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# PART I

## The Challenge



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## 2 Implications of climate science for negotiators

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*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.

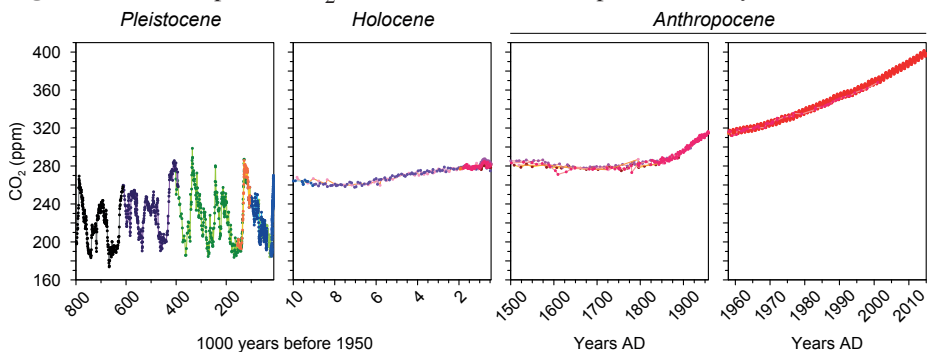
The power of these statements, which reflect the scientific assessment, lies in the fact that the member countries of the IPCC have formally approved the formulations by consensus.

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<sub>2</sub> concentrations over the past 800,000 years



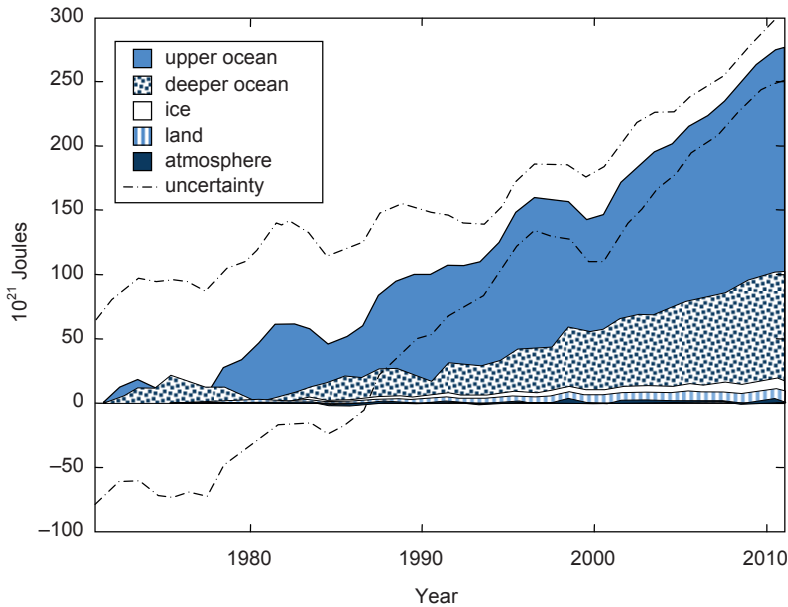
*Notes:* Measurements of atmospheric CO<sub>2</sub> concentrations on air trapped in bubbles in various Antarctic ice cores (left three panels), and direct measurements at Mauna Loa since 1958 (rightmost panel). Current concentrations are far outside the natural range of variations during the past eight ice age cycles. The stretched time scale highlights the rapid acceleration of the CO<sub>2</sub> increase: in the past 60 years CO<sub>2</sub> 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 ERSI; 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  $250 \cdot 10^{21}$  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<sub>2</sub> 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<sub>2</sub> remains in the atmosphere for many millennia owing to the buffering

effect of the ocean water with respect to CO<sub>2</sub>. 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

