. (2015), "Health and climate change: policy responses to protect public health", *The Lancet*.

WHO (2009), *Global Health Risks: Mortality and burden of disease attributable to seletected major risks*, Geneva.

WHO (2008), *The World Health Report 2008 - primary Health Care (Now More Than Ever)*, Geneva.

Winsemius, H., B. Jongman, T. Veldkamp, S. Hallegatte, M. Bangalore and P. J. Ward (2015), "Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts", forthcoming in World Bank Policy Research Working Paper series, Washington, DC.

World Bank (2015), *World Development Indicators*, Washington, DC.

World Bank and National Statistical Office of Malawi (2013), "Malawi Poverty Map", Washington, DC.

About the authors

The Office of the Chief Economist of the Climate Change Group at the World Bank Group includes Stephane Hallegatte, Mook Bangalore, Laura Bonzanigo, Tamaro Kane, Ulf Narloch, Julie Rozenberg, David Treguer, Adrien Vogt-Schilb, and Marianne Fay, the Chief Economist for Climate Change. The team is currently leading a work programme on 'Poverty and climate change' and has produced a chapter for this eBook based on some of the programme's results. The final report of this work programme (titled *Shock Waves: Managing the Impacts of Climate Change on Poverty*) will be released in November 2015.

27 Policy options in low-income countries: Achieving socially appropriate climate change response objectives

Alice Akinyi Kaudia[1]
Ministry of Environment and Natural Resources, Kenya

Low-income countries have been propelled through international discourse to accord higher priority to adaptation to climate change compared to mitigation. The INDC 'bottom-up' approach to reaching the 2°C target gives the flexibility for low-income countries to articulate policies responsive to the needs of their communities and national development priorities. These include the entitlement of developing countries to growth and reduced climate change-induced scarcity of natural resources like water, food, energy, wood and fiber. Therefore, the negotiations should strike a balance between mitigation and adaption and include financial support to carry out these policies in line with Article 4.7 of the convention on implementation of commitments by developing countries. In this spirit, this chapter recommends that the target output of COP21 should be a legally binding agreement applicable to all that would be based on the principles of the UNFCCC and, in particular, the principle of Common but Differentiated Responsibilities based on respective capabilities. Challenges with enforcement and the feasibility of all aspects of actions being legally binding should be anticipated.

1 I acknowledge the initial inputs in terms of review and drafts of ideas on the topic from Prof. Shem Wandiga of the Institute of Climate Change and Adaptation at the University of Nairobi, Richard Munang of UNEP regional office for Africa and Joab Osumba.

1 Introduction: Incorporating social inclusion in low-income development strategies

All developing countries aspire to rapid growth. Extrapolating from Somanathan's review of India's situation in this book, slowing down growth would be very economically, socially and politically costly for many developing countries. This focus on growth is notable in the position taken by the 'BRICS' (Brazil, Russia, India, China and South Africa) at UNFCCC negotiations and as shown by India's experience where, because of the need to safeguard committing only to what can be accommodated by national policy, the country submitted an INDC with a focus on reduction of CO_2 and not on the entire portfolio of GHGs (Moarif and Rastogi 2012). How such a decision will play with the rest of the low-income countries, and especially those that can benefit from methane auction due to their predominantly livestock economy, remains to be seen at COP21. In any case, efforts required to meet the demands of the Alliance of Small Island States (AOSIS) and those of Least Developed countries (LDCs) require strong mitigation efforts from the BRICs. This could threaten their rapidly growing economies.

Besides growth, social concerns are evident in the aspirations captured in continental development blueprints. For example, the Africa Union Agenda 2063 aspires that Africa should be "an integrated, prosperous and peaceful Africa, driven by its own citizens and representing a dynamic force in the global arena" (African Union 2014). Overall, Africa's Vision 2063 aspiration provides a foundation for policy orientation with respect to climate change negotiations in the sense that prosperity and peace cannot be achieved if climate-related natural disasters – which constitute up to 70% of disasters in countries like Kenya (Government of Kenya 2009) – lead to loss of achieved development and aggravate poverty. Indeed, summarising the evidence from 60 studies examining the links between climate and human conflict after controlling for location-specific and time-specific effects, Hsiang et al. (2013) conclude that a one standard deviation change in climate towards warmer temperatures or more extreme rainfall increases the frequency of interpersonal violence by 4% and intergroup conflict by 14%. These results suggest the possibility of amplified human conflict in the future as the inhabited world is expected to warm by between two and four standard deviations by 2050.

In pursuing this aspiration, African governments are initiating programmes on a continental scale that, if implemented effectively, should transform growth and human development towards a strategy that is compatible with the continent's environmental resources. For example, the free movement of people, goods and services among the East Africa Partner States and the pursuit of common climate change policies by the Regional Economic Communities are indications of the growing political will to pool and consolidate economic development to attain economies of scale benefits and associated efficiencies towards the Vision 2063. Such regional programmes present optimistic indications.

Addressing the social concerns of low-income countries should then drive the negotiation pathways that low-income parties adopt through the Group of 77 and China, the African Group of Negotiators (AGN), the Small Island Developing States (SIDS), and other low-income regional negotiation groups. The risks posed to the SIDS are particularly critical given that continued sea-level rise, which has already reached 0.19 meters according to the IPCC Fifth Assessment Report (AR5), is real and the sea level could rise by between 0.5 and 1.0 metres relative to 1986-2005 by the end of the century under a business-as-usual scenario (see the chapter by Stocker in this book).

Acknowledging the growth-related constraints on mitigation efforts by many high-emitter fast-growing middle-income countries, what are appropriate and implementable socially inclusive policy objectives for low-income countries and how should they pursue these objectives? Section 2 discusses these policies. Taking Kenya as an example, Section 3 discusses what could be an ambitious but implementable INDC for a low-income country. Section 4 gives examples of policies that have been carried out in this regard. Section 5 concludes with the commitments low-income countries should pursue at the negotiations.

2 Socially inclusive targets for low-income countries

The poor are generally more exposed to climate risks and more vulnerable because of their lesser resilience to negative shocks, especially so in low-income countries (see the chapter by Hallegate et al. in this book). On the environmental side, socially inclusive policies require securing the availability of environmental goods and services like water, energy, food, biodiversity and quality air, as well as ensuring a healthy and hence productive population despite climate change.

Meeting these objectives will help low-income countries transition to de-carbonised lifestyles in their quest to reach 'secure middle-class status', i.e. when about 20% of the population has achieved that status.[2] Then, through their willingness to pay taxes, enough public goods are likely to be available and sufficiently 'good' policies are likely to be chosen to protect most of the population from adverse shocks.

Yet, 'good' policies are not a sufficient condition for the effective uptake of climate change mitigation, particularly in low-income countries where social expression of affluence is exhibited by 'living large' – multiple, large cars per household, a big house, food waste due to over-purchasing and so on, all of which are important contributors to GHG emissions. This is a major challenge for the low-income countries that are still far from having reached 'middle-class status' where the enforcement of climate-friendly policies is limited because of the confounding interplay between weak institutional settings, and the negative influence exercised by politically influential groups.

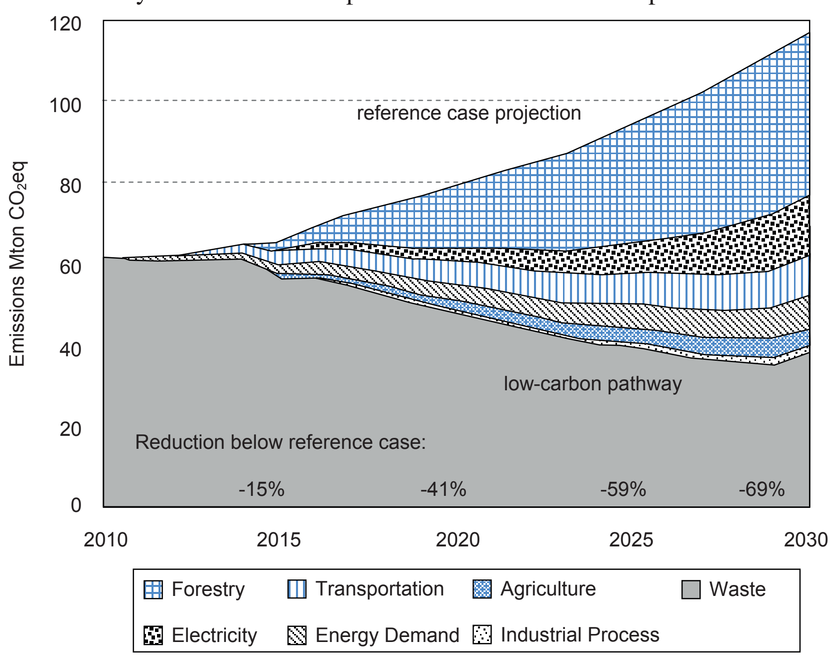
3 Are the INDCs of low-income countries appropriate?

A socially relevant agreement applicable to all should embrace policies that provide low-income groups with security and rights to life-supporting goods and services. Consideration of eradication of absolute poverty, equity, justice, rights, and halting or at least slowing the loss of biological diversity (an important source of income for the rural poor; see the chapter by Hallegate et al. in this book) should be the anchor points for the negotiation position of low-income countries. The challenge in reaching this objective arises from the diversity of needs and actions that are captured in the INDCs by low-income countries.

2 In 2010, only 10% of Kenyans had reached the struggler status (daily per capita income, yp, above the \$1.25/day poverty line and below \$10) and 2% had reached middle-class status ($\$10/d<y_p<\$50$). Projections for 2030 are 23% and 5% of the population, respectively. Birdsall (2015) argues that around 20% of a country's population reaching middle-class status is a threshold to safeguard against impacts of negative shocks.

While all INDCs submitted by low-income countries could not be reviewed at the time of writing, early submissions by Gabon, Mexico, Kenya and Ethiopia illustrate some of the challenges. Let me illustrate this with Kenya's experience, which is typical of a low-income country moving up the growth ladder while aspiring to pursue climate-friendly policies. According to Kenya's INDC submission, its GHG emissions, estimated at 73 $MtCO_2eq$ in 2010, are very low with an estimated 75% attributable to land-use activities including agriculture, forestry and free-range rearing of livestock. Figure 1 shows that under a business as usual (BAU) scenario where Kenya aspires to attain a 10% GDP growth by 2030, the country's GHG emissions are projected to be 143 $MtCO_2eq$ by 2030; slightly double the 2010 estimates. According to Kenya's National Climate Action Plan, the country's INDC is to reduce its GHG emissions by 30% by 2030. This ambition is against a historical contribution of only 0.1% to total global emissions, with per-capita emissions at less than 1.26 $MtCO_2eq$ compared to the global average of 7.58 $MtCO_2eq$. The wedge decomposition in Figure 1 shows that that forestry has the highest GHG abatement potential, underscoring the importance of REDD+ to Kenya's INDC.

Figure 1 Kenya's sectoral decomposition of GHG abatement potential



Source: Government of Kenya (2012b).

Kenya's submission, typical of low-income countries, suggests that these countries are subtly being pushed by COP19 and COP20 decisions to take up climate change mitigation targets that may not be feasible to attain if the principles of equity and fairness enshrined in the spirit of the UNFCCC convention are not honoured by developed countries. While it is understood that the commitments by low-income countries are interpreted as 'voluntary', a legally binding agreement applicable to all might not provide the necessary degree of freedom to low-income countries unless this is categorically specified in the agreement. The implications of high aspirations of INDCs against a background of limited emissions and limited means of implementation could overshadow balanced negotiations and the subsequent implementation of Nationally Determined Contributions (NDCs) post COP21. Besides, the INDCs of low-income countries are based on mitigation activities that require capital-intensive investments. This explains why, as in the case of Kenya, the INDC submissions of low-income countries are contingent on external financial resources and on technological capability.

4 Policies to support the implementation of a negotiated agreement

Taking Kenya as an example, I will review fiscal policies and environment and climate change policies aimed at mitigation and adaptation.

4.1 Fiscal policies

Fiscal policies, conceptualised broadly to embrace sustainable development in the context of a response to climate change, can be effective in encouraging a transition towards a sustainable production and consumption of critical life-supporting resources like water, energy, food and other natural resources (GGKP 2015). Well-designed and properly targeted fiscal policies would produce many benefits that include:

- *Reducing emissions through the introduction of taxes to curb polluting GHG emissions by applying the 'polluter pays' principle*. In Kenya, the government has introduced a tax for older vehicles and limited the age of vehicles that can be imported to a maximum of eight years.

- *Pricing electricity*. Lee et al. (2014) report that the large majority of households in Kenya within a few hundred meters of the grid are not connected due to high connection fees. A recent presidential directive of May 2015 that reduces connection fees from about US$35 to $15, payable in instalments through monthly bills, should help increase connectivity to the grid. But connection to a grid is does not guarantee supply and use of electricity; weak grid infrastructure and frequent power outage deny users services.
- *Pricing resources and managing consumption for efficiency and equity consideration*. Price is the most important decision-influencing factor for resource-poor communities. This is why a climate-friendly innovation like a clean, energy efficient cook-stove with evident climate and health benefits to the poor and costing $50 will not reach many households over decades. Differentiated pricing should be applied either to curtail consumption or enable consumption by different segments of society.
- Along with energy, water is a key natural resource that can be managed by a pro-poor policy regime to ensure pro-poor distributional and efficiency impacts along with potential climate benefits. Some countries, like South Africa, have differentiated water tariffs so that the poor pay less than high-income consumers.

4.2 Environment and climate change policies

Most low-income countries rely on their natural capital to develop a green growth development strategy. In Kenya, tree-planting would be the least-cost approach to tackling climate change (UNEP 2008). This implies that these low-income countries should focus on environment and natural resource management.

Environmental policies

Environmental policies are critical for climate change and are very interconnected. Policies that have demonstrated impact are those relating to waste management, energy, air pollution and human health and forestry. To accommodate space limitations, only Kenya's experience is reported here.

Policies that have incentivised minimising waste through increased resource-use efficiency and cleaner production have encouraged industries to invest in clean technology and processes, often resulting in multiple wins: increased profits, compliance with environment polices and regulations, secured dependable large market-share and improved public image. A case in point is Chandaria Industries Limited. Its line of personal hygiene products has achieved these outcomes through no, or low-cost, investment in regular energy audits, resulting in 25%, 2% and 63% reductions in energy, material and water use, respectively, in the manufacturing process (UNEP 2015).

Energy, and especially domestic energy, policies are closely linked to climate change mitigation, indoor air pollution and human health. In low-income countries like Kenya – where over 70% of households depend on wood-fuel as the primary source of energy for cooking and where cooking devices are still typically three–stone stoves – policies that promote the adoption of cleaner cooking devices have the co-benefit of contributing to improving human health. The adoption of improved stoves with higher thermal efficiency is noted to have the potential to reduce the chronic respiratory illnesses associated with indoor air pollution from short-lived organic pollutants, such as the soot emitted by traditional stoves. According to the World Health Organization, these emissions account for 14,300 deaths in Kenya annually (Global Alliance for Clean Cookstoves 2013).

Closely related to clean wood-fuel efficient technologies is the great potential of minimising GHG emissions through a slowdown in the rate of deforestation. As discussed by Angelsen his chapter in this book, REDD+ is potentially very promising, yet it has not materialised due to the combination of insufficient financial support and the slow pace of policy and political-level commitments to forest conservation. These limitations are compounded, in my view, by the volatile carbon markets that are controlled internationally. If developed countries transform their consumption and production systems towards highly efficient technologies that reduce GHG emissions, then existing cap and trade systems are likely to collapse.

Policies directly related to climate change

Following COP15, low-income countries started to develop policies to mitigate climate change. Some are anchored in the need to pursue national development against the background of a commitment to implementing decisions of the UNFCCC. For example, in Kenya, climate change has been integrated into the national planning process at the national and county level and for state and non-state actors. Climate Innovations Centers established through the InfoDev project of the World Bank have had a positive impact through climate change-driven investments at different levels and scales. Initially established in Kenya, Climate Innovation Centers have spread to other developing countries in the Caribbean, and to Vietnam, Ghana and South Africa. The technology solutions produced through these centres – like the production of livestock fodder using hydroponic solution in Kenya – reduce the release of soil carbon and hence contribute to the mitigation of climate change (although the impact is yet to be quantified). Such technology solutions in low-income countries will require finance that has so far proved elusive (see the chapter by Buchner and Wilkinson in this book).

5 What developing countries should target at the negotiations

Social inclusion, the eradication of absolute poverty, ensuring employment (especially for the young), equity, climate-driven risk management, rights-based development, entitlement to a life within a clean environment, along with education, gender and youth considerations, are the social issues that should influence the position of low-income countries at the upcoming climate change negotiations.

As discussed above, failure to focus on adaptation is a risk to be managed during the negotiations. Such a risk is evident from a report on climate change actions by cities, industries and other non-state actors by UNEP (2015). The report shows that out of over 180 analysed initiatives by industries, cities and other non-state actors, fewer than 10 included a focus on adaptation, indicating an over-focus on mitigation activities while an emphasis on adaptation measures is urgent for low-income countries. A lack of emphasis on initiatives focusing on adaptation in the determination of INDCs suggests the possibility of a commitment to targets that might not be met because of limited implementation capacity in low-income countries. This implies that there should then be an emphasis on the inclusion of transparency for high-income countries in the form of effective monitoring, reporting and verification (MRV) (see the chapters by Aldy and Pizer and Wiener in this book). In light of these observations, the following negotiation positions should be considered by low-income countries to ensure that the proposed agreement continues to address their policy objectives while ensuring that resource-poor communities are able to adapt to changing climatic conditions.

More concretely, evaluation of the common position of the G77 and China and the common African position to COP20, as well as the outcomes of the Geneva and Bonn inter-session negotiations in February 2015 and June 2015, respectively, suggest that socially relevant negotiation points should articulate the following:

- Equal treatment of mitigation, adaptation and means of implementation in the climate policy compact.
- Ambitious mitigation actions by low-income countries and specific measurable, verifiable and reportable GHG reduction targets by developed countries that can lead to a steep decline in global emissions in line with a 2°C warming scenario, based on a uniform baseline for all Parties;
- A financial flow architecture that will ensure ease of access by low-income countries to predictable, adequate finance that will support adoption of and scaling up of low-emission, climate-friendly technologies at different scales of use;
- Appropriate financing for capacity building aimed at diffusing knowledge and understanding of the impact of unsustainable lifestyles and the importance of climate-friendly technologies by national and community-level actors;
- Ambitious international financing towards adaptation actions in line with the Cancun climate finance commitments of $100 billion disbursement annually by 2020 – for the subsequent periods, adequate (large-scale and increasing) and predictable funding must be planned for and mobilised; and
- Last but not least, while the agreement will be applicable to all parties, continued compliance with the UNFCCC Charter recognising that the CBDR principle should be the over-arching reference document for the global climate change architecture as we elaborate a KP successor. In particular, the CBDR principle should be the

under-pinning principle if the world is to attain the aggregate commitments as for low-income countries are the most vulnerable to climate change (see the chapter by Mekonnen in this book).

Depending on the socio-political dynamics at the COP, the negotiation points listed above could influence the outcome of COP21. The slow pace at the Bonn negotiations in June 2015 and the decision by Parties to allow Co-Chairs to work on the text points towards continued challenges ahead. Regardless of the nature and content of the agreement that will be generated, drastic action to prevent further changes in climatic conditions is of the utmost priority for low-income countries. And building the capacity of vulnerable communities to adapt to climate change is a matter that does not need negotiation but calls for immediate action by all Parties.

References

African Union (2014), *Agenda 2063: The Africa We Want*, 2nd Edition, Addis Ababa.

Africa Progress Panel (2014), "With clock racing down to Paris, APP convenes meeting on climate change", 31 October.

Angelsen, A. (2015), "REDD+: What should come next", Chapter 28 in this book.

Aldy, J. and W. Pizer (2015) "Comparing emissions mitigation pledges: Metrics and institutions", Chapter 12 in this book.

Birdsall, N. (2015), "Does the Rise of the Middle Class Lock in Good Government in the Developing World", *European Journal of Development Research* 27(2): 217-229.

Buchner, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional' finance", Chapter 33 in this book.

Castro, P. and A. Michaelowa (2008), *Climate strategies Report: Empirical Analysis of CDM Projects*, Cambridge, UK: Climate Strategies.

Government of Kenya (2009), Draft National Disaster Risk Management Policy for Kenya, Ministry of State for Special Programs, Nairobi.

_____(2012b), National Climate Change Mitigation Analysis, Ministry of Environment and Natural Resources, Nairobi.

_____ (2015), Intended National Determined Contribution, A submission to the UNFCCC Secretariat.

Global Alliance for Clean Cook-stoves (2013), "Kenya Country Action Plan (CAP) 2013".

Green Growth Knowledge Platform (2015), *Fiscal Policies and ihe Green economy Transition: Generating Knowledge-Creating Impact*, Report of the Third Annual Conference, Venice, 29-30 January.

Hallegate, S., M. Bangalore et al. (2015) "Climate change and poverty: Natural disasters, agricultural and ecosystem impacts, and health shocks", Chapter 26 in this book.

Hsiang, S., M. Burke and W. Miguel (2013), "Quantifying the Influence of Climate on Human Conflict", *Science* 341(6151).

Lee, K., E. Brewer, C. Christiano, F. Meyo, E. Miguel et al. (2014), "Barriers to Electrification for 'under grid' households in rural Kenya", NBER Working Paper No. 20327, Cambridge, MA.

Mekonnen, A. (2015), "A view from Africa", Chapter 5 in this book.

Moarif, S. and N. P. Rastogi (2012), "Market-based climate mitigation policies in emerging economies", Center for Climate and Energy Solutions, Arlington, VA.

Stocker, T. (2015), "Implications of Climate Science for Negotiators", Chapter 2 in this book.

United Nations Environment Programme (UNEP) (2009), *Kenya Atlas of Our Changing Environment*, Nairobi.

_____ (2015), *Climate commitments of subnational actors and business: A quantitative assessment of their emission reduction impact*, Nairobi.

Somanathan, E. (2015), "A view from India", Chapter 7 in this book.

Wiener, J. (2015), "Prospects and Improvements for an effective verification and monitoring system", Chapter 13 in this book.

About the author

Alice Kaudia is Environment Secretary at the Ministry of Environment and Natural Resources, Government of Kenya. She holds a PhD in Forestry Extension and Development from the University of East Anglia, UK and a Bachelor of Science in Agriculture (Honours) Degree from the University of Nairobi. She has consulted widely for international and national environment and natural resources management agencies including FAO, ICRAF, CARE-Kenya/Somalia, African Academy of sciences among others. Dr. Kaudia is also a Distinguished non-resident Research Fellow at the African Centre for Technology Studies. Her research interests are in gender issues in environment and natural resources management, landscape restoration, climate change and the green economy

28 REDD+: What should come next?

Arild Angelsen[1]
Norwegian University of Life Sciences and CIFOR

While REDD+ has been a remarkable success as an idea and as a flagship of international climate negotiations, its implementation has been slower and the results smaller than most expected when the initiative was launched in 2005. The Warsaw Framework (2013) established the structure for an international REDD+ mechanism, but the corresponding funding to make it operational has not been forthcoming. National REDD+ policies are shaping up in major forest countries, but face continuous political struggles with vested interests for continued forest exploitation and/or legitimate development objectives. So far, REDD+ efforts have not been able to change – at any scale – the basic deforestation logic and to make living trees worth more than dead trees. The way forward, this chapter argues, is for REDD+ countries to assume a stronger role and ownership in the implementation of REDD+, and to incorporate it in their INDCs and in their domestic emission targets. Corporate efforts – through the greening of supply chains – can play a major role, pushed by consumer pressure and environmental watchdogs, and complemented by domestic policy reforms. International agreements should nudge countries towards making stronger commitments, and provide funding for capacity building and partial incentives for forest conservation through result-based mechanisms.

1 I thank the editors, Michael Bucki, Maria Brockhaus, Jan Börner, Amy Duchelle, Leif-John Fosse, Anne Larson, Christopher Martius, Ashwin Ravikumar, Denis Sonwa, William Sunderlin, Lou Verchot, Christina Voigt, Grace Wong and Sven Wunder for useful discussions and critical comments on an early draft of this chapter. All views are mine.

1 Introduction

> *"Through effective measures against deforestation we can achieve large cuts in greenhouse gas emissions - quickly and at low cost. The technology is well known and has been available for thousands of years. Everybody knows how not to cut down a tree"*
>
> (Jens Stoltenberg, (then) Prime Minister of Norway, COP 13, 2007)

The AFOLU sector (agriculture, forestry and other land uses) is responsible for 24% of global GHG emissions (Smith et al. 2014). Tropical deforestation alone is estimated to account for approximately 10% of the global emissions (Harris et al. 2012), but will – due to the comparatively low mitigation costs – constitute a much larger share of a cost-efficient global mitigation plan. Efforts to reduce forest emissions are spearheaded through the REDD+ initiative. REDD+, the acronym for 'Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries', has been among the most prominent ideas in international climate negotiations during the past decade. It has also achieved unprecedented visibility for forest issues in the political and corporate spheres. The Warsaw framework (UNFCCC COP19 in 2013) and a new set of decisions to be agreed at COP21 (in Paris in December 2015) provide the structure for an international REDD+ mechanism. Mission completed.

Well, not yet. The funding that is supposed to back up an international REDD+ mechanism has not been forthcoming, neither from carbon markets nor from other sources. At the national level, REDD+ implementation has focused on capacity building, while the policy reforms needed to scale up REDD+ projects face strong opposition from entrenched business interests. Ten years after REDD+ first appeared on the UNFCCC agenda (in 2005), we are still waiting for the concept to be applied at a scale that will reduce emissions substantially.

The early optimism was reflected in the opening quote in this chapter and in the influential *Stern Review*, which claimed that, as the opportunity costs of forest conservation are often low, emission cuts could be achieved cheaply and quickly (Stern 2006, p. ix). Given the failure to reach a substantial scale, REDD+ is increasingly viewed with a healthy dose of cynicism. But, I would argue, this is in part due to how REDD+

has been interpreted (see Section 2.1 below). Viewed as a mechanism for large-scale, results-based funding from developed to developing countries, REDD+ has failed and is unlikely ever to be realised at the envisioned scale (Section 2.2). Viewing REDD+ as a broad set of policy instruments at different scales, significant progress has been made toward achieving the ultimate goal: reduced emissions (Section 2.3).

The future success of REDD+ hinges on successfully pursuing actions within three areas. Developing countries must assume a stronger ownership of REDD+ and the efforts for reduced forest emissions, and make it part of their contribution to curbing climate change (Section 3.1). This is then complemented by corporate-consumer initiatives for greener supply chains and deforestation-free commodities (Section 3.2). International support for capacity building should continue, but the magnitude of the support will only be sufficient to provide partial financial incentives and compensation for the opportunity costs of conservation (Section 3.3).

2 Taking stock

2.1 Evolving REDD+

REDD+ was conceived within the global climate negotiations (UNFCCC) and envisioned as a mechanism whereby developed (Annex I) countries would incentivise and compensate developing (non-Annex I) countries for verifiably achieved emission reductions. This results-based payment mechanism could be mirrored within countries, to ensure that forest owners and users are incentivised and compensated for the carbon sequestered and stored in forests. Other policies, such as effective enforcement of protected forest areas, were also assumed to play a role in national and local implementation. While UNFCCC has provided a global arena for discussions and decisions, most of the actions have been among multilateral and bilateral donors, national and state governments, and private actors (corporations and NGOs).

In this process, REDD+ has changed in three significant ways (Angelsen and McNeill 2012). First, REDD+ has moved from having a single to multiple *objectives*. Initially (from 2005 to 2008), contributing to the “stabilisation of greenhouse gas concentrations in the atmosphere” was the principal objective of REDD+, but other objectives (referred to as "co-benefits" or "non-carbon benefits") have been added to the debate: protecting biodiversity, reducing poverty/enhancing local livelihoods, strengthening indigenous rights, improving governance, and expanding capacity for climate adaptation.

Second, the *implementation* focus has moved from results-based payments to a portfolio of policies. Creating a market for forest climate services presupposes a demand (created by emission caps), a well-defined commodity in the form of verified emission reductions (measured emissions, and a credible reference level), well-defined sellers (carbon rights clarified), and a marketplace with associated rules and regulations (Angelsen 2014). These elements are not yet in place in most countries. REDD+ must therefore be pursued as a broader set of national forest conservation policies (Angelsen 2009). The results-based payment idea has survived and is still seen (in different versions) as a key component of REDD+ policies and projects, but alongside other instruments (Sills et al. 2014).

Third, the *funding* for REDD+ was initially supposed to come mainly from an international carbon market. That demand for REDD+ credits has not materialised due to the lack of a global climate agreement with cap and trade (CAT) that includes REDD+ credits, either as an offset mechanism in a compliance carbon market or indirectly through, for example, auctioning emission allowances to generate revenues for a global REDD+ fund. As a result, 90% of international funding is currently coming from public sources, mainly official development aid (ODA) budgets (Norman and Nakhooda 2014).

