Chapter 2
The Ultimate Objective of Climate Response Strategies, and a Desirable and Feasible International Framework

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Abstract In this chapter, the author examines the appropriateness and feasibility of the so-called 2 degree target as the ultimate objective of climate response strategies under Article 2 of the UNFCCC. Thereafter, a desirable and feasible international framework is discussed. First, the author presents a brief history and various interpretations of the Article 2 of the UNFCCC, and then examines the target from a purely climate change viewpoint (vertical balance), followed by another viewpoint of efficient allocation of scarce resources (horizontal balance). Based on the above analysis, the author tries to work out a desirable and feasible Post-Kyoto international framework. The author finds the top-down approach typically embodied in the Kyoto Protocol has failed. Finally, the author concludes global leaders should revisit the target, as the 2 degree target has no solid foundation and is not feasible. And, as for the international framework, the author argues for pursuing a bottom-up approach (pledge and review) that came out at the end of Copenhagen negotiation process. The author further argues all efforts, such as contribution in the field of adaptation, technology development and diffusion, and financing, should be integrated with mitigation efforts.

2.1 The Ultimate Objective (Article 2 of the UNFCCC), and the 2 Degree Target

Article 2 of the UNFCCC describes the ultimate objective of climate response strategies as follows:

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant

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> provisions of the Convention, 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. (Article 2 of the UNFCCC)

So far, it is generally perceived that to limit the increase of global average surface temperature within two degrees since preindustrialization is a globally agreed target of climate response strategies. This chapter examines whether this *2 degree target* is appropriate and feasible.

2.1.1 Brief History of Article 2

Climate change has been deemed as one of globally urgent issues, and every year diplomats from all over the world get together and negotiate in search of an international framework to follow the Kyoto Protocol, the main commitments of which are due to expire at the end of 2012. The Conference of the Parties to the UNFCCC (COP) and Meeting of the Parties to the Kyoto Protocol (MOP) are the typical fora for negotiation. No doubt, the topic of their negotiations is how to cope with *global warming*. In the 1970s, however, *global cooling* had been the major concern. In the USCIA (1975), there is the sentence: "[w]hile still unable to explain how or why climate changes, or to predict the extent and duration of change, a number of climatologists are in agreement that the northern hemisphere, at least, is growing cooler" (p. 28). In the other report by the Government of the United States, both global warming and cooling have been pointed out as a future perspective (USCEQ and DOS 1980). Gradually, the theory of warming, rather than cooling, became more dominant, and in the late 1980s, climate change in the sense of global warming was recognized as one of the most important issues in international politics.

The first international conference to address global warming, the International Conference on the Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variations and Associated Impacts, was held in Villach, Austria in October 1985 sponsored by the United Nations Environment Programme (UNEP) in cooperation with the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). One of the recommended actions proposed by this conference was that "UNEP, WMO and ICSU should establish a small task force on greenhouse gases, or take other measures, to . . . initiate, if deemed necessary, consideration of a global convention" (WMO 1986). The Government of the United States was not convinced with this recommendation as they were not prepared by government officials (for a more detailed background explanation, refer to Agrawala 1998). But this resulted in the US initiative to set up IPCC in 1988 (Hecht and Tirpak 1995).

The first major international conference where both governments and scientists participated, the Conference on the Changing Atmosphere—Implications for Global Security, was held in Toronto, Canada in June 1988 sponsored by WMO. In this conference, broad issues including climate change were discussed, and in respect of climate change, several actions were urged. One of them is to reduce CO_2 emissions by approximately 20% by 2005 in comparison to the 1998 level. As to the concentration level, the statement said that "[s]tabilizing the atmospheric concentrations of CO_2 is an imperative goal," and that "[i]t is currently estimated to require reductions of more than 50% from present emission levels" (Toronto Conference Statement 1988).

The Noordwijk Declaration adopted at Noordwijk, the Netherlands, in November 1989 played an important role as it included a pioneering sentence that led to current wording in the Article 2 of the UNFCCC. It stated that emissions should be limited to the extent that the earth system could naturally absorb. Then it continued that "[s]uch a level should be reached within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and permit economic activity to develop in a sustainable and environmentally sound manner" (Noordwijk Declaration 1990). If one compares this wording with that of the Article 2 of the UNFCCC mentioned earlier, one would be impressed by the resemblance of those two wordings. The last part of the Declaration, i.e., mutual supportiveness of sustainable economic activity and climate protection, was not included at the beginning, but was eventually added at the request of the participants (Oppenheimer and Petsonk 2005).

The First Assessment Report of IPCC published in 1990 pointed out the need for a Framework Convention on Climate Change, and it urged "[t]he international negotiation on a framework convention should start as quickly as possible after the completion of the IPCC First Assessment Report" (IPCC 1991). Based on this report, the United Nations General Assembly (UNGA) established the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change (INC), and negotiation toward concluding the UNFCCC began. The point at issue was US-EU confrontation on whether to set reduction targets for 2000 for developed countries. The United States opposed the EU's pressure to do that. It is noteworthy to know the fact, in view of the current situation, that Japan did propose *Pledge and Review* and the United Kingdom and France supported the idea, although it has finally waned (Hecht and Tirpak 1995).

As to the GHG concentration level, a sentence appeared that "[w]e agree that the ultimate global objective should be to stabilize greenhouse gas concentration at a level that would prevent dangerous anthropogenic interference with climate" in declaration 10 of policy consideration at the Second World Climate Conference held in Geneva, Switzerland in October/November, 1990 (Jager and Ferguson 1991). The EU introduced a similar concept during INC negotiation, i.e., the concept of stabilizing greenhouse gases at levels which prevented dangerous anthropogenic interference with climate and that would allow ecosystems to adapt naturally (Hecht and Tirpak 1995). The author would like to draw readers' attention to the difference between the EU's wording and that of the Noordwijk Declaration. The former lacks the phrase of mutual supportiveness of sustainable economic development and climate protection, which the latter has. It is the author's view that this difference has had a lasting effect until now.

