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Benoit Mayer
Excerpt
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1 Introduction

Climate change is one of the greatest challenges of our time – an age where our impacts, as human societies, have extended beyond our immediate environment and are now affecting entire planetary equilibria. The stakes of addressing climate change are higher than traditional questions in international law about peace among nations, individual welfare or economic development. Climate change challenges just about everything we know and care about, from individual rights and welfare to social harmony and civilization, environmental protection and ecological balance. Cataclysmic scenarios of runaway climate change raise chilling prospects where even our survival as a species could potentially be threatened.

Yet, tackling climate change is a daunting task. Profound transformations are needed in our economies, societies, political systems and individual ways of life. Our model of development needs to be fundamentally altered in order to take planetary limits into consideration. Law needs to play a central role in these changes, but existing governance institutions are ill-fitted to the task. States remain the main center for decisions, but national interests, as they are generally understood, are often inconsistent with a rational utilization of global commons. By seeking to satisfy populations, democratic institutions are often inclined to take decisions patently contrary to the interests of future generations. After more than a quarter of a century of some of the most complex transnational political debates, international efforts to address climate change have achieved little success.

This introduction lays the foundations for the following chapters. Firstly, it takes stock of what science has to tell us about climate change. Secondly, it identifies the main goals of laws and politics addressing climate change. Thirdly, it presents the elements constituting the international law on climate change. Lastly, it introduces the outlines of this textbook.

I. THE SCIENCE OF CLIMATE CHANGE

The international law on climate change relies on a scientific understanding of our influence on the climate. The following provides synthetic explanations of the “greenhouse” effect, the origin of anthropogenic greenhouse gas (GhG) emissions, their impact, projections of future changes and the possibilities to alter these projections.

A. The "Greenhouse" Effect

Life, as we know it, is possible only because the temperature in many places on Earth remains stable within a certain range. This temperature is determined by complex planetary equilibriums. The temperature on the Earth's surface depends on what is often called an "energy budget" – the difference between the quantity of energy that the Earth receives almost exclusively from the Sun and the quantity of energy it releases to space. Energy enters or leaves the Earth system through electromagnetic radiations such as infrared radiations, visible light and ultraviolet radiations. Like any other warm object, both the Sun and the Earth emit electronic radiations through which they release some energy. The Earth's surface gains energy by absorbing electromagnetic radiations from the Sun and thus warms. In turn, the Earth loses energy by emitting electromagnetic radiations toward the space and thus cools. When the Earth's surface absorbs as much energy as it releases, the Earth's energy budget is balanced and temperature remains stable.

Not all electromagnetic radiations are identical. Their wavelength depends on the temperature of the body from which these radiations are emitted. Extremely hot objects such as the Sun emit high-energy electromagnetic radiations characterized by a short wavelength, including ultraviolet radiations as well as visible light. Far cooler objects like the Earth's surface emit far less intense radiations with a longer wavelength, such as infrared radiations. The human eye does not perceive the infrared radiations emitted by the Earth day and night – all we can see is the visible light emitted by the Sun (or artificial sources) and its reflection by objects around us. Infrared cameras, however, perceive the radiations that objects around us emit days and nights, whose specific wavelength varies as a function of the object's temperature.

Our atmosphere is not totally transparent to all electromagnetic radiations. It acts like a tinted window – a selective filter which reflects or absorbs some electromagnetic radiations while letting others go through. In particular, our atmosphere lets some ultraviolet radiations and almost all visible light enter the Earth system, but it stops some longwave infrared radiations from leaving the Earth system (see Figure 1.1). Due to their physical properties, some gases tend to be opaque to infrared radiations: when these gases are present in the atmosphere, they reflect a proportion of the infrared radiations emitted by the Earth's surface back toward the Earth's surface. Thus, the presence of these gases in the atmosphere causes an additional warming of the Earth's surface, both day and night, by preventing some of the heat absorbed from the Sun during the day from being released to space. Without this partial opacity of its atmosphere to infrared radiations, the Earth's surface would – like the surface of Moon – instantly reach sub-freezing temperatures at night when it stops being exposed to sunlight. This would make many forms of life impossible.