2.2 Global negotiations and commitments

The Warsaw framework for REDD+ is a set of decisions in seven areas made at COP13 in 2013: finance; coordination; national monitoring; safeguards; reference levels; measuring, reporting and verification (MRV); and drivers; with a few outstanding issues (safeguards and non-carbon benefits) to be concluded at COP21 in Paris (December 2015). The agreement is a major diplomatic achievement. Parties with divergent views and interests were able to reach consensus, but arguably at the cost of clarity, specificity and concrete actions. Most importantly, a large-scale funding mechanism for REDD+ has yet to be established, although the decisions recognises "the key role that the

Green Climate Fund [GCF] will play in channelling financial resources to developing countries and catalysing climate finance" (UNFCCC 2011, par. 70). GCF funding is to be provided principally by developed (Annex I) countries, which at COP16 (Cancun, 2010) committed to contributing US$100 billion per year by 2020. It is, however, highly uncertain whether this promise will be fulfilled, and what share will go to REDD+.

Approximately $8.7 billion of international funding has been pledged from 2006 to 2014 for REDD+, with annual pledges declining after 2010 (averaging $605 million since 2010) (Norman and Nakhooda 2014). While some donors are experimenting with light versions of performance-based funding, at least 61% of the public funding pledged so far is for readiness activities, such as capacity building and information systems. Three-quarters of the funding comes from five donor countries (Norway, the US, Germany, Japan and the UK), with Norway being the REDD+ superpower (contributing 41% of the total, or $3.5 billion). A significant share of the funding is channelled through multilateral programmes,[2] while Norway has bilateral agreements with Brazil and Indonesia, each totalling $1 billion. These two countries are expected to receive about 40% of the international funding. The share is justifiable based on their share of tropical forest cover and emissions, but questionable as development aid which has poverty reduction as its primary aim.

The current international pledges – approaching $10 billion – represent an unprecedented level of funding to a single environmental effort in developing countries. Yet, this amount constitutes only a small fraction of the estimated funding needed if REDD+ countries are to be compensated for their emissions reductions. For example, paying for a 50% reduction in the current rate of deforestation, if valued at $5 per tCO_2, would cost around $9-10 billion *per year*.[3] This funding gap (between this amount and the current pledges) is unlikely to be filled in the near future, and REDD+ as an international, results-based mechanism risks never achieving its envisioned scale and role. This is in spite of the many attractive features, including the fact that reduced forest emissions remains one of the most cost-efficient mitigation options.

2 These include the World Bank's BioCarbon Fund, Forest Investment Program (FIP) and FCPF, the UN-REDD Programme, and the Congo Basin Forest Fund.

3 Assuming current (2000-2010) emissions from tropical deforestation to be in the order of 1GtC/year (Baccini et al. 2012), that REDD+ achieves a 50% reduction (with reference level = historical emissions) and that the price is $5/$tCO_2$, the annual international transfer to REDD+ countries is $9.2 billion (1*3.67*0.5*5 = 9.2).

2.3 National politics and local realities

Brazil has been the poster child for successful reductions of forest emissions, with annual Amazonian deforestation after 2009 being only one-quarter of the rates over the period 2001-2008.[4] The decline is due to a combination of factors: removal of agricultural subsidies, granting of conditional agricultural credit, establishment of protected areas, improved enforcement of laws and regulations, and supply chain interventions combined with an appreciation of the real until 2011 that made export less profitable (e.g. Nepstad et al. 2014).[5] Recent developments are, however, disquieting. There are signs that regional deforestation rates have increased, and that conservation policies have been relaxed.[6] The revised Forest Code (2012) increased the amount of land that can be deforested legally, new protected areas have become more difficult to establish, and the development/farm lobby has gained momentum at the expense of environmental interests.

The Brazilian success demonstrates that strong policy reforms that directly affect the cost-benefit calculus of landowners have a strong impact. The fact that policy reforms were mainly undertaken pre-REDD+, and that the country does not even have a national REDD+ strategy as such, does not diminish the lessons to be learned from Brazil (and other countries such as Costa Rica and Mexico).

Indonesia, the other important REDD+ country, has undertaken a number of policy reforms, but it remains to be seen whether they will slow down deforestation rates.[7] The Letter of Intent with Norway (2010) resulted in a two-year moratorium on forest conversion, effective from May 2011 (and extended twice, until May 2017). The real impact of the moratorium is debated, as it is limited to primary forests and peatlands, thus leaving more than 40 million hectares of logged-over forests and peatlands open to conversion. In addition, several loopholes exist; for example, it only applies to new concessions and an exception is made for the production of vital commodities. Other bureaucratic and legal reforms in support of traditional forest management, as well

4 See www.inpe.br.
5 Evidence of the importance of the real exchange rate for deforestation is given in Arcand et al. (2008).
6 See http://e360.yale.edu/feature/what_lies_behind_the_recent_surge_of_amazon_deforestation/2854/.
7 Deforestation was significantly down in 2013, after having risen for a decade, but it is too early to say if this represents a trend shift, and whether the shift reflects lower commodity prices (palm oil) or policy changes (see http://blog.globalforestwatch.org/2015/04/tree-cover-loss-spikes-in-russia-and-canada-remains-high-globally/).

as recent signals and changes of practice from the corporate sector, are nevertheless encouraging.

The third major rainforest country, the Democratic Republic of Congo, has had comparably low deforestation rates, due to civil war and unrest, political instability and forest inaccessibility for commercial exploitation. The main challenge is to keep the rates low, while securing peace and economic development. REDD+ implementation in such fragile states raises particular challenges (Karsenty and Ongolo 2012). Yet, the development transition presents a unique opportunity and the country has made significant progress on REDD+ (Lee and Pistorius, 2015)

In these and other REDD+ countries, the political economy issues remain a strong – and perhaps the most critical – barrier to implementation: deforestation happens because some people or companies benefit from it (from the poor African smallholder, to the rich Brazilian cattle-owner and the Indonesian palm oil company). The large beneficiaries often hold the power to block or slow down policy reforms. The concept of REDD+ was to make it beneficial to conserve forests, but the cost-benefit equation of most land owners has not shifted in favour of forest conservation. And, perhaps not all actors should be compensated for the opportunity costs of forest conservation. Can we justify spending development aid (most of the international funding) on rich and powerful agents of deforestation? The question is particularly pertinent as the process of allocating concessions and land rights in the first place often is flawed.

A broad consensus has emerged in response to this dilemma. The big holders (large commercial farmers and companies) should be discouraged from undertaking deforestation by direct regulation (concessions, licences, minimum forest requirements, etc.) *without* compensation. The smallholders (semi-subsistence farmers) should be encouraged to undertake forest conservation by Integrated Conservation and Development Programmes (ICDPs), the workhorse for international conservation initiatives for decades. ICDPs typically consist of a mix of interventions: information and education, local management and control, direct regulation, alternative income creation, and – more recently in REDD+ projects – some form of performance-based payment to communities or individuals (Sunderlin and Sills 2012).

Local and sub-national REDD+ projects exist in 47 countries. Most of these are self-defined and not part of a national REDD+ strategy as such (Simonet et al. 2014). In an in-depth review of 23 initiatives, de Sassi et al. (2014, p. 421) conclude that most projects have served their explorative roles, but "are struggling to make the transition from pilots to sustained REDD+ interventions". Most initiatives initially planned to sell REDD+ credits from the project area, but only four of them have done so. More generally, lack of funding has not enabled the basic political economy forces that drive deforestation and forest degradation, and that seek to maintain business-as-usual, to be changed. Challenges also abound in other areas, notably in the form of unclear and insecure land tenure and carbon rights, and safeguards and co-benefits that protect the livelihoods of local stakeholders. The national-level policy learning from local demonstration sites is also limited.

Many underestimated the technical and practical challenges of designing and implementing REDD+, assuming that advanced remote-sensing technologies would just make it 'plug and play'. This is far from the reality. Few issues are purely technical; they are embedded within political systems and in arenas of conflicting interests. Estimating changes in forest carbon stocks requires ground trothing to establish emission factors credibly. Information must be harmonised and coordinated across scales and actors. For example, in Indonesia, multiple and inconsistent maps of the forest area and the size and location of concessions, used by different government agencies, have held up the REDD+ process. Finally, realistic benchmarks (reference levels) are needed to estimate actual reductions (as compared to a BAU scenario), and to ensure additionality (see the chapter by Aldy and Pizer in this book).

REDD+ has, nevertheless, initiated advances in forest governance, in part due to major improvements in forest monitoring. For example, the monitored tropical forest area with good or very good forest inventory capacities increased from 38% in 2005 to 66% in 2015 (Romijn et al. 2015). Countries that participated in capacity-building programmes showed more progress. Interestingly, countries with poor monitoring capacities in the past tended to overestimate net forest loss. This might appear to be welcome news, but it also raises a warning if exaggerated historical deforestation rates become the benchmark for measuring success and the basis for making payments.

3 The REDD+ road ahead

Any proposal for how to solve the climate gridlock should place itself along a continuum between: (i) the necessity of what is needed to stay within the 2°C target; and (ii) the political reality of what is feasible. Many proposals are rightly criticised for being either insufficient or unrealistic, or sometimes both. In this section, I focus on three key topics that are critical for future progress: national commitments and policies; corporations and consumers; and international agreements and funding. The selection of these topics is based on the following three observations. First, national policies are key determinants of deforestation rates, more so than international funding and local REDD+ projects. Second, deforestation is increasingly driven by global trade involving multilateral corporations that have strong influence over the supply chains. Third, the global climate regime over the short-to-medium term will likely be a bottom-up, 'pledge and review' system, based on the countries' Intended Nationally Determined Contributions (INDCs).[8]

3.1 National commitments and policies

To achieve substantial emission reductions, forest conservation will increasingly have to be considered as REDD+ countries' contribution to the global effort of limiting climate change, as integrated into national green/low-emission/low-carbon/sustainable development strategies. In a post-2020 climate regime that "reflects the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances" (UNFCCC 2014, par. 3), this could imply that middle-income countries factor REDD+ partly into their domestic target and partly as a conditional pledge subject to international support.

Analysing the policy process in key REDD+ countries, Di Gregorio et al. (2012, p. 69) argue that "achieving emission reductions through REDD+ requires four preconditions for overcoming politico-economic hurdles: (i) the relative autonomy of the State from key interests that drive deforestation and forest degradation, (ii) national ownership over REDD+ policy processes, (iii) inclusive REDD+ policy processes, and (iv) the

8 http://unfccc.int/focus/indc_portal/items/8766.php

presence of coalitions that call for transformational change." When the REDD+ process is driven by international actors, it is unlikely to make a difference on the ground.

National governments are therefore in the driver's seat for achieving reduced forest emissions. They have the primary ability for achieving this goal, and – some would argue – also the primary responsibility. Governments can implement a range of specific policies that have proved efficient in limiting deforestation. I have reviewed these elsewhere (Angelsen 2010, Angelsen and Rudel 2013), and they include: (i) reducing/removing agricultural subsidies to deforestation agents/crops/areas, (ii) avoiding road building that makes forested areas more accessible, and (iii) establishing and enforcing protected areas.

Subsidised emissions are not just a problem for fossil fuel emissions. A recent report by the Overseas Development Institute points to the pervasive effect of subsidies on key commodities, such as beef and soy in Brazil, and palm oil and timber in Indonesia. The subsidies amount to $40 billion per year for these two countries combined. "These subsidies are likely to have a far more significant impact on private investment in activities that drive deforestation, than current REDD+ finance" (McFarland et al. 2015, p. 43). Reducing these subsidies, or making them conditional on compliance with zero-deforestation practices, represents a win-win change for conservation and development, although some groups will stand to lose from such a reform.

3.2 Corporations and consumers

In parallel with the UNFCCC process, a number of initiatives at the global and national levels have involved the private sector as a key partner in REDD+. The most noted national example is the Soy Moratorium of Brazil, adopted in 2006. This made traders agree not to sell soy from farmers who had cleared Amazon forests (Nepstad et al. 2014). Internationally, 'zero deforestation' initiatives have resulted in several global companies making significant efforts in greening their value chains.[9] Studies among business executives also confirm that corporate reputation, media attention and customer pressure are the most important reasons for taking climate issues into

9 An example is the Palm Oil Scorecard: http://www.ucsusa.org/global-warming/stop-deforestation/palm-oil-scorecard-2015#.VYPp0fnq3St

consideration, well ahead of policy regulation and investment opportunities (Enkvist and Vanthournout 2008). Security of supply (in areas where production is not sustainable) is likely to become more important as land competition and climate extremes increase in frequency and severity.

In the New York Declaration on Forests (2014),[10] signatories committed to doing their part to halve current deforestation rates by 2020 and to end deforestation by 2030. They also agreed to ensure that the production of four key commodities (palm oil, soy, paper, and beef) did not add to deforestation. So far, the declaration has been signed by 36 countries, 20 states/provinces, 53 companies, and 4 indigenous peoples groups.

A combination of higher awareness of the costs and risks involved in continued climate change, consumer pressure and demand for green products, and 'naming and shaming' by NGOs and other watchdogs can strengthen this trend even further. With international climate negotiations proving ineffective in delivering credible emission cuts, private actors can define new standards and rules in (international) environmental governance, and gain what Green (2013) labels "entrepreneurial authority". Supply chain reforms need to be backed by domestic legislation and supportive policies to make them function better and to hold companies accountable, while encouraging frontrunners.

A very different ballgame would emerge if companies were allocated emission caps, and these could be offset through buying REDD+ credits. The private sector would then become a major funder for REDD+. The very modest demand for carbon credits in the voluntary market suggests that only policy regulations in the form of emission caps can create sufficient demand.

3.3 International agreements and funding

The initially envisioned role of REDD+, or perhaps the core of REDD+, was a massive transfer of resources to incentivise forest conservation in developing countries. With that scenario unlikely to unfold, how could an international agreement advance the implementation of REDD+?

10 See http://www.un-redd.org/portals/15/documents/ForestsDeclarationText.pdf.

'Pledge and review' seems to be the new, or indeed the only, game in town: countries make their pledges through their submission of the INDCs, which are then subject to an assessment and review process (A&R). In the best scenario, this process would help align national contributions with the 2°C target, enhance transparency and build trust. The Paris Agreement is likely to recognise the need to "achieve net zero greenhouse gas emissions within the second half of this century", which implies building and maintaining terrestrial carbon sinks counterbalancing residual emissions in other sectors. Halting and reversing the loss of carbon in forests and soils could become the main contribution of many developing countries in their INDCs. In other words, rather than REDD+ being seen solely as a vehicle to generate international funding, part of it could be claimed as a national contribution to the global efforts of curbing climate change, particularly for middle-income countries. The A&R process could play a similar role for REDD+ as for other mitigation areas. A major step forward would be if the INDCs and A&R process could also focus on policies and possibly establish some consensus on key policy reforms.

The GCF and possible other mechanisms to be established can provide funding for capacity building, upfront investments, concessional finance and possibly also direct payments for results (i.e. for reduced emissions). International funding for REDD+ (and climate funding in general) should arguably focus on the poorest countries, rather than middle-income countries like Brazil that have sufficient resources to cover the domestic costs of forest conservation.

The limitations for international transfers to be a game changer should be recognised. First, in spite of the low costs of REDD+ compared to most other mitigation options, the realistic level of funding is small compared to the overall costs and associated co-benefits. Second, the real cost of REDD+, the opportunity costs of forest conservation (mainly the foregone profit from agricultural production on forest land conserved) does not lend itself easily to the dominant ODA modalities. Third, designing results-based funding schemes is hard (reference levels, criteria, spending pressure, and so on; see Angelsen 2013). Policy reforms can only be bought by foreign money to a very limited extent (Collier 1997).

4 Concluding thoughts

REDD+ is frequently presented as one of the climate success stories, partly because the idea looks so simple and appealing, partly because of the unusual inclusiveness of the process (the wide variety of active CSO and IP observers), partly because of the funding mobilised and activities generated, and partly because UNFCCC has for once reached a balanced agreement despite huge technical challenges. Powerful actors – from presidents and finance ministers in REDD+ countries to top executives in international corporations – are engaged like never before in debates on the role of forests in the global carbon cycle. The issues of transparency, accountability, tenure and rights and indigenous peoples have been put on domestic political agendas by REDD+. The dramatic change in the global narrative and the political momentum generated are reasons for cautious optimism.

But a thorough reality check is needed. The envisioned results in terms of reduced emissions have – by and large – not been delivered. Brazil is a success story, although little of its success can be attributed to REDD+. For other countries, there are few stories of substantial early progress in terms of reductions in deforestation (and its harder-to-measure twin, forest degradation). Old and new business-minded coalitions have blocked progress, suggesting that REDD+, if implemented, would actually make a difference.

Arguably, many were overly optimistic about REDD+ as a cheap and quick fix. Change takes time. REDD+ has improved the capacity, created an enabling environment, and raised the awareness of the role of forests in climate change (Lee and Pistorius, 2015). The momentum might eventually lead to results on the ground. But to keep that momentum going, current REDD+ efforts must deliver significant, measurable reductions in forest emissions by the end of this decade.

To achieve significant reductions in forest emissions, the REDD+ countries themselves must take the driver's seat with a focus on domestic policy reforms and enabling environments; the corporate sector should continue the greening of its supply chains, pushed by consumers, watchdogs and demand-side policies; and the international regime must gently nudge the countries to stronger pledges and provide finance to nudge and supplement domestic efforts in the poorest countries.

References

Aldy, J. and W. Pizer (2015), "Comparing emission mitigation pledges: Metrics and institutions," Chapter 12 in this book.

Angelsen, A. (ed.) (2009), *Realising REDD+: National strategy and policy options*, Bogor, Indonesia: CIFOR.

Angelsen, A. (2010), "Policies for reduced deforestation and their impact on agricultural production", *PNAS* 107(46): 19639–19644.

Angelsen, A. (2013), "REDD+ as performance-based aid: General lessons and bilateral agreements of Norway", WIDER Working Paper, UNU-WIDER, Helsinki.

Angelsen, A. (2014), "The economics of REDD+", in S. Kant and J. Alavalapati (eds), *Handbook of Forest Resource Economics*, London: Routhledge, pp. 290-316.

Angelsen, A. and D. McNeill (2012), "The evolution of REDD+", in A. Angelsen et al. (eds), *Analysing REDD+: Challenges and Choices*, Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Angelsen, A. and T. K. Rudel (2013), "Designing and Implementing Effective REDD+ Policies: A Forest Transition Approach", *Review of Environmental Economics and Policy* 7(1): 91-113.

Arcand, J.-L., P. Guillaumont and S. Guillaumont Jeanneney (2008), "Deforestation and the real exchange rate", *Journal of Development Economics* 86(2): 242-262.

Baccini, A., S. J. Goetz, W. S. Walker, N. T. Laporte, M. Sun et al. (2012), "Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps," *Nature Climate Change* 2(3): 182-185.

Collier, P. (1997), "The Failure of Conditionality", in C. Gwin et al. (eds), *Perspectives on Aid and Development*, Washington, DC: Overseas Development Council.

de Sassi, C., W. D. Sunderlin, E. O. Sills, A. E. Duchelle, A. Ravikumar et al. (2014), "REDD+ on the ground: Global insights from local contexts", in E. O. Sills et al. (eds), *REDD+ on the Ground: A Case Book of Subnational Initiatives Across the Globe*, Bogor, Indonesia: Center for International Forestry Research, pp. 420-439.

Di Gregorio, M., M. Brockhaus, T. Cronin and E. Muharrom (2012), "Politics and power in national REDD+ policy processes", in A. Angelsen et al. (eds), *Analysing REDD+: Challenges and choices*, Bogor, Indonesia: Center for International Forestry Research (CIFOR), pp. 69-90.

Smith P., M. Bustamante et al. (2014), "Agriculture, Forestry and Other Land Use (AFOLU)" in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Enkvist, P. and H. Vanthournout (2008), "How companies think about climate change", *McKinsey Quarterly* 2: 46.

Green, J. F. (2013), *Rethinking private authority: Agents and entrepreneurs in global environmental governance*, Princeton, NJ: Princeton University Press.

Harris, N., S. Brown, S. C. Hagen, A. Baccini and R. Houghton (2012), "Progress toward a consensus on carbon emissions from tropical deforestation", Winrock International Policy Brief, WHOI & Meridian Institute, Washington, DC.

Karsenty, A. and S. Ongolo (2012), "Can 'fragile states' decide to reduce their deforestation? The inappropriate use of the theory of incentives with respect to the REDD mechanism", *Forest Policy and Economics* 18: 38-45.

Lee, D. and T. Pistorius (2015), "The Impacts of International REDD+ Finance", San Francisco, US: Climate and Land Use Alliance.

McFarland, W., S. Whitley and G. Kissinger (2015), "Subsidies to key commodities driving forest loss", ODI Working Paper, London.

Nepstad, D., D. McGrath, C. Stickler, A. Alencar, A. Azevedo et al. (2014), "Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains", *Science* 344(6188): 1118-1123.

Norman, M. and S. Nakhooda (2014), *The State of REDD+ Finance*, Washington, DC: Center for Global Development.

Romijn, E., C. B. Lantican, M. Herold, E. Lindquist, R. Ochieng et al. (2015), "Assessing change in national forest monitoring capacities in 99 tropical countries", *Forest Ecology and Management* (forthcoming).

Sills, E. O., S. S. Atmadja, C. de Sassi, A. E. Duchelle, D. L. Kweka et al. (eds) (2014), *REDD+ on the ground: A case book of subnational initiatives across the globe*, Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Simonet, G., A. Karsenty, C. de Perthuis, P. Newton and B. Schaap (2014), "REDD+ projects in 2014: an overview based on a new database and typology", in *Les Cahiers de la Chaire Economie du Climat*, Paris: Dauphine Université.

Stern, Sir N. (2006), *Stern Review: The Economics of Climate Change*, Cambridge, UK: Cambridge University Press.

Sunderlin, W. D. and E. O. Sills (2012), "REDD+ projects as a hybrid of old and new forest conservation approaches," in A. Angelsen et al. (eds), *Analysing REDD+: Challenges and choices*, Bogor, Indonesia: Center for International Forestry Research (CIFOR).

UNFCCC (2011), Decision 1/CP.17: "The Durban Platform", Bonn.

UNFCCC (2014), Decision 1/CP.20: "Lima Call for Climate Action", Bonn.

About the author

Arild Angelsen is Professor of Economics at the Norwegian University of Life Sciences (NMBU) and Senior Associate at the Center for International Forestry Research (CIFOR) in Indonesia. He has done extensive research on causes of tropical deforestation, and its interaction with poverty, tenure and government policies. Recent work deals with how efforts to REDD+ can be included in a global climate regime, the national strategies and policies needed to achieve REDD+, and local experiences.

He has edited three REDD+ books: *Moving Ahead with REDD: Issues, Option and Implication* (2008), *Realising REDD+: National Strategy and Policy Options* (2009), and *Analysing REDD: Challenges and Choices* (2012), and served on several expert committees. He also works on environmental income and in experimental economics.

29 Curbing carbon without curbing development

Paul Collier
Oxford University

The poorest countries have a strong interest in curbing global carbon emissions, because they have relatively more to lose from global warming. But they also have a strong interest in economic growth – only if they grow rapidly can they address the mass poverty which is their current experience. These two objectives potentially conflict. Global restrictions on carbon energy could impede the development of poor countries by denying them cheap energy, and also directly threaten the income of those poor countries which export carbon fuels. Hence, they need global arrangements which are effective, but which do not damage their economic interests. To date, the approach has been for richer countries to set themselves emissions targets while the poorest countries do nothing. This has neither been sufficiently effective in curbing emissions, nor has it provided the poorest countries with viable mechanisms for compensation. In this chapter I propose a different approach which targets the gradual closure of the global coal industry. Any effective approach to climate change will require drastic shrinkage of the coal industry. Focusing on the practicalities of closing coal, instead of the abstract concept of curbing carbon emissions, makes it easier to tap the potential moral pressure of ordinary citizens. Without this pressure, no conference agreement is likely to be implemented. Further, focusing on closing coal opens up straightforward ways by which the interests of poor countries might be protected.

Introduction: The dilemma for poor countries

To address climate change, carbon emissions will need to be curtailed. This is in the interest of poor countries because they are among the countries which are most vulnerable to climate change. This is partly because poor countries are mostly already hotter than rich ones, partly because they will mostly lose a higher proportion of their GDP, and partly because of the structure of their economies, with a far higher proportion of their population dependent upon climate-sensitive agriculture. However, while addressing climate change is in their interest, poor countries are also potentially threatened by global measures to curb carbon emissions. This is because curtailing carbon emissions conflicts with the need of poor countries for large increases in energy consumption as an integral part of their development process, and with the need to clear forest for the expansion of cultivation. Further, many of poor countries are heavily dependent upon the export of carbon-based energy to finance their imports.

These tensions cannot be resolved by the pretence of a bifurcation between 'rich' countries that are 'guilty' of causing climate change and 'developing countries' which are merely the 'victims'. This ethical bifurcation is untenable. First, there is no longer a bifurcation between 'developed' and 'developing' countries, but a continuum from the very poor, such as Malawi, to very rich such as Qatar, with China, now an above-middle-income giant, being the largest carbon emitter. Second, neither individuals nor entire societies are morally liable for the adverse consequences of carbon emissions prior to the recent time at which those adverse consequences became understood. Third, even for those recent emissions where some moral responsibility can reasonably be invoked, how should that liability be assigned between those countries which burn carbon-based energy, notably Europe, and those which extract it and sell it for others to burn, notably the Middle East, since both have evidently benefited? To date, negotiations have arbitrarily assigned all responsibility to the locations where energy is burnt rather than extracted, but this lacks moral rationale.

The interest of poor countries is therefore to encourage effective international action, from which they would benefit, while safeguarding their scope for rapid economic development. To be effective, proposed actions must be based on a global consensus on shared responsibility for curtailing future emissions. While the interests of the poorest countries such as Malawi will need to be protected, and high-income countries such as Saudi Arabia and Germany will need to make the earliest sacrifices, middle-income countries such as China and Poland will need to accept the duty to undertake costly actions.

Why current approaches have had limited success

To date, the international approach to climate change has largely been ineffective. It has been based on national emissions targets for OECD countries, implemented primarily through a mixture of regulatory measures, the promotion of energy efficiency, a pan-European cap-and-trade scheme and national carbon taxes. This has several weaknesses.

First, its implications for individual action by firms and households are highly unspecific. Carbon emissions could potentially be curbed by a myriad of behavioural changes which would generate largely unobserved, and mostly small, reductions in emissions. Unfortunately, this completely diffuses the responsibility for behavioural change and this feature in turn maximises the difficulty of achieving change. Indeed, the only practical mechanism for achieving such diffuse coordination is the price mechanism – carbon would need to be taxed, globally, to a common degree. However, this poses extreme political difficulties. Societies differ considerably in the degree to which citizens see their government as responsible for the price of carbon products. In many countries petrol is heavily subsidised; in Nigeria, for example, an attempt to remove this subsidy led to a violent national strike. As Sandel (2012) has argued, the market mechanism is contentious as a means of allocating morally charged resources. Concern over climate change has intentionally (and understandably) made carbon morally charged. The idea that the solution to a negative global externality is a global tax, while technically appealing to economists, is likely to be radically unacceptable to many people.

It is indeed notable that to date the civil society campaigns to arrest climate change, and the economic policy advice to a achieve it, have been radically divergent. Civil society has emphasised personal moral responsibility – people should buy smaller cars, reduce their air travel, and suchlike – whereas economists have proposed the issuance of emissions rights which would be tradable on global markets. The tradable rights central to cap-and-trade can be efficient and generate mutual gains, but to many people they will appear to be morally repugnant – the ethical equivalent of medieval 'indulgences' in which a price is placed on the 'right to sin', with its implications that the rich will be able to continue sinning while the necessary behavioural change is undertaken by poorer societies. Thus, the ethical weakness of the technical solution inadvertently undermines the overarching moral basis for global action.

Similar criticisms can be made of the Clean Development Mechanism, by which firms in developed countries buy emissions rights from firms in poorer countries which are paid to refrain from actions that they would otherwise have taken that would have increased their emissions. This opens considerable scope for scams and so only environments with reasonably trusted governance have met the criteria for verification. In practice this has meant that the main beneficiary from cap-and-trade has been China. Even before the ethics of such transactions are considered, it is apparent that an arrangement which required the US to make very large payments to China would not be acceptable to US citizens, so it is difficult to imagine this approach becoming global. Ultimately, 'international mechanisms' whereby continued emissions by some countries are offset by actions in others may prove to be ethically corrosive even if in principle they yield mutual benefits.

An alternative approach: Focus on coal

Carbon taxes, cap-and-trade, and emissions targets are all highly technocratic – they are very distant from the sort of practical actions that ordinary people can readily envisage. Yet carbon emissions are substantially reducible to one practical, concrete action: *closing the world's coal industry*. Coal is the king of carbon emissions. All technocratic mechanisms for curbing emissions implicitly involve the closure of the coal industry, but they have singularly failed to make this apparent, let alone addressing how, practically, it might happen. I now outline an alternative approach to curbing emissions which focuses on this practical issue of how gradually to close down the world's coal industry. Central to this approach is the protection of the developmental interests of poor countries (Harstad 2012, Collier and Venables 2014).