Finally in 1992, the UNFCCC was agreed and adopted with the final wording of Article 2 shown at the top of this section, incorporating the mutual supportiveness of the economy and the environment introduced in Noordwijk.

2.1.2 Interpretation of Article 2

2.1.2.1 Article 2 and IPCC

The essence of Article 2 is summarized as follows: The ultimate objective of climate response strategies is to stabilize the GHG concentration at a level that is not dangerous. There are three conditions however. Such a level should be achieved within the time frame firstly to allow the eco-system to adapt, secondly not to threaten food production, and thirdly to allow economic growth in a sustainable manner.

The most appropriate interpretation of Article 2 can be found in Chap. 1 of the Fourth Assessment Report of IPCC.[1] The following paragraph is drawn from the executive summary of the chapter.

> The choice of a stabilization level implies the balancing of the risks of climate change (risks of gradual change and of extreme events, risk of irreversible change of the climate, including risks for food security, ecosystems and sustainable development) against the risk of response measures that may threaten economic sustainability. (IPCC 2007c, p. 97)

In other words, the choice of stabilization level is a balance between too few response strategies (resulting in adverse climate impacts), and excessive response strategies (resulting in adverse economic impacts). The subtitle of this book, *A Balanced Approach to Climate Change*, comes from this. In the text part of Chap. 1, there is the following description.

> The criterion that relates to enabling economic development to proceed in a sustainable manner is a double-edged sword. Projected anthropogenic climate change appears likely to adversely affect sustainable development, with adverse effects tending to increase with higher levels of climate change and GHG concentrations. Conversely, costly mitigation measures could have adverse effects on economic development. This dilemma facing policymakers results in (a varying degree of) tension that is manifested in the debate over the scale of the interventions and the balance to be adopted between climate policy (mitigation and adaptation) and economic development (IPCC 2007c p. 99).

So far, discussions on the Article 2 have inclined to focus on what constitutes *dangerous anthropogenic interference* with the climate. But as shown above, it is noteworthy to remember that this view reflects only one side of the coin. There is the other side, i.e., mutual supportiveness of sustainable economic development and climate response strategies.

What constitutes dangerous anthropogenic interference is, no doubt, the main issue in the article. This is, according to IPCC, beyond what science (IPCC) can decide. It says:

[1] The author was one of the lead authors of this chapter.

> Defining what is dangerous interference with the climate system is a complex task that can only be partially supported by science, as it inherently involves normative judgments (IPCC 2007c, p. 97).

So far, many climate experts have tried to define *dangerous interference with the climate*. The author will introduce several of them.

Yamin et al. (2006) proposed three criteria in defining the concept. They were as follows: what is dangerous, to whom it is dangerous, and how much is dangerous? Let us take the first one, what is dangerous. Even if one is successfully able to define *dangerous* for some event, the definition may not apply for other events. For example, a dangerous level of geophysical impacts such as the collapse of thermohaline circulation (THC), of biophysical impacts such as the extinction of some eco-systems, and of impacts on human health and well-being such as the malaria epidemic, must be different from each other.[2]

IPCC, instead of defining danger in general term, tried to respond to the issue by proposing the well-known figure for the *reasons for concern* that showed the relationship between temperature increase and impacts to various categories (IPCC 2001).

In Fig. 2.1, risks are classified into five categories from Risks to Unique and Threatened Systems (bottom) to Risks from Future Large-Scale Discontinuities (top). The *X*-axis shows temperature increase since 1990. The figure shows impacts in each risk category evolving through to 2100. Risks from future Large-Scale Discontinuities literally mean risks that will arise abruptly and are irreversible once they occur. Typical examples are the collapse of THC that may cause a cooling effect on northern Europe, and deglaciation of the West Antarctic Ice Sheet (WAIS) that may cause a maximum sea level rise of 5 m (IPCC 2007b). The second category from the top shows economic impacts. For some extent of temperature increase, impacts are either positive or negative, but become negative if the temperature continues to increase. The third category shows impact by regions, and the fourth explains the relationship between temperature rise and extreme weather. The fifth category shows impacts on ecosystems. It should be noted that the relationship between temperature change and impacts are shown in gradation, and no threshold can be found. Among the five categories, the top and the bottom ones occur abruptly and are irreversible, and the other three occur gradually. The latter are sometimes called Type I, and the former Type II.

Science cannot tell, however, what risk category and at what temperature increase should be deemed as *dangerous* based on this figure. IPCC admitted that no single dimension is paramount (IPCC 2001, p. 68).

[2] Yamin et al. (2006), recognizing it is almost impossible to define the dangerous level relying on just one event, proposed an alternative approach, i.e., using the word “tolerable” instead of “dangerous.”