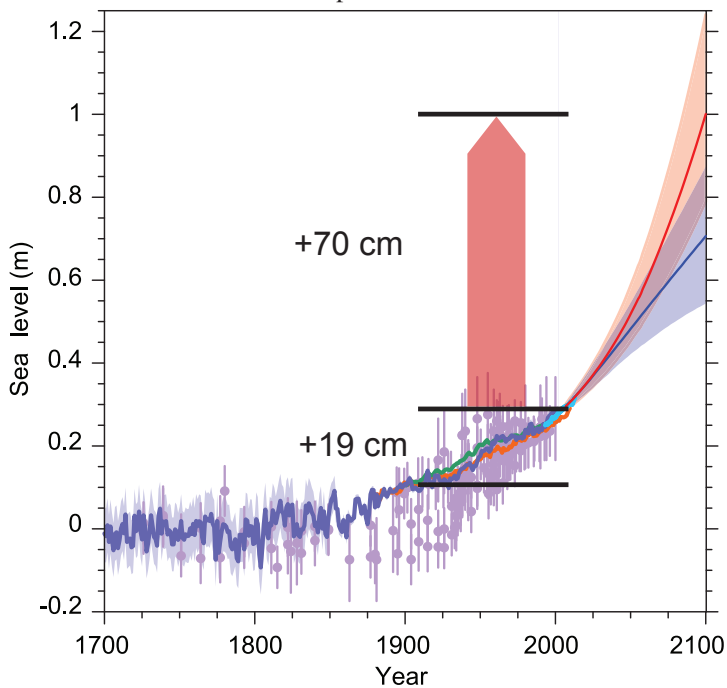


a fairly accurate estimate of the mean temperature of the water after, say, five minutes of heating at a selected level of power. What we will not be able to tell the cook is at what moment a water vapour bubble will form at the bottom of the container and rise to the surface. Fortunately, the cook will 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<sub>2</sub> 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

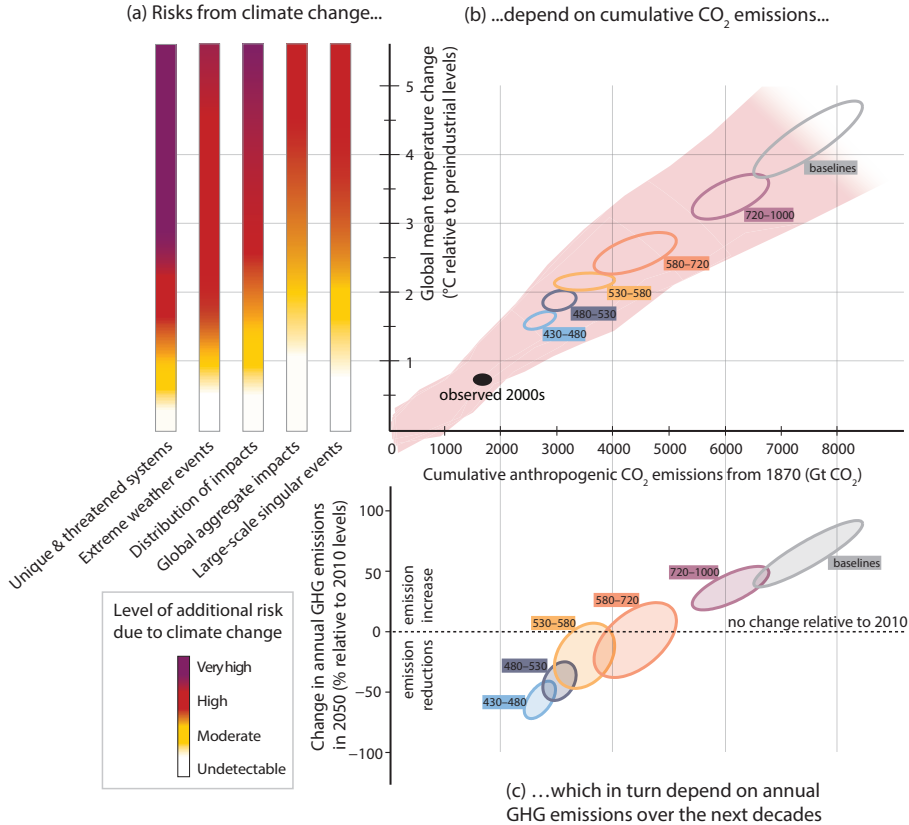
late 21st century and the total cumulative emissions of CO<sub>2</sub> since industrialisation (IPCC 2013b). The larger the cumulative emissions, the higher the peak temperature in the 21st century will be. The important point is that the warming is recognised as a function of all effected emissions, 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,<sup>1</sup> 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.