While emissions have been the overwhelming focus of policy attention, the corresponding issue of curbing the extraction of carbon-based energy from beneath the ground has received little practical attention. It may be much easier to control carbon emissions at the point of fuel extraction than at the point of consumption. While consumption is the result of a myriad of decisions by billions of people, extraction is the result of a very limited number of decisions by a small group of firms. As a result, it is highly specific as regards moral agency – specific both in terms of the particular people whose decisions need to change and the particular actions that they need to take. This is important because the moral force of an action is not well-determined by its ultimate consequences. Pinker (2007) demonstrates how moral attribution can be teased out of the way we use ordinary language: 'the concept of causation we apply when choosing our verbs is also the concept we apply when we hold people responsible. We single out the acts that a person *intentionally*, and *directly*, and *foreseeably* caused.' (p. 228). If the power of moral agency is to be harnessed to curb carbon emissions, the generalised, diffused responsibility of everyone for every act that might directly or indirectly emit carbon, which is the approach taken by carbon pricing, is precisely wrong. Instead, public policy needs to focus on a very few salient emissions that can be directly connected to major decisions of a few key actors. On this approach, there is no doubt as to what the focus should be – it should be on closing the world's coal industry. Ultimately, closing coal will not be enough, but as the single most important action, which is also likely to be the least costly, it is the right place to start. Practical success in closing coal would provide momentum for more complex actions which are correspondingly more demanding.

Coal accounts for around a quarter of all carbon emissions and around 40% of all known CO_2 in fossil fuel reserves. However, while it is the single most important source of carbon emissions, it is not an economically valuable source. Its energy output per unit of carbon emissions is lower than gas, and its cost of extraction and transformation into usable energy is higher than other fossil fuels. As a result, even before the fall in energy prices in late 2014, although coal constitutes 40% of the CO_2 in fossil fuel reserves, it constituted only 16% of the economic value of those reserves. As a result of the fall in global energy prices, the market value of coal mining companies has fallen by around 80%, which is a far larger drop than oil companies. This is an indication that the economic rents on coal extraction (the surplus of value over cost), which were already modest, are now very small. By closing coal ahead of other fossil fuels, there would be a larger impact on carbon emissions for a given loss of energy, and only a small loss of economic rents. Should CCS technology ever become viable, clean coal may redevelop, but to date it has proved to be far more difficult than envisaged (for example, Norway has recently abandoned its programme of research).

Further, by taking measures that directly curb the supply of coal instead of starting from curbing the demand for carbon energy, the problems posed by the ‘green paradox’ and international ‘leakage’ would be reduced. The green paradox arises as producers of carbon energy increase extraction in anticipation of the loss of future rents. Potentially this could happen with coal, since there are very large stocks in the ground. But the collapse in rents reduces such inter-temporal substitution of production – if there are no significant rents to protect, producers gain nothing by pre-empting anticipated controls. Additionally, the possibility of future CCS technology provides an incentive for leaving coal in the ground until it can be sold at a premium price as clean energy.

Leakage arises because those countries which act responsibly, curbing their carbon emissions, inadvertently create an incentive for other countries to do the opposite (see Fischer 2015). Action on both supply and demand faces this problem. If some countries (a ‘coalition of the willing’) act to reduce their demand for carbon energy, this reduces the world price of carbon energy and so increases consumption in other countries. Similarly, if some countries reduce their supply of coal, this increases the world price of coal and so increases coal production in other countries. However, the extent of leakage depends upon the price elasticity of response. The leakage from curbing carbon demand depends upon the elasticity of demand for carbon-based energy; this is high because there is a lot of scope for substitution from other fuels. In contrast, the leakage from curbing coal production depends upon the elasticity of coal supply, which is low. Hence, curbing coal production is likely to be the more efficient approach, less subject to being undermined by leakage, than curbing the demand for carbon energy.

Considerably more carbon-based energy has already been discovered than can safely be burnt, and so some of it must remain *permanently* unused. This creates the phenomenon of ‘stranded assets’. McGrade and Ekins (2015) estimate that to achieve the target of keeping the increase in temperature to only 2°C, a third of known oil reserves will be stranded and over 80% of known coal reserves. A key issue for poor countries is whether their own carbon assets will become ‘stranded’. For many poor countries, dependent upon carbon-energy for their exports, the threat of their currently valuable carbon energy assets becoming stranded is even more serious than the threat from climate change.

The new awareness that not all carbon-based energy can be used, and that coal is the least efficient source of carbon energy, is currently inducing the governments of high-income countries to inhibit the extraction of new coal deposits in low-income countries. For example, the Board of the World Bank is disinclined to approve loans for coal mining projects. There is a superficial rationality to saying that if we have already discovered more than we can burn there is little point in financing further discovery, a point made by McGlade and Ekins (2015). But the scope for new discoveries is far greater in poor countries. For example, according to World Bank data for the year 2000, the value of discovered sub-soil natural assets per square kilometre was five times greater in the OECD than in Africa. It is highly unlikely that this is because there was less to be discovered in Africa, it simply reflects Africa's much lower past investment in prospecting (itself a consequence of past poor governance). This was indeed confirmed during the carbon super-cycle of 2003-14, during which high prices induced a major increase in global search. Analysing the pattern of new discoveries and prospecting, Ross (2012) concludes that 'the vast majority of the world's new hydrocarbon supplies will come from developing countries in the next few decades' (p. 10). These new carbon discoveries in poor countries have the potential to provide transformative revenues, but many of them still require substantial investments in order to be extracted; examples being off-shore gas in Mozambique and Tanzania, and oil in Kenya and Uganda. Badly managed carbon regulation and NGO pressure for portfolio divestment programmes could have a chilling effect on many of these investments.

Freezing the discovery and new investment processes would therefore massively disadvantage poor countries. As a consequence, it would maximise the conflict of interest between poor countries and rich ones. Yet action on climate change requires a global consensus in order to generate moral pressure. What is needed is a morally reasonable basis for agreeing a path to reduce the production of coal. Two approaches have been proposed.

Harstad's (2012) approach is that a coalition of willing high-income countries should reduce global coal production by buying up commercial coal production and closing it. The approach of Collier and Venables (2014) is that coal production should be reduced through a sequence of closure according to the income level of the country. The Harstad proposal is technically the more efficient since the least valuable coal mines would be closed first, wherever they might be located. However, it would be exposed to nationalist critiques brought by coal miners threatened with losing their jobs. For example, even an attempt by an Australian company to purchase a potash mine in Canada was vetoed politically because there was seen to be a risk that the mine would be closed by the foreign purchaser to increase market dominance. Further, by relying on an international market process it inadvertently undermines moral pressure. Allowing rich countries to reduce global carbon emissions by buying up and shutting down mines in poorer countries might be seen as weakening rather than implementing the moral case for collective action on climate change.

In contrast, the Collier-Venables proposal attempts to harness the moral energy generated by popular concern about climate change. It does so by using a fair basis for the sequence of coal closures to generate intense moral pressure on specific decision-takers at specific times. The sequence would require high-income coal producers to act first – specifically, Germany, the US and Australia. Until these three countries have begun closing their coal mines, no action would be required of others. However, once they have started to implement a closure plan, middle-income coal producers would be required not to expand their production. Once high-income producers have completed their closures, upper-middle-income countries such as Poland would be required to start their own closure programmes. Only once they start to close their mines would lower-middle-income countries such as Indonesia be required not to expand their production. At this point, a variant of the Harstad proposal could be added: oil producers in high-income countries could become subject to a ring-fenced cap-and-trade scheme. They would be permitted to buy rights to increase emissions from those coal mines in middle-income countries which were required to close. This would be morally attractive; for example, some of the oil rents of Norway and Saudi Arabia would be diverted to compensate Polish miners for their loss of jobs. The superiority of this over generalised transfer mechanisms is its specificity – clear and substantial losers are compensated, and clear and substantial beneficiaries of carbon rents are required to provide it. The process of closure would continue through lower-middle-income countries, eventually reaching low-income countries such as Mozambique.

Meeting rising energy demand in poor countries

The above approach could effectively defuse tensions between action on climate change and development in respect of the *production* of carbon-based energy. Low-income and lower-middle-income producers would be given considerable time before they were required to take action, with the precise duration depending upon how rapidly richer countries took action. However, it would not address the concerns of low-income *users* of carbon-based energy. Addressing climate change, especially through supply-side measures such as closing coal, will inevitably increase the global cost of energy. Poor countries will need large increases in their consumption of energy as they develop. To what extent is this higher cost of energy an impediment for them?

While it is in principle a legitimate concern, in practice it is minor. This is because in most poor countries the key energy-related impediment to growth is not the price of energy but its availability. Energy has been supplied through badly run public monopolies with the result that it has been highly unreliable. In consequence, firms have had to meet their electricity needs through individually owned diesel generators at very high unit cost. This is commonly listed in surveys of firms as their primary impediment. By increasing the availability of electricity governments of poor countries could substantially reduce its effective unit cost to their firms and households, even though the global unit cost of energy will be rising.

Poor countries have several means of meeting rising energy demand that are consistent with the above strategy for addressing climate change through closing coal. Several poor countries have their own coal supplies and so would be able to meet electricity demand through domestic coal for several decades. For the majority that do not have their own coal, both hydropower and solar power will become viable options for power generation. Africa and Central Asia have huge potential for hydro. For example, Ethiopia, with high rainfall on high ground and consequent kinetic energy from water run-off, is developing its vast potential in hydropower with prospects of very low unit costs of electricity. Solar energy has to date been more challenging because favourable endowments of sunlight have been offset by the high capital cost of solar panels. Rural Africa is littered with abandoned solar panels. However, as costs continue to fall this may be in the process of being overcome (Collier and Venables 2012). The combination of coal, hydro and solar power becoming available to poor countries implies that they have scope to ramp up the supply of electricity. While it would technically be possible to develop a climate-related scheme by which international public money was devoted to financing this expansion, politically this has proved to be infeasible. The present proposal would achieve the equivalent of a financial transfer to poor countries through privileging them in respect of the sequence of closure of the global coal industry. This would not be politically easy, but it is arguably considerably less difficult than a direct transfer of finance.

Conclusion

Effectively addressing climate change is more in the interest of poor countries than of rich ones. Poor countries are more threatened by climate deterioration. However, past approaches to climate change – notably through emissions targets, cap-and-trade, the Clean Development Mechanism, and carbon taxes – have been relatively ineffective, while future, more effective approaches along the same lines have the potential to be detrimental to poor countries. I have suggested a switch from market-dependent solutions to greater emphasis upon moral pressure, by focusing on the sequential closure of coal. Because coal is the king of carbon emissions, any effective approach to curbing emissions will involve radical reductions in coal production. Yet over the past three years, despite technocratic attention on climate change, global coal consumption has actually increased. This reflects the severe disconnect between the technocratic solutions and what ordinary citizens recognise as morally actionable changes in behaviour. Without the moral energy of mass public opinion, technocratic solutions may be agreed in conferences, but they will not be implemented when subjected to the continuous pressures of political interests. It would be easier for people to grasp that coal has to be closed than that a mechanism such as cap-and-trade should be implemented. It would also be easier for people to recognise that the coal industries of rich countries should close before those of poor countries than for them to agree to large financial transfers from rich to poor.

References

Collier, P. and A. J. Venables (2014), "Closing Coal: Economic and Moral Incentives", *Oxford Review of Economic Policy* 30(3): 492-512.

Collier, P. and A. J. Venables (2012), "Greening Africa? Technologies, endowments and the latecomer effect", *Energy Economics* 34(S1): S75-S84.

Fischer, C. (2015), "Options for avoiding carbon leakage", Chapter 21 in this volume.

Harstad, B. (2012), "Buy Coal: A Case for Supply-Side Environmental Policy", *Journal of Political Economy* 120(1): 77-115.

McGlade, C. and P. Ekins (2015), "The Geographic Distribution of Fossil Fuels unused when Limiting Global Warming to 2 Degrees", *Nature* 517: 187-190.

Pinker, S. (2007), *The Stuff of Thought,* London: Allen Lane.

Ross, M. L. (2012), *The Oil Curse: How Petroleum Wealth Shapes the Development of Nations*, Princeton, NJ: Princeton University Press.

Sandel, M. (2012), *What Money Can't Buy: the Moral Limits of Markets*, New York: Farrar, Strauss and Giroux.

About the author

Paul Collier is Professor of Economics and Public Policy at the Blavatnik School of Government, Oxford University, Co-Director of the International Growth Centre, and a Professeur Invite at Sciences Po, Paris. He specialises on the economics of Africa, founding and directing the Centre for the Study of African Economies. Among his numerous books, *The Plundered Planet: How to Reconcile the Environment and Prosperity* (Oxford University Press, 2010), covers the tensions between tackling climate change and the development objectives of poor countries.

30 Towards resilient and low-carbon cities

Anthony G. Bigio
George Washington University

Variations among cities of the developing world in terms of per-capita income, exposure to climate vulnerabilities, and GHG emissions levels are very significant and have to be taken into account in order to support their active engagement in global climate action. Ninety per cent of all urban growth by mid-century will occur in the developing world, and this build-up will require great quantities of energy and natural resources, further depleting the carbon budget. These cities will play an ever-greater role in global GDP generation and GHG emissions, and their exposure to climate change impacts will also increase. Urban climate action in the developing world will require good governance, technical capabilities and financial support. In view of the multiple priorities facing city governments, climate adaptation has to be mainstreamed within the sustainable provision of urban services and the build-up of urban resilience to natural hazards. Similarly, GHG mitigation should be embedded within green growth and urban welfare strategies, driven as much by quality of life goals as by climate protection considerations. Compact urban growth, connected infrastructure and coordinated governance can provide the way forward, and the resulting urban morphology can greatly contribute to reducing urban emissions. Further co-benefits can be obtained by integrating mitigation and adaptation strategies at the urban scale. Some cities in OECD countries are achieving significant GHG reductions and showing that a post-carbon urban future is possible. International city networks have emerged as vehicles for innovation sharing, learning, and advocacy for the recognition of cities in global climate action. For further action to take off in the cities of the developing world, a global climate deal should (a) increase the amount of international funding for urban adaptation, especially in LDCs; (b) multiply opportunities for channelling carbon financing into urban green growth; (c) make international financial support dependent

on innovative national urban policies; and (d) support urban learning, networking and knowledge-sharing programmes.

1 Diversity and complexity of cities in the developing world

Globally, cities currently account for 80% of GDP production and over 70% of GHG emissions, while hosting 54% of the world's population. As in the rest of the world, cities in developing countries and emerging economies concentrate population and economic assets, and contribute disproportionately to their countries' generation of wealth. As urban agglomerations attract national production, consumption, and provide transit for incoming and outgoing goods, they are also the centres of highest energy usage and therefore of highest GHG emissions. With the share of global GDP being increasingly generated elsewhere than the G20 countries, an ever-greater share of emissions will originate from cities in emerging economies in the near future.

As international negotiations are approaching the 21st Conference of the Parties in Paris, a global framework agreement to counter climate change should be shaped so that cities become fully engaged in its implementation. For this to happen, it is imperative to recognise the diversity and complexity of the urban settlements in developing countries and emerging economies, and to unpack the generic concept of 'cities of the global South' in order to engage them more effectively in climate action.

While GDP per capita is a coarse measure of wealth and welfare, it is still helpful in decoding the specific climate change challenges that various types of developing and emerging cities are already facing and will increasingly face in the future. Cities in least developed countries (LDCs) are likely to present a profile of low energy usage, accompanied by low GHG emissions levels, but a high level of urban risk and exposure to climate change impacts. This, in turn, is the result of a low level of infrastructure provision, a high percentage of the resident population living in informal housing, unmitigated natural hazards, and a low institutional capacity to manage urban growth as well as enforcing urban planning legislation, providing basic urban services and emergency response systems (Revi et al. 2014).

At the other extreme of the spectrum of cities in the developing world we find the complex urban agglomerations of Upper Middle Income Countries, with sophisticated modern infrastructure, generalised formal housing, high energy usage and high GHG emissions levels. These are in many cases boosted by the intensive export-oriented manufacturing activities that have displaced industrial production from Europe, North America and Japan. However, depending on their location (but especially if located in coastal zones), many such cities may be also exposed to high levels of unmitigated urban risk and vulnerable to climate impacts.

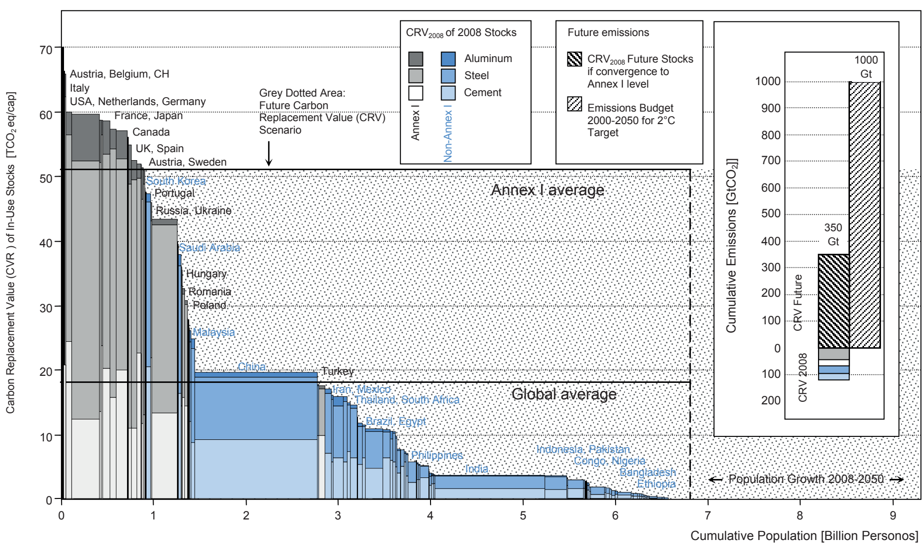
2 Combined challenges of future urbanisation and climate change

Cities have become the dominant form of human settlement on the planet, with urbanisation galloping ahead at a much faster rate than global population growth. This ‘great acceleration’ is in its overwhelming majority taking place in the cities of developing countries and emerging economies, where over 2.3 billion new residents are expected out of a global forecasted population increase of 2.5 billion by mid-century. The regional distribution of urbanisation will be uneven, with the vast majority expected to take place in Asia and Africa. By mid-century, the urban population of Africa is likely to triple and that of Asia to increase by over 60%. Future increases in the world’s urban population are also expected to be highly concentrated in just a few countries. Taken together, China, India and Nigeria are projected to account for 37% of the increase of nearly 2.5 billion people in the urban population by 2050 (UN DESA 2014).

The relationship between urbanisation and economic growth is also very varied, and while the two are historically strongly correlated, in LDCs and in Africa in particular they appear to follow quite separate trajectories. The economies of many African cities may continue to stagnate or grow very slowly, putting additional strains on infrastructure, housing, welfare, and governance. An increasing proportion of urban informality will be the unavoidable consequence of further urbanisation with little or no economic growth, further exposing resident populations to urban risks and depriving them of the improved welfare generally associated with urban life.

Two trends, however, are common to all fast-paced global urbanisation in the 21st century: sprawl (i.e. the increase of the urban land footprint per inhabitant), and an increasing consumption of natural resources and energy for the production of buildings and urban infrastructure. If unmitigated, both have significant implications for the future trajectory of GHG emissions growth. Urban sprawl locks in greater distances between functional city locations, greater infrastructure and energy requirements, and ultimately creates a higher dependency on fossil fuels to keep urban systems operational, while causing labour productivity losses. The construction of the built environment represents huge commitments of natural materials, their extraction, processing and transport, with related energy consumption and emissions outcomes (Seto et al. 2014). These become the 'stocks' of emissions embedded in the built-up cities versus the 'flows' from recurrent or yearly urban energy usage, the only ones to be accounted for in standard urban emissions inventories.

Figure 1 Carbon replacement value per capita of existing stocks by country and as yet unbuilt stocks if developing countries converge on the current Annex I level



Source: Figure 12.12 in IPCC (2014), using data from Müller et al. (2013).

As illustrated in Figure 1, the carbon replacement value (CRV) for reference year 2008 (CRV2008) of key building materials (aluminium, steel and cement) currently embedded in the national building stocks varies greatly, and is largely correlated to per capita GDP. The average CRV for Annex I countries has been calculated at 50 tCO_2eq/capita. Were that average of carbon intensity to be reached by all expected future construction and urban build-up by mid-century, one third of the available carbon budget (1,000 Gt CO_2) would be consumed (with 75% probability). Of this overall emissions budget for the planet to remain within the 2°C temperature increase, approximately 420 $GtCO_2$ have already been emitted during the period from 2000 to 2011.

Table 1 Emerging cities will play a significant role in growth of the global economy and carbon emissions to 2030

Urban group	Projected base GDP growth from 2012–2030 (US$ trillions)	Projected base case emissions growth from 2012–2030 (Mt CO_2)	Projected population in 2030 (BNS)	Per capita in 2030 (tonnes of CO_2 per person)
Emerging cities e.g. Bangalore, Kunming, Pune, Puebla	16	3,230	~1.3	~7.0
Small urban areas inc. villages, small towns, peripheral industrial areas pop. < 0.5 million	16	1,220	~2.2	~4.6
Established cities e.g. Stuttgart, Minneapolis, Stockholm, Hiroshima	11	390	~0.4	~12.1
Global megacities e.g. Beijing, New York, London, Rio de Janeiro	10	1,050	~0.6	~7.1
Total growth	~52	~5,890	Total population in 2030 ~4.5	
Share of world growth	~87%	~65%	Share of world population in 2030 ~4.5	

Source: Figure 2 in GCEC (2014).

In the analysis of the Global Commission on the Economy and Climate, "emerging cities will play an increasingly significant role in growth of the global economy and carbon emissions to 2030. Already in 2014 the GDP generated by China's ninety largest cities amounted to over US$6 trillion, the equivalent of Germany and France's economies combined". Under a business as usual (BAU) scenario, 468 cities will account for over

60% of global income growth over the period 2012-2030, and for nearly half of energy related emissions growth (GCEC 2014).

The subset of 291 ‘emerging cities’ (rapidly expanding, middle-income, mid-sized cities in China, India and other emerging economies) is likely to account for over a quarter of global income growth (US$16 trillion) and over a third of global energy-related emissions growth (3,230 Mt CO_2) over the period 2010-2030. According to the Global Commission, action by this group of cities represents the most significant short- to medium-term global opportunity for avoiding lock-in to long-lived high-carbon urban infrastructure.

‘Small urban areas’ will account for a similar amount of income growth, but for a significantly lower growth in emissions of about 1,220 Mt CO_2 by 2030. This is consistent with the projected increase of urban centres with a population below 100,000, in which 40% of the world’s population are supposed to reside by mid-century. Another 21% will reside in cities of between 100,000 and 1,000,000 inhabitants. This is where much of the urbanisation in LDCs will take place. The lower level of emissions growth in small urban areas is explained by their regional location and by agglomeration dynamics, which concentrate manufacturing and infrastructure in larger urban centres. Governance and institutional capacity are scale and income dependent, i.e. they tend to be weaker in smaller cities and in low-revenue settings. However, as the bulk of urban growth momentum is expected to unfold in small to medium-sized cities in the developing world, significant opportunities for GHG emissions reductions might be precisely in those urban areas where governance and institutional capacities to address them are weakest (Seto et al. 2014).

Cities in general, and particularly those in the developing world, are subject to a number of specific impacts of climate change: ambient temperature rise amplifies the urban heat island effect and generates heat waves, with severe consequences for the resident population, particularly the young, the elderly and the vulnerable; higher temperatures interact with air pollutants and worsen air pollution; more sudden and intense episodes of precipitation overwhelm drainage systems and multiply urban flooding risks; coastal erosion, storm surges and sea level rise threaten wetlands, riverine outflows, as well as seaboard infrastructure and housing in many locations already exposed to land subsidence; and finally, the provision of drinking water is impacted by climatic strains on the resource base. Such impacts are expected to increase significantly by mid-century and onwards, depending on the future trajectories of emissions and of related global warming.

With urbanisation unfolding at such a rapid pace, increasing amounts of urban population, infrastructure, built environment and economic assets will be exposed to these impacts. As cities grow, and especially where urban expansion is not mastered or controlled but is purely driven by demographics and agglomeration economics, they eventually occupy areas at greater risk, be they exposed to intense flooding and landslides, typhoons or hurricanes, or below sea level. This is especially relevant for the low-income, informal settlements typical of LDCs, and for marginal neighbourhoods in middle-income countries.

3 Synergies of urban adaptation, development and resilience

The challenges of urban adaptation to climate change come on top of massive and as yet unmet development needs, especially in LDCs where often weak governance and limited financial and technical resources cannot match the fast pace of urbanisation and the increasing demands for basic urban infrastructure, shelter and welfare. Investments aimed at favouring growth and the productivity of urban agglomerations are required in order to provide the economic and fiscal basis for further urban expenditures. Against this backdrop, LDC governments often perceive urban adaptation as an additional exogenous burden caused by the cumulative historical GHG emissions of wealthier nations. Adaptation is rarely considered as a short-term priority, also in view of the high level of unmitigated exposure to natural hazards that many cities in the developing world are facing. Finally, the limited availability of financial resources for climate adaptation hampers much needed urban responses.

However, urban climate adaptation can be synergistic with investments related to natural hazard risk mitigation, the provision of basic infrastructure, the protection of the urban environment, and the improvement of welfare for the resident population, especially the poor. When such synergies are obtained, adaptation can be more easily mainstreamed in the strategic investment plans of the rapidly urbanising cities of the developing world. Climate change impacts can be mitigated via pre-emptive actions, rather than in a more costly, disruptive and less efficient emergency response modality.

For instance, Durban in South Africa "has adopted and is implementing an eco-systems based adaptation strategy, including a large-scale community reforestation programme where community level '*tree-preneurs*' produce indigenous seedlings and help plant and manage the restored forest areas as part of a larger strategy to enhance biodiversity refuges and water quality, river flow regulation, flood mitigation, sediment control, and improved visual amenity. Advantages include employment creation, improved food security, and educational opportunities". Also, "[i]n Quito, where reduced freshwater supplies are projected with glacier retreat and other climate-related changes, local government has formulated a range of adaptation plans, including encouraging a culture of rational water use, reducing water losses, and developing mechanisms to reduce water conflicts" (Revi et al. 2014).

The benefits of adaptation can therefore be measured not only in terms of avoided damages and losses that would be inflicted on a given city by the impacts of climate change, but also in terms of additional improvements to the overall quality of the agglomeration to be obtained via such investments. For instance, the protection of certain areas from increased risk of flooding and mudslides may result in the upgrading of informal neighbourhoods, with significant social benefits; the management of larger volumes of runoff can lead to the protection of wetlands and waterways with amenity co-benefits for all residents; planting green canopies over central streets may reduce the impact of the heat island effect and of heat waves, while also providing the city with more greenery and more liveable public spaces; a coastal defence project may include the creation of a sea-front promenade and its costs may be offset by increased real estate values and the benefits of waterfront regeneration. Adaptation to climate change can thus become embedded in sustainable urban development and generate further rewards.

4 Synergies of urban mitigation, green growth, and welfare

Similar considerations apply to the task of reducing GHG emissions from cities in developing countries and emerging economies, starting with those that have taken over the bulk of worldwide manufacturing and that are expected to grow the most in population, urban footprint, GDP, energy usage and GHG emissions in the next decades. The green growth paradigm seems to provide the best possible approach to achieve substantial reductions to projected GHG emissions from these cities, and more.

For cities that are expected to add significant amounts of built environment between now and mid-century, the challenge and the opportunity lie in embracing a low-carbon urban development framework, delinking economic growth from energy intensity and energy production from fossil fuels. Important synergies are also to be found between carbon reductions and improvements in urban air quality and related public health and urban welfare, which are much sought-after by residents of large developing and emerging cities. The synergies of air pollution reduction and GHG emissions abatement are significant and may provide the necessary public support for the climate change mitigation agenda.

In the words of the Global Commission on the Economy and Climate, "[n]ew analysis … suggests that the United States could save $200 billion per year if it pursued smarter, more compact growth policies, primarily due to savings in the cost of providing public services and capital investments such as roads. According to the World Bank, China could save up to US$1.4 trillion in infrastructure spending up to 2030 if it pursued a more compact, transit-oriented urban model – equivalent to around 15% of China's GDP in 2013. Analysis for the Commission suggests that more compact, connected urban development could reduce global urban infrastructure requirements by more than US$3 trillion over the next 15 years (2015-2030)" CGEC (2014: 11).

Compact urban growth, connected infrastructure and coordinated governance are the three 'Cs' recommended by the Commission to reduce urban investment requirements, capture productivity gains, abate GHG emissions, significantly improve the quality of urban environments for their resident populations, and lighten the load of cities on natural ecosystems. The IPCC's Working Group III recommends a sustainable low-carbon urban morphology based on density, land-use mix, connectivity and accessibility (Seto et al. 2014).

A similar approach has been tested by urbanist Peter Calthorpe in simulating alternative urban growth and GHG emission scenarios for the United States. Based on current estimates, 60 million new units will have to be added to the housing stock by 2050. The BAU or 'trend sprawl' scenario would increase urbanised land by 38%, and require about US$50,000 per unit of on-site infrastructure alone. In a 'simple urbanism' scenario the demand for urbanised land would be slashed by two thirds, and the costs of on-site infrastructure by half. The increased density and lower infrastructure costs would be achieved by altering the mix of single-family, multi-family homes and town-houses, which would represent 55%, 31% and 14% of the additional stock, respectively, against 67%, 23% and 10% of the BAU scenario. The 'green urbanism' scenario, which would complement compact land-use with aggressive standards for mobility, fuel-efficiency, building efficiency and building retrofits, and high contributions of renewables to energy generation, would reduce additional GHG emissions by three quarters and air pollution by half (Calthorpe 2010).