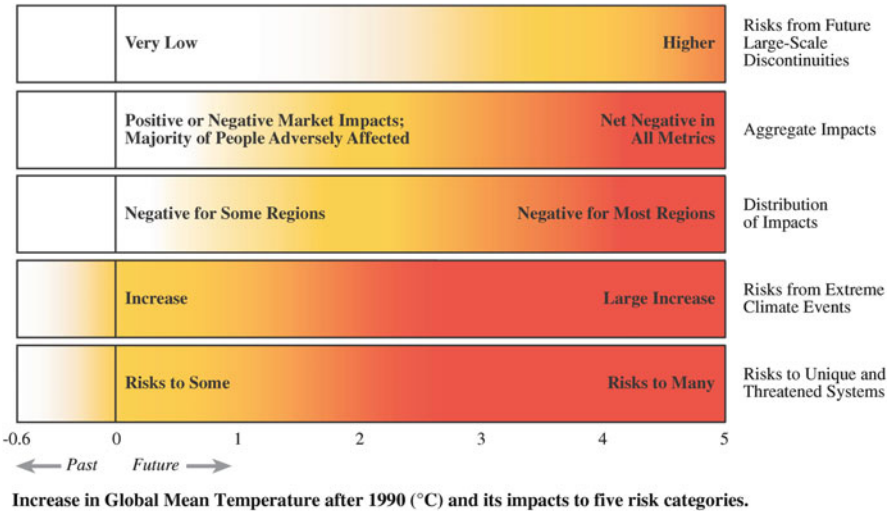

Fig. 2.1 Reasons for Concern: Increase in global mean temperature after 1990 (°C) and its impacts to five risk categories. The figure shows five categories of climate impacts in proportion to the temperature increase. The *X*-axis shows temperature increase and the *Y*-axis shows different categories of risks. The nature of risk category is explained in the chart. For example, the uppermost category corresponds to risks from Future Large-Scale Discontinuities. The darker the color is, the higher the risk. Note that *adaptation has not been taken into account*. This figure is generally called a burning embers diagram. *Source:* Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Figure TS-12. Cambridge University Press. This figure is published with permission of IPCC

2.1.2.2 Tolerable Windows Approach

The well-known approach defining dangerous anthropogenic interference with the climate system (DAI) is the tolerable windows approach (TWA), and Parry et al. (2001) is one of the most frequently cited examples of this approach. The study proposes to distinguish DAI by introducing the concept of agreed tolerable level. To what extent human society can tolerate, for example, additional people exposed to the risks of water shortage, hunger, malaria transmission, and coastal flooding, is the concept of this approach. This study focuses on Type I risks. Once we have an agreement on the tolerable level, we will be able to distinguish DAI.

More specifically, the study estimates future concentration levels, resulting temperature increases and the number of people exposed to these risks based on the IS92a scenario (one of the scenarios used in the IPCC 2nd assessment report) without mitigation and adaptation. Then the study calculates the concentration and temperature increases below which the number of people exposed can be constrained at a tolerable level. Once the GHG concentration level has been agreed, the emission reduction to achieve that level can be identified. This concept seems to be objective at a glance. But it immediately encounters several problems. First of all, it may be rather difficult to reach global agreement on the tolerable number of people exposed who are at risk. Secondly, if agreed, the number of people exposed at the same concentration level will increase due to population increase, especially in developing countries. Whether it is feasible to revise either the tolerable number of people or concentration level regularly is another concern. Thirdly, it may be almost impossible to weigh the exposure risks against each other.

The sustainability approach is another way to find a tolerable level. This approach tries to distinguish DAI by focusing on Type II risks that may threaten sustainability, such as extinction of species or occurrence of huge and irreversible phenomena (THC, WAIS, etc.). Oppenheimer (2005) argues that "[c]omplete loss of either the WAIS or the Greenland Ice Sheet (GIS) would raise global mean sea level by roughly 5 and 7 m, respectively—much of Bangladesh, or—the most populous areas of southern Florida—would simply disappear underwater. ... If there is an outcome of climate change that is likely to be viewed as dangerous across political or cultural division, loss of one or both of these ice sheets is it." The paper continues that if sea level rise due to disintegration of ice sheets is 1 m per millennium (1 mm per year), it will be manageable, but if it is more than 1 m per century (10 mm per year), adapting to it would become highly problematic. The problem is that "science cannot provide the probability of disintegration as a function of time." Then, by introducing a precautionary approach, the paper stresses "*my* precautionary evaluation of current understanding of the ice sheets would support 2 °C warming above the current global mean temperature as a long-term target." This is a value judgment. Furthermore, Oppenheimer did support 2 °C warming above the *current level* but not above the *preindustrial level*.

One of the important factors that make the climate change issue very complex is uncertainty. There is uncertainty about the link between economic activities, emissions, resulting concentration levels, temperature changes, and damages. Among these, it is noteworthy to know that climate sensitivity (the equilibrium surface temperature increase from a doubling of atmospheric CO_2 concentration) is as wide as between 2 and 4.5 °C. O'Neill and Oppenheimer (2002) argue that it is necessary to limit temperature increase from 1990 within 1 °C, 2 °C, and 3 °C in order to avoid severe reef system damage, disintegration of the WAIS, and shutdown of THC, respectively. It continues that because of the uncertainty in both climate sensitivity and other factors, the CO_2 stabilization level at 450, 550, or 650 ppm corresponds to an increase of 1.2–2.3 °C, 1.5–2.9 °C, and 1.7–3.2 °C.[3] Taking these into consideration, this study adopted 450 ppm CO_2 as the concentration level. In this case, the range of corresponding temperatures is about 1.2–2.3 °C. This means that if one set this concentration level as a target, the corresponding temperature increase must be shown in range. Conversely, if one set a particular temperature as a target, the corresponding level of CO_2 concentration will be shown in range.

[3] Climate sensitivity was estimated to be between 1.5 and 4.5 °C when the paper was written.