<sup>1</sup> Note that WG I reports emission reductions in gigatonnes of carbon (GtC), while WG III reports emissions in gigatonnes of carbon dioxide (GtCO<sub>2</sub>) (1GtC = 3.667 GtCO<sub>2</sub>). 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



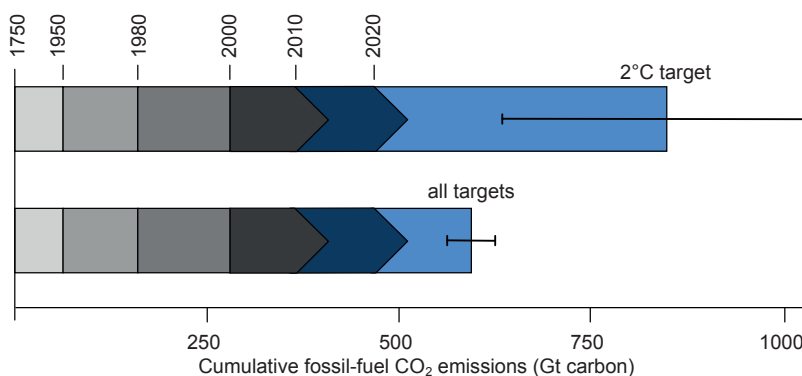
Notes: Panel (a) identifies five key climate change-related risks whose levels increase with rising temperatures. Due to the near-linear relationship between cumulative anthropogenic CO<sub>2</sub> emissions and warming (panel (b)), the risk level is tied to a total amount of CO<sub>2</sub> emitted. 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 (UNFCCC 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.

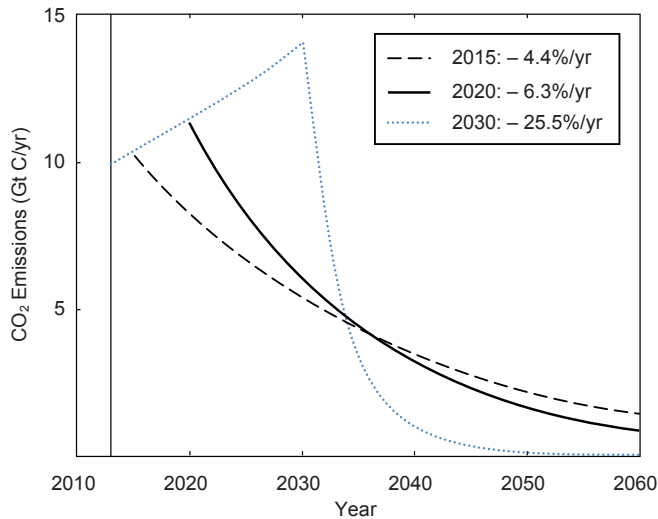
Source: Figure made by M. Steinacher, based on Steinacher et al. (2013).

## 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<sub>2</sub> 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](http://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](http://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.

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

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*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<sub>2</sub> 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.<sup>1</sup> 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**

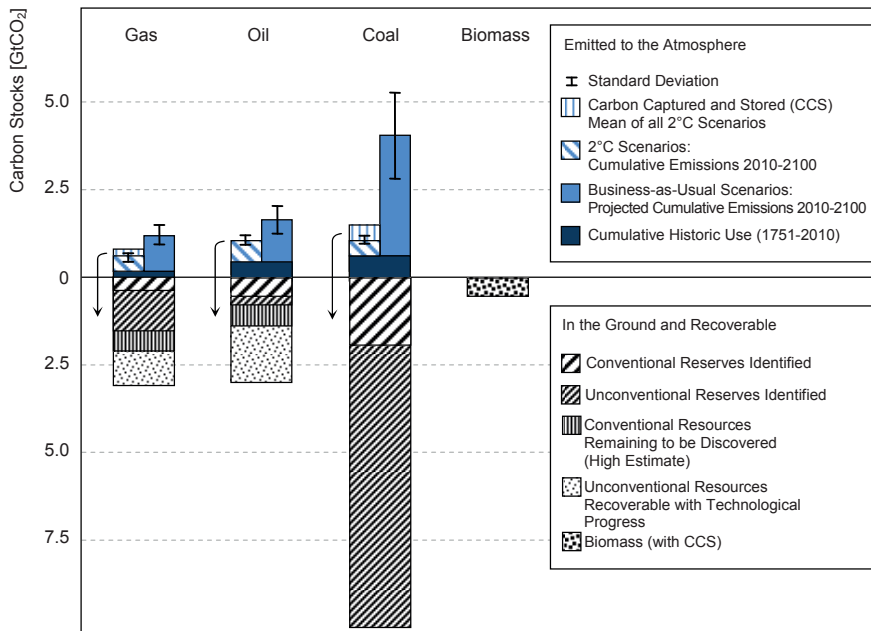
Limiting climate risks by keeping global mean temperature increase below 2°C (with a greater than 66% probability) implies a remaining carbon budget of about 1,000 (750-1,400) GtCO<sub>2</sub> (IPCC 2014e). If current trends continue, this budget will be completely