This selective opacity to infrared radiations is called the *greenhouse effect*. The analogy with a greenhouse is somewhat inaccurate because the inside of a greenhouse warms through a different mechanism. A greenhouse operates by preventing airflow: it traps the air warmed by contact with the surface and reduces cooling by *convection* (the circulation of warm air away from the source of heat). By contrast, the atmosphere regulates the temperature of the Earth's system by filtering inputs and outputs of electromagnetic *radiations*. Although the analogy is slightly misleading, it is very common. The gases that contribute to the "greenhouse" effect are called greenhouse gases (GhGs). Most of our atmosphere is composed by nitrogen and oxygen that are completely transparent to infrared radiations, but it also contains relatively small amounts of such GhGs, in particular water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

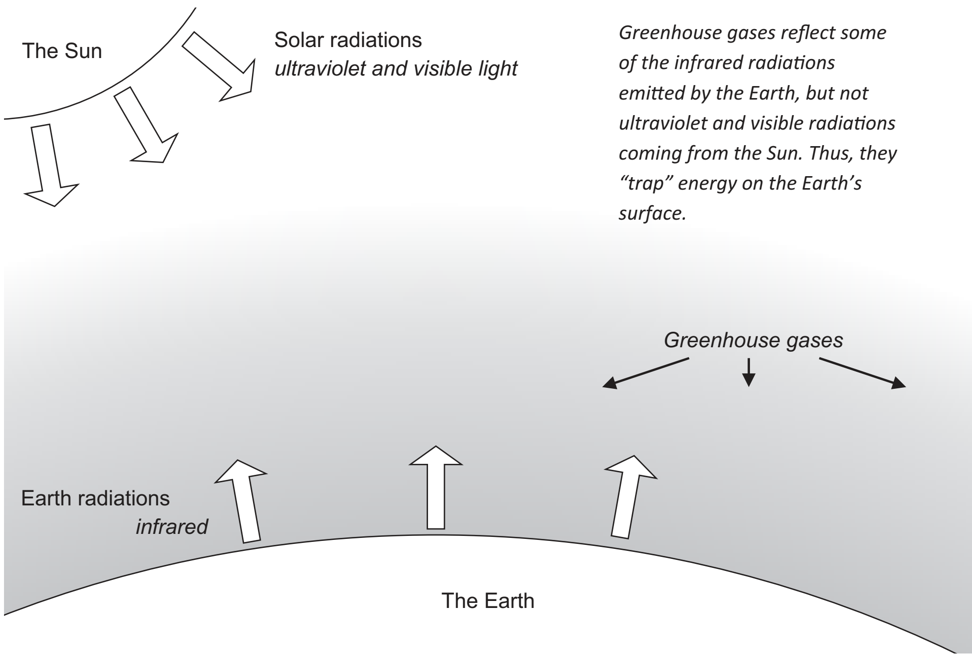

Figure 1.1 The greenhouse effect

B. Anthropogenic GhG Emissions

Since the Industrial Revolution in late eighteenth-century England, most societies have gradually turned to a model of industrial development which relies heavily on the combustion of fossil fuels – coal, then oil and gas – as a source of energy. Fossil fuels were formed gradually over millions of years through the decomposition of buried dead organisms. Today, they provide us with a convenient source of energy to produce electricity, propel vehicles and cook, among other things. Yet, burning fossil fuels releases GhGs into our atmosphere. Other human activities have released significant quantities of GhGs in our atmosphere, including deforestation, the decomposition of organic wastes, agricultural processes, the production of cement or the production of synthetic organic compounds used for fridges and air-conditioning systems.

Over time, the combustion of fossil fuels and other diverse human activities have caused the emission of tremendous amounts of GhGs into our atmosphere. Carbon dioxide is the main GhG produced by human activities. Since 1750, more than 2 teratons of carbon dioxide ($TtCO_2$) were emitted as a result of such industrial processes – this represents $2e^{+12}$ tons, or 2,000,000,000,000 tons. Other GhGs, such as methane, nitrous oxide and carbon compounds which have a much higher opacity to infrared radiations, have also been emitted in smaller quantities, but they often have a much stronger warming potential. A ton of CFC-13 emitted into the atmosphere, for instance, has as much global warming effect over a century as 13,900 tons of carbon dioxide (see Table 1.1).