In view of the above, a new approach of defining DAI utilizing probability density function emerged. Mastrandrea and Schneider (2004) presented a metric for assessing DAI, i.e., a cumulative density function (CDF) of the threshold for dangerous climate change. Based on Fig. 2.1 above, the study set the threshold temperature above which each risk category becomes red (or dark), and assumed that the probability of DAI increased cumulatively at each threshold temperature by a quintile, making the first threshold the 20th percentile. The median, 50th percentile threshold for DAI, is 2.85 °C. Then if this temperature increase is deemed to be DAI, and without any response measures, the probability to hit DAI within 100 years will be around 45%. If one set 1.925 °C (25th percentile of Cumulative Density Function) as DAI, the probability will increase to more than 85%. On the other hand if 4.026 °C is deemed to be DAI, the probability will be reduced to less than 10%. Even in this case, there still remains the most important and difficult issue of a value judgment on what constitutes DAI.

2.1.2.3 Cost–Benefit Analysis

So far, discussions have focused on TWA. There is a different approach that pursues the optimal target by comparing the cost of response measures and the damage avoided (benefit). This is called Cost Benefit Analysis (CBA). William Nordhaus of Yale University pioneered the introduction of this concept in climate change mitigation (Nordhaus 1992, 1994, 2008; Nordhaus and Boyer 2000). The basic concept of CBA is to compare the cost of mitigation and the monetary value of damage avoided, and to find the optimal point where marginal abatement cost and marginal benefit become equalized. By proceeding with mitigation until this point, total social welfare (including that of future generations) will be maximized. While TWA is a concept that focuses on DAI in Article 2 of the UNFCCC, CBA is a concept that focuses not only on DAI itself but also on three conditions (especially compatibility of climate protection and sustainable economic growth) described in the article.

Nordhaus named his model, Dynamic Integrated Climate and Economy model (DICE). This is an inter-temporal general equilibrium model that integrates a climate model and an economic model. In his 1992 paper, Nordhaus, based on CBA, compared the net present value of economic welfare of the following four policy choices with a no-control scenario: First, the optimal case (maximization of economic welfare), second, stabilization of GHG concentration at the 1990 level, third, limiting global temperature increase to 0.2 °C per decade after 1985, with an upper limit of a total increase of 1.5 °C from 1900, and fourth, geo-engineering[4] (Nordhaus 1992). The outcome was +$199 billion for the first case, −$5.2 trillion

[4] The purpose of geo-engineering is "to limit climate change by altering the amount of solar radiation that reaches the earth. . . . The most prominent option involves throwing particles (sulfates or particles engineered specifically for this purpose) into the stratosphere" (Barrett 2010).

for the second case, and −$30 trillion for the third case. As the fourth case is based on imaginary technologies that will prevent climate damage at no cost, this case has no feasibility.[5]

Keller et al. (2005) examined an optimal policy by combining TWA and CBA. Based on the sustainability approach which is a kind of TWA, it assumed that both bleaching of the coral reef and disintegration of the WAIS may be deemed to be DAI, and set a threshold of 1.5 °C and 2.5 °C temperature increases since 1770, respectively. Then, based on Nordhaus's RICE (Regional Dynamic Integrated model of Climate and the Economy) model with an addition of new technology of sequestration of CO_2 into geological reservoirs, it reviewed the following four cases (1) the Business as Usual (BAU) case, (2) the optimal case, (3) the optimal case under the precondition that temperature change does not exceed 2.5 °C, and (4) same as (3) above but with a temperature increase limit of 1.5 °C. Both 2.5 °C and 1.5 °C were set subjectively in order to avoid disintegration of the WAIS and extinction of coral reefs, respectively. By adopting a climate sensitivity of 3.4 °C from another study, Keller et al. calculated the peak concentration level to avoid disintegration of the WAIS and extinction of coral reefs as 460 and 370 ppm CO_2, respectively. In order to achieve these levels, further calculation showed that emissions in 2050 should be reduced to 8 billion tons of carbon (27% reduction) for the former case and to 0.6 billion tons of carbon (93% reduction) for the latter case, both from BAU. What the latter case means is that within a few decades, global emissions must become zero. The authors of the paper, faced with this result, thought it almost infeasible as our society have already committed to cross 1.5 °C. Conversely, Kelly et al. argue that the cost of choosing the 3rd policy choice of optimal policy with the 2.5 °C constraint over optimal policy is equivalent to a one-time investment of around 2% of the present value of Gross World Products, although it depends on discount rate. In view of the disastrous nature of the disintegration of the WAIS, even if the optimal policy with WAIS constraint may be costly, it should not be prohibitive. They conclude that the policy with WAIS constraint would be a superior choice over the optimal policy.

Tol and Yohe (2006a) is a unique study from the standpoint of CBA. By pointing out the impossibility of defining DAI objectively, they proposed the concept of "Dangerous Emission Reduction." This concept was defined as an emission reduction that aimed to stabilize concentration at too low a level. In this case, because of the adverse effect on the economy, vulnerability to climate change would be augmented. They calculated the damage avoided (as a percentage of GDP) in proportion to the extent of mitigation. They assumed five cases of peak concentration of GHGs: 450, 550, 650, 750, and 850 ppm CO_2 equivalent (CO_2-eq). Their calculation showed that the most effective policy would be the one to reduce emissions from BAU to stabilizing at 850 ppm CO_2-eq. The damage avoided (policy benefit) would diminish in any other policy. In some regions, lowering the stabilization level from 550 to 450 ppm CO_2-eq would even result in the

[5] Nordhaus's most recent study will be discussed later in relation to the Stern Review.

increase of damage. They explained this phenomenon from two aspects. One aspect is that the mitigation cost for 450 ppm CO_2-eq is too costly, and the economy would be adversely affected, leading to increased vulnerability. Even though there are some reservations with this model, such as lack of assumption of a large-scale, abrupt change like the deglaciation of the WAIS, this study is worth the attention in showing the risk that excessive reduction may cause.