Compact urban growth is thus articulated to achieve urban quality, encourage mass transit and non-motorised transportation, and create urban environments of high livability, in addition to the pursuit of GHG abatement. In the developing world, Curitiba in Brazil has been the regional pioneer for transit-oriented development since the 1970s, and its example has been followed by a number of more recent large-scale urban retrofits of mass transit systems, such as Bogotá's *Transmilenio*, which have contributed to limiting traffic congestion and air pollution, increasing labour productivity, reducing GHG emissions, and improving public health and quality of urban life in various Latin American cities.

Thus, the benefits and costs of carbon mitigation need not be measured only through dedicated GHG abatement cost curves, but rather as part of broader assessments of green growth yielding multiple parallel benefits as a result of sustainable urban strategies.

5 New urban policy directions, innovations, and city learning

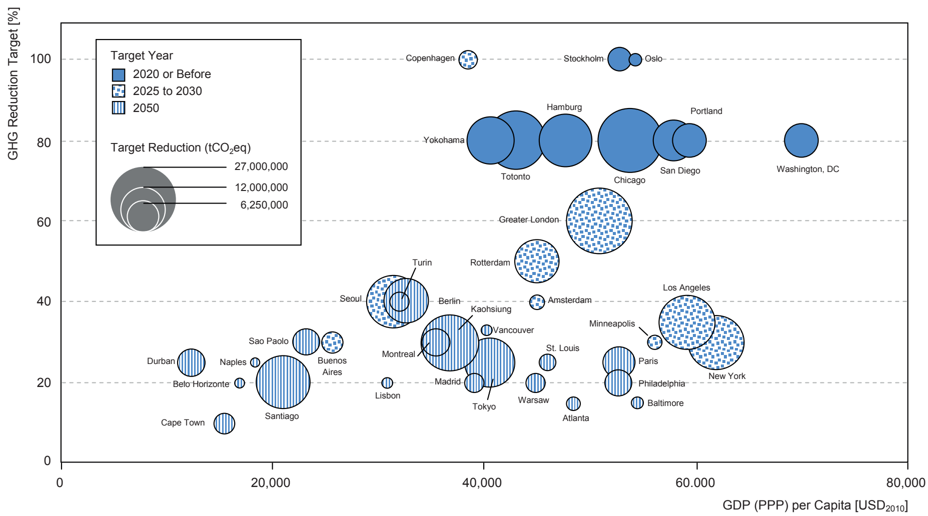
In the previous sections of this chapter, adaptation and mitigation, as well as their respective linkages with sustainable urban development and green growth, have been addressed separately. However, recent urban practices worldwide are demonstrating that the most successful urban climate policies integrate the adaptation and mitigation agendas. Many Climate Actions Plans – the ‘road maps’ that urban governments prepare in order to embark on, and then monitor, their strategies for climate action – include investments for adaptation as well as for mitigation, and many such actions naturally converge.

For instance, investments in providing a higher level of thermal insulation of the building stock, whether via the construction of green buildings or retrofitting existing ones, will certainly provide adaptation to a warmer climate, but will also mitigate GHG emissions on account of lower building energy usage. Green infrastructure meant to manage excessive, sudden runoff and to provide protection against flooding will also generate urban cooling comfort and absorb carbon emissions. Effective waste management and recycling will provide protection of urban waterways and public spaces from uncontrolled dumping, but also methane sequestration and a reduced consumption of natural resources.

Many cities in OECD countries have been generating substantive innovations by internalising the climate change agenda and making it an opportunity for countercyclical economic investments, urban renewal, job creation, jumpstarting the urban green economy, and developing specific and exportable know-how on managing cities in a warming world. Some cities have already achieved deep cuts in local GHG emissions and have increased their resilience and adaptation to climate change impacts. Urban commitments to mitigation often surpass the ones of national governments, showing that cities can lead the way forward.

As illustrated in Figure 2, some cities such as Copenhagen, Stockholm and Olso are ‘ahead of the curve’ and are showing that the urban economy can be entirely decarbonised, and indeed have committed to do so by 2030 or by 2050. Such cities clearly benefit from a high GDP per capita, a long-standing commitment to environmental sustainability and urban quality of life, a pro-active policy environment and supportive populations. Their mix of GHG abatement solutions includes compact urban form and density, non-motorised transportation and mass-transit systems, energy efficiency of the built environment, on-site and off-site renewables, heat and energy co-generation from waste management, as well as carbon offset programmes. Their examples pave the way for more urban innovation globally.

Figure 2 Mitigation targets for 42 cities



Source: Figure 12.21 in IPCC (2014); baseline emissions, reduction targets, and population from self-reported data submitted to Carbon Disclosure Project (2013).

In the EU's policy context, the Covenant of Mayors was set up in 2009 as a voluntary network of local governments committed to the EU goal of a 20% reduction in GHG emissions by 2020 over the 1990 baseline, with 20% of renewables in the energy mix. With vast control over local infrastructure, built environment construction regulations, waste management, and utility provision, city and regional governments are best suited to assess local energy usage, formulate GHG reduction strategies, and mobilise civil society and private-sector actors. Over 6,000 local governments representing 200 million citizens have signed on to the Covenant and are currently implementing emissions abatement programmes, many of which promise to surpass the EU-wide stated goal.

Not many cities in the developing world have gone as far, although some champions have emerged and many adaptation and mitigation projects are currently being implemented. Cities like Mexico City, Rio de Janeiro and Medellin in Latin America, Amman in the Middle East, Bangkok, Jakarta, Beijing and Shanghai in East Asia, Addis Ababa and Durban in Africa, Mumbai and Dhaka in South Asia, and many others are tackling climate change challenges. The plethora of developmental priorities that cities in the developing world have to contend with, as well as the limits to financial and technical resources available, constrain the extent to which climate change has been addressed so far.

Over the past decade there has been a great increase in development assistance for urban climate change mitigation and adaptation by numerous multilateral and regional banks and agencies. They provide financial resources and technical assistance for specific investments, as well as for urban risk assessments, citywide emissions inventories and the development of low-carbon strategies, as well as for the expansion of carbon markets. Their support, as well as that of some key foundations, also facilitates the transfer of innovations from OECD cities to developing and emerging cities. Research programmes in major universities worldwide have generated a rich literature of case studies on the specifics of urban climate change, better informing urban decision making.

Some major international city networks have emerged, such as ICLEI and C40, which focus their work on policy and experience sharing and on providing assistance to their members for urban climate action planning and implementation, including in the cities of the developing world. Working through effective mayor-to-mayor collaboration, they play an invaluable role in prompting innovations, facilitating exchanges, and raising the priority of urban climate change action worldwide.

6 An international framework in support of resilient and low-carbon cities

Paradoxically, despite the finally prevailing view that cities are ‘part of the solution’ and not only ‘part of the problem’ in the global fight against climate change, they do not have any official role or ‘seat at the table’ in the context of international negotiations. These are conducted within the UNFCCC by national governments and their delegations. The Compact of Mayors, the World Mayors Council on Climate Change and other municipal networks have emerged in the past decade to ensure that the essential voice of cities is heard at the negotiations and beyond. Going forward, INDCs should clearly report their urban components so that the contributions of cities in mitigating GHG emissions may be internationally accounted for and recognised for the importance they have in meeting this global challenge.

The ongoing momentum of climate action in cities can be greatly boosted by a framework agreement at the international level, especially if it contains specific provisions to engage and support cities in the developing world, based on their specific characteristics, challenges, constraints, GHG emissions levels and climate vulnerabilities. Below are four recommendations on how an international framework agreement could provide support:

1. **Increase the amount of international funding for urban adaptation, especially in LDCs**. This could allow many cities critically at risk of climate impacts to carry out essential investments in coastal protection, flood control, water supply and other priority areas. The Green Climate Fund should provide the funding; multilateral and regional development banks should be the delivery vehicles and provide the related technical assistance, as they are engaged with assisting cities with infrastructure investments.
2. **Multiply opportunities for channelling carbon financing into urban green growth**. The growing relevance of emission trading schemes and carbon pricing already includes cities in the OECD as well as emerging economies. For cities to better participate in carbon markets, carbon emissions reductions originating from many urban sectors should be integrated and certified. The Global Protocol for Community-scale GHG emissions is becoming the internationally recognised standard and should be further endorsed.
3. **Make international financial support dependent on innovative urban policies**. Policy guidelines should ensure that financial resources for urban climate action integrate adaptation with sustainable urban development, and mitigation with green growth policies. Technical assistance for urban risk assessments and emissions inventories should be multiplied to develop optimal strategies, as the basis for political support and financing. Private sector actors could be further engaged in providing know-how.
4. **Support international learning, networking and knowledge-sharing programmes**. The voluntary efforts of membership-based associations need to be

supported financially as they can greatly accelerate the up-take of climate action in the developing world's cities. Specific knowledge-sharing programmes on metropolitan governance, climate-friendly fiscal policies and creditworthiness can facilitate the access of cities in emerging economies to capital markets and make their climate strategies more effective.

References

Calthorpe, P. (2010), *Urbanism in the Age of Climate Change*, Washington, DC: Island Press.

Carbon Disclosure Project (2013), *CDP Cities 2013: Summary Report on 110 Global Cities*, London.

Global Commission on the Economy and Climate (GCEC) (2014), *The New Climate Economy: Better Growth, Better Climate*.

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Müller, D.B., G. Liu, A. N. Løvik, R. Modaresi, S. Pauliuk et al. (2013), "Carbon Emissions of Infrastructure Development", *Environmental Science & Technology* 47: 11739–11746.

Revi, A. , D. E. Satterthwaite et al. (2014), "Urban areas", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Seto, K.C., S. Dhakal et al. (2014), "Human Settlements, Infrastructure, and Spatial Planning", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

UN DESA (2014), *2014 Revision of World Urbanization Prospects*, New York: United Nations.

About the author

Anthony G. Bigio is Adjunct Professor at George Washington University's Sustainable Urban Planning graduate programme, and an urban advisor with over 30 years of international experience. He retired from the World Bank in 2013 after a two-decade career in urban development spanning projects on cities and climate change, urban resilience, urban environmental management, earth observation for development, low-cost housing, urban poverty reduction, and urban cultural heritage. He was a Lead Author for the Intergovernmental Panel on Climate Change's Fifth Assessment Report's chapter on human settlements, infrastructure and spatial planning, and technical reviewer of the chapter on urban impacts of climate change. He is Green Growth Advisor for The Growth Dialogue, a policy programme of GW Business School; member of the Advisory Boards of the New York-based UCCRN (Urban Climate Change Research Network) and of the EU-funded POCACITO research project (Post-Carbon Cities of Tomorrow). He consults and lectures internationally on urban resilience and urban green growth and has published extensively on the topics of urban development, climate change and urban cultural heritage.

31 Meaningful technology development and transfer: A necessary condition for a viable climate regime

Heleen de Coninck and Shikha Bhasin
Radboud University; Energy research Centre of the Netherlands (ECN)

Technology development and transfer, or 'technology cooperation', facilitating climate change mitigation and adaptation, is widely understood to be an integral part of the solution to human-induced climate change. It is embedded in the UNFCCC's negotiating text, and has gained weight over the years as a necessary condition for a viable climate regime – especially with the establishment of the Technology Mechanism that emerged as part of the Cancun Agreements. The Technology Mechanism's implementation, however, has seen mixed success so far, and is limited by resources and politics. This chapter explores necessary conditions and concrete options for a treaty in Paris (and beyond) that provides for successful technology development and transfer for climate change mitigation and adaptation. Conditions include (1) global and active recognition, in all UNFCCC bodies, that capabilities and innovation systems in the field of adaptation and mitigation technologies need to be strengthened before markets can be effective; (2) financial commitments that allow for the Technology Mechanism to fulfil its mandate as agreed in the Convention; and (3) a variety of practical arrangements, including a research and development cooperation body to be instituted within the Technology Mechanism.

1 Introduction: The transformational challenge

This chapter investigates whether and how meaningful provisions for technology development and transfer in a climate regime can contribute to broad participation from developed and developing countries. This translates into what individual countries stand to gain from the overall agreement, and from the technology part specifically (Barrett and Toman 2010), as well as what is needed for the availability of low-carbon technology in all countries. The most commonly used argument for technology development and transfer (sometimes summarised as 'technology cooperation') under the UNFCCC revolves around R&D for cost reduction; although we have heard for years now that deep emission reductions can be achieved by technologies that are available today (e.g. IPCC 2014, Pacala and Socolow 2004), reducing costs through research is thought to be key for successful implementation of those technologies (see the chapter by Toman in this book).

If only it were that simple. The problem of technology implementation goes well beyond cost reduction. Technology functions in a social and cultural context (Cherlet 2015), market failures are prominent (Grubb et al 2013), and the incumbent socio-technical regime is incredibly robust (Geels 2002). As an example, achieving a global low-carbon energy system requires bringing about change in every single aspect of energy demand and supply, involves many actors, is up against huge vested interests and technological lock-in, and hence requires a major intervention in economic and cultural systems. Such a complex, multi-level change to the fundamental attributes of a system is often characterised as transformational change (O'Brien 2011, IPCC 2014). As transformational change is essential for staying within a 2°C global mean temperature rise, the climate negotiations ought to place more emphasis on taking the conversation on transformational technological cooperation forward.

Transformation (in energy, but also in other mitigation and adaptation-relevant sectors) is an issue for every country, but in developing countries the challenges are compounded by lower capabilities, weak institutions and widespread poverty. The specific situation of developing countries needs to be taken into account in the UNFCCC, both in the area of mitigation and adaptation.

The UNFCCC allows for a conversation on transformations, notably in the specific circumstances of developing countries, in its discussions around technology development and transfer, which is where long-term challenges, enabling environments, national systems of innovation, and capabilities are discussed. Provisions for technology development and transfer are engrained in the Convention but have had cursory follow-up (Haselip et al. 2015). Recently, the Technology Mechanism has been set up as the first international body explicitly aimed at enhancing climate technology development and transfer in both adaptation and mitigation (see below for further discussion). Although it is too early to tell whether its efforts will bear fruit, and an overall estimate of the (monetary) size of the effort to bring about transformational change is definitely several orders of magnitude bigger, it is clear that the current funding (of around US$30 million over five years) and the arrangements (based on one-off contributions from donor countries) provide too little to make a difference for a 2°C trajectory (Coninck and Puig 2015). Moreover, its mandate is not used to the full because of political barriers, including a hidden anxiety on the part of the current technology leaders to create their own competitors (Coninck and Sagar 2015). Therefore, this chapter indicates what key improvements can be made to the UNFCCC Technology Mechanism, and what the 2015 climate change deal, agreed at COP21, could include on technology.

2 What does 'technology development and transfer' mean?

As the word 'technology' is often misinterpreted, it is used with some hesitation in this chapter. Technology, to climate policy researchers and practitioners, evokes thoughts of renewable energy, electric vehicles and CO_2 capture installations. However, among scholars in innovation studies, and among a sizeable group of climate change negotiators, the word technology also incorporates the complex fabric of capabilities, institutions, connections, networks, policies and cultures that are an inalienable part of any strategy for renewable energy, electric vehicles or CO_2 capture installations. Many case studies support this view, for instance studies of the development of the solar and wind energy industry in India (Chaudhary et al. 2015) and the PV or battery industry in China (Gallagher 2014).

Technology development and transfer, as intended in the Convention, goes well beyond R&D agreements as discussed in Toman's chapter in this book – the Convention acknowledges that it is also about credible mechanisms that allow developing countries to 'catch up' technologically, to develop their own appropriate innovation capabilities, to make use of indigenous knowledge, and to become full participants in the global technological market place. Such mechanisms ought to enable developing countries to implement their own mitigation strategies and to benefit economically from other countries' mitigation strategies by becoming suppliers of the required knowledge and installations, much like China has managed for solar PV and other technologies. 'Catching up technologically', then, is very much a development question, relating to education systems, effective government interventions and entrepreneurial spirit. This is also indicated in Mekonnen's chapter in this book, specifically in relation to Africa.

The IPCC's definition for 'technology transfer' reflects this by comprising international transfer of installations and hardware, but also transferring and developing local capabilities, institutions and other non-hardware elements that are required for realisation of the hardware and the ability to improve on it (IPCC 2000). Therefore this chapter treats 'technology' in its manifestations as hardware (the installations), software (operational, manufacturing and innovation capabilities) and 'orgware' (institutional and policy capabilities). There are many documented examples of why this is relevant, from the implementation of energy-saving lightbulbs in Kenya and Ghana, which demonstrated the crucial role of local capabilities and manufacturing (Byrne 2013), to low-carbon and energy-efficient cement in sub-Saharan Africa, which relied on a range of factors, such as market liberalisation, government support for industrial development, activities of equipment suppliers, and OECD-based multinationals, local technical capacity and information and finance access (Ionita et al. 2013).

Consequentially, the question answered in this chapter is not limited to the hardware installation question of how do we get more solar PV and CCS installed globally, as discussed in the chapters in this book on CCS by Tavoni and on renewable energy by Bossetti. Rather, it answers the more political question of how participation and feasibility of an international climate regime can be improved by making technology part of the portfolio of agreements, and doing this in a meaningful way. The technology theme can thus also be seen as a building block or an enabler of mitigation and adaptation strategies in development, as discussed in the chapter by Stewart, Rudyck and Oppenheimer.

3 Assessment of current provisions for technology within and outside the UNFCCC

3.1 Technology in the UNFCCC: 1992-2009

Technology has been an item in the UNFCCC since its inception in 1992; it is mentioned in Article 4.5, which states (UNFCCC 1992):

> *The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and knowhow to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. (…).*

Clearly, the Convention obliges developed countries to assist in technology transfer, and it also explicitly mentions the relevance of building capabilities.

The technology development and transfer item under the UNFCCC went without much in terms of conclusions on actions in the field of technology development and transfer. This situation got worse over the years, as the developing countries continued to find evidence that developed countries were not compliant with the provisions of Article 4.5. In addition, discussions around intellectual property rights stalled progress in the negotiations, even up to the ministerial level (Abdel-Latif 2015).

The main activity that has been undertaken under the realm of the UNFCCC in the period until the Copenhagen Accord is the formulation of Technology Needs Assessments (TNAs), which aim to outline and prioritise activities around technology transfer under Article 4.5 in developing countries (and if appropriate, financed by Annex II countries). The first round of TNAs or similar activities in 60 countries was summarised in a synthesis report (UNFCCC 2006), which suggested that the technology and capacity needs, as well as barriers to technology transfer, are relatively clear but that actions to address them are not pursued in most cases. Even after improvements in later rounds, it is unlikely that the TNAs significantly influenced decisions by developed countries for the allocation of assistance. Speculations about the reasons for this presumed lack of impact could include the appropriateness and user-friendliness of the documents, the often still far from ideal inclusiveness of the process of drafting the TNAs, and their insensitivity to matters of political timing.

3.2 Technology Mechanism: 2010 to present

One of the achievements of the Bali Action Plan (2007) and the Cancun Agreements (2010) (UNFCCC 2010) has been the development of a Technology Mechanism (TM) under the UNFCCC. After nearly two decades of painful and fruitless discussions on technology transfer, here was an outcome that developed and developing countries could accept and that helped cement the Cancun Agreements, an important package deal. Indeed, without the Technology Mechanism (in addition to discussions on loss and damage, the Green Climate Fund and the Adaptation Fund), developing countries would not have accepted the start of the breakdown of the firewall between Annex I and non-Annex I countries as agreed at COP 17 in Durban, and would not have committed to all countries submitting Intended Nationally Determined Contributions (INDCs). Technology is considered to be one of the mainstays of developing countries' negotiating points, and the Convention will have to deliver on it if it wants a balanced treaty that is agreeable to developing countries.

Moreover, as countries are submitting their INDCs, the emphasis on mechanisms to deliver technology development and transfer is even more evident. Several developing countries have put forward emissions reduction targets that are dependent on international support through technology transfer and cooperation, finance and capacity building. For example, as also noted by Kaudia in her chapter in this book, Kenya's INDC states plainly that its ambition to cut emissions by 30% by 2030 relative to the BAU scenario is "subject to international support in the form of finance, investment, technology development and transfer, and capacity building" (Republic of Kenya 2015). Mexico's INDC includes a commitment to lower its emissions by 40% by 2030 compared to BAU that is conditional on similar provisions (Republic of Mexico 2015).

The Technology Mechanism was designed to include a “policy arm” (the Technology Executive Committee, or TEC) and an “implementation arm” (the Climate Technology Centre and Network, or CTCN). The TEC was created with the intention of “providing an overview of needs for the development and transfer of technologies for mitigation and adaptation”, and to suggest policies and initiatives to encourage ‘technology cooperation’. The CTCN was expected to “facilitate national, regional, sectoral and international technology networks, organizations and initiatives to mobilize and enhance global clean technology capabilities, provide direct assistance to developing countries, and facilitate prompt action on the deployment of existing technologies” (UNFCCC 2010). It was envisaged that linkages between the Technology Mechanism and the Financial Mechanism would also be established, but so far no agreement could be reached on such a link.

The TEC has met over ten times since it started operations in 2011. It has produced a number of policy briefs on relevant topics, but it has not lived up to the hopes of being the go-to place for technological advice and a trusted source of information on technology development and transfer for developing countries. One of the issues seems to be lack of resources, and another the composition of the TEC – most members, both from developed and developing countries, are climate negotiators, which hampers practical discussions and replicates the same deadlocks and differences that can be observed in the climate negotiations (Coninck and Sagar 2015). If selection of TEC members could be based more on expertise, it might grow into the body that was envisaged when it was installed.

The CTCN is designed in such a way that it has more distance from the UNFCCC, as it operates mainly on its own account (although strategic guidance is given by a negotiator-populated Advisory Board). Its main activity so far is responding to requests by developing countries, through their newly instituted National Designated Entities, established especially for the CTCN. It is also supposed to develop a global network of organisations that are actors in the climate technology space – private, public, civil society and research actors. This Climate Technology Network is the hope of the developing countries – the diverse institutions (including companies, research organisations and NGOs) in the network are the places where capabilities for operation, maintenance, manufacturing and innovation on climate technology ought to be built.

Notably, although the mandate of the CTCN includes R&D cooperation (UNFCCC 2011), no activities have been facilitated in this space so far.

The CTCN started in February 2014, so is relatively young. Responding to requests, based on currently available information, seems to work properly. Requests vary from policy and technical assistance to research cooperation, and are so far evenly spread between adaptation and mitigation. The main weakness of the CTCN so far resides in the 'N', which non-Annex I Parties actually find the most important. There is no vision for what the Climate Technology Network will do, how it will be built up, and in particular how it will amount to relevant capabilities in developing countries, in particular least-developed countries. The CTCN director has also be calling for increased funding for the CTCN, which despite an earlier mandate in COP documents, does not enjoy structural funding and needs to fundraise from donors to be able to pursue its activities.

3.3 Non-UNFCCC technology interventions and financing

The vast majority of the activities around technology development and transfer, of course, take place outside of the UNFCCC. For instance, the private sector acts as an exporter and developer of technology, as a financier, and as a project developer. In order to address the barrier of accessing finance for riskier climate technologies, multilateral development banks have installed Climate Investment Funds that are funded by developed country development ministries. Numerous national, bilateral and international programmes that operate outside of the climate field contribute to global technology development and transfer, technology cooperation, green growth and the like (Hultman et al. 2012, Ockwell et al. 2015). It is hard to ascertain the level of technology cooperation (and the finance supporting it) outside of specific programmes. In addition, several authors have indicated that it is – probably unintentionally – even difficult to obtain an overview of just the public sector-initiated interventions on climate technology (Hultman et al. 2012, Coninck and Puig 2015, Ockwell et al. 2015).

4 Practical way forward for technology in the 2015 climate change agreement

No one believes that the UNFCCC will be the one and only institution for the global development and transfer of mitigation and adaptation technologies, or to facilitate grand transformative changes of the global energy system. However, many, in particular those based in developing countries, view the technology arrangements in the 2015 Paris climate change agreement as a condition for agreement as well as for implementing INDCs.

Moreover, developing countries value 'technology' as conditional to their right to development – specifically, fair access to technology, an opportunity to develop capabilities and the chance to play a role in the global technology market. Contrary to this, the behaviour of developed countries in the technology sphere is seen as protecting own technology interests. This can be understood in terms of an attempt to lower domestic political and social tensions in times of economic crisis and mounting international competition.

A balanced climate agreement would require provisions for technology cooperation to go forward. These could include the following elements:

- For technology cooperation on R&D, the Paris agreement should include provisions for an R&D cooperation body, possibly under the Technology Mechanism. Several authors have alluded to this in slightly different forms. We have argued earlier (UNEP 2010, Bhasin 2013) that the Technology Mechanism could facilitate setting up a multilateral single or distributed research body, similar to the CGIAR Research Programmes and Funds (established as the Consultative Group on International Agricultural Research). This could focus on R&D of low-carbon technologies cutting across national borders based on global public goods concerns relating to climate change. This would encourage scientific innovations and boost innovation capacities of developing countries. Similarly, in his chapter in this book, Toman argues for an int````ernational agreement to coordinate national RD&D programmes for low-carbon energy and to share the fruits of discoveries.
- As for improved innovation capabilities in developing countries, developed countries need to acknowledge that it is in their own interest to assist developing

countries in building these capabilities, as only when that happens will developing countries be able to achieve their INDCs and commit to further contributions to reducing emissions. The Technology Mechanism, in particular the CTCN through its network, could play a key role in this, but is not yet living up to expectations; more resources and an ambitious interpretation of its mandate are badly needed. In addition, the CTCN could encourage NDEs to submit requests that aim to increase capacity of a sector or the national innovation system.

- Climate technology development and transfer needs finance too. The Parties should elaborate on the provisions for financing technology development and deployment. They could decide in Paris to encourage partnerships between the Technology Mechanism bodies and multilateral development agencies, private sector associations, as well as specific climate-change financing bodies such as the Green Climate Fund. Until now, Parties in the UNFCCC have not agreed on a 'technology window' in the Green Climate Fund, or any other form of structural funding for technology activities. Without such provisions assuring financing, technology in the climate regime will not be able to play its envisioned role.

Since IPR remains a sticking point in the technology development and transfer negotiations, the TEC could attempt to bridge the gap between developing and developed countries by allowing discussion of a number of open licensing mechanisms (such as 'patent pools', open access, patent information databases, etc.) and supporting capacity building within developing country NDEs or other agencies. This should aim at contributing to developing countries' understanding of the legal nuances of using these pools, technology management, and familiarising scientists and lawyers in developing countries with patent drafting. It should also support the identification of projects that can benefit open-access technologies (Bhasin 2013). At the very least, discussion based on case-by-case evidence of the role of IPR in technology cooperation would be helpful, as the current oversensivity to the topic is blocking progress.

Technology is broadly viewed as a key building block in the climate regime and part of the package deal that will eventually be struck at COP21 in Paris. Despite sparse attention to the theme, the strength, financing, and design of the technology provisions in the Paris agreement will determine whether developing countries will accept the outcome of COP21. Ambitious yet realistic provisions around R&D cooperation, innovation capabilities and finance is urgently needed, so that 'technology' can be the dealmaker it ought to be.

References

Abdel-Latif, A. (2015), "Intellectual property rights and the transfer of climate change technologies: issues, challenges, and way forward", *Climate Policy* 15(1): 103-126.

Barrett, S. and M. Toman (2010), "Contrasting future paths for an evolving global climate regime", *Global Policy* 1(1): 64-74.

Bhasin, S. (2013), "International Technology Cooperation: Lessons for the Upcoming Technology Mechanism of the United Nations Framework Convention on Climate Change", Briefing Paper 20/2013, Germany Development Institute, Bonn.

Byrne, R. (2013), *Climate Technology & Development Case study: Compact Fluorescent Lamps (CFLs)*, London: Climate Strategies.

Chaudhary, A., C. Krishna and A. Sagar (2015), "Policy making for renewable energy in India: lessons from wind and solar power sectors", *Climate Policy* 15(1): 58-87.

Cherlet, J. (2014), "Epistemic and Technological Determinism in Development Aid", *Science, Technology & Human Values* 39(6): 773-794.

Coninck, H. C. and D. Puig (2015), "Assessing climate change mitigation technology interventions by international institutions", *Climatic Change* 131(3): 417-433.

Coninck, H. C. and A. S. Sagar (2015), "Technology in the 2015 Paris Climate Agreement and beyond", forthcoming.

Gallagher, K. S. (2014), *The Globalization of Clean Energy Technology*, Cambridge, MA: MIT Press.

Geels, F. W. (2002), "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study", *Research Policy* 31(8): 1257-1274.

Grubb, M., J. C. Hourcade and K. Neuhoff (2013), *Planetary Economics: Energy, climate change and the three domains of sustainable development*, London: Routledge.

Haselip, J., U. Hansen, D. Puig, S. Trærup and S. Dhar (2015), "Governance, enabling frameworks and policies for the transfer and diffusion of low carbon and climate adaptation technologies in developing countries", *Climatic Change* 131(3): 363-370.

Hultman N., K. Sierra, J. Eis and A. Shapiro (2012), *Green growth innovation: new pathways for international cooperation*, Washington: GGGI and the Brookings Institution.

Ionita, R., L. Würtenberger, T. Mikunda and H. de Coninck (2013), *Energy efficiency and GHG reduction in the cement industry. Case study of Sub-Saharan Africa*, London: Climate Strategies.

IPCC (2000), *Methodological and Technological Issues in Technology Transfer,* Cambridge, UK: Cambridge University Press.