Anthropogenic GhG emissions were historically concentrated in a few developed States, mainly in Europe and North America. Yet, many other countries are now following the same model of industrial development and GhG emissions have been rapidly increasing in emerging

Table 1.1 Main anthropogenic GhG emissions

Greenhouse gas	Carbon dioxide equivalence[a]	Main sources[b]
Carbon dioxide (CO_2)	1	Combustion of fossil fuels; deforestation and land-use change
Methane (CH_4)	28	Extraction and use of fossil fuels; decomposition of wastes in landfills; agriculture (e.g. rice cultivation); ruminants
Nitrous oxide (N_2O)	265	Agricultural activities (e.g. use of fertilizers); fossil fuel combustion; biomass burning
Chlorofluorocarbons (CFCs)	Up to 13,900	Refrigerants, aerosols, solvents and diverse industrial uses
Hydrofluorocarbons (HFCs)	Up to 12,400	
Perofluorocarbons (PFCs)	Up to 8,210	

[a] Global warming potential on a 100-year period, according to G. Myhre *et al.*, "Anthropogenic and Natural Radiative Forcing" in T.F. Stocker *et al.* (eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2013) 659, Appendix 8.1, at 731. On the concept of global warming potential, see *ibid.*, at 710–712.

[b] See T.F. Stocker *et al.*, "Technical summary" in Stocker *et al.* (eds.), *supra* note 1, 33, at 53–59.

economies and in the developing world generally. China became the largest GhG emitter in 2005 and it is currently responsible for as much GhG emissions as the United States and the European Union combined.[1] Yet, China's population is significantly larger than the United States and the European Union taken together, and per capita emissions in China remain lower than in many developed States.

The pursuit of industrial development by an increasing number of countries, in a context of rapid global demographic growth, has gradually increased the pace of anthropogenic GhG emissions. A first teraton of anthropogenic carbon dioxide was emitted over more than two centuries, between 1750 and 1970. The second teraton was emitted in 40 years, between 1970 and 2010. At the current rate of 40 gigatons of carbon dioxide ($GtCO_2$) emissions per year, it would take another 25 years to emit another $TtCO_2$. Yet, the pace of anthropogenic GhG emissions is increasing, and the third teraton may have been entirely emitted before the end of the 2020s.[2]

Anthropogenic emissions of GhGs into our atmosphere have been so massive that the chemical composition of the Earth's atmosphere has been significantly affected. This had the effect of altering the opacity of our atmosphere to shortwave electromagnetic radiations, thus amplifying the greenhouse effect by reducing the release of energy into space. This is causing a steady increase in the global average temperature, which can be observed and measured year after year at a speed unprecedented in geological history.

The impact of anthropogenic emissions on the concentration of GhGs in the atmosphere has been measured in many ways. The Mauna Loa observatory in Hawaii started to measure the

[1] WRI, CAIT Climate Data Explorer, "Total GHG emissions excluding land-use change and forestry" (2013).

[2] R.K. Pachauri *et al.*, *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* (IPCC, 2015) 45.

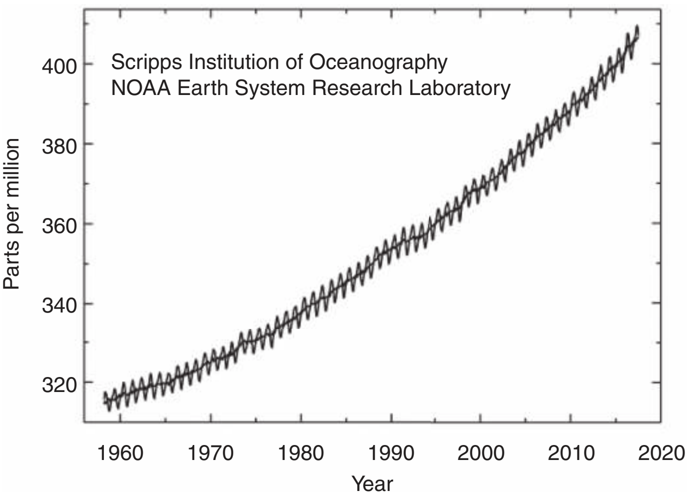

Figure 1.2 Concentration of carbon dioxide (CO2) in the atmosphere at Mauna Loa Observatory
Note: Reproduced with permission from the US National Oceanic and Atmospheric Administration.