TWA cannot set DAI based on science, and even if the level is agreed politically, the level is subject to re-examination in view of preconditions described in the latter part of Article 2, in particular compatibility of climate protection and sustainable economic growth. Conversely, CBA can show an optimal concentration level taking into account the cost of response measures. CBA, however, cannot be free from criticism (Schneider 1993; Azar and Lindgren 2003; Azar 1998).

Azar (1998) mentioned four inherent shortcomings with respect to CBA. They are as follows: firstly, the difficulty of taking low probability but high impact catastrophic damage, such as collapse of THC, into account; secondly, the difficulty of calculating the monetary value of nonmarket damages such as loss of human life and biodiversity; thirdly, the difficulty in setting discount rate levels, i.e., no globally agreed discount rate would exist, although equity between current generation and future generations will be influenced heavily by discount rate; and finally, ethical difficulty. CBA is a tool where, if *total* benefit exceeds *total* cost, then such a policy is justified. However, there may be cases where particular individuals (or parties concerned) are worse off even in the socially optimal solutions. CBA assumes that any individual or parties concerned who are better off would compensate to such person or parties who are worse off. This is not guaranteed, however. Azar continued to point out that any CBA, though it appeared to be scientific at a glance, would be based on a value judgment, and urged that in showing the result of CBA, one should make it clear of his or her value judgment. The author of this chapter agrees to these points.

What is noteworthy here, however, is that Azar also describes that “this does not mean that cost–benefit optimization models cannot and should not play any role in climate change policies.” One can argue whether CBA is the most appropriate tool in search of the ultimate objective of response strategies or not. What is important here is that it is always indispensable to take cost into consideration to achieve any goal.

2.1.3 2 Degree Target at the G8 Summit and International Negotiations

Apart from academic discussions on the meaning of the ultimate objective of climate response measures, the so-called 2 degree target (to limit global average temperature increase within 2 °C above preindustrial level) seems to have its own momentum without profound discussions among policy makers and diplomats as well. This subsection will trace how the 2 degree target has emerged and examine its current situation.

As far as the author knows, 2 degree target first appeared on the political agenda at the 1939th Council Meeting—the Environment of the European Union held in June 25–26 in 1996, just 18 months before the Kyoto negotiation. There was the following sentence in item 6 of the Community Strategy on Climate Change—Council Conclusion. "Given the serious risk of such an increase and particularly the very high rate of change, the Council believes that global average temperatures should not exceed 2 degrees above preindustrial level . . .."

Readers must pay attention that the reasoning of the target is explained as *given the serious risk*. There is no explanation about what constitutes serious risk, nor any reasoning why. This means that the 2 degree target has been agreed *politically within the EU* and is not based on solid science. Tol (2007) argued that "[t]his target is supported by rather thin arguments, based on inadequate methods, sloppy reasoning, and selective citation from a very narrow set of studies. . . . Overall, the 2 °C target of the EU seems unfounded." In any case, this remained as the EU target for a while.

It was at the Heiligendamm Summit in 2007 when the target was put on the global stage. German chancellor Angela Merkel strongly pushed George W. Bush, then President of the United States, to insert the 2 degree target in the statement, but this was in vain. Instead, the phrase *halving of global emissions by 2050* appeared in the declaration for the first time.

The Bali Action Plan was adopted at COP 13 held in Bali, Indonesia, in December 2007. The Action Plan, citing particular tables (Table TS.2; and Box 13.7) in the IPCC 4th assessment report, decided to launch a comprehensive process up to and beyond 2012 in view of adopting a decision at COP 15.

At the Hokkaido Toyako G8 Summit the following year, similar wording to the previous year's Summit was adopted, but the leaders stressed the need of *all* major economies' contribution. In the declaration adopted the next day by the Leaders Meeting of Major Economies on Energy Security and Climate Change where emerging economies such as China and India participated, the phrase of halving global emissions by 2050 was omitted. The declaration reads "[t]aking account of the science, we recognize that deep cuts in global emissions will be necessary to achieve the Convention's ultimate objective." This means major developing countries were not convinced by the 2 degree target.

A dramatic change occurred at L'Aquilla Summit in 2009 when Mr. Barak Obama attended as US President. This year's Summit was particularly important because it was held half a year before COP 15 in Copenhagen when people expected that some kind of Post-Kyoto framework would be agreed. For the first time in G8 Summit history, the words 2 degrees appeared in the Declaration accompanied by 80% or more reduction by 2050 by developed countries. In spite of the inclusion of the 2 degree target, the leaders remained to *recognize* the broad scientific view, and they have *not agreed* to the view yet.

The Declaration of Leaders adopted at the Major Economies Forum on Energy and Climate held following the G8 Summit and where major developing countries participated, was different from that of the Summit in two important points. First of all, the words *broad scientific view* were replaced by *scientific view* and the numerical target of 50% reduction was withdrawn and replaced by the phrase *substantially reducing global emissions by 2050*. Leaders from developing countries refused to accept to recognize the *broad* scientific view that the increase in global average temperature above preindustrial level ought not to exceed 2 °C. Although there was broad *political or diplomatic* support of the 2 degree target among developed countries, there were and still are conflicting views on the target in the academic or scientific field.