<sup>1</sup> 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<sub>2</sub> 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<sub>2</sub> 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.<sup>2</sup> 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

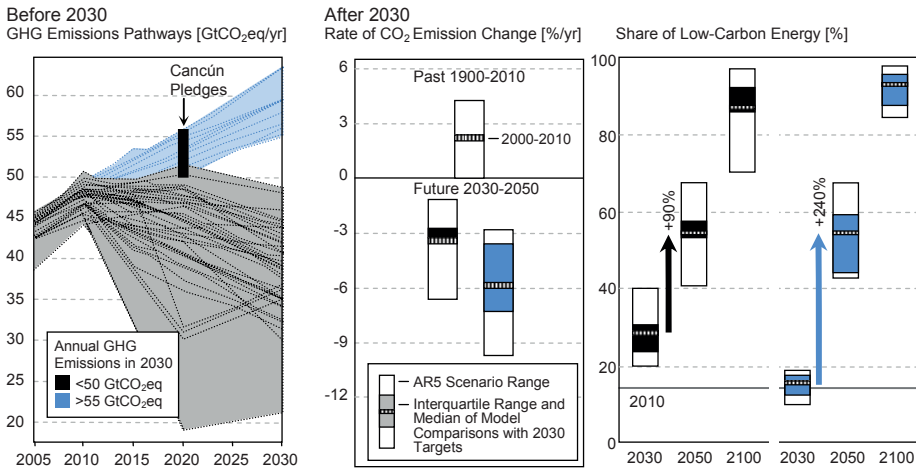
2 By reducing the disposal space for waste GHGs in the atmosphere, climate policy not only reduces the resource rents of the owners of coal, oil and gas assets, but it also creates a 'climate rent'. These revenues from carbon pricing overcompensate the loss in resource rents (Bauer et al. 2013); they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

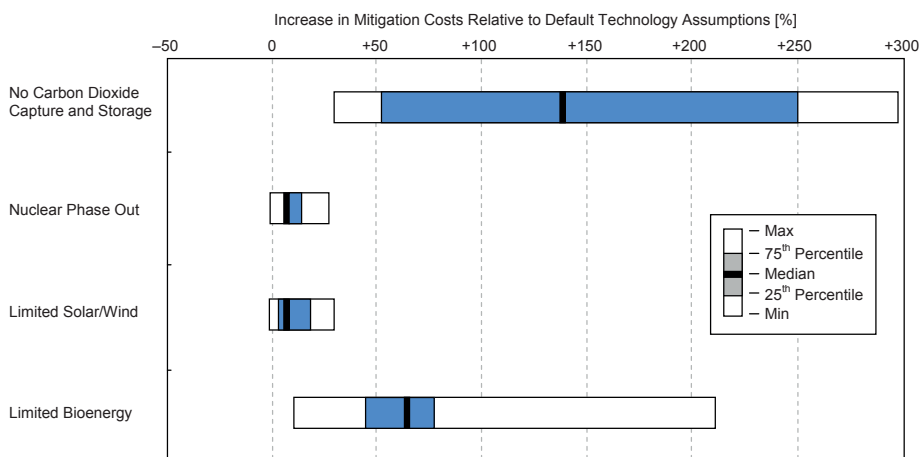
**Figure 2** Increasing technological challenges associated with the energy system transformation in delayed relative to immediate mitigation scenarios consistent with staying below the 2°C limit with a roughly 50% probability



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<sub>2</sub>-equivalent in 2030), delayed mitigation scenarios (blue, GHG emissions >55 Gt CO<sub>2</sub>-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).