concentration of carbon dioxide in 1958. Apart from seasonal variations caused by photosynthesis in the Northern hemisphere, its measures revealed a steady increase in the concentration of carbon dioxide, from 315 parts per million (ppm) in 1958 to more than 400 ppm today (see Figure 1.2). Many other direct measurements have been made to the concentration of diverse GhGs in the atmosphere since the 1960s, first from land-based observatories and increasingly now from satellite systems, evidencing similar increases in the concentration of methane, nitrous oxide and other GhGs in the atmosphere. Indirect measures were also made, for instance, through analyzing air bubbles trapped for centuries in deep ice sheets in Greenland and Antarctica, in order to retrace the historical evolution in the composition of our atmosphere.[3]

Based on such information, scientists with the relevant expertise are unanimous in concluding that human activities such as the massive combustion of fossil fuels result in changes in the composition of our atmosphere which increase the greenhouse effect and warm the Earth's surface beyond the pre-industrial range of temperatures. The Intergovernmental Panel on Climate Change (IPCC), an institution created to assess available scientific knowledge in a transparent manner in order to inform policy-makers, has concluded that "warming of the climate system is unequivocal"[4] and that there is clear evidence that this warming is caused by the increase in the atmospheric concentrations in GhGs, in particular carbon dioxide.[5] Although scientific evidence is different in nature from mathematical conclusions, the amount of data that have been collected over the last decades provides compelling evidence of an ongoing change in our climate caused by anthropogenic GhG emissions. As the first working

[3] See generally Dennis L. Hartmann *et al.*, "Observations: atmosphere and surface" in T.F. Stocker *et al.* (eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2013), 159, at 165–180.
[4] L.V. Alexander *et al.*, "Summary for policymakers" in Stocker *et al.* (eds.), *supra* note 3, 3, at 4.
[5] *Ibid.*, at 13.

group of the IPCC concluded, "human influence on the climate system is clear" and "evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing [i.e. increase in the greenhouse effect], observed warming, and understanding of the climate system."[6]

C. The Impacts of Increased GhG Concentrations in the Atmosphere

The IPCC has further noted that "since the 1950s, many of the observed change are unprecedented over decades to millennia."[7] By altering the chemical concentration of the Earth's atmosphere, human societies are causing far-reaching, often irreversible changes in multiple complex planetary systems. The nature and ambit of these changes, and their consequences for us as a civilization and species, cannot be predicted with certainty. There is no certainty that life on Earth will be able to adjust to a substantial and rapid change in GhG concentrations and its far-reaching consequences.

The first, most simple consequence of an increase in the concentration of GhGs in our atmosphere is an increase in the global average temperature. As of mid-2017, the best estimate is that the global average surface temperature on Earth increased by around 1.1 degrees Celsius between 1880 and 2016.[8] Heat records were repeatedly broken in recent years. As of mid-2016, 2015 stood as the hottest year on record, immediately followed by 2014; the ten hottest years on record were all after 1998. The IPCC noted that "[e]ach of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850,"[9] when the first reliable global temperature measurements were made.

Yet, climate change does not only affect temperatures. Referring to climate change as "global warming" belittles the long chain of consequences that a slight change in global average temperature is having on multiple complex planetary systems. Warming, for instance, increases evaporation, thus altering the water cycle, with consequences on precipitation patterns throughout the world. Floods *and* droughts occur more often, and so do some extreme weather events, such as tornadoes, in some parts of the world. Wildfires are also occurring more often in certain regions of the world as a consequence of changes in temperature, rain and wind systems. The level of the sea is rising as the consequence of the melting of glaciers and ice sheets, but also because, just like the mercury in a thermometer, the water of the ocean expands when it warms. At the same time, oceans are becoming more acidic because of the absorption of some carbon dioxide from the atmosphere as soluble carbon acid (H_2CO_3). Ocean acidification makes it more difficult for some plankton to develop; this alone could wreak havoc in marine biology throughout the food chain. On land too, ecosystems are deeply affected by changes in temperature and aridity, which exacerbate risks of extinction for many vegetal and animal species.[10]

6 *Ibid.*, at 15.
7 *Ibid.*, at 4.
8 World Meteorological Organization, *Statement on the State of the Global Climate in 2016* (WMO, 2017) 2. See also Alexander *et al.*, *supra* note 4, at 5, noting an increase of 0.85 degrees Celsius between 1880 and 2012.
9 Alexander *et al.*, *supra* note 4, at 5.
10 See generally Christopher B. Field *et al.*, "Summary for policymakers" in Christopher B. Field *et al.* (eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014) 1.