Almost all people concerned expected the negotiation at COP 15 would be a memorable one (refer to the Bali Action Plan described above), and as a matter of fact, prime ministers and presidents from major countries including the United States and China got together at COP 15 to negotiate face to face. Unfortunately they failed to agree any legally binding international framework. Instead of adopting a top-down approach[6] based on the 2 degree target that several European leaders proposed, each country voluntarily pledged (or agreed to pledge) its emission target. Although the Copenhagen Accord adopted at COP 15 describes that countries shall enhance their action to combat climate change "recognizing the scientific view that the increase in global temperature should be below 2 degree Celsius," it does not say from when. In the following paragraph, the word 2 degree appears again, but the meaning of the sentence is quite unclear.[7] One can point out that the global financial and economic crisis following the Lehman shock and the climategate scandals[8] may have influenced this outcome, but it is the author's impression that not all the participating countries were convinced of the 2 degree target (above preindustrial level).

The declaration of the Muskoka G8 Summit in Canada in 2010 was almost the same as the previous year with one exception. It said "we recognize the scientific view the increase in global temperature should not exceed 2 degree Celsius compared to pre-industrial levels." Note that the words *broad scientific view* was replaced by *scientific view*. No explanation of this change has been made public.

What is remarkable other than climate change are descriptions of the MDGs especially with regard to the most vulnerable States. Among the eight goals of MDGs, leaders launched the Muskoka Initiative to tackle, in particular, reduction of child mortality and improvement of maternal health. Due to economic recessions in many parts of the world, and also paradigm shift from the top-down to bottom-up

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[6] Top-down approach in this chapter means an approach to pursue legally binding international framework based on the ultimate target (e.g., the 2 degree target). Under the approach, total emissions necessary to achieve the target has been set at first, then, the emissions will be allocated to all participating countries (numerical targets). Though not all the Parties of the Kyoto Protocol assume numerical targets, the Protocol itself is the product of such approach.

[7] The exact wording is as follows; We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report *with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius*, and take action to meet this objective consistent with science and on the basis of equity (emphasis added).

[8] Please refer to Chap. 11.

approach in Copenhagen the previous year, attention may have been shifted from a vertical balance (focusing only on climate change) to a horizontal balance (efficient allocation of scarce resources between urgent global issues).

At the COP 16 held in Cancun, Mexico, the Conference of the Parties *recognized* the urgent need of significant reduction in global greenhouse gas emissions, with a view to hold the increase in global average temperature within 2 °C above preindustrial levels. At the Deauville Summit held in May 2011 in the midst of Arab Spring reform movements and Japan's nuclear power plant accident in Fukushima Prefecture, the G8 leaders endorsed what was recognized in Cancun.

At the COP 17 held in Durban, South Africa, the Conference of the Parties noting the significant gap between the Parties' mitigation pledges toward 2020 and aggregate emission pathways consistent with temperature increase of 2 °C or 1.5 °C above preindustrial levels, decided various issues including "to launch a process to develop a protocol, another legal instrument or a legal outcome" to which all Parties including United States and China would join, to be agreed by 2015, and to come into effect and be implemented from 2020.

The point here is that, though policy makers and diplomats *recognized* the need for substantial emission reductions with a view to limit temperature increase at 2 degrees above preindustrial level, they have yet to *agree* to the 2 degree target itself. That said, the EU's strategy to hold up the flag of the 2 degree target seems to be quite successful. At first, it was just the EU's target. Now it seems to be a global target. The author has some doubt, however, whether global leaders or diplomats really understand what the 2 degree (not to mention 1.5 degree) target means to their countries and the world. The author will explain the reasons in the following subsections.

2.2 2 Degree Target from the Viewpoint of Vertical Balance: What Does It Mean?

2.2.1 Is a 2 Degree Increase Dangerous?

As explained earlier, the ultimate objective of response strategies is to stabilize GHG concentration at a level not dangerous for the climate system. If a certain increase of temperature since preindustrialization is deemed dangerous, then the GHG concentration level corresponding to the temperature increase is deemed to be a dangerous level. In this sense, it is essential to know whether a 2 degree increase is dangerous or not.

According to IPCC (2007b), if the temperature increases between 1 and 3 °C *above 1990 levels,* the effects will be mixture of net benefits and net costs, depending on regions and sectors. It continues to describe, however, that "[i]t is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2–3 °C (p. 65)." It is clear in this context that the increase of temperature is relative to

1990 levels. The temperature has already increased by 0.74 °C from 1906 to 2005 (IPCC 2007a, p. 5). When the recent high rate of change is taken into account, it may be reasonable to assume that the temperature increase from preindustrial level to that in 1990 would be around 0.6 °C (refer to footnote 2 of the Chap. 6). If this assumption is correct, a 2–3 °C temperature increase above 1990 corresponds to 2.6–3.6 °C above preindustrial level. In view of the above, one cannot draw a conclusion that the 2 °C increase above preindustrial level, which corresponds to a 1.4 °C increase from 1990, is deemed to be a dangerous level.

2.2.2 No Adaptation Is Unrealistic

As explained already, Fig. 2.1 does not take adaptation[9] into consideration. Needless to say, the history of the human being is a history of adaptation. It is quite unrealistic that people will do nothing, for example, in the face of a gradual sea level rise. Anybody will try to prevent the collapse of an embankment. Even if a 2 °C temperature increase is deemed to be dangerous, adaptation can reduce the damage, making the dangerous temperature increase upward. This is another reason to argue that the 2 degree temperature increase from preindustrial level cannot be deemed to be dangerous.

2.2.3 Catastrophe and 2 Degree Target

Refer to Fig. 2.1 again. Among the five risk categories, the category of risks from future large-scale discontinuity is the most serious risk with respect to climate change. No one will argue that this kind of risk should not be deemed to be dangerous. Typical examples of future large-scale discontinuity are collapse of THC or Meridional Overturning Circulation (MOC), disintegration of the WAIS, and deglaciation of the Greenland Ice Sheet (GIS). IPCC (2007a) describes these risks as follows.