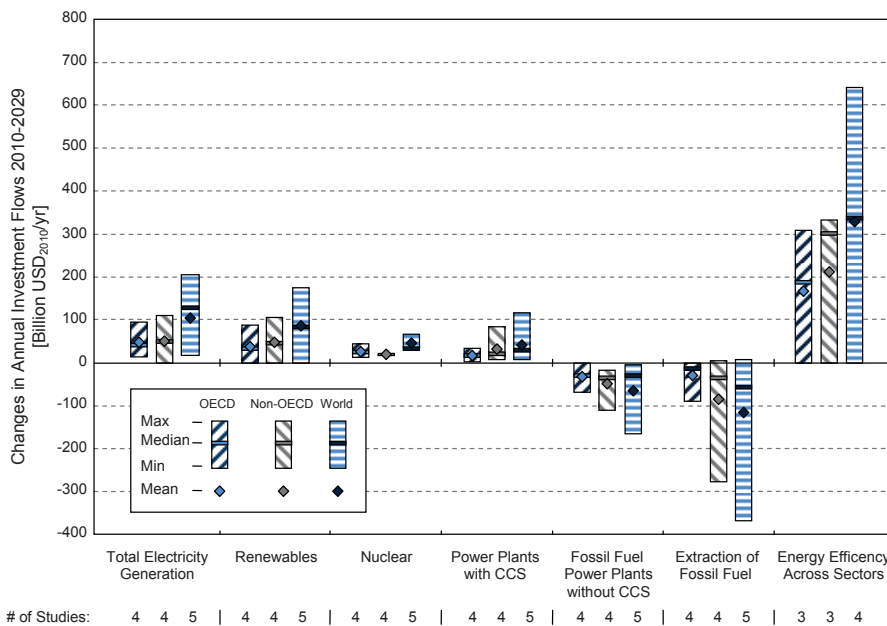
### 3 Triggering short-term mitigation action

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).

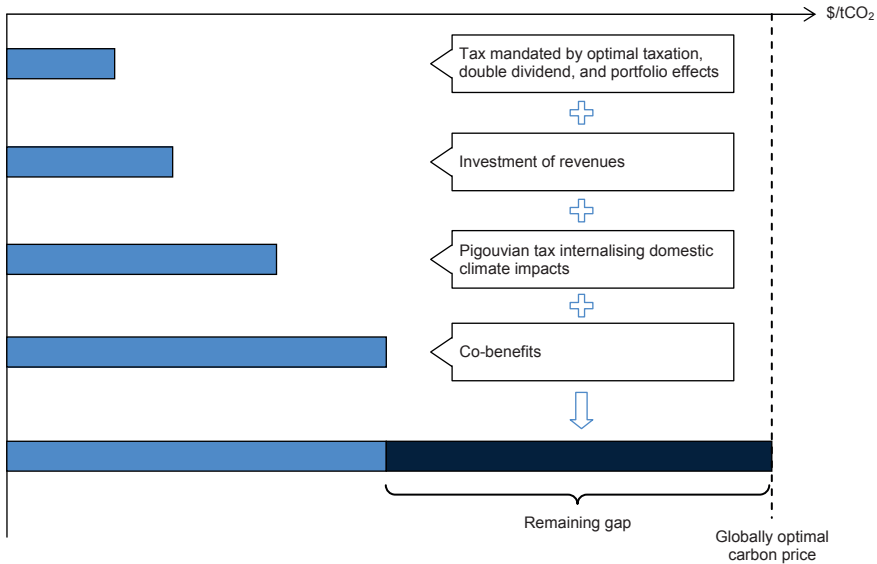
These unilateral incentives show that finance ministers might be interested in carbon pricing even though they are not primarily interested in emissions reductions (Franks et al. 2014). Still, mitigation efforts that are purely motivated by national interests are not expected to achieve the globally 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).

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## 4 The state of climate negotiations

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**Brian P. Flannery<sup>1</sup>**  
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.*

<sup>1</sup> 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.<sup>2</sup>

## 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.<sup>3</sup> 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.

<sup>3</sup> 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.<sup>4</sup> 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<sup>5</sup> 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.<sup>6</sup>

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.

<sup>6</sup> 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 to *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.<sup>7</sup>

## 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.

<sup>7</sup> 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,<sup>9</sup> 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.<sup>10</sup> 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<sub>2</sub> 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 CO<sub>2</sub> 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.

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