These transformations in planetary systems are and will be impacting human societies very severely. Food production could be hindered by adverse climatic conditions in large production regions. Human health is affected by heat waves as well as by the diffusion of some pathogens, such as malaria and dengue fever, to regions where they did not use to be prevalent – and where populations may have lower immunity.[11]

The most severe adverse impacts of climate change occur in some of the least developed States, affecting those populations who live under the less forgiving climate of tropical regions, depend more directly on natural resources (in particular, subsistence agriculture) and have the least resources to cope with changes in their environment. The notion of "climate justice," further discussed throughout this book, sheds light on the disconnect between the industrial nations which benefit most from GhG emissions and the least developed nations which suffer the most from the impacts of climate change.[12] Yet, developed States are not immune from the consequences of climate change, some of which – such as food crises, epidemics, economic recession, migration or conflicts – will stop at no borders.[13]

D. Projections

While the impacts of climate change can already be observed throughout the world, they will inevitably become more severe in the coming years, decades and centuries. This would be the case even if all anthropogenic GhG emissions were to stop suddenly, as planetary systems pursue their slow adjustment to a different atmospheric chemistry. Sea-level, for instance, would continue to rise over centuries by probably one to several meters in the absence of any additional anthropogenic GhG emissions. Continuing GhG emissions, however, raise the risk of a sea-level rise in the scale of tens of meters over several centuries.[14] A "large fraction of species" will face extinction in the coming centuries.[15] The impacts on food production, livelihood, economic growth, health, migration and conflicts cannot be predicted with certainty, but they are likely to be critical.

Overall, the severity of climate change largely depends on GhG emissions in the coming years and decades. Large amounts of additional GhG emissions will result in more dramatic consequences. Global average surface temperature will likely increase by more than 4 degrees Celsius by the end of the century, and further in the following centuries, if the growth in global GhG emissions goes unimpeded. While most debates on the impacts of climate change focus on the twenty-first century, scientists estimate that current anthropogenic greenhouse gas emissions will have a profound impact on the climate system, ecosystems and human societies "for the next ten millennia and beyond."[16]

Predictions come, however, with a certain degree of uncertainty – and catastrophic scenarios cannot be ruled out. The planetary systems at stake, from the climate system to the evolution of ice sheet and ocean streams, are extremely complex. One of the greatest sources of scientific

[11] *Ibid.*
[12] See e.g. Teresa M. Thorp, *Climate Justice: A Voice for the Future* (Palgrave Macmillan, 2014).
[13] See A. Guzman, *Overheated: The Human Cost of Climate Change* (Oxford University Press, 2013).
[14] Pachauri *et al.*, *supra* note 2, at 16.
[15] *Ibid.*, at 13.
[16] Peter U. Clark *et al.*, "Consequences of twenty-first-century policy for multi-millennial climate and sea-level change" (2016) 6:4 *Nature Climate Change* 360.

uncertainty regarding the reaction of the climate system to continuing anthropogenic GhG emissions stems from the feedbacks of planetary systems to GhG emissions. A feedback is a natural reaction in a system that either amplifies (positive feedback) or mitigates (negative feedback) the consequences of an interference with this system. Some "negative" feedbacks could reduce the impact of anthropogenic GhG emissions. For instance, an increase in carbon dioxide concentrations in the atmosphere could accelerate photosynthesis and vegetation growth, which could remove some carbon dioxide from the atmosphere and mitigate climate change, although this phenomenon is likely to have a fairly insignificant impact at the global scale.[17] By contrast, "positive feedbacks" refer to phenomena that could amplify the impact of anthropogenic GhG emissions. Multiple positive feedbacks have been documented. For instance, the melting of glaciers, ice sheets or ice seas changes the color of large regions of the Earth. Seas and rocks are darker than ice: they reflect less sunlight and warm faster. Ice melting thus decreases in the Earth's "albedo" (or "whiteness"), which hastens the pace of warming, especially in the polar regions. Another positive feedback relates to the increase in wildfires, which release large amounts of GhGs, thus amplifying climate change.[18]