> MOC: . . . very unlikely that the MOC will undergo a large abrupt transition during the course of the twenty-first century. Longer-term changes in the MOC cannot be assessed with confidence (IPCC 2007a, p. 72).
>
> WAIS: Current global model studies project that the Antarctic Ice Sheet will remain too cold for widespread surface melting, and will gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance (IPCC 2007a, p. 80).
>
> GIS: If a global average warming of 1.9–4.6 °C relative to preindustrial temperatures were maintained for millennia, the Greenland Ice Sheet would largely be eliminated except for remnant glaciers in the mountains (IPCC 2007a, p. 80).

[9] There is no such explanation about the figure. But there is a clear description on this point about a similar figure found on page 16 of IPCC (2007b).

As shown above, there is a risk of melting of the GIS if an average warming of 1.9–4.6 °C relative to preindustrial level continues for 1,000 years. However, firstly as the 2 degree increase is almost in the lower boundary of disintegration of the GIS, secondly as there still exist uncertainties in climate science, and thirdly as melting may occur only if the warming continues for about 1,000 years, the author thinks it will be rather premature to set a 2 degree increase limitation as a target. Of course, this does not mean to neglect catastrophic damage. It is not appropriate to disregard catastrophe in view of the fat tail way of thinking advocated by Professor Martin Weitzman (see Sect. 2.2.6.1). If the insurance premium for avoiding catastrophe is reasonable, we should buy such insurance. As shown in Sect. 2.2.5 later, in view of the fact that to stabilize GHG concentration at the lower level of 350 ppm CO_2 will not be sufficient to maintain a temperature increase of 2 degrees above preindustrial level, the cost to achieve the 2 degree target will be tremendously high. This may adversely affect sustainable economic development. If so, pursuing the 2 degree target may correspond to excessive mitigation measures. Without a visible threat and surrounded by scientific and socioeconomic uncertainty, it must be too hard for policy makers to persuade the general public to allow promotion of such policies. Instead, it is the author's view that we should promote R&D in geo-engineering technologies as a contingency plan in preparation for a very low probability but highly catastrophic event (refer to Sect. 2.4.6).

2.2.4 Feasibility of 2 Degree Target

In this subsection, the author examines the feasibility of the 2 degree target from two different aspects; technology and per capita emissions.

2.2.4.1 Technology Is the Key

Without very a high technology improvement ratio, the 2 degree target will be unachievable. The author explains the reason by relying on the famous Kaya Identity. The simplest form of the Identity is as follows:

$$CO_2 = \frac{CO_2}{GDP} \times GDP \tag{2.1}$$

$$\frac{1}{CO_2}\frac{\partial}{\partial t}(CO_2) = \frac{1}{(CO_2/GDP)}\frac{\partial}{\partial t}\left(\frac{CO_2}{GDP}\right) + \frac{1}{GDP}\frac{\partial}{\partial t}(GDP) \tag{2.2}$$

Equation (2.2) above shows that in order to reduce CO_2 emissions, society must either reduce CO_2 intensity ratio or GDP growth ratio, or must do both. In this context, the author calls the reduction ratio of CO_2 intensity, as technology improvement ratio.[10]

Calculation based on CO_2 Emissions from Fuel Combustion by the International Energy Agency (IEA) shows that annual average technology improvement ratio during the past 38 years from 1971 to 2008 has been 1.1% (the highest was 2.9% in 1981 and the lowest was −1.6% in 2003). The average annual BAU GDP growth ratio from 2000 to 2050 is estimated as 2.56% per year (RITE estimate).[11]

In order to limit the temperature increase by 2.0–2.4 °C above preindustrial level, global CO_2 emissions in 2050 must be reduced at least 50% relative to that of 2000 (IPCC 2007c). This means that, although it does not precisely correspond to the 2 degree target, and there will be several different pathways to attain the 2 °C target (Rogelj et al. 2011), a 50% reduction target can be used to evaluate the feasibility of the 2 degree target.

Table 2.1 shows the tradeoff between GDP loss relative to BAU and the needed technology improvement ratio to reduce global emissions by 50% (base year 2000). From this table it is clear that, to reduce 50% emissions without compromising GDP, the average annual technology improvement ratio must be around 3.9% every year for 50 years from the year 2000. The fact that we have never experienced such a high technology improvement ratio even in a year in the past 38 years, and that between 2000 and 2008 this ratio has been as low as 0.1%, tells us that, firstly, a 50% reduction target is very challenging, secondly, large GDP losses may be inevitable to achieve the target without an unprecedented technology improvement ratio, and thirdly, technological improvement is the key to achieve substantial reductions. It is noteworthy that even with an annual 2.5% technology improvement ratio, the GDP loss will be as large as 50%.

Next, please refer to Table 2.2. This table shows the relationship between CO_2 emission reductions and GDP loss based on the assumption that past technology improvement will continue at the same pace in the future. Under this assumption, should global leaders decide to cut global emissions by 50% by 2050, the resulting GDP loss from BAU will be around 76%. According to the estimate by RITE, global GDP in 2050 will be around \$113 trillion (three times larger than \$36.6 trillion in 2005). Therefore, a 75.5% reduced GDP in 2050 (\$27.7 trillion) will be

[10] Strictly speaking, this index includes any change that is nothing to do with technology. One such example is a change in life style. After the nuclear accident in Japan, the lifestyle has changed toward energy saving. But to make the story simple, the author calls this figure technology improvement ratio.