IPCC (2014), *Climate Change 2014: Mitigation of Climate Change* (see the Introduction to this book for the report's complete reference).

Kaudia, A. A. (2015), "Policy options in low-income countries: Achieving socially appropriate climate change response objectives", Chapter 27 in this book.

Mekkonen, A. (2015), "A view from Africa", Chapter 5 in this book.

O'Brien, K. (2011), "Global environmental change II: From adaptation to deliberate transformation", *Progress in Human Geography* 36(5), 667-676.

Ockwell D., A. S. Sagar and H. C. de Coninck (2015), "Collaborative research and development (R&D) for climate technology transfer and uptake in developing countries: towards a needs driven approach", *Climatic Change* 131(3), 401-415.

Pacala, S. and R. Socolow (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies", *Science* 30s: 968-972.

Republic of Kenya (2015), "Kenya's Intended Nationally Determined Contribution (INDC) under the UNFCCC" (accessed 13 August 2015).

Republic of Mexico (2015), "Mexico's Intended Nationally Determined Contribution (INDC) under the UNFCCC" (accessed 13 August 2015).

Stewart, R., B. Rudyck and M. Oppenheimer (2015), "A building blocks strategy for global climate change", Chapter 15 in this book.

Tavoni, M. (2015), "Carbon capture and storage (CCS): Promise or delusion?", Chapter 24 in this book.

Toman, M. (2015), "International cooperation in advancing energy technologies for deep decarbonisation", Chapter 22 in this book.

UNEP (2010), "An exploration of options and functions of climate technology centres and networks", UNEP Discussion Paper, Paris.

UNFCCC (1992), *United Nations Framework Convention on Climate Change*, Bonn.

UNFCCC (2006), *Synthesis report on technology needs identified by Parties not included in Annex I to the Convention*, Bonn.

UNFCCC (2010), "Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010", Bonn.

UNFCCC (2011), "Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention to be presented to the Conference of the Parties for adoption at its seventeenth session. Draft conclusions by the chair", Bonn.

About the authors

Heleen de Coninck is Associate Professor of Innovation Studies in the Environmental Science Department at Radboud University's Faculty of Science. Before joining Radboud University in 2012, she worked for over ten years in the Policy Studies unit of the Energy research Centre of the Netherlands (ECN). Her main field of work is climate change mitigation and policy analysis, in particular low-carbon technology, innovation and development questions at the international level. Heleen is currently the chair of Climate Strategies, a climate policy research network that aims to improve the linkage between climate policy research and the negotiations at the European and UN level. Heleen holds master's degrees in Chemistry and in Environmental Science (2001), and conducted her PhD (2009) on technology in the international climate regime at the VU University Amsterdam in collaboration with Princeton University and ECN.

Shikha Bhasin is a Researcher in the Policy Studies team of the Energy research Centre of the Netherlands (ECN). Her expertise lies in areas of international climate mitigation policies, low-carbon innovation systems, and international technology cooperation. She holds an MSc from the London School of Economics and Political Science in Global Politics, with a specialisation in the International Political Economy of Environmental Negotiations. Before joining ECN in 2014, Shikha worked with the German Development Institute on a cross-country low-carbon technology trajectory research project, and has written several papers on questions of technology policies, innovation, and cooperation.

PART VII

Climate Finance

32 The macroeconomics of climate policy: Investments and financial flows

Emanuele Massetti
Georgia Institute of Technology

This chapter illustrates the plausible implications of climate mitigation policy on investments in power generation and on the energy sector in general. The chapter also discusses climate policy related financial flows. The goal is to inform policymakers about a wide range of macroeconomic effects of climate policy and on plausible investment needs in developed and developing countries.

1 Introduction

A large number of studies have examined the technology transformations and the economic cost of many different scenarios of climate mitigation policy (Clarke et al. 2014). Virtually all the scenarios provide estimates of the economic cost of climate mitigation and detailed information on the least-cost technological options to achieve the desired level of greenhouse gas (GHG) concentrations. The technical feasibility and the macroeconomic cost for society of alternative pathways to stabilise the emissions of GHGs are of paramount importance for policymakers and climate negotiators.

The priorities of the research community are thus well justified. However, policymakers and negotiators also need other valuable information, such as on investments and other financial flows induced by climate mitigation policy. For example, the distribution across countries and over time of investment needs is important when negotiating burden-sharing agreements. Economists suggest that carbon taxes or trading of emissions permits are the most efficient policy tools to decarbonise our economies, and that carbon tax revenues can be used to increase the efficiency of the tax system. Policymakers have often expressed interest in using carbon tax revenues to boost mitigation and adaptation efforts. It is thus important to know in advance the expected financial flows from carbon pricing. There are also other politically sensitive questions that cannot be addressed without a broad overview of the macroeconomic consequences of climate policy. For example, all scenarios that stabilise GHG emissions in line with a 2°C target indicate that consumption of fossil fuels must be drastically cut and consumption of bioenergy must increase to many times above the present level. What are the financial implications for fossil fuels producers? What is the long-run effect of climate mitigation policy on the balance of payments of large exporters of fossil energy? How large are the revenues expected to be for the producers of biomass?

Unfortunately, none of these questions has been answered in a satisfactory manner. The most recent Working Group III report to the IPCC, for the first time, has a whole chapter dedicated to cross-cutting investment and financial issues of climate mitigation policy (Gupta et al. 2014). Nevertheless, one of the main messages from this chapter is that the literature still has very large gaps.

There are, however, a growing number of studies that provide insights on a wide range of macroeconomic impacts of climate policy. The goal of this chapter is to survey this literature and to present results and insights that, albeit still partial and uncertain, have implications for climate change negotiations. There are also a growing number of studies that look at the current global climate finance landscape (e.g. Buchner et al. 2014 and the chapter by Buchner and Wilkinson in this book). This chapter will not review those studies and will focus only on the literature that uses Integrated Assessment Models (IAMs) to estimate future investment needs and financial flows.

The rest of the chapter is structured as follows: Section 2 reviews the literature that develops scenarios of future investment needs in climate change mitigation; Section 3 assesses potential revenues from carbon pricing; Section 4 reviews estimates of investment needs in climate change adaptation; and conclusions follow.

2 Investment needs

Without climate policy, the largest fraction of investments in the power sector is expected to go to fossil fuel generation (Gupta et al. 2014). The mean estimate of annual investments in fossil fuel generation among the surveyed studies is equal to US$182 (95 to 234) billion in 2010–2029 and $287 (158 to 364) billion in 2030–2049. This is equivalent to about 50% of total investments in power generation from 2010 to 2049. Of these investments, 80% are expected to go to non-OECD economies.

All the surveyed studies see a strong growth in renewables in the BAU scenario, with annual mean investments ranging from $131 billion to $336 billion from 2030 to 2049. Investments in nuclear power generation are also expected to grow, but there is more uncertainty here in the literature. Between 2030 and 2049 the surveyed studies generate scenarios that range between zero, which implies a phase out of nuclear, to $155 billion per year.

Climate policy that aims to stabilise GHG concentrations at between 430 and 530 ppm CO_2-eq by 2100 (with about 50% probability of achieving the 2°C target) sharply redirects investments from fossil fuel generation to renewables, nuclear power and fossil fuel power plants with carbon capture and storage. Renewable generation technologies and nuclear will require higher up-front capital investments but no, or only little, expenditure on fuels. Fossil fuel power plants with carbon capture and sequestration (CCS) will require both higher up-front capital costs and higher expenditure on fuels, due to the loss of efficiency in order to capture CO_2.

By shifting investments away from fossil fuel power plants, climate policy has the potential to increase investment needs. However, by making power generation more expensive, mitigation policy increases the incentive to reduce the demand for electricity, which decreases the need for investments. Which of the two effects prevails is a matter of empirical investigation.

Overall, the median scenarios suggest that investments in power generation will increase under climate policy, by about $100 billion per year until 2029 and by $400 billion per year between 2030 and 2049. Additional data is reported in Table 1. This investment amount is largely equivalent to the present global flow of investments in power generation (McCollum et al. 2013). To put this into perspective, $400 billion per year is equivalent to 0.5% of gross world product in 2013. However, assuming a 2.5% growth rate from now to 2050, the incremental investments will be equal to just 0.2% of gross world product in 2050. Other studies have found that investments in power generation may instead decline with respect a BAU scenario due to a sharp decline in electricity demand (Carraro et al. 2012, Iyer et al. 2015).

None of the estimates cited above includes investments for the grid or for storage of renewable power generation, because virtually none of the studies surveyed by the IPCC provided this information. One study finds that an additional $17 billion per year is necessary to upgrade transmission and distribution lines and to build storage capacity to manage renewable power generation (Riahi et al. 2012).

Investments in energy efficiency are hard to assess because energy efficiency can be increased in many ways. Energy efficiency improvements are often embodied in new vintages of capital and it is hard to disentangle the cost of each component of complex machineries. Energy efficiency is also increased by investing in new materials and new management practices that cannot be easily quantified. Two studies surveyed by the IPCC suggest that incremental investments in energy efficiency may top $600 billion per year in 2030 and $800 billion per year in 2050 (Gupta et al. 2014 and Table 1).

It is also very rare that models estimate how complex factors such as institutions affect the cost of financing. Iyer et al. (2015) find that investments in climate change mitigation increases after accounting for differences in institutional qualities in different areas of the world.

Very few models track expenditures in research and development (R&D) for climate mitigation. There is wide agreement that climate mitigation policy will trigger innovation and expenditure in R&D will increase, but it is very hard to estimate future investment needs. One message from the literature is that energy-related R&D investments will probably increase manyfold compared to the present level. But in absolute terms the increment is not going to be very large. Investments in energy-related R&D are equal to about 0.02% of GDP at present (Bosetti et al. 2009). Using data from Table 1 and assuming a constant 2.5% growth of the global economy, the additional investments in R&D would be equal to between 0% and 0.08% of global GDP in 2030 and to about 0.07% in 2050.

Table 1 Change of average annual investment in mitigation scenarios

	2010-2029					2030-2049				
	No. of studies	Median	Min	Mean	Max	No. of studies	Median	Min	Mean	Max
World										
Total electricity generation	5	126.3	16.5	104.1	205.2	2	249.9	132.9	249.9	367.0
Renewables	5	85.4	-3.2	86.0	175.6	2	115.6	19.1	115.6	212.1
Nuclear	5	31.6	27.7	43.1	66.8	2	86.8	61.1	86.8	112.6
Power plants with CCS	5	29.8	6.3	40.7	117.2	2	250.1	180.4	250.1	319.9
Total fossil power plants	5	-29.7	-165.8	-65.6	-2.1	2	-202.6	-267.2	-202.6	-138.0
Extraction of fossil fuels	5	-55.9	-368.9	-115.7	8.3	2	-495.7	-724.6	-495.7	-266.8
Energy efficiency across sectors	4	335.7	0.8	328.3	641.0	1	458.0	458.0	458.0	458.0
R&D in energy sector*	3		4.5		78.0			115.0		126.0
Non-OECD										
Total electricity generation	4	48.3	-1.1	51.4	110.1	3	378.9	215.0	347.3	448.1
Renewables	4	44.5	-1.5	48.4	105.9	3	226.8	25.7	173.4	267.6
Nuclear	4	20.0	16.4	19.8	23.1	3	120.4	83.6	117.6	148.8
Power plants with CCS	4	19.7	4.4	32.0	84.4	3	219.6	66.9	247.9	457.2
Total fossil power plants	4	-34.8	-110.8	-48.8	-14.9	3	-159.5	-351.5	-191.5	-63.6
Extraction of fossil fuels	4	-33.9	-278.5	-85.4	4.9	3	-451.3	-1384.5	-722.5	-331.8
Energy efficiency across sectors	3	301.3	0.4	211.5	332.7	2	681.0	571.8	681.0	790.1
OECD										
Total electricity generation	4	40.1	13.3	47.2	95.1	2	81.6	81.1	81.6	82.1
Renewables	4	32.0	-1.7	37.8	88.7	2	31.1	6.6	31.1	55.5

	2010-2029					2030-2049				
	No. of studies	Median	Min	Mean	Max	No. of studies	Median	Min	Mean	Max
Nuclear	4	24.7	11.3	26.1	43.7	2	15.2	7.9	15.2	22.5
Power plants with CCS	4	14.6	1.9	16.0	32.8	2	88.3	39.2	88.3	137.3
Total fossil power plants	4	-28.9	-71.6	-32.6	-1.1	2	-52.9	-84.3	-52.9	-21.5
Extraction of fossil fuels	4	-13.2	-90.4	-28.3	3.4	2	-363.0	-659.9	-363.0	-66.1
Energy efficiency across sectors	3	186.4	0.4	165.0	308.3	1	113.8	113.8	113.8	113.8

Notes: Mitigation scenarios that stabilise concentrations within the range of 430–530 ppm CO2-eq by 2100. Change relative to respective average baseline investments. For a complete list of references, see notes to Figures 16.3 and 16.4 in Gupta et al. (2014).

Source: Data used to draw Figure 16.3 and 16.4 in Gupta et al. (2014). * R&D investments are from UNFCCC (2007), Carraro et al. (2012) and McCollum et al. (2013) for 2010-2029 and from Carraro et al. (2012), Marangoni and Tavoni (2014), McCollum et al. (2013), Bosetti et al. (2009) and IEA (2010).

There are also very few studies that assess the impact of climate policy on investments for the extraction of fossil fuels. This is a sector that will be crucially affected by climate mitigation policy. The implications of climate mitigation policy for fossil fuels extraction are obvious, but estimating investment needs is very hard because reliable data are not available. The scenarios reviewed by the IPCC reveal a few robust messages. First, climate policy will drastically reduce demand for fossil fuels. With policies consistent with a 2°C target, revenues and rents from oil extraction will collapse. Investments in oil extraction drop to just a small fraction of present investments (Carraro et al. 2012, Gupta et al. 2014). Coal and natural gas, even if equipped with carbon capture and storage, will eventually not be profitable because the capture rate is lower than 100%.

This has striking and often overlooked consequences for fossil fuel-exporting countries, especially those with large non-conventional, expensive resources. The reverse of the medal of energy security in developed countries is economic insecurity in fossil fuel-exporting developing and transition economies. There is time for a smooth transition, but actions should be taken now to build skills and capital on a large scale in countries that often lack dynamic economies.

Conversely, some countries may become large exporters of biomass. All the 2°C scenarios assessed by the IPCC rely on massive use of bioenergy at the end of the century (Clarke et al. 2014). The implicit assumption of these models is that international trade of biomass will equate global demand and supply. However, the models do not keep track of the financial implications of a new commodity market that could be as valuable as the oil market today (Favero and Massetti 2014). The 2°C-consistent scenarios suggest that rents from oil resource owners shift to land owners in countries with high biomass productivity, such as Brazil and Russia. In some cases, this will be only a domestic reallocation of rents. In other cases, there will be an international redistribution of wealth.

3 Revenues from carbon pricing

Climate mitigation policy can be implemented in a variety of ways. Command-and-control policies and market tools can be used alternatively or jointly. If emission allowances are auctioned, under general conditions, carbon taxes and cap-and-trade generate the same flow of revenues. In a thought experiment, the carbon tax can be multiplied by the level of GHG emissions to estimate the size of these flows (Carraro et al. 2012). A 2°C-consistent carbon tax would generate up to $3 trillion per year of revenues in OECD economies in 2050; this is equivalent to 3.5% of OECD aggregate GDP. There is large potential for tax reform programmes that shift the tax burden from labour and other productive assets to negative environmental externalities (Goulder 1995, Parry and Bento 2000).

In developing countries, carbon tax revenues would range between 5% and 10% of GDP in 2025 and up to between 20% and 25% of GDP in 2050 (Carraro et al. 2012). These are strikingly high figures, although for some developing countries, collecting these taxes may be a challenge. Carbon tax revenues may be higher than all current tax revenues in many developing countries (Tol 2012). In order to manage such large financial flows, institutions and markets in the Least Developed Countries must be strengthened (Tol 2012).

What will the time profile of these hypothetical carbon price revenues look like? This is an important question for fiscal planning. As a 2°C scenario requires very low or zero GHG emissions at the end of the century, tax revenues must eventually go to zero. The time profile of carbon-pricing revenues between now and the end of the century depends on how fast emissions will decline and on how fast the carbon price will increase. If the carbon price increases faster than emissions decline, revenues will follow a hill-shaped pattern. If emissions decline at a faster pace than the carbon price, carbon-pricing revenues will decline constantly.

It must be noted that a carbon-pricing scheme implies that activities that remove emissions from the atmosphere must be subsidised. The subsidy should be exactly equal to the carbon price. This means that all the scenarios that have total net negative emissions at the end of the century also assume that policymakers are able to subsidise them using revenues from other taxes.

Climate change economists usually run IAMs assuming a globally uniform – thus economically efficient – carbon price. Efficiency allows achieving the global temperature target at the least cost. The underlying hypothesis is that any equity issue can be solved by compensating low-income consumers using the efficiency gains. For example, high-income countries may reduce the cost of mitigation in developing countries by either implementing a global cap-and-trade programme with free allowances for developing countries or by directly investing in decarbonisation measures (see the discussion in the chapter by Stavins in this book). The financial implications of such distribution schemes are huge and often unexplored, with a few notable exceptions (e.g. McKibbin et al. 1998).

For example, an allocation scheme that promotes equity by equalising the abatement effort internationally would generate average annual financial flows to developing countries that range between $67 billion and $800 billion (McCollum et al. 2013). In some regions, financial flows would represent a large fraction of GDP (McCollum et al. 2013). There may be institutional, political, financial and macroeconomic limitations to implement these transfers. These very important considerations are rarely discussed. There may be a costly trade-off between efficiency and equity.

The IPCC review cited above indicates that non-OECD countries may need anywhere from zero to $100 billion of incremental investments in power-generation capacity per year until 2029, with a median estimate of about $50 billion (see Table 1). From 2030 to 2049, investment needs may increase to $270 billion per year in the median scenario. However, as already noted, these estimates are still highly uncertain.

4 Investment needs for adaptation

Assessing investment needs for adaptation to climate change is much harder than for mitigation. It is reasonable to expect that most of the adaptations to climate change will be private and relatively low-scale because adaptation is not plagued by global coordination problems (Mendelsohn 2000). Switching crop types, increasing irrigation, and changing planting and harvesting dates are examples of private adaptation in agriculture, one of the most climate-sensitive sectors. Increasing the use of air conditioning is another example of private adaptation. Unfortunately, there are no estimates of investment needs for these private adaptations.

There are instead some studies that quantify investments needed for large-scale public adaptation projects. However, the evidence from the literature is limited (Chambwera et al. 2014). The often-cited figure of $100 billion per year to finance adaptation in developing countries (UNFCCC 2007) is not supported by a strong peer-reviewed literature.

Negotiators and policymakers should be aware that estimating exact investment needs for adaptation is virtually impossible. First, there are large uncertainties over future local climate patterns. Second, there is high uncertainty over the impacts of future climate change. Third, it is not clear what will be the adaptations chosen by individuals, firms and governments. Finally, investments in adaptation to climate change cannot be easily disentangled from other investments.

The only reliable data exist for investments in protection against sea-level rise (Agrawala and Fankhauser 2008). Investments to protect major coastal cities are expected to be in the order of a few billion dollars per city for the initial construction and 2% per year for maintenance costs (Hallegatte et al. 2013). At the global level, sea level rise protection that satisfies cost-benefit criteria is expected to be equal to 0.02% of global GDP in the worst-case scenario of sea-level rise for this century (Nicholls et al. 2010). Estimates of investments in R&D for adaptation to climate change are highly speculative.

5 Conclusions

What lessons for policymakers and climate change negotiators can be drawn from the literature?

First, there will be winners and losers in climate policy. Climate mitigation policy will sharply increase the demand for wind and solar power generation, and for nuclear and hydro power plants. Efficient cutting-edge technologies and energy management know-how will be in high demand. Producers of these goods will greatly benefit from climate mitigation policy. Also, the forestry sector and producers of biomass that can substitute fossil energy will substantially gain. The biggest losers in climate mitigation policy are fossil fuel producers.

Countries with economies that rely heavily on fossil fuel extraction will suffer very sharp losses if they do not transform their industries. Countries that are not able to become producers of renewable technologies and high-efficiency consumption and capital goods will also likely lose from mitigation policy. This distribution between winners and losers is important because it greatly influences international climate negotiations. There will probably never be a global agreement without some sort of compensation for countries that are expected to lose large rents from fossil fuels.

Second, if governments use carbon pricing as a policy tool – either carbon taxes or auctioned emissions permits – they will be able to collect large carbon revenues. Economic theory does not suggest that these funds should be used to increase government spending; neither does economic theory encourage recycling these funds in mitigation or adaptation projects. Carbon tax revenues should be used where they yield the highest social return. For example, in developed countries they may be used to reduce distortionary taxes, such as taxes on labour. Developing countries may use the carbon funds for poverty alleviation and development. There is no universal answer; the optimal use will vary from country to country.

Third, the largest fraction of the investments in climate mitigation technologies will occur in developing countries. Discussions on how to finance these investments – i.e. burden sharing – must necessarily be at the centre of international negotiations. It will likely be impossible to implement a globally efficient climate policy without large transfers from high- to low-income countries. The consequence of not agreeing on burden sharing is either a low-profile or inefficient climate agreement.

Fourth, most of the investments necessary for both mitigation and adaptation will likely be private. After the right incentives are in place – e.g. a carbon tax – governments will not need to invest in solar power plants. Governments also will not need to invest in private adaptations because individuals and firms already have the incentive to do so. Governments need to invest resources where markets fail – in regulation of the new technologies, R&D in basic research and in public adaptations. In a world with limited government budgets, it is important that governments give high priority to fixing market failures rather than to sponsoring projects that crowd out private investments.

Fifth, if the right incentives are in place and credit markets are functioning well, private investors will be able to finance their investments using global financial markets. Net additional investments to de-carbonise the economy are expected to be large in absolute terms, but modest when compared to GDP. The limited evidence summarised in Table

1 indicates an increment equal to at most 0.4% of GDP in 2050, if one assumes that the world economy will grow at a constant rate of 2%. Financial markets can move resources from sectors where they are not needed (e.g. coal mines) to sectors in expansion (e.g. solar and wind).

Today there is a large gap between observed and desired investments in mitigation (see Buchner et al. 2015). This gap is the result of weak climate policies. The gap in climate mitigation policy generates a gap in investments. Theory and empirical evidence suggest that once the environmental externality has been corrected in a convincing way, investments will flow where needed. Markets are obviously not perfect and governments must intervene to adjust these inefficiencies. But, these seem to be second-order problems. Policymakers and negotiators should focus on the core problem of climate change: emissions of GHGs are an externality that is not paid by polluters. If policymakers close the 'policy gap', the investment gap will also disappear.

References

Agrawala, S. et al. (2008), "Economic and Policy Instruments to Promote Adaptation", in *Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments*, Paris: OECD Publishing.

Bosetti, V., C. Carraro, E. Massetti, A. Sgobbi and M. Tavoni (2009), "Optimal energy investment and R&D strategies to stabilize atmospheric greenhouse gas concentrations", *Resource and Energy Economics* 31(2): 123-137.

Buchner, B., M. Stadelmann, J. Wilkinson, F. Mazza, A. Rosenberg and D. Abramskiehn (2014), *Global Landscape of Climate Finance 2014*, Climate Policy Initiative.

Buchner, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional finance'", Chapter 33 in this book.

Carraro, C., A. Favero and E. Massetti (2012), "Investments and public finance in a green, low carbon, economy", *Energy Economics* 34: S15-S28.

Chambwera, M., G. Heal et al. (2014), "Economics of adaptation", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Clarke L., K. Jiang et al. (2014), "Assessing Transformation Pathways", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Favero, A. and E. Massetti (2014), "Trade of woody biomass for electricity generation under climate mitigation policy", *Resource and Energy Economics* 36(1): 166-190.

Goulder, L. H. (1995), "Environmental taxation and the double dividend: a reader's guide", *International Tax and Public Finance* 2(2): 157-183.

Gupta S., J. Harnisch et al. (2014), "Cross-cutting Investment and Finance Issues", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

Hallegatte, S., C. Green, R. J. Nicholls and J. Corfee-Morlot (2013), "Future flood losses in major coastal cities", *Nature Climate Change* 3(9): 802-806.

International Energy Agency (IEA) (2010), *Global Gaps in Clean Energy RD&D: Updates and Recommendations for International Collaboration*, Paris.

Iyer, G. C., L. E. Clarke, L. A. Edmonds, B. P. Flannery, N. E. Hultman, H. C. McJeon and D. G. Victor (2015), "Improved representation of investment decisions in assessments of CO2 mitigation", *Nature Climate Change* 5: 436-440.

Marangoni, G. and M. Tavoni (2014), "The clean energy R&D strategy for 2°C", *Climate Change Economics* 5(01): 1440003.

McCollum, D., Y. Nagai, K. Riahi, G. Marangoni, K. Calvin et al. (2013), "Energy investments under climate policy: a comparison of global models", *Climate Change Economics* 4(04): 1340010.

McKibbin, W. J., P. J. Wilcoxen and R. Shackleton (1998), "The potential effects of international carbon emissions permit trading under the Kyoto Protocol", Asia Pacific School of Economics and Management, Australian National University.

Mendelsohn, R. (2000), "Efficient adaptation to climate change", *Climatic Change* 45(3-4): 583-600.

Nicholls, R. J., N. Marinova, J. A. Lowe, S. Brown, P. Vellinga et al. (2011), "Sea-level rise and its possible impacts given a 'beyond 4 C world' in the twenty-first century", *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 369(1934): 161-181.

Parry, I. W. and A. M. Bento (2000), "Tax deductions, environmental policy, and the 'double dividend' hypothesis", *Journal of Environmental Economics and Management* 39(1): 67-96.

Riahi K., F. Dentener, D. Gielen, A. Grubler, J. Jewell et al. (2012), "Energy Pathways for Sustainable Development", in *Global Energy Assessment: Toward a Sustainable Future*, Cambridge, UK: Cambridge University Press and Laxenburg, Austria: International Institute for Applied Systems Analysis, pp. 1203–1306.

Stavins, R. (2015), "Linkage of regional, national, and sub-national climate policies in a future international climate agreement", Chapter 20 in this volume.

Tol, R. S. (2012), "Leviathan carbon taxes in the short run", *Climatic change* 114(2): 409-415.

UNFCCC (2007), *Investment and Financial Flows to Address Climate Change*, Bonn.

About the author

Emanuele Massetti is an Assistant Professor at the School of Public Policy at the Georgia Institute of Technology, a Research Network Affiliate at CESIfo and a Research Affiliate at FEEM and CMCC. Prior to joining Georgia Tech he was researcher at FEEM for about a decade. He holds a PhD in Economics from the Catholic University of Milan and in 2011-2013 he was Postdoctoral Fellow at the Yale School of Forestry and Environmental Studies. His research explores a broad range of topics about the economics of climate change mitigation and adaptation policy. Massetti has consulted for UNDP, OECD and EBRD. In 2011-2014 he has served as Lead Author for the Working Group III report to the Fifth Assessment of the IPCC.

33 Pros and cons of alternative sources of climate change financing and prospects for 'unconventional finance'

Barbara Buchner and Jane Wilkinson
Climate Policy Initiative

Achieving a transformational change to a low-carbon and climate-resilient global economy requires a massive shift of financing towards climate-friendly activities. In less than a decade, the global financial landscape has undergone significant upheaval and change, and our understanding of opportunities to unlock climate finance has grown. Public and private actors have improved their awareness of the risks and opportunities associated with climate action, and are exploring new ways of investing in climate outcomes, increasing alignment between their policy and business interests and the pressing need to scale up climate finance. This chapter looks at the current global climate finance landscape, discusses the potential sources, actors, and instruments relevant for supporting climate finance for developing countries, and provides more evidence about whether different options contribute to the mobilisation of climate finance.

1 Who pays? Climate finance and the new global deal

As the Paris Summit in December 2015 approaches, countries are preparing emissions reduction targets and plans of action. One of the key questions is how and whether these actions will be financed. In particular, whether the historically rich group of developed countries will make good on their six-year old goal to deliver US$100 billion per year by 2020 to help poorer countries mitigate and adapt to climate impacts.

The absence of an internationally agreed definition of ‘climate finance’ is a major barrier to understanding the magnitude of climate finance and the barriers to climate finance investments. This chapter considers climate finance to include all primary private and public financial investment flows that specifically target low-carbon or climate-resilient development. This definition is consistent with that applied by the Climate Policy Initiative in its *Global Landscape of Climate Finance* reports (Buchner et al. 2011a).