Some powerful positive feedbacks, or "tipping points," could have abrupt consequences leading to catastrophic "runaway" climate change – a scenario where our climate would continue to warm even without further anthropogenic GhG emissions due to self-sustaining positive feedback. Such a tipping point could occur as a consequence of a thawing of permafrost – soils that have been frozen for thousands of years, in particular in Siberia, the north of Canada and Alaska. The permafrost contains great quantities of frozen organic materials. The thawing of the permafrost is already setting free large amounts of methane and carbon dioxide, significantly amplifying climate change.[19] A runaway climate change scenario could cause extremely dangerous consequences for humankind. The likelihood of such a scenario is difficult to assess due to the lack of any historical precedent. We are, in other words, in uncharted territory.

E. Ways Forward

The impact of GhG emissions on the atmosphere has not always been known. Empirical evidence of climate change started to emerge in the early 1960s; by the mid-1980s, a strong scientific consensus had been achieved.[20] Thirty years later, even though the impacts of climate change are becoming more obvious and more dramatic every year, global GhG emissions continue to grow steadily. Depending on response measures taken in the coming years and decades, global GhG emissions could continue to increase and reach catastrophic levels, or they could soon peak and quickly decrease.

To inform decision-makers of the consequences of their decisions, the IPCC developed different scenarios of GhG emission pathways, or Representative Concentration Pathways (RCPs), for the twenty-first century. Each of these scenarios is characterized by a particular radiative forcing – an intensity of the greenhouse effect – by the end of the twenty-first century.[21]

17 Stocker *et al.*, *supra* note 3, 33 at 57–58.
18 *Ibid.*, at 58.
19 Alexander *et al.*, *supra* note 4, at 27.
20 See S.R. Weart, *The Discovery of Global Warming* (Harvard University Press, 2008).
21 See Pachauri *et al.*, *supra* note 2, at 21. A complete explanation of the representative concentration pathways can be found in U. Cubasch *et al.*, "Introduction" in Stocker *et al.* (eds.), *supra* note 3, 119, at 147–150, Box 1.1. See also

The current annual rate of anthropogenic GhG emissions is about 50 $GtCO_2eq$,[22] which represents an aggregate impact equivalent to the emission of 50 billion tons of carbon dioxide. If no or little action is taken to mitigate climate change, as per scenario "RCP8.5," the rate of global GhG emissions will continue to increase. Scenario RCP8.5 assumes a rate of about 100 $GtCO_2eq$ per year by the end of the twenty-first century. It is estimated that the global average temperature would increase by more than 4 degrees Celsius before the end of the twenty-first century and, if the same course of action is maintained, by 8 degrees Celsius by 2300. The summer Arctic ice sea would have totally disappeared by 2060 and one could sail over the North Pole. Even on the basis of the most conservative estimates, the sea level would possibly exceed one meter by 2100, reaching several meters by 2500, possibly even tens of meters in the circumstance of a catastrophic collapse of massive ice sheets in Antarctica and Greenland. Sea-water acidity would rapidly increase, with great impacts on marine ecosystems. Heatwaves, floods, droughts, wildfires, famines, conflicts for access to natural resources, mass migration and possibly epidemics would make the world a much, much more difficult place to live for future generations. Tipping points could trigger a runaway climate change scenario. Things could get totally out of control. The possibility of a global civilizational collapse – the end of humankind within a few centuries – could certainly not be excluded.[23]