1.1 Since its emergence, the $100 billion goal has been both a touchstone of good faith and a hallmark of mistrust

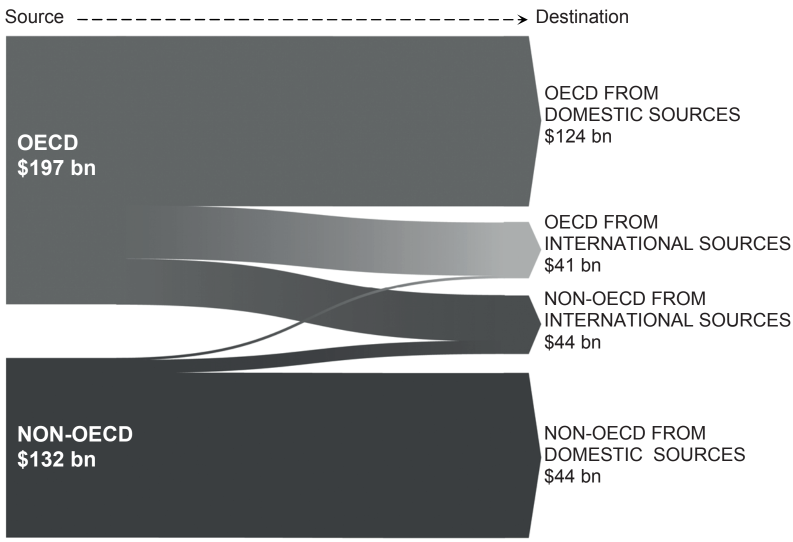
For Paris to succeed, countries must find a way to deal with the $100 billion question meaningfully and transparently. Crucially, they must also move beyond it. Dealing with it is no easy thing. To begin with, the language of the original agreement was vague, making it difficult to implement or to track progress. For example, what is climate finance? What alternative sources are ‘legitimate’? Second, despite known tracking difficulties, demonstrating progress transparently has now itself become a raison d’être, which if unmet, threatens to stall progress and undermine trust. The biggest challenge by far, however, may be moving beyond the dollars and cents, expectations, and political division that serve only to distract from achieving real impact on the ground.

While the challenges are big, the opportunities associated with getting financing right are even bigger. Much progress has been made in recent years to improve tracking systems and build knowledge about how *climate finance – as opposed to pure climate policy* – works. With this knowledge, there is a real opportunity for governments in Paris to deliver the seeds of a systemic shift that can take the $100 billion, a sizeable amount of which will be public finance from developed countries, and ensure it *supplements* and *complements* public resources from developing countries, and that together these public resources unlock trillions of dollars in private capital sitting in the margins to support the world’s transition to a low-carbon, climate-resilient future.

1.2 The world is making progress on the $100 billion goal

The $100 billion goal emerged at the height of the 2008-2009 financial crisis. Global economic recovery has been dynamic, bumpy, and complex – a situation that has presented challenges for economic, financial, and climate policymakers. After 2009, most economies shifted to a lower growth path (UN WESP 2015), which has been felt in weaker public finances. Even within this context, global climate finance flows reached $331 billion in 2013 (Buchner et al. 2014).[1] While investment in developing and developed countries was almost equally split, $34 billion, or roughly 10% of all investment, was transferred from developed to developing countries.

Figure 1 Cross-border climate finance flows



Source: Climate Policy Initiative 2014 (http://climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2014/)

In terms of transfers to developing countries, $22 billion was transferred as bilateral overseas development assistance, of which $11 billion was grants and $10 billion was loans. In addition, $3-4 billion was provided as non-concessional finance by bilateral development finance institutions (Buchner et al. 2014). Multilateral development banks

1 The authors of the *Global Landscape of Climate Finance* reports have repeatedly stressed that the overall estimates and the $100 billion UNFCCC climate finance goal are not comparable. For more information, see the 'methodology' in Buchner et al. (2014).

(MDBs) provided the remainder of public flows, while private finance accounted for around $2 billion.[2]

1.3 While the progress is significant, it falls far short of estimated global need.

The IEA estimated that from 2011 to 2050, an additional $1.1 trillion is needed each year in the energy sector alone to keep global temperature rise below 2°C (IEA 2014). The biggest challenge to shift resources from traditional, fossil-based activities to low-carbon ones is that aided and abetted by government subsidies across countries (IEA 2014),[3] investment in fossil fuel-intensive industries continues to outpace investment in clean energy and climate resilience and has a lifecycle that goes many years into the future.[4]

The good news is that the capital is available and important global trends present opportunities across countries to unlock billions more in low-carbon and climate-resilient investments around the world. The New Climate Economy (NCE) estimated that $89 trillion would be invested globally in infrastructure by 2030 – before accounting for climate action (NCE 2014).[5] At the same time, the cost of some renewable energies has fallen significantly, making these technologies price-competitive with polluting alternatives (see the chapter by Bosetti in this book, and also Buchner et al. 2014).[6] Project developers and households are installing more, for less. Oil prices also have dropped dramatically in the past year, presenting governments with a once-in-a-generation opportunity to level the carbon playing field by eliminating subsidies and pricing carbon without large cost impacts to consumers.

2 The Bloomberg New Energy Finance (BNEF) database categorises flows as coming from a developed country if they originate with a company or entity headquartered in an OECD country. This estimate is a very conservative lower bound estimate and excludes foreign direct investment to avoid double counting.

3 See the chapter by Massetti in this book for illustrations of plausible implications of climate mitigation policy on investments in power generation and on the energy sector in general.

4 For example, $950 million was invested in coal, oil and gas extraction, transportation and refining and fossil fuel power plants. In 2013, governments paid $550 billion in global consumer subsidies to support fossil fuels, compared with just $121 billion to support renewable energy (IEA 2014).

5 Reviewing a number of studies in his chapter in this book, Massetti suggests that without climate policy, the largest fraction of investments in the power sector is expected to go to fossil fuel generation – the mean estimate of annual investments in fossil fuel generation among the surveyed studies is equal to $182 billion in 2010–2029 and $287 billion in 2030–2049. This is equivalent to about 50% of total investments in power generation from 2010 to 2049.

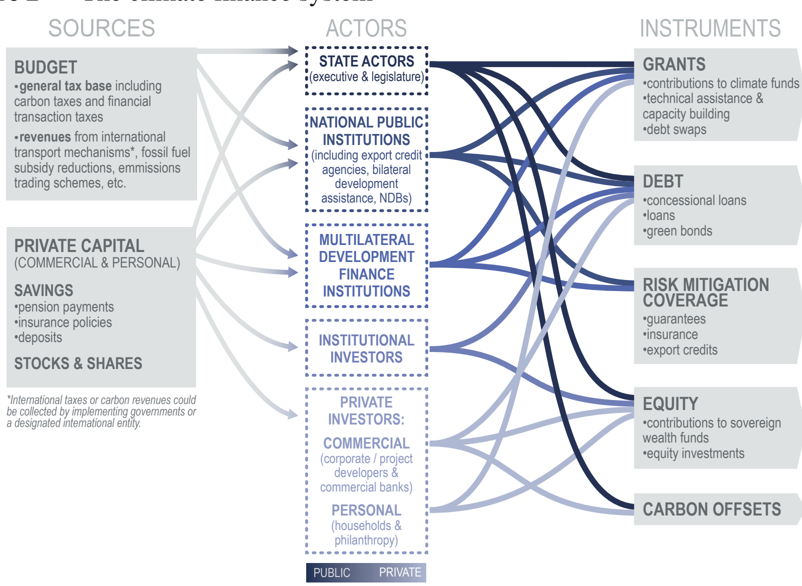
6 See the chapter by Bosetti in this book for a better understanding of how the costs of different renewable energy technologies are likely to evolve.

2 Concrete options to achieve financial transformation

Significant analysis has improved our understanding about the sources, actors, and instruments of climate finance (CPI and Cicero 2015). We know now that the global climate finance system is a complex continuum of relationships and transactions (see Figure 2), driven by public finance, policies and incentives on the one side, and the need to balance risks and returns on the other.

The international community has helped to develop a more comprehensive picture of climate finance than existed in 2009 when the $100 billion goal emerged. This in turn is helping to improve understanding about where the world stands in relation to global finance and temperature goals, but more importantly, to identify which kinds of support correspond best to different needs, and whether resources are being optimised (CPI and Cicero 2015). For example, in general, the public sector should fund the cost of public goods and services, and risks that the private sector isn't willing or able to bear. Continuing to develop understanding of climate finance flows should ultimately help actors learn how to spend money wisely and effectively redirect financial resources from high- to low-carbon uses.

Figure 2 The climate finance system



Source: CPI and Cicero (2015).

2.1 Get domestic enabling environments right

In 2013, 74% of climate finance originated and was spent in the same country or region. This percentage rose to 90% for private investments, highlighting that investors everywhere prefer familiar policy environments that provide incentives and confidence around returns.

Domestic public finance, supplemented by international resources where necessary, can fund the establishment of institutions and capacity, technical assistance, incremental costs, project-specific grants, and loans. Direct equity investments of public finance, alongside commercial tranches, can help build confidence, speed up financial closure, or take more risky positions in mezzanine structures. Governments can also take positions as shareholders, particularly in companies that deliver strategic goods and services such as electricity and water, and which are or were state monopolies (Buchner et al. 2013). Active and passive shareholding is practiced by governments in developed and developing countries. In China in 2012, 84% of climate investments had some degree of public shareholding, and rates of public shareholding are also high in the US (68%) and Germany (54%) (Buchner et al. 2013, 2014).

Examples of policies that help level the carbon playing field across actors include:

- Regulatory standards such as emissions and performance standards, technology and production standards, which increase the cost of emitting carbon by penalising actors who fail to meet established standards, and create incentives to seek out low-carbon options;
- Feed-in-tariff or support policies and renewable-portfolio standards, which have helped to drive diffusion and pay for incremental costs (IPCC 2014a,b);
- Policies to support research and development in technology, which can complement adaptation and mitigation policies, and if properly implemented, can reduce costs; and
- Technology-push policies such as publicly funded research, development and deployment, combined with financing support for technology adoption, which can help to overcome the 'valley of death' between small-scale prototype phases and successful commercialisation (IEA 2014, IPCC 2014a,b, FS-UNEP-BNEF 2015).

2.2 Support public finance institutions as agents of change

Development finance institutions (such as multilateral and national development banks), bilateral development agencies, and even possibly new institutions such as the Green Climate Fund, pool experience and toolsets that can pay for goods and services that private actors cannot or will not pay for, and which can help investors manage risks.

Bilateral agencies have a substantial role in supporting adaptation activities (almost 50% of their total contributions in 2013 were grants targeting adaptation; Buchner et al. 2014). Bilateral DFIs and MDBs can raise funds on capital markets in addition to government contributions, and also play a pivotal role in mobilising private finance by providing risk coverage, concessional and non-concessional lending and technical assistance, and by managing and implementing projects for climate funds. The emergent Green Climate Fund could play a catalytic role in ensuring that vulnerable countries' needs are met, particularly where national development bank-type institutions do not exist, by helping to realign incentives and find new ways to mainstream climate risk mitigation.

National development banks (NDBs) are also increasingly key players in low-carbon economic development as executors of public development mandates. They have the capacity to mainstream climate considerations across broader national policy portfolios (such as infrastructure, rural development and urban planning), and can reduce perceived trade-offs, build complementarity and increase co-benefits, making it easier to dedicate public financial resources (OECD 2009, IPCC 2014a,b). Especially in less mature markets where costs and risks can make financing unaffordable, by using lower cost public capital, NDBs can significantly lower financing costs that would otherwise make investments prohibitive (NCE 2014). NDBs committed $70 billion in 2012, and many also function as channels of multilateral and bilateral development finance (Buchner et al. 2013).

2.3 Alternative sources may be difficult to implement

An important lesson to emerge since 2009 is that 'alternative sources' identified previously (see, for example, AGF 2010) have had mixed results, particularly in relation to the $100 billion goal:

- Developed and developing countries and regions around the world have introduced *carbon pricing through carbon markets and taxes* (CPI and Cicero 2015, and Wang and Musiric 2015). The value of global ETSs as of 1 April 2015 is about $34 billion, while the existing carbon taxes around the world are estimated to be valued at $14 billion (see the chapter by Wang and Musiric in this book). The value of the global carbon market is expected to reach €70 billion in 2015 (*Business Green* 2015).[7] However, in relation to the $100 billion, carbon markets have failed on two counts. First, the markets have not yet resulted in a global carbon price that is adequate to deliver significant finance to developing countries. Second, even where carbon markets generate funds, they have delivered little by way of new finance transferred to developing countries. Earmarking revenues from auction schemes, or grandfathering allowances, has happened in some domestic contexts within the EU ETS, but it is still uncommon practice globally.
- *International transport* has been seen as an attractive source of potential climate finance as it is not currently subject to emissions reduction measures, and lies outside the national boundaries of emissions accounting systems. With revenues benchmarked to carbon prices in the range of $20-25/t$CO_2$, the AGF estimated these could generate around $10 billion in climate finance per year by 2020 (AGF 2010). Securing international agreement is the main barrier to implementation.
- Appetite for levying an *international financial transactions tax* may have stirred following the public bailout of many private banking institutions following the 2008 financial crisis. However, concerns about market distortions and deeply entrenched national positions mean such an instrument is unlikely to be implanted on a global scale.

7 As secondary transactions, the value of carbon markets is not captured by climate finance tracking exercises such as CPI's *Global Landscape of Climate Finance*.

- The *green bond market* has grown since its initiation in 2008 to $64 billion[8] in total by May 2015. Half of this amount was issued in 2014 alone, demonstrating the significant momentum the market has achieved in a relatively short time. The bonds themselves are simply 'hypothecated' bonds – that is, the use of proceeds for the bond is linked to green activities and the value of the bond equals the value of these green assets. However, this does not translate into the bonds being secured by these green assets. Rather, they are backed by the balance sheet of the issuer, thereby enjoying the same risk profile. This allows investors who are interested in green activities to purchase the bonds, but to not suffer any extra credit risks. A total of 98% of green bonds come from institutions in the developed world, specifically the UK, US and Europe. Investors consist of *institutional investors* such as pension funds and insurance companies that are familiar with setting aside allocations for investment-grade bonds from these issuers. Further issuance of green bonds, especially by sovereigns in developing countries, including major emerging economies, could unlock cross-border climate finance.

A review of 'alternative' sources of finance demonstrates that often these require government actions in addition to carbon pricing – for example, to 'earmark' or 'hypothecate' public revenues – to fund climate finance, and often require multilateral agreement to implement. Further, many of these sources can blur the boundary between public and private action, both because the source is unclear, and also because public investors may sometimes take quasi-commercial positions, as shareholders, insurers, and institutional investors. Finally, it is clear that 'alternative' sources are less likely to succeed in the immediate term wherever they require international agreement, while those that require secondary actions by governments to dedicate proceeds or revenues can face strong domestic political opposition.

8 Source: CPI analysis; Bloomberg data (accessed 29 April 2015).

3 Conclusion

Significant coordination and strong government leadership will be needed to align policies, pricing signals, and financial instruments across the world to steer finance towards a low-carbon and climate-resilient future. However, the costs of transformation may be lower than once thought, with economies of scale, better knowledge, and linked global markets all playing a role in making investment go further. If countries get it right, the New Climate Economy estimates that making envisaged infrastructure climate-compatible would only cost an additional $4.1 trillion, or 5% of projected investments, which might also be offset by lower operating costs (NCE 2014).

The climate negotiations in Paris could play an important role in paving the way for such a low-carbon, climate-resilient future. Most importantly, COP21 could nudge the UNFCCC climate finance stream towards an outcome that acknowledges progress, and anchors future progress in the real economy. Across the world, and especially in developing countries with their growing energy demands and huge infrastructure needs, nationally sponsored development plans that insist on climate as an integral component of development will unlock innovation and pipelines of projects. Coordinated action by public actors in developed and developing countries could help to systematise options to reduce risks and close financial and technical gaps, resulting in more effective mobilisation of climate finance. Specifically, a number of elements could signal progress in changing in the narrative:

- *A common language*. COP21 could help create a common ground for definitions related to climate finance, crucially moving beyond the decoupling of climate from development, to mainstream climate action and globalise the development issue.
- *The landscape of climate finance*. By acknowledging the variety of actors, sources, instruments and complex interactions (see Figure 1) – including, for example South-South finance flows and the role of domestic private finance in developing countries – COP21 could broaden the view on possible options to scale up climate finance, acknowledging also that there are multiple pathways to get to the $100 billion target (and beyond). In this context, lessons on practical and operational solutions could be highlighted to fast-track climate investments that meet countries' needs and use financial resources most effectively.

- *Transparency of climate finance*. One of the conditions for improving trust between Parties and for reaching an ambitious agreement at COP21 is enhanced transparency on the implementation of the commitment by developed countries to mobilise $100 billion a year by 2020, from a variety of sources, to support climate adaptation and mitigation actions in developing countries. To this end, COP21 could highlight progress made by various actors towards better understanding the current climate finance picture and pathways to the $100 billion and agree on a work programme, outside of the UNFCCC, to further add clarity after Paris.
- *An aspirational climate finance goal*. COP21 could explicitly recognise that the $100 billion target is not an end point but a starting point that should aim to unlock domestic investments in developing countries, recognising that solutions come mainly domestically, possibly triggered by international support. By considering an aspirational climate finance goal, and avoiding further numerical targets, COP21 could enable a focus on impact and results on the ground, setting the basis for moving the world most effectively onto a low-carbon, climate-resilient pathway.

By moving the discussions within the UNFCCC climate finance negotiations away from pure politics toward the real economy, the Paris Agreements could turn the $100 billion into trillions in the near future, closing the gap between finance delivered and finance needed. A core condition for this to happen is that COP21 builds the trust amongst Parties about the overarching goal, and establishes a clear pathway forward, with milestones for the road from Paris to 2020, and beyond.

References

AGF (2010), "Report of the Secretary-General's High-Level Advisory Group on Climate Change Financing", New York: United Nations (available at http://www.un.org/wcm/webdav/site/climatechange/shared/Documents/AGF_reports/AGF_Final_Report.pdf).

Bossetti, V. (2015), "The role of renewables in the pathway towards decarbonisation", Chapter 23 in this book.

Buchner B., A. Falconer, M. Hervé-Mignucci, C. Trabacchi and M. Brinkman (2011), *The Landscape of Climate Finance*, Venice: CPI (available at http://climatepolicyinitiative.org/publication/the-landscape-of-climate-finance/).

Buchner B., M. Herve-Mignucci, C. Trabacchi, J. Wilkinson, M. Stadelmann et al. (2013), *Global Landscape of Climate Finance 2013*, Venice: CPI (available at http://climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2013/).

Buchner B., M. Stadelmann, J. Wilkinson, F. Mazza, A. Rosenberg and D. Abramskiehn (2014), *Global Landscape of Climate Finance*, Venice: CPI (available at http://climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2014/).

Business Green (2015), "Global Carbon Market Value to Hit €70bn This Year", 6 January (available at http://www.businessgreen.com/bg/analysis/2388683/global-carbon-market-value-to-hit-eur70bn-this-year).

CPI and Cicero (2015), "Background Report on Long-term Climate Finance", prepared for the German G7 Presidency.

Frankfurt School-UNEP Centre/BNEF (2015), *Global Trends in Renewable Energy Investment 2015*, Frankfurt.

International Energy Agency (IEA) (2014), *IEA World Energy Investment Outlook*, Paris (available at http://www.iea.org/publications/freepublications/publication/weio2014.pdf).

IPCC (2014a), "Summary for Policymakers", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

IPCC (2014b), "Summary for policymakers", in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (see IPCC (2014a) in the introduction to this book for the report's full reference).

Massetti, E. (2015), "The macroeconomics of climate policy: Investments and financial flows", Chapter 32 in this book.

New Climate Economy (NCE) (2014), *Better Growth, Better Climate*, Washington, DC: The Global Commission on the Economy and Climate (available at http://newclimateeconomy.report/)

OECD (2009), *Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance*, Paris.

United Nations (2015), *World Economic Situation and Prospects 2015*, New York.

Wang, X. and M. Murisic (2015) "Taxing carbon: Current state-of-play and prospects for future developments", Chapter 19 in this book.

About the authors

Barbara Buchner is Senior Director of Climate Policy Initiative. She leads CPI's global climate finance programme and directs the European office's research and operations. In 2014, Barbara was named one of the 20 most influential women in climate change. She directs CPI's work as Secretariat of the Global Innovation Lab for Climate Finance, a public-private initiative that identifies climate finance instruments with the potential to drive investment at scale. She is the lead author of CPI's *Global Landscape of Climate Finance* analyses, which served as the basis for the 2014 IPCC Working Group III report chapter on climate finance. She holds a PhD in Economics from the University of Graz and was a Visiting Scholar at the Massachusetts Institute of Technology.

Jane Wilkinson is an expert in both land use and climate finance and advises leaders in the Ministry of Finance in Indonesia, Unilever Corporation, and G7 governments, among others. Jane joined CPI in 2012 and has since played a key role developing CPI's land use and climate finance programs. She founded the Indonesia program in 2012 and has been a lead contributor on numerous CPI reports including the *Global Landscape of Climate Finance, The Landscape of Public Climate Finance in Indonesia*, and the

Background Report for the G7 on Long-Term Climate Finance. Prior to joining CPI she was a professional diplomat for the Australian Government. She holds a Bachelor Of Laws from Monash University.

34 Harnessing the animal spirits of finance for a low-carbon transition

Jean-Charles Hourcade
Centre National de la Recherche Scientifique (CNRS)

This chapter starts from an apparent contradiction between the quest for upgrading the funding for a low-carbon transition and the constraints impinging upon the world economy in the aftermath of the 2008 financial crisis. It argues that new financial tools are needed to remove this contradiction and trigger a massive wave of low-carbon investments, and explains why carbon prices alone cannot do the job. It points out that, in the absence of a benevolent lender, high upfront costs of low-carbon projects under uncertainty about the cost of equipment and the duration of the maturation phase of the projects mean that investments which could be profitable are frozen. The creation of Climate Remediation Assets (CRAs) based on a governments' public guarantee, along with carbon pricing, would remove this barrier to investing in low-carbon activities. Based on this guarantee, project developers can obtain carbon certificates from their banks and reimburse them in certified emission reductions and not in cash. This is possible because the central bank provides the banking system with liquidity corresponding to the carbon certificates which, once recuperated by the central bank, appear as CRAs on its balance sheet. The chapter then discusses how, by creating a new vehicle suitable for bridging long-term assets and short-term cash balances, CRA-based devices could both trigger a low-carbon transition and help drive the world economy out of the current state of doldrums and instability.

1 Introduction

Time is running out to act on climate change; it is also running out to act on poverty eradication and sustainable development. These challenges cannot be met independently from each other, because there will be no involvement of developing countries if climate policies slow down their exit from poverty, and because climate change might create tensions that make development unsustainable. This is why we have to resist the temptation to postpone significant climate action until the end of the current adverse economic context. Finance, the key constraint in the aftermath of the 2008 crisis, cannot but be part of the solution. This chapter explores how.

Paradoxically, given its influence on our economies, finance has until recently been a minor topic in climate negotiations. One exception was the Brazilian proposal in 1997 for a compliance fund to implement the common but differentiated responsibility (CBDR) principle (UNFCCC 1997). This was symptomatic of doubts of non–Annex 1 countries about the willingness of Annex 1 countries to make the transfers[1] needed to compensate for the impacts of significant carbon prices on their economies.[2] COP16 in Copenhagen (in 2009) marked a turning point by establishing a Green Climate Fund (GCF), but it did so in a context where pressures on public budgets and a fragile economic recovery in OECD countries had exacerbated ‘donor fatigue’. Discussions on the GCF are at risk of remaining an adversarial exercise between the ‘North’ and the ‘South’ and of missing the key challenge, which is the redirection of investments all over the world towards a low-carbon transition of an order of magnitude beyond what can be expected from public finance.[3]

Section 1 shows why, to overcome these drawbacks, the ‘mental map’ of policy analysts must account for the time profile of investments needed to achieve a low-carbon transition and also incorporate finance in the toolkit of incentives to be mobilised. Section 2 suggests reforms of the prevailing financial intermediation

1 Limits to these transfers were an implicit motivation of the Byrd-Hagel resolution of the US Senate (1997) (see http://www.nationalcenter.org/KyotoSenate.html) and of the EU request of ‘concrete ceilings’ to imports of emissions allowances through cap-and-trade systems (see Hourcade and Ghersi 2002).

2 These impacts are high in countries that are still in a development phase and require energy-intensive materials to build basic infrastructures (Luderer et al. 2012).

3 The global estimated need in infrastructure investments between now and 2030 is US$89 trillion, rising to $93 trillion if climate is to be properly addressed (New Climate Economy 2014). The major challenge is obviously the redirection of a large fraction of the $89 trillion.

through the creation of carbon assets valued at an agreed notional price of mitigation activities. Section 3 shows how these reforms can help drive the world economy out of the current economic doldrums and gain support for climate policies from climate-agnostic policymakers in charge of economic policies who are focused on the short-term challenges of employment and debt reduction.

2 Finance and carbon pricing

The Kyoto Protocol was the outcome of a succession of diplomatic *faits accomplis* (Bodansky 2001) with many possible interpretations. The dominant interpretation was governed by a mental map in which a world carbon market would connect *abatement cost curves* all over the world and *select-cost-efficient techniques* given the uniform carbon price imposed on all the carbon emitters.

The difficulties in establishing a world cap-and-trade system generated an extensive literature on the wedges between technical costs, GDP variations, and welfare variations.[4] Less attention has been dedicated to the fact that, in the models establishing the superiority of this policy tool, technologies are assumed to be selected according to their present expected value for a given discount rate. This ranking is made regardless of the time profile of the operating costs of projects. This amounts to an assumption of unlimited access to financing, which seems quite unrealistic.

Figure 1 depicts the time profile of the expected operating accounts of two example projects. Project A, with a capital-intensive technology, has a higher expected present value (i.e. the discounted sum of lower purchase of fossil fuels minus the capital expenditures and operational costs) than project B, but it might not be selected because of its higher upfront costs. During the incubation phase of the project, a bad surprise regarding these costs (indicated by the dashed lines) might indeed generate a deficit of operating accounts beyond a 'danger line', D, i.e. the level of deficit the decision-maker does not want to cross. These bad surprises can come from a mismanagement of

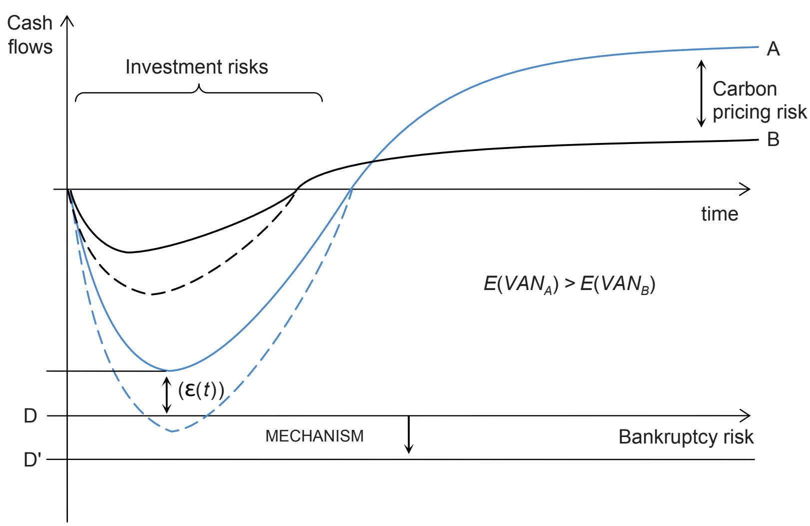
4 These wedges come from the propagation of higher energy prices throughout the economies, uncertainty about the efficiency of the compensatory transfers, incomplete and fragmented markets (energy, labour, real estate) and pre-existing fiscal systems.

projects, a cost increase for certain equipment, or a discovery of technical difficulties in non-mature technologies.

This situation is typical of households that require very short payback periods for their investments in energy efficiency. This is also the case of firms with limited access to finance (be it via debt, equity or self-finance). In the absence of a benevolent lender with unlimited lending capacities, onerous debt-servicing lowers their operating surpluses and poses a threat to dividend payments to their shareholders if their bank loses confidence. Ultimately, the value of the firm might be affected, with a risk of bankruptcy or hostile takeover.

Carbon pricing improves the relative efficiency of low-carbon projects, but it does so during the operation phase only for projects not stifled by the existence of the 'danger line'. One can argue that sufficiently high carbon prices could encourage decision-makers to take the risk. But they would have to be very high because the cost of approaching and crossing the danger line is highly non-linear and because they would have to cover the 'noise' of other unfavourable signals (such as real estate prices, oil prices and exchange rates) indicated by ε(t) in Figure 1. Financial devices are thus needed to move the 'danger line' (from D to D′), to decrease the risks arising from overruns of upfront investment costs, and to increase the effect of carbon pricing.

Figure 1 Investment risks, finance and carbon pricing



The existence of this danger line does not only constrain low-carbon projects, it characterises a business environment in which managers have to pay close attention to the short-term value of the firm. In this 'shareholder business regime' (Roe 1994),[5] managers do not have full latitude to use the net profits of their firm to maximise its long-term growth. Put simply, investors face a 'Buridan's ass' dilemma.[6] They pay no attention to which direction long-term investments should go, and are not helped by the difficulty of the present system of financial intermediation to fund productive investments. Ultimately, private savers are reluctant to maintain investment rates in the industry, preferring instead speculative or liquid assets. This interplay between financial factors and heightened uncertainty (Lewis 2014) is now recognised as having a prominent role in the gap between real growth and potential growth, and in a chronic excess of savings over investments (Blanchard 2015). The question, then, is whether there exist financial devices designed to support low-carbon investments that can reduce this gap.

3 Towards the creation of Climate Remediation Assets (CRAs)[7]

To understand the type of mechanism suitable to operate this redirection of investments, it is useful to remember historical examples of links between finance and deep technological revolutions. In the nineteenth century, the impressive deployment of railways was unleashed thanks to various (country-specific) forms of public guarantees on investments and the creation of assets on the lands adjoining the lines. This combination reassured investors that they could recuperate valuable assets in the case of insufficient revenues from the traffic between two connected cities (Fogel 1964, Landes 1969). An equivalent to this device for triggering the low-carbon transition would be for governments to provide a *public statutory guarantee on a new asset, which allows the central bank to provide new credit lines refundable with certified reductions of*

5 For the implications of a 'shareholder value regime' and a 'managerial business regime' on growth, see Hallegatte et al. (2008).

6 The legend satirises Buridan, a theologian at the Sorbonne, who recommended postponing action until having received full information about the context. In this legend, the donkey dies of hunger and thirst because it hesitated too long in making a decision between eating hay or drinking water.

7 The rationale for this device is described in Hourcade et al. (2012), and a version centred on the European context is developed in Aglietta et al. (2015).

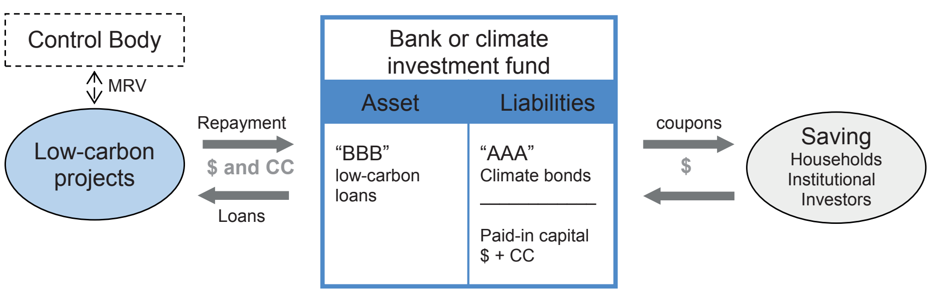
CO_2 emissions. The targeted credit facility would make possible bigger loans to low-carbon investments by lowering the financial risk. The facility could be operationalised through four steps.

1. *The international community recognises that climate remediation activities generate 'something of value'*. This value of Climate Remediation Activities (VCRAs) could be expressed through a notional price per tonne of avoided CO_2 emissions to be incorporated in new investments. It would comprise both the costs of meeting the 2°C target and the various co-benefits of mitigation activities (air pollution, benefits from recycling the revenues of carbon pricing, energy security). Controversies around the social cost of carbon (SSC) have cast doubts over the possibility of agreeing on such a value. But there are three differences between the concepts of the SSC and the VCRA. First, the VCRA would not be used to weigh climate change damages over the long run against the costs of mitigation; it would be estimated for a given target, and disputes about the discount rate would matter less. Second, countries might agree to the same VCRA for different reasons based on their own perceptions of the domestic co-benefits of climate mitigation within, for example, the estimated space of carbon prices given by the IPCC (US$55 to $140 per tonne of CO_2 in 2030 for a 450 ppm scenario) (Clarke et al. 2015). Third, contrary to a real carbon price, a VCRA would not directly hurt existing capital stock, would have less direct distributive impacts, and would therefore be at less risk of being blocked by a coalition of vested interests.
2. *Governments commit, on a voluntary basis, to backing (up to a predetermined quantity) carbon certificates (CCs)* to be allocated to low-carbon projects and priced at the VCRA. This allocation of CCs would lower the danger line stifling the capital-intensive low-carbon projects since, for example, a $100 loan would be reimbursed $50 in cash and $50 in carbon certificates. This would require an effective system of MRV along the lines described by Wiener in his chapter in this book, and monitoring by an independent body under the UNFCCC that would set the rules for the attribution of CCs per type of project in each country.
3. *Building on the governments guarantee, CCs are accepted* by financial intermediaries as *repayment for part of low-carbon loans,* because CCs can be either converted into climate remediation assets eligible for quantitative easing programmes launched by

central banks, or can be used as a guarantee for refinancing by the central banks of low-carbon loans up to their carbon value. Ultimately, after effective carbon emission reductions have been verified, the carbon certificates would be converted into Climate Remediation Assets that enter on the central bank's balance sheets (see Box 1).

4. *Banks or specialised climate funds* use the carbon-based monetary facility *to back highly rated climate-friendly financial products*, such as 'AAA' climate bonds, to attract long-term saving. This could be done by turning BBB portfolios of projects into AAA climate bonds via the public guarantee to CCs and the various pooling methods. Provided they have confidence in the declared value of CRAs, institutional investors might be interested in safe and sustainable bonds instead of speculative financial products for both ethical and regulatory purposes. This mechanism (illustrated in Figure 2) is critical for the redirection of private savings, without which the low-carbon transition will not trigger the virtuous economic circle developed in the next section. An important point for the political economy of the climate negotiations is that part of the CCs could be used to scale up the Green Climate Fund in order to secure multilateral cooperation and to avoid the Nationally Appropriate Mitigation Actions (NAMAs) being funded only by bilateral overseas assistance and the possible 'greenwashing' of this assistance.

Figure 2 Carbon certificates and the redirection of long-term saving towards low-carbon investments



This mechanism ultimately comes down to the issuing of money backed by a public guarantee and, akin to the case of US railways, backed by the real wealth of low-carbon infrastructures as collateral. It would rely on two major pillars in addition to the MRV process.

The first pillar is the value of CRAs, so far neglected in a literature that has focused on the financial channels and the evolution of prudential rules to improve the financial intermediation system. VCRAs play a critical role for four reasons. First, as it has the same efficiency effect as a carbon price, a VCRA hedges against the cost of fragmentation and political arbitrariness of low-carbon initiatives and carbon finance innovation. In this respect, it can constitute a lever for the deployment of climate finance devices, as described by Buchner and Wilkinson in their chapter in this book. Second, it helps countries make their INDCs economically consistent, since the loans will incorporate the same implicit carbon value. Third, because it is the discounted value of the flow of social values – which increases over time – it offsets the penalty imposed by discount rates on long-lived investments. Fourth, it hedges against the risk of lax monetary creation and of 'carbon bubbles', because the CCs have a nominal face value from which speculators on secondary bond markets cannot depart too much.

The second pillar is the quantitative commitments made by governments. Political realism suggests that this kind of system can be launched only by a 'club of the willing'. Contrary to what Nordhaus (2015) envisages for carbon pricing clubs, the incentive to join the club and to observe its rules would not be provided by penalties but by automatically depriving defaulting countries of access to the credit facilities opened by the system. Such a system needs agreed-upon rules on governments' commitments to back a given amount of carbon savings investments backed by governments, which go beyond the scope of this chapter. One key principle, developed in Hourcade and Shukla (2015), would be to organise rules such that they act as pull-back forces inciting countries to narrow the distance between their emissions and a normative trajectory. What matters is that these rules would not play the same role as in the case of the Kyoto Protocol;[8] there would be no immediate consequence for domestic energy prices and the amount of international transfers would be controlled ex ante (only a share of the credit lines opened thanks to governmental backing).

8 Unlike the very successful Montreal Protocol on reducing ozone-depleting substances that included trade restrictions between parties and non-parties, Article 18 of the Kyoto Protocol prohibited the use of a compliance mechanism that would entail "binding consequences" unless adopted by amendment of the Treaty. As under the GATT, under the Kyoto Protocol a sanction against a party had to be approved by the party it was aimed at! (Mathys and Melo 2011). The reasons for this outcome are explained in Hourcade and Ghersi (2002).

Box 1 The creation of CRAs and the circuit of balance sheets

Table 1 shows how a central bank's balance sheet is transformed by the creation of a CRA starting from a $1,000 loan to a low-carbon entrepreneur expected to realise 10 units of CO_2 emissions reduction and a VCRA set at 10/tCO_2. The loan is divided into two credit lines (Table 1): $900 lent at rate r_l and financed by deposits remunerated at rate r_d, and $100 equivalent lent by the central bank to a commercial bank that can be paid back with certified carbon certificates (CCs). Prudential rules about minimum capital requirement only apply to the first credit line (900 r_l) as a zero coefficient risk is applied to the second credit line backed by a government guarantee. The net worth increase of the commercial or development bank is only $0.08*900r_l$ instead of $0.08*1000r_l$ in the BAU case (i.e. conventional funding of the project).

The CB now owns a new $100 claim on the commercial bank. Thanks to the $1,000 loan, the entrepreneur launches the low-carbon project (LCP) with an expected return of R^{LC}, giving total expected revenues of $1,000 R^{LC}. Under the assumption that the project realises the 5 units of expected emission reductions, two lines appear on the liability side of the entrepreneur's balance sheet: $900 paid back with the monetary revenues of the project at the interest rate r_l, and $100 paid back with carbon certificates.

Table 1 Balance sheets at time of opening the low-carbon loan

Central bank		Commercial bank		Entrepreneur	
Asset	Liability	Asset	Liability	Asset	Liability
				100 R^{LC}	
Loan CO_2		$+900r^l$	$+900r^d$		$+900r^l$
+100	+100	+100	+100		+100
			$+0.08(900r^l)$		
10 CO_2	100				
Reduction of CO_2	Drawing rights				

As the project realises emission reductions, the entrepreneur receives CCs. At the loan maturity (Table 2), the entrepreneur has reimbursed the entire $900 debt with the project revenues and has received 10 CCs for the project's emissions reductions. The first credit line of the balance sheet of the commercial bank becomes null and only the second credit line remains.

Table 2 Balance sheets at the end of the payback period of the low-carbon loan before the asset swap

Central bank		Commercial banks		Entrepreneur	
Asset	Liability	Asset	Liability	Asset	Liability
				1000 R^{LC}	
Loan CO_2		+0	+0	-900r^l	+0
+100	+100	+100	+100	+10 CC	+100
			+0		
10 CO_2	100				
Reduction of CO_2	Drawing rights				

Then the central bank performs an asset swap, as it accepts the 10 CC as repayment of its $100 financial claims and the second credit line corresponding to the 'carbon debt' of the low-carbon project can be cancelled out (Table 3). The total amount of carbon-based liquidities that the central bank can still issue is reduced by 100.

Table 3 Balance sheets after the carbon asset swap

Central bank		Commercial banks		Entrepreneur	
Asset	Liability	Asset	Liability	Asset	Liability
10 CC				1000 R^{LC}	
~~Loan CO_2~~		+0	+0	-900r^l	+0
~~+100~~	+100	~~+100~~	~~+100~~	~~+10 CC~~	~~+100~~
			+0		
~~10 CO_2~~	~~100~~				
Reduction of CO_2	Drawing rights				

Other circuits are possible. Commercial banks with a high share of low-carbon projects in their loan book would have a less risky balance sheet, as it would benefit from a public guarantee. They could keep part of the carbon assets. Banks would then be rewarded with a reduction of the cost of their prudential capital constraint by applying a zero risk coefficient – in the same fashion as with sovereign bonds – to the fraction of the loan that comes from central bank liquidities backed by the value of emission reductions. Firms could also keep the CRAs in their balance sheet to improve their value in terms of the Capital Asset Pricing Model.

4 Crowding out, or dragging the world out of the economic doldrums?

The primary aim of a CRA device is to trigger a wave of low-carbon investments that are currently blocked by their upfront cost in today's uncertain economic context, and many such investments exist.[9] Further, this device would facilitate the deployment of price-based mechanisms – the amount of financially viable low-carbon investments for a given carbon price would be higher and the existence of a VCRA and of a strong MRV process would make it easier to turn the product of mitigation activities into financial carbon assets. Governments will have a real incentive to implement carbon-pricing policies to generate more carbon assets, which will balance the public budget.

The fact that these devices are good for climate mitigation does not imply that they are good for the economy in general. The strong arguments in favour of the 'green growth hypothesis' (OECD 2009, World Bank 2012) are often countered by the 'crowding out' argument (Popp 2012), i.e. that to bias investments in favour of low-carbon projects would crowd out other investments that could be socially and economically beneficial and would thus generate no positive impact on economic growth.

This argument has to be revisited in the current adverse world economic context of a gap between potential growth and real growth. One of the sources of this gap is the

9 One good analysis of the orders of magnitude of this leverage can be found in De Gouvello and Zelenco (2010) in their hypothesis of a low-carbon development facility.

saving glut, diagnosed by Ben Bernanke in 2005, due to a high propensity to save and a low propensity to invest. This leads to difficulties in maintaining sufficient demand to sustain normal levels of output, and explains the warnings about the 'depression economics' (Krugman 2009) and secular stagnation (Summers 2014). The CRAs could help prevent this via the creation of intermediaries that are able to bridge long-term assets and short-term cash balances so that savings are invested productively without incurring the risks of excessive leverage, maturity mismatch (illiquid long-term assets financed by short-term assets) and interconnectedness (unsecured liabilities of money market funds), which fostered the systemic crisis.[10]

Illustrative simulations suggest that, over the short run, the CRAs would boost investments and final demand by backing credit facilities with equipment and infrastructures as collateral. Their macroeconomic impact could be important because they imply incremental investment efforts (around 0.5% of GDP over the forthcoming decades) with a high ripple effect because the level of redirected investments is around 8-9% of the gross capital formation.[11] This redirection would entail inevitable tradeoffs and choices, but would not mean sacrificing social priorities. It would bring the economy closer to its potential growth by reducing the saving glut and satisfices the social aims through low-carbon techniques. Over the long run, it would translate into reality Schumpeter's message that long-lasting innovation waves can take off only when their promise is supported by the 'animal spirits of finance'. Instead of generating long-term investment shortfalls and repeated speculative bubbles, these animal spirits would trigger a wave of 'green' innovation (Stern 2010, Stern and Rydge 2012) that is necessary to sustain a long growth cycle, much as oil, automobiles and mass production did in the previous century.

A low-carbon transition supported by the CRA device could thus have a macroeconomic value that should be of interest to climate-agnostic policymakers. In addition to reducing the gap between the propensity to save and the propensity to invest, it would also help

10 Multilateral finance institutions (the ADB, the World Bank, the EBRD, and the EIB) invest in principle on long-run horizons. But the scope of their interventions remains limited and they are not suitable for driving savings towards the multiplicity of scales of investments that are needed, including small-scale ones. Insurance companies work on reducing risks of long-term investments, but do not invest in these themselves. On the limits of the current financial institutions, see UNEP- (2015), Canfin-Grandjean Commission (2015) and OECD (2015).

11 Simulations carried out on the basis of the of the International Energy Agency's *World Energy Outlook* (IEA 2014) and published in Hourcade et al. (2014).

to address one of the major 'fault lines' of the world economy as pointed out by Rajan R.G. (2010), that is, the development strategy of developing countries. This strategy is currently based on export-led growth, which is implies excessive dependence on the ability of foreign consumers to pay. It constrains domestic demand and to leads to under-valuations of currencies.

Governments are hesitant to alter this strategy because of the uncertainty over recovering jobs lost in the export-led sectors through the domestic-oriented production sectors, and the risk of excess protection in domestic-oriented production sectors resulting in inefficient projects. A CRA device would facilitate this strategic change. In addition to generating important North-South flows in support of INDCs directed towards domestic markets and activities, it would address the IMF's warning about the lack of infrastructure investments (IMF 2014) and, given the sectors concerned (energy access, buildings, transportation), would contribute to inclusive development (World Bank 2012). It would also decrease the need for a 'war chest' of official reserves in foreign currencies, since the CRAs would become a de facto common numeraire for interbank settlement payments.

5 Conclusions

I have argued that harnessing the animal spirits of finance to enable a low-carbon transition is necessary for launching ambitious climate policies and would help bring the world economy out of the current context of economic uncertainty. The proposed Climate Remediation Assets (CRAs) are a way to achieve the required ambitious climate policies. CRAs would be instrumental in implementing the "*paradigm shift*" adopted in Cancun *"towards building a low-carbon society that offers substantial opportunities and ensures continued high growth and sustainable development"* and *"equitable access to sustainable development" (UNFCCC 2011).* The underlying intuition is that the required climate policies question the implicit social contract at the national and international levels that relies on cheap energy and cheap fossil fuels, which has led both households and enterprises to adopt behaviours based on capital stock (mobility, housing modes, location of human settlements) that cannot be altered overnight.

Finance is, with fiscal systems, a key component of any new social contract. Monetary-based finance would in effect be saying: *"My government really thinks that avoiding carbon emissions is something of value. By adopting CRAs it is giving clear and immediately tangible support to investment initiatives in low-carbon projects and technologies, and in doing so it is proving its commitment to combatting global warming and to a more sustainable development, and helps me to take part"*.

This is a form of forward contract that has to be passed within each country, but will realise its potential only if it quickly involves most of the international community. This is possible because a fully-fledged CRA system would not require adversarial negotiations over the division of the remaining global CO_2 emissions budget (Averchenkova et al. (2014). It needs an agreement on the economic and social value of mitigation activities and on rules to coordinate the amount of CRAs that governments commit to backing. These rules will be a way of translating the CBDR principle between countries – with different historical responsibilities for both climate change and the current drawbacks of the financial system – in the context of a cooperative process.

References

Aglietta M., E. Espagne and E. Perissin-Fabert (2015), "A proposal to finance low carbon investments in Europe France Strategy", France Stratégie Policy Brief (available at http://blog.en.strategie.gouv.fr/2015/02/policy-brief-proposal-finance-low-carbon-investment-europe/).

Averchenkova, A., N. Stern and D. Zenghelis (2014), "Taming the Beasts of "burden-Sharing": An Analysis of Equitable Mitigation Actions and Approaches to 2030 Mitigation Pledges", Policy Paper, Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment.

Blanchard, O. (2015), "Ten take aways from the rethinking macro policy: progress or confusion?", IMF Direct, 1 May (available at http://blog-imfdirect.imf.org/2015/05/01/ten-take-aways-from-the-rethinking-macro-policy-progress-or-confusion/).

Bodansky, D. (2001), "Bonn Voyage: Kyoto's uncertain revival", *The National Interest* 65: 45-55.

Buchner, B. et al. (2013), *The Global Landscape of Climate Finance 2013*, Climate Policy Initiative.

Buchner, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional finance'", Chapter 33 in this volume.

Clarke, L., K. Jiang et al. (2014), "Assessing transformation pathways", in *Climate Change 2014: Mitigation of Climate Change* (see IPCC (2014b) in the introduction to this book for the report's full reference).

De Gouvello, C. and I. Zelenko (2010), "Scaling up the financing of emission reduction projects for low carbon development in developing countries. Proposal for a low carbon development facility", World Bank Policy Research Working Paper, Washington, DC.

Fogel, R. W. (1964), *Railroads and American Economic Growth: Essays in Economic History,* Baltimore, MD: The Johns Hopkins Press.

Hallegatte, S. M. Ghil, P. Dumas and J.-C. Hourcade (2008), "Business cycles, bifurcations and chaos in a neo-classical model with investment dynamics", *Journal of Economic Behavior & Organization* 67(1): 57-77.

Hourcade, J.-C. and F. Ghersi (2002), "The Economics of a Lost Deal: Kyoto - The Hague –Marrakesh", *The Energy Journal* 23(3): 1-26.

Hourcade, J.C. and Shukla P. (2015), "Climate policy architecture for the Cancun Paradigm Shift: building on lessons from history", forthcoming in *International Environmental Agreements: Politics, Law and Economics*.

Hourcade, J.-C., B. Perrissin Fabert and J. Rozenberg (2012), "Venturing into uncharted financial waters: An essay on climate-friendly finance", *International Environmental Agreements: Politics, Law and Economics* 12(2): 165-186.

Hourcade, J.-C., M. Aglietta and B. Perissin Fabert (2014), "Transition to a low-carbon society and sustainable economic recovery, A monetary-based financial device", study funded by the Caisse des Dépôts et Consignations, VINCI, BNP, and Entreprises pour l'Environnement.

International Energy Agency (IEA) (2014), *World Energy Investment Outlook – Special Report*, Paris.

International Monetary Fund (IMF) (2014), *World Economic Outlook – Recovery Strengthens, Remains Uneven*, Washington, DC.

Krugman, P. (2008), *The Return of Depression Economics and the Crisis of 2008*, New York: W. W. Norton & Company, Inc.

Landes, D. (1969), *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present*, Cambridge and New York: Cambridge University Press.

Lewis C., N. Pain and J. Strasky (2014), "Investment Gaps after the Crisis", OECD Economics Department Working Paper, Paris.

Luderer G., E. De Cian, J.-C. Hourcade, M. Leimbach, H. Waisman and O. Edenhofer (2012), "On the regional distribution of mitigation costs in a global cap-and-trade regime",, *Climatic Change* 114(1): 59-78.

Mathys, N. and J de Melo (2010), "Trade and the Environment: The Challenges Ahead", CEPR Discussion Paper No. 8032, London.

New Climate Economy (2014), *Better Growth, Better Climate: The New Climate Economy Report*, The Global Commission on the Economy and Climate.

Nordhaus, W. (2015) "Climate clubs: Overcoming free-riding in international climate policy", *American Economic Review* 105(4): 1339-1370.

OECD (2009), Declaration on Green Growth Adopted at the Meeting of the Council at Ministerial Level on 25 June 2009 (C/MIN(2009)5/ADD1/FINAL), Paris.

OECD (2015), Climate Change: OECD-DAC External Development Finance Statistics (available at http://www.oecd.org/dac/stats/climate-change.htm).

Popp, D. and R. Newell (2012), "Where does energy R&D come from? Examining crowding out from energy R&D", *Energy Economics* 34(4): 980-991.

Rajan R.G. (2010) *Fault Lines, How Hidden Fractures Still Threaten The World Economy*, Princeton, NJ: Princeton University Press

Canfin-Grandjean Commission (2015), *Mobilizing Climate Finance: A Roadmap to Finance a Low-Carbon Economy*, Report of the Canfin-Grandjean Commission (available at http://www.elysee.fr/assets/Report-Commission-Canfin-Grandjean-ENG).

Roe, M. J. (1994), *Strong Managers, Weak Owners: the Political Roots of American Corporate Finance*, Princeton, NJ: Princeton University Press.

Stern, N. and J. Rydge (2012), "The new industrial revolution and international agreement on climate change", *Economics of Energy and Environmental Policy* 1: 1-19.

Stern, N. (2012), "How can we respond and prosper: The New Energy-Industrial Revolution", Lionel Robbins Memorial Lecture Series, London School of Economics.

Summer, L. (2014), "Bold reform is the only answer to secular stagnation", (available at http://larrysummers.com/2014/09/08/bold-reform-is-the-only-answer-to-secular-stagnation/#sthash.bUJi1sLw.dpuf).

UNEP (2015), "Financial reform, Institutional Investors and Sustainable Development: A review of current policy initiatives and proposals for further progress", Inquiry Working Paper 15/07 (available at http://apps.unep.org/publications/pmtdocuments/-Financial_Reform,_Institutional_Investors_and_Sustainable_Development___A_Review_of_Current_Policy_Initiatives_and_Proposals_for_Further_Progress-201.pdf)

UNFCCC (1997), "Proposed elements of a protocol to the United Nations framework Convention on Climate Change presented by Brazil in response to the Berlin Mandate" (AGBM/1997/misc.1/add.3), Bonn.

UNFCCC (2011), "Decision 1/CP16, The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention", Bonn.

Wiener, J. (2015) "Towards an effective system of monitoring, reporting and verification", Chapter 13 in this volume.

World Bank (2012), *Inclusive Green Growth: The Pathway to Sustainable Development*, Washington DC.

About the author

Jean-Charles Hourcade is Director of Research at the Centre National de la Recherche Scientifique (CNRS) and was previously head of CIRED (1987-2012). He is an established figure for over the last 20 years in the field of economic modelling research on climate change and energy issues, publishing widely on the subject and leading several EU research projects. He is the scientific coordinator of the French research networks R2DS, dedicated to sustainable development issues, and of the Chair ParisTech long-term modelling for sustainable development. At the international level, he is involved in many international research networks, has been an expert for most international agencies about environmental and energy (OECD, UNEP, WB, IEA, UNESCO) and participated actively in the French negotiating team between COP1 and COP6. He was also convening lead author for the 2nd and 3rd IPCC Assessment Reports and lead author for the 4th and 5th reports. Finally, he is a member of the Steering Group of the LCS-RNet and has chaired it since 2011.

35 Measuring vulnerability to climate change for allocating funds to adaptation

Patrick Guillaumont
Ferdi

The debates on financing adaptation to climate change have so far not really addressed its allocation across developing countries. This chapter examines how the concessional funds for adaptation should be allocated. The principle proposed is a 'vulnerability-based allocation' (VBA) whereby funds are allocated to developing countries primarily according to their vulnerability to climate change, for which they are not responsible. To this end, a physical vulnerability to climate change index (PVCCI) is proposed, as tentatively established by Ferdi, which aggregates the physical impacts of climate change according to their main identifiable channels. The index is likely to be updated regularly. Its average level is given for some groups of countries, such as LDCs and SIDS. To determine the allocation of adaptation funds, the index should be used in a simple formula that also includes income per head, since the poorer countries are, the less resilient they are to climate change. The choice of the parameters of the formula will express, in a transparent way, the consensus of the international community on the principles of the allocation of 'adaptation credits' by country. A tentative simulation shows the relative share that each group of countries would receive (with more than half going to LDCs), as well as the ratios of the level of allocation per head to the average for developing countries (which are high for SIDS and for LDCs). Adaptation credits could be used by countries via accredited financial institutions to which they would submit their adaptation programs or projects.

1 Introduction: The geographical allocation of adaptation funds within 'climate finance'

The discussions on financing the responses to climate change in developing countries too often mingle separate issues. Indeed, adaptation to climate change cannot be dissociated from economic development, or be designed regardless of mitigation of climate change, which is itself essential in development strategy. But these interactions are at the operational level. They do not negate the need to distinguish between the respective sources of funding available for development, adaptation and mitigation, in particular between the respective concessional sources, and their justification.

Two problems arise in financing each of these three purposes: first, the mobilisation of resources; and second, their allocation among recipient countries. The mobilisation of resources has so far held much more of the attention of negotiators and experts than their allocation (Brender and Jacquet 2015, Canfin and Granjean 2015; Westphal et al. 2015). The final declaration of the July 2015 UN Conference on Financing for Development (held in Addis Ababa) is revealing in this regard. Concerning climate finance, it recalls the commitment of developed countries to mobilise US$100 billion per year from 2020 "from a wide variety of sources to address the needs of developing countries", as well as the need for transparent methods of reporting climate finance (United Nations 2015, para. 60). It welcomes the implementation of the Green Climate Fund (GCF) and the decision of its Board "to aim for a 50:50 balance between mitigation and adaptation over time on a grant equivalent basis and to aim for a floor of 50 per cent of the adaptation allocation for particularly vulnerable countries, including least developed countries, small island developing States and African countries "(United Nations 2015, para. 61). The rule to be used for sharing of the GCF between adaptation and mitigation has not yet been decided for the remaining and major part of the $100 billion; the same holds for the aim of a minimum of half to go to vulnerable countries.

It is assumed here that the total amount of climate resources mobilised for developing countries is a given (see the chapters by Buchner and Wilkinson and Massetti in this book), as well as the sharing of these resources between mitigation and adaptation. It is also assumed that it has been decided that the share will be provided in a concessional manner, and that concessional resources will be additional to those already mobilised for development.

Using these assumptions, we examine how concessional resources for adaptation should be allocated among developing countries. This chapter first presents the principles the allocation should meet, and stresses the need to take into account the vulnerability to climate change of each country (Section 2). Section 3 discusses the nature of the vulnerability to be considered and proposes a new index that is independent of countries' political choices. Finally, Section 4 discusses how the principles can be implemented and the index used in a global allocation system for adaptation funds (Section 4).

2 Principles of allocation of climate change adaptation funds among developing countries: Specificity of adaptation

For climate change adaptation funds, as with development assistance, three principles of allocation must be combined: effectiveness of the use of the funds with regard to the objective, equity in their distribution between countries, and transparency. To allocate the funds in a multilateral framework, transparency can be sought through an allocation formula that expresses the consensus of stakeholders. This has been done by the multilateral development banks (MDB) with a 'performance-based allocation' (PBA) formula that leads to an allocation of the available resources on the basis of a predominant performance indicator[1] as well as income per head (with a lower level of this expressing greater needs for a country). The application of this formula has seen many changes, complications and exceptions, which have been criticised and greatly reduce the transparency of allocation (see, in particular, Kanbur 2005, Guillaumont and Wagner 2015, Guillaumont et al. 2015a). For the allocation of adaptation funds among developing countries, it is possible to use a different formula that ensures transparency while avoiding the criticism aimed at PBA.

1 Derived mainly from the Country Policy and Institutional Assessment (CIPA), a composite index used by the MDBs.

2.1 Allocation for mitigation and allocation for adaptation: Two rationales

It is not possible to simultaneously determine the desirable geographical allocation of funds for adaptation and funds for mitigation, because their objectives are different.

Mitigation of climate change largely corresponds to the production of a global public good. It must be implemented in individual countries, but in the interest of the whole planet. Effectiveness is mainly assessed here in terms of avoided CO_2, rather than in terms of the development of the countries where mitigation is implemented. With regard to effectiveness, the corresponding funds should be used where mitigation opportunities are greatest (for a discussion, see the chapter by Massetti in this book). However, granted on a concessional basis to poor countries, these credits can also help the countries to implement a strategy of clean development, an example being funds for the maintenance of tropical forests (see also the chapter by Angelsen in this book). This criterion of needs can be satisfied by a simple condition of eligibility or by a modulation of concessionality according to income per head.