Alternative scenarios exist where serious efforts are made to mitigate climate change. Such efforts would not prevent further impacts of climate change as planetary systems slowly adjust to changes in atmospheric chemistry, but they would most likely avoid some of the worst consequences of a runaway climate change. The IPCC's most optimistic scenario, scenario "RCP2.6," assumes that drastic efforts are made to mitigate climate change. In particular, it assumes that a peak in global GhG emissions is reached in the 2020s and that it is followed by a very rapid decrease in global GhG emissions thereafter. Net global GhG emissions by the end of the twenty-first century would be null or even negative as efforts would be made to remove GhG from the atmosphere through reforestation and geoengineering. In these circumstances, the global average temperature would possibly be held under 2 degrees Celsius above pre-industrial levels by the end of the twenty-first century and could remain relatively stable thereafter. Sea-level rise would perhaps not increase by more than a further 50 cm before the end of the century and it could be limited to between one and a few meters by 2500. Some sea ice would be maintained all year round over the Arctic Ocean. Even then, however, many great risks would remain for many populations throughout the world. Biodiversity losses, extreme weather events, conflicts and other social impacts of climate change would not all be avoided. Some low-lying coastal regions and island States, for

O. Edenhofer *et al.*, "Summary for policymakers" in R. Pichs-Madruga *et al.* (eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014) 1, at 11–13.

[22] This includes carbon dioxide emissions as well as emissions of other greenhouse gases, weighted on the basis of their global warming potential over one hundred years. On carbon dioxide equivalence of other GhGs, see above, Table 1.1.

[23] On the notion of civilizational collapse, see Jared M. Diamond, *Collapse: How Societies Choose to Fail or Succeed* (Penguin, 2011). Although many civilizations have collapsed in the past, a global civilizational collapse only becomes possible in the age of globalization. See a discussion of the risk of such catastrophic crisis in M.L. Weitzman, "On modeling and interpreting the economics of catastrophic climate change" (2009) 91:1 *Review of Economics & Statistics* 1.

instance, would become uninhabitable as a consequence of sea-level rise. The risk of a global civilizational collapse would be significantly reduced, but a succession of crises is certainly unavoidable. Even this very "best" scenario involves great harm to human societies and ecosystems.

II. CLIMATE CHANGE LAWS AND POLICIES

Laws and policies can foster processes through which societies address climate change. They can promote efforts to decrease GhG emissions or even perhaps efforts to remove GhGs from the atmosphere. Moreover, laws and policies can also foster preparedness to the impacts of climate change. Thus, two categories of action are generally distinguished: efforts toward mitigating climate change and efforts toward adapting to its impacts. As climate change is already occurring and no amount of climate change mitigation will avoid all harms, climate change mitigation and adaptation are both necessary. In the long run, however, adaptation efforts will become more challenging if mitigation efforts are not successful.

A. Climate Change Mitigation

Laws and policies have been adopted to mitigate global anthropogenic climate change. Such efforts consist primarily in reducing sources of GhG emissions, but they can also seek to remove GhGs from the atmosphere through enhancing sinks and reservoirs.

Reducing sources of GhG emissions is the most obvious way to promote climate change mitigation. This can be done through sector-specific measures ranging from power generation to automobile traffic, cement production and waste disposal. Reductions in GhG emissions can often be achieved through improved efficiency. For instance, coal plants can be required to use the latest available technology in order to emit less GhG when producing as much power. More efficient power grids can reduce energy waste in transmission. Better air traffic control can reduce fuel consumption for each flight. Gains in efficiency result in savings which, sometimes, balance the cost of the particular measure. For instance, purchasing a more efficient car would lead to savings in fuel expenses which could balance the additional investment. Yet, while gains in efficiency may come at no or little cost, their outcome is limited to incremental reduction in GhG emissions. A more efficient car still burns oil.

Sources of GhG can also be reduced through more structural changes, often involving behavioral change – alterations to the way we live and consume. Walking or even taking public transportation instead of driving a car is an example of behavioral change leading to a reduction in GhG emissions. Such changes can also be induced at a collective level, for instance, through laws and policies. Shifting power generation away from a reliance on fossil fuels by investing in renewable or nuclear energy is a typical way to reduce GhG emissions through changes in production patterns. Building a national railway system to divert passengers from air or car transportation could also lead to substantial reductions in GhG emissions. Such measures are typically more costly than gains in efficiency and require more time for implementation, but they also lead to much greater climate benefits. While gains in efficiency may help reduce GhG emissions in the short term, more structural changes are necessary to ensure a turn to carbon-neutral ways of life.