In contrast, adaptation concerns each country individually, and the funds a country receives for adaptation are supposed to be used for its own development. They can be channelled in different ways and according to specific criteria, but their use cannot be dissociated from that of development assistance. There is therefore a risk of fungibility undermining the additionality of resources. It is the specificity of the criteria applied to the allocation of adaptation funds that allows them to be differentiated from the other flows for development.

2.2 Adaptation: The ethical basis of a criterion of vulnerability to climate change

The specificity of vulnerability to climate change is obviously that most poor countries facing it are not responsible for it.[2] This vulnerability constitutes an allocation criterion for meeting the principle of equity (or need), which is without equivalent. There may be

2 As noted by, among others, Kaudia in her chapter in this book that highlights the importance of adaptation for poor countries.

a precedent in the allocation of official development assistance (ODA), where structural economic vulnerability is sometimes considered as one of the possible allocation criteria. But for vulnerability to climate change the justification is stronger, for two reasons. First, and most importantly, there is a moral debt of the developed countries responsible for climate change owed to those who suffer from it. Birdsall and de Nevers (2012) speak of a 'causal responsibility', which creates an 'entitlement' for countries affected by climate change. Second, as will be seen below, it is possible to design a vulnerability index that is more clearly independent of countries' own choices than the index commonly used to measure structural economic vulnerability, namely, the UN's Economic Vulnerability Index (EVI).

Even if the idea of using an index of vulnerability to climate change as a criterion for the allocation of funds for adaptation was first presented in conjunction with the use of structural economic vulnerability as a criterion for the allocation of ODA (Guillaumont 2008, 2009 , 2015), it is independent of ODA because of its ethical basis. The idea was first proposed by Ferdi (Guillaumont and Simonet 2011, 2014) and by the Center for Global Development (CGD) (Wheeler 2011, Birdsall and De Nevers, 2012), as well as in works prepared for the World Bank's *World Development Report 2010* (Barr et al. 2010; Füssel, 2010, World Bank 2010), although these various works do not converge on the way to assess the vulnerability to be taken into account for allocation.[3]

3 The few works since devoted to this topic seem to have been about the allocation of resources from the Green Climate Fund, dealing simultaneously with mitigation and adaptation (Polycarp et al. 2013), or dealing separately with adaptation (Noble 2013), but without using a quantitative criterion of vulnerability to climate change.

3 An index of vulnerability to climate change as a criterion for the allocation of the adaptation funds

3.1 What kind of indicator for measuring vulnerability?

There are many indices of vulnerability to climate (change?).[4] However, not being designed for this specific purpose, they generally do not meet the requirements for serving as a criterion for the allocation of adaptation resources.

First, the index must be independent of countries' policies. If a country's policy leads to a reduction of vulnerability by increasing the capacity for adaptation, i.e. resilience, this should not be a reason to reduce the allocation. Indeed, vulnerability includes two components which logically impact on the allocation but in opposite directions. Truly exogenous vulnerability, which results from a shock suffered by the country for which it is not responsible, unquestionably deserves external support. This is not the case for vulnerability that could be reduced by a country improving its ability to adapt. Good political resilience,[5] which lowers vulnerability, could be a possible performance criterion (if it is considered useful to have such a criterion). This distinction applies in particular to resilience that results both from structural factors – such as income per head or human capital, which are generally taken into account separately in the allocation process, with a low level resulting in more support – and resilience policy, weakness in which may lead to less support. Most of the available indices mix the two types of vulnerability, which of course enables them to offer a broad view of countries' vulnerabilities, but makes them inappropriate for allocation.[6]

Second, and for similar reasons, for international comparison and allocation it does not seem appropriate to use vulnerability indices corresponding to an assessment of the economic damage expected from climate change.[7] Considerable progress has been

4 Survey in Fussel (2010), Guillaumont et al. (2015a) and Miola et al. (2015).

5 That can be translated into special measures such as external reserves, insurance mechanisms, and so on.

6 A significant example is given by the index ND-GAIN (University of Notre Dame Global Adaptation Index) (Chen et al. 2015).

7 Wheeler (2011) refers to the agricultural productivity losses estimated by Cline (2007) for the CGD.

made in the assessment of this damage, as evidenced in the review of the 'new climate economy' literature by Dell et al. (2014). The chapter by Hallegate et al. in this book provides examples. However, these estimates are inevitably open to debate and partial, as stressed by the authors. For example, agricultural production losses resulting from increased aridity in the distant future depend not only on the evolution of rainfall precipitation and temperatures, but also on the evolution of techniques, research, and agricultural policies. In addition, some economic damage from climate change is even more difficult to predict and measure (e.g. in the area of peace and security). Generally, damage estimates involve assumptions about adaptation policies that are specific to each country, and each country should make its own decision if the principles of ownership and alignment are to be met. Estimates of the costs of potential damage or adaptation carried out on a global scale are extremely useful for the global mobilisation of resources, but they cannot serve as the basis for the allocation of adaptation credits between countries.[8]

Third, the relevant vulnerability for the allocation of adaptation funds, because of the above-mentioned ethical argument, is vulnerability to climate *change*, not climate vulnerability in itself, which has always existed in various forms in different regions of the world. The latter 'climate' vulnerability does not entail the responsibility of developed countries in the same way.

In short, we propose the use of a *physical* index of vulnerability to climate change that is *exogenous*, implies no socioeconomic estimates, and captures in an adaptive way the impact of climate *change*, rather than just the climate itself. Since the index will reflect a change that is likely to continue, and the only non-debatable change is one that is observed (the prospects for which vary with the arrival of new observations), the index must be constantly updated.

8 The World Bank highlights the fragility of the 'across country' conclusions on the costs of adaptation (World Bank 2010a, p. 89).

3.2 A Physical Vulnerability to Climate Change Index (PVCCI)

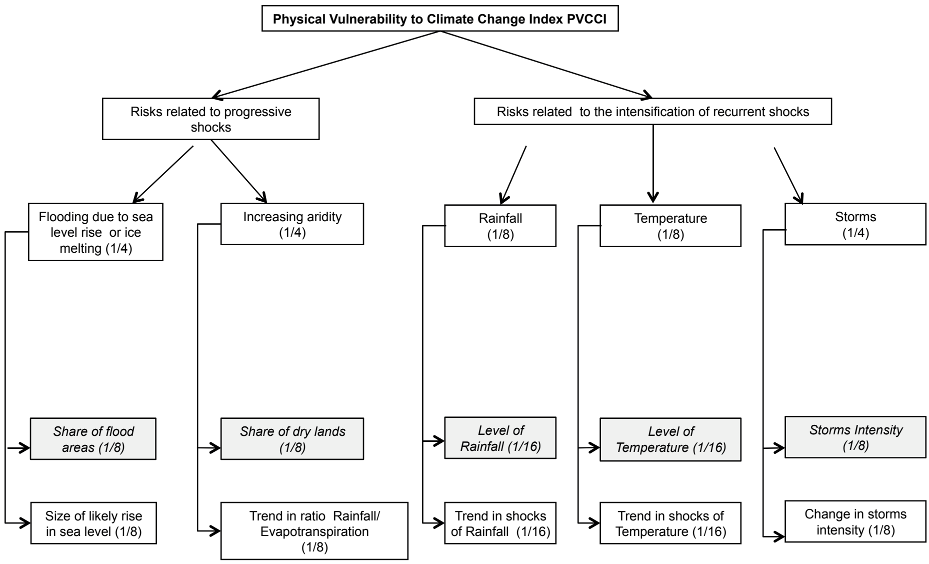
An indicator of vulnerability to climate change which meets the above-mentioned criteria (exogeneity of components, absence of socioeconomic variables, and a focus on the impact of the change) was set up by Ferdi in 2011 (Guillaumont and Simonet 2011) and subsequently revised on several occasions to use new data or to incorporate methodological improvements (Guillaumont and Simonet 2014; Guillaumont et al. 2015b). It is a dynamic, forward-looking indicator – although based on past data – that relies on a distinction between two kinds of risks that arise from climate change:

1. risks related to *progressive shocks*, such as the rise in sea level (risk of flooding), a rising trend for temperatures, or a decreasing trend in rainfall precipitation (risk of desertification); and
2. (2) risks associated with *the intensification of recurrent shocks*, whether rainfall shocks, temperature shocks, or cyclones.

For each of these two types of shock, the index – like the EVI – relies on a distinction between the size of shocks and the exposure to shocks. Since the sources of vulnerability are heterogeneous and the vulnerability of each country is specific, the indices corresponding to the various types of shocks are aggregated through a quadratic average, which gives more weight to those components that reflect vulnerability more.

In its current structure, the PVCCI does not include resilience (i.e. the capacity to adapt to shocks), since, as outlined above, resilience is determined by two categories of factors that influence the allocation in opposite directions: structural factors (income per head and human capital), and resilience policy.

Figure 1 Components of the Physical Vulnerability to Climate Change Index



Note: The boxes correspond to the last rows of the graph respectively refer to exposure components (in italics) and to the size of the shocks component.

3.2 Groups of countries most vulnerable to climate change

The Addis Ababa declaration welcomes the objective of the Green Climate Fund to allocate half of its resources to 'vulnerable countries', identifying the LDCs, SIDS and African countries. For the consensus to operate, it should rely on a quantitative assessment. Estimates of the index may indeed differ according to the method of calculation. The latest Ferdi estimates[9] do not provide evidence of an average level of physical vulnerability to climate change for LDCs that is significantly different from that of other developing countries, but structural economic vulnerability among LDCs (using the EVI index) is significantly higher, which is to be expected as EVI is a criterion for the identification of least-developed countries. However, the PVCCI does not include structural resilience, which is much lower in LDCs (and Africa) due to lower levels of human capital and income per head. LDCs are therefore especially

9 Calculations by Sosso Feindouno at Ferdi.

vulnerable to climate change if we consider 'structural vulnerability', including the physical vulnerability and the structural factors of low resilience.

For the SIDS, the average level of the PVCCI is slightly higher than that of other developing countries (and close to that of LDCs, which is not the case for EVI).

Table 1 Physical Vulnerability to Climate Change Index by country group

Group of countries	Average	Median	St. dev.	Min.	Max.
Developing countries (108)	45.6	44.7	7.3	31.4	63.2
LDC (47)	46.0	42.2	7.2	33.2	59.0
Non LDC (61)	45.2	45.8	7.5	31.4	63.2
SIDS (24)	47.8	48.2	9.1	31.4	63.2
SIDS-LDC (10)	47.5	48.1	9.1	33.2	59.0
SIDS Non-LDC (14)	48.0	48.2	9.4	31.4	63.2

There is in fact a large spread in the index scores within each country category, which is a major reason for determining the allocation country-by-country on the basis of criteria such as the PVCCI rather than by membership of a category. We can then examine the results for each category.

4 Implementation: Design and use of 'adaptation credits'

Now, assume that there is a consensus on an index of physical vulnerability to climate change, which is available to most developing countries. How can it be used for the allocation of adaptation funds? A consensus on an allocation formula is still needed which, from this index and other possible criteria, may determine an allocation of the total adaptation fund between countries. An 'adaptation credit' would correspond to the 'normal allocation' estimated for each country. On this basis, a country could apply to various financial institutions through which the adaptation funds would be channelled.

4.1 Measurement of the 'adaptation credits' from an allocation formula

The formula should express the simple idea that the adaptation funds must meet the needs of countries affected by climate change, for which they are not responsible and which they are less able to cope with the poorer they are. The formula should be based on two essential criteria: physical vulnerability to climate change, and income per head (and/or the level of human capital). The variables corresponding to the two criteria would be introduced preferably in a multiplicative function, in order to show the elasticity of the allocation to each criterion.

The model may seem akin to the PBA that all the multilateral development banks use to allocate their concessional credits (Guillaumont and Wagner 2015). However, it is different for two reasons. First, it includes an indicator of vulnerability, while the MDBs so far have not integrated economic vulnerability in their model.[10] Second, and most importantly, in the PBA the criterion of 'performance' (essentially governance) plays a major role. Priority is given to effectiveness over equity. For the allocation of adaptation funds, the priority is instead on equity, because of the ethical basis for the financing of adaptation. It is essential that the adopted measure of vulnerability to climate change reflects a vulnerability *for which they are not responsible*, in order to justify the support of the international community. Income per head is utilised to reflect the need for concessional adaptation resources, with a low level indicating low structural resilience.

This approach is similar to the point of view expressed by Birdsall and de Nevers (2012), but it differs from the way in which some authors – influenced by the PBA and thus giving a major weight to the 'performance' measure – consider the allocation of funds for adaptation (Barr et al. 2010, World Bank 2010b). The model proposed here is a *vulnerability*-based allocation (VBA) rather than a PBA.

Using the same calibration of the variables as in the PBA model used by the MDBs and the same functional form, a model has been built from only three variables: level of income per head (AY), a measure of PVCCI (V), and the size of the population (P).[11] The results of a simulation carried out for illustrative purposes[12] on a sample of 106

10 An exception is the Caribbean Development Bank. The European Commission has recently used EVI for the allocation of assistance (European Commission 2015).

11 According to the following formula, allocation to country $i = P^a i.\ AY^b i.\ V^c i.$

12 Simulations run by Laurent Wagner at Ferdi (here with the following parameters: a = 1; b = 2; c = 4). Simulations with a parameter a<1 are legitimate due to the structural resilience of small countries.

countries, using the latest version of Ferdi's PVCCI and figures for income per head and population from 2014, are given in Table 2. The table shows the following:

1. Column (1): The relative share of the allocation for LDCs, SIDS, low-income countries (LICs), lower-middle-income countries (LMICs), upper-middle-income countries (UMICs), and sub-Saharan African countries (SSA).
2. Column (2): The relative share of the population in each group.
3. Columns (3) and (4): An index of the relative allocation per capita, respectively a weighted average, given by the ratio of (1) to (2), and a simple average (index > 1 if the allocation per capita is higher than the global average), with some indicators of the spread within each group (in columns (5) to (7)).

According to this simulation, LDCs would receive over half of the adaptation credits. The SIDS group would receive a level of credits per head that is close to the average, due to the fact that many SIDS have a fairly high level of income per head. When an exponent lower than one is applied to the population size, in order to reflect a lower resilience due to small size, the allocation per head of the SIDS becomes higher than average. Of course, there is a wide range of scores for the index across countries.

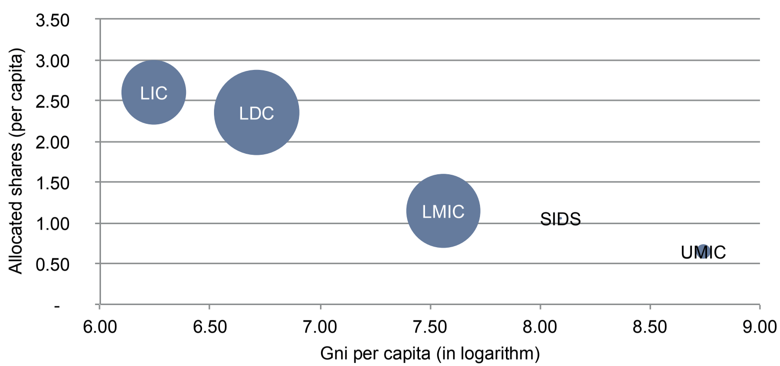
Figure 2 summarises these observations by representing for each group of countries both the relative level of the allocation per head as a function of GNI per head, and the relative share of the total allocation (shown by the size of the bubbles).

It should be underlined that the 'normal allocations' are designated from continuous criteria and not from category membership. If LDCs receive half of the adaptation credits, this is due not to a quota but to their characteristics. Some LDCs may only be a slightly vulnerable to climate change and receive few credits for adaptation, while at the same time they may have a high economic vulnerability that is likely to lead to a relatively high level of ODA per head. Middle-income non-LDCs may be highly vulnerable to climate change, so justifying a fairly high level of allocation for adaptation, without being eligible for a high level of ODA. In this regard, the allocation of adaptation credits based on an indicator of vulnerability to climate change should help to achieve the 'smooth transition' wanted by the United Nations for the countries graduating from the LDC category, many of which are vulnerable to climate change.

Table 2 Vulnerability-based allocation of adaptation resources for 106 developing countries

	Share of allocated resources (%) (1)	Share of total population (%) (2)	Relative allocation per capita (weighted average) (3)=(1)/(2)	Relative allocation per capita (simple average) (4)	Relative allocation per capita (std. deviation) (5)	Relative allocation per capita (max.) (6)	Relative allocation per capita (min.) (7)
LIC	42.22%	20.03%	2.11	2.60	3.12	10.14	0.15
LMIC	48.37%	49.38%	0.98	1.15	1.40	4.99	0.01
UMIC	9.41%	30.59%	0.31	0.65	0.73	2.63	0.00
LDC	55.75%	30.28%	1.84	2.36	2.74	10.14	0.02
SIDS	1.71%	1.77%	0.97	1.06	1.07	3.75	0.01

Figure 2 Relative allocation per capita for adaptation and GNI per capita (a=1)



Under the influence of donors, governance factors might be introduced in the model of allocation of funds for adaptation, with a positive sign as a criterion of effectiveness or performance. A logical criterion would then be an indicator of resilience policy. But, as seen above, resilience related to a country's own willingness is difficult to measure. What could an alternative measure be? Could it be general economic performance through a measure similar to that used for the PBA? Or the quality of a country's policy to combat global warming, which is a more relevant criterion of allocation for mitigation than adaptation? Or an evaluation of the portfolio of projects implemented in the country using foreign aid?

None of these options seems legitimate with regard to the ethical argument specific to adaptation stated above. Should adaptation credits be reduced for a fragile state due to bad governance related to its fragility? When using credits, the quality of adaptation projects can be controlled.

4.2 Use of adaptation credits by countries: Competition between the accredited bodies

How could a country use its 'adaptation credit' ?

It seems to be agreed that a number of institutions will be accredited to receive additional climate resources from the international community (not only the Green Climate Fund, but also the MDBs, UNDP, and various bilateral development agencies). In the proposed system, a developing country to which an adaptation credit is allocated will be allowed to draw any part of this credit from the accredited institution of its choice. An international body (which may be the Green Climate Fund) will be responsible for keeping an account of the allocations received by the accredited institutions and the drawings made from them. The total amount of adaptation credits would not exceed that of the allocations. The allocations and the credits could be measured in terms of their grant element, so that projects can be implemented under the financial conditions that are most appropriate in each case.

Each country holding an adaptation credit may thus present to the institution of its choice projects or adaptation programmes. The accredited institution will ensure that it is a real adaptation project or programme, and will then analyse its modalities with the country, as it does for its other operations. Each country can thus use its adaptation credit through the institution that offers the best financial conditions and technical services.

In the above, we have assumed that from the total resources mobilised for adaptation, what each accredited institution manages is determined on a discretionary basis by the adaptation fund donors. One might also imagine that the Green Climate Fund, instead of becoming an additional institution for direct funding of adaptation projects or programmes, could intervene simply as a refinancing body for the accredited institutions or as a subsidising instrument for eligible projects or programmes. Accredited institutions would then receive their resources partly and on a discretionary basis from bilateral sources, and partly (or only, if so decided by the international community) through the Green Climate Fund, depending on the quality of the programmes and projects that are submitted. Consistency with development programmes and projects would be achieved at the operational level by the accredited institutions, which are skilled in the art. Compliance with the objective of adaptation would be achieved through the mode of financing, in particular the Green Climate Fund, whose function for adaptation would then be redefined.

The use of funds described above for the adaptation process is legitimate only if donors are willing to ensure that mobilised funds are used to adapt, regardless of the risks of fungibility. The contribution of developed countries should be based on each country's responsibility for global warming. The proposal only aims at allocating the amount of additional resources that will be mobilised for adaptation by the international community. Donors can, of course, provide more adaptation resources than they will be committed to providing. They will be all the more inclined to do so since their development assistance, without being reduced, will be adapted to climate change.

References

Angelsen, A. (2015), "REDD+: What should come next?", Chapter 28 in this book.

Barr, R., S. Fankhauser, and K. Hamilton (2010), "Adaptation Investments: A Resource Allocation Framework | Grantham Research Institute on Climate Change and the

Environment", *Mitigation and Adaptation Strategies for Global Change* 15 (8): 843–858.

Birdsall, N. and M. de Nevers (2012), "Adaptation Finance, How to Get Out from between a Rock and a Hard Place", CGD Policy Paper No. 001, Washington, DC: Center for Global Development (available at http://www.cgdev.org/sites/default/files/1425965_file_Birdsall_de_Nevers_Adaptation_Finance_FINAL_0.pdf).

Brender, A. and P. Jacquet (2015), "Comment 'financer le climat'?", in J. Mistral (ed.), *Le climatva-t-il changer le capitalisme ? La grande mutation du XXIe siècle*, Paris: Eyrolles, pp. 121-134.

Buchener, B. and J. Wilkinson (2015), "Pros and cons of alternative sources of climate change financing and prospects for 'unconventional finance'", Chapter 33 in this book.

Canfin, P. and A. Grandjean (2015), Mobiliser les financements pour le climat (available at http://www.elysee.fr/communiques-de-presse/article/rapport-mobiliser-les-financements-pour-le-climat-de-pascal-canfin/).

Chen, C., I. Noble, J. Hellman, M. Murillo and N. Chawla (2015), "University of Notre Dame Global Adaptation Index Country Index Technical Report", Technical Document, University of Notre Dame (available at http://index.nd-gain.org:8080/documents/nd-gain_technical_document_2015.pdf).

Cline, W. R. (2007), *Global Warming and Agriculture: Impact Estimates by Country*, Washington, DC: Center for Global Development and Peterson Institute for International Economics.

Dell, M., B. F. Jones and B. A. Olken (2014), "What Do We Learn from the Wheather? The New Climate-Economy Literature", *Journal of Economic Perspectives* 52(3): 740-798.

European Commission (2015), Workshop on "Indicators and Data for Climate Resilient Development: From Data to Information and Knowledge to Policy Actions", JRC Science Hub-European Commission, Brussels (available at https://ec.europa.eu/jrc/en/event/workshop/indicators-and-data-climate-resilient-development).

Füssel, H.-M. (2010), *Review and Quantitative Analysis of Indices of Climate Change Exposure, Adaptive Capacity, Sensitivity, and Impacts*, Washington, DC: World Bank.

Green Climate Fund (2015), "Analysis of the Expected Role and Impact of the Green Climate Fund", Songdo, Republic of Korea (available at http://www.gcfund.org/fileadmin/00_customer/documents/MOB201503-9th/06_-_Analysis_of_the_Expected_Role_and_Impact_of_the_Green_Climate_Fund_20150228_fin.pdf).

Guillaumont, P. (2008), "Adapting Aid Allocation Criteria to Development Goals. An Essay for the 2008 Development Cooperation Forum, UN ECOSOC", Ferdi Working Paper, Cleremont-Ferrand, France.

Guillaumont, P. (2015), "Measuring Structural Vulnerability to Allocate Development Assistance and Adaptation Resources", Ferdi Working Paper No. 68, Cleremont-Ferrand, France (available at http://www.ferdi.fr/en/publication/p68-measuring-structural-vulnerability).

Guillaumont, P., S. Guillaumont Jeanneney and L. Wagner, (2015a) "How to take into account vulnerability in aid allocation criteria and lack of human capital as well: improving the performance based allocation", Ferdi Working Paper No. 13, Cleremont-Ferrand, France

Guillaumont, P. and C. Simonet (2011), "Designing an Index of Structural Vulnerability to Climate Change", Ferdi Working Paper, Cleremont-Ferrand, France

Guillaumont, P. and C. Simonet (2014), "Facing Climate Change in the LDCs: How to Fit the Istanbul Programme of Action", in Istanbul Programme of Action for the LDCs (2011-2020). Monitoring Deliverables, Tracking Progress-Analytical Perspectives, LDC IV Monitor, Commonweath Secretariat, pp. 287-317.

Guillaumont, P., C. Simonet, M. Closset and S. Feindouno (2015b), "An Index of Physical Vulnerabilty to Climate Change, Who Are the Most Vulnerable Countries?", Ferdi Working Paper, Cleremont-Ferrand, France (forthcoming).

Guillaumont, P. and L. Wagner (2015) "Performance Based Allocation (PBA) of Foreign Aid: Still Alive?", in M. Arvin (ed.), *Handbook on the Economics of Foreign Aid*, Cheltenham, UK: Edward Elgar (forthcoming).

Kanbur, R. (2005), "Réformer la formule :unemodeste proposition pour inclure des critères de résultatsdans les procéduresd'allocation de l'aide de l'IDA", *Revue d'économie du développement* 13: 238.

Massetti, E. (2015), "The macroeconomics of climate policy: Investments and financial flows", Chapter 32 in this book.

Miola, A., V. Paccagnan, E. Papadimitriou, and A. Mandrici (2015) "Climate Resilient Development Index: Theoretical Framework, Selection Criteria and Fit for Purpose Indicators", Report EUR 27126 EN, European Commission Joint Research Centre, Brussels.

Kaudia, A. (2015) "Policy options in low-income countries: Achieving socially appropriate climate change response objectives", Chapter 27 in this book.

Noble, I. (2013) "Options for Resource Allocation in the Green Climate Fund (GCF): Possible Allocation Principles and Criteria – Adaptation", Background Paper 3, Options for Resource Allocation in the Green Climate Fund, Climate Analytics (available at http://climateanalytics.org/files/gcf_allocation_options_background_paper_3.pdf).

Polycarp, C., A. Douglas, N. Bird and M. Birjandi-Feriz. (2014), "Making the Green Climate Fund's Allocations Add Up to Its Ambition", Climate Finance Series Working Paper, World Resouces Institute (available at http://www.wri.org/publication/green-climate-fund-allocation).

United Nations (2015)"Outcome of the Third International Conference on Financing for Development: Addis Ababa Action Agenda", A/CONF.227/L.1, New York.

Westphal, M., P. Canfin, A. Ballesteros and J. Morgan. (2015), "Getting to $100 Billion: Climate Finance Scenarios and Projections to 2020", World Resources Institute Working Paper (available at http://www.wri.org/publication/getting-100-billion-climate-finance-scenarios-and-projections-2020).

Wheeler, D. (2011) "Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance," Center for Global Development Working Paper No. 240 (available at http://www.cgdev.org/publication/quantifying-vulnerability-climate-change-implications-adaptation-assistance-working).

World Bank (2010a), *Economics of Adaptation to Climate Change - Synthesis Report*, Washington, DC: World Bank (available at http://documents.worldbank.org/curated/en/2010/01/16436675/economics-adaptation-climate-change-synthesis-report).

World Bank (2010b) *World Development Report 2010: Development and Climate Change*, Washington, DC.

About the author

Patrick Guillaumont, Président of the Fondation pour les Etudes et Recherches sur le Développement International (Ferdi), is Emeritus Professor at the University of Auvergne and Director and Founder of the Revue d'économie du développement. He is also a member of the European Development Network (EUDN) and Fellow of the Oxford Center for Studies on African Economies (CSAE).

Publication of this eBook, incorporating 35 separate chapters, was timed to coincide with the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change. As negotiators prepare for Paris, hopes are running high that a new climate agreement will be adopted. But these hopes are tempered by historical experience. For the past 25 years, countries have tried, and failed, to come up with a cooperative arrangement capable of putting the world on a path to limit climate change.

Will Paris be any different? It is too soon to tell, but it seems that Paris will at least provide a foundation upon which the world can build effective action. The new Paris Agreement – assuming one is adopted – will likely reaffirm the global goal of limiting climate change. It will probably create a platform for revealing the actions and targets that countries have pledged to undertake voluntarily. And it will likely track progress towards meeting the collective goal.

The big question is what all of this will add up to. As argued in this eBook, whether Paris ultimately succeeds will depend on whether it gets countries to establish an explicit or implicit carbon price, whether it supports a massive increase in energy R&D, whether it finances a transformation in the world's energy system, and whether it helps the world's most vulnerable countries and peoples to adapt. If Paris succeeds, 25 years from now, global emissions should be a lot lower than today, and trending further downwards.

"*A few days before the launch of the COP21 climate conference in Paris, this book appears as an indispensable reference for the multiple global warming agenda issues to be discussed there and in the years to come. It provides a rigorous, lucid and exhaustive account of the unprecedented challenges faced by the world in addressing the climate risk as a true global community, but also of the effective and politically agreeable policies for achieving that goal.*"

François Bourguignon, Professor, Paris School of Economics and former Chief Economist of the World Bank

"*Even if the Paris COP21 proves to be successful in yielding a successor agreement to the Kyoto Protocol, it will still be necessary to do much more than what conceivably would be enshrined in that instrument. This volume is an important contribution for thinking about those additional steps and the substantial predicaments that policymakers are bound to confront as they persevere – as they must – in dealing with climate change. Bravo for the timing and content of this book!*"

Ernesto Zedillo Ponce de León, Former President of Mexico and Director of the Yale Center for the Study of Globalization

"Climate change is both an unprecedented threat to development and an opportunity for countries to come together to transform the world's energy system for a sustainable future. COP21 will hopefully lay a foundation for collective action, but follow through will be crucial, and this book is particularly welcome for showing how the world can build on the foundation laid in Paris."

Kofi A. Annan, Chairman of the Kofi Annan Foundation, 7th Secretary – General of the United Nations (1997-2006)

Centre for Economic Policy Research

33 Great Sutton Street, London EC1V 0DX
Tel: +44 (0)20 7183 8801
Email: cepr@cepr.org www.cepr.org

ISBN 978-1-907142-95-6

9 781907 142956 >

CEPR Press