[11] The methodology of the RITE estimate is as follows; based on past per capita GDP and its growth rate obtained by the UN World Development Indicator, RITE estimated each country's annual per capita GDP up to 2050. Then, based on the estimated per capita GDP and population projection by the UN2008 medium estimate (UN World Population Prospects 2008), RITE estimated GDP up to 2050. Next, those figures were added up to obtain annual world GDP. Finally, using these figures, the average annual GDP growth ratio was calculated. The outcome is very similar to those of IEA and US DOE/EIA forecasts. Refer to http://www.rite.or.jp/Japanese/labo/sysken/research/alps/baselinescenario/RITEALPS_ScenarioA_POPGDP_20110405.xls.

Table 2.1 Tradeoff between GDP loss and technology improvement

To achieve 50% reduction in 2050 (base year 2000)	
GDP loss (%) against BAU	Technology improvement ratio (%)
0	3.91
10	3.70
20	3.46
30	3.20
40	2.89
50	2.52
80	0.69

Source: Compiled by the author based on GDP by RITE estimate

Table 2.2 Relationship between CO_2 reduction and GDP losses in the case where the technology improvement ratio remains the same as in past years (comparison between 2050 and 2000)

In case the annual technology improvement ratio is 1.1%	
CO_2 reduction (%)	GDP loss (%)
0	50.9
10	55.8
20	60.8
30	65.7
40	70.6
50	75.5

Source: Compiled by the author based on GDP by RITE estimate

three-fourths of that in 2005 (or 30% less than that in 2009). The general public will never accept such a policy. Furthermore, even if emissions remain at the same level in 2000 (base year), the GDP loss will be as high as 51%.

Through the above discussions, it is almost impossible to achieve substantial reductions without a drastic change of technology improvement ratio. In view of past experience as well as economic and population growth especially in developing countries, and also as we do not know enough about future technologies, it will be very challenging to reduce 50% global emissions in 2050 without sacrificing rather large GDP losses. In this sense, it is the author's belief that the feasibility of the 2 degree target is too slim, if not impossible.

2.2.4.2 From the Viewpoint of Per Capita Emissions

The feasibility of halving global emissions by 2050 relative to the 2000 level can be checked from a different aspect: feasibility of per capita CO_2 emission reductions both in developed and developing countries. Refer to Fig. 2.2. Note that the figure focuses only on CO_2 (not GHG) emissions.

Global CO_2 emissions were 22.7 billion tons in 2000 (13.8 billion tons from Annex I countries and 8.9 billion tons from Non-Annex I countries). Per capita emissions were 3.7 tCO_2 (11.0 tCO_2 for Annex I and 1.8 tCO_2 for Non-Annex I countries). Halving emissions in 2050 require that global CO_2 emissions be reduced to 11.35 billion tons. According to the UN World Population Prospects 2008,

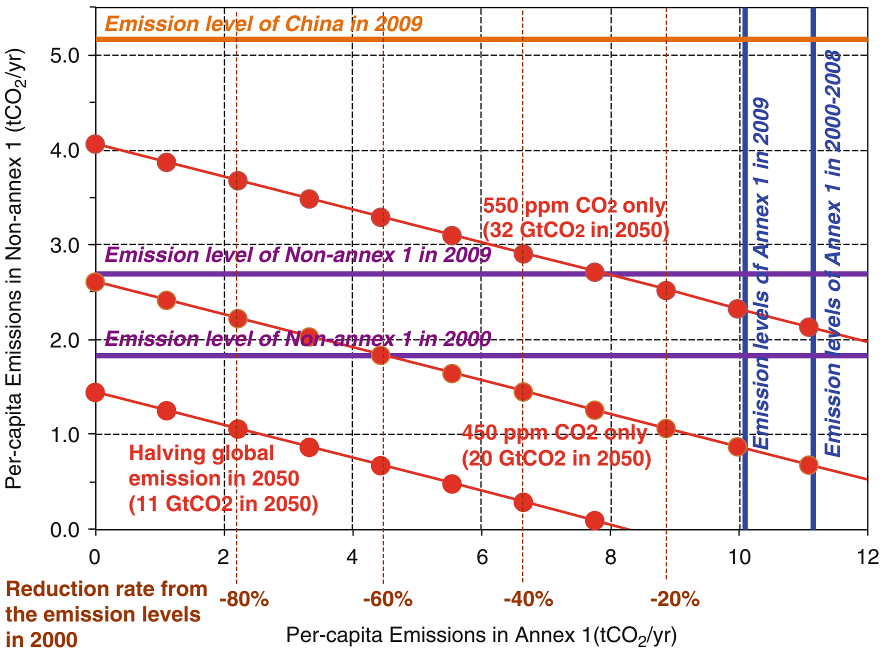

Fig. 2.2 Per capita emissions for halving global CO_2 emissions in 2050 (Base year 2000). The figure shows combinations of per capita emissions of Annex I and Non-Annex I countries. The *X*-axis and *Y*-axis show per capita emissions of Annex I countries and Non-Annex I countries, respectively. The three diagonal lines show combinations of Annex I and Non-Annex I countries' per capita emissions for stabilizing at 550 ppm CO_2 (the *top line*), at 450 ppm CO_2 (*middle line*), and to halving global emissions in 2050 (the *bottom line*). Any *dots* in the *same line* can achieve the same target by different combinations of Annex I and Non-Annex I per capita emissions. Per capita emissions of Annex I countries and Non-Annex I countries in 2000 were 11.0 tCO_2 and 1.8 tCO_2, respectively. While the former figure slightly decreased to 10.1 tCO_2 in 2009, the latter increased to 2.7 tCO_2. *Source:* Provided by Dr. Keigo Akimoto of RITE

the population in 2050 is estimated to reach 9.2 billion (1.4 billion for Annex I and 7.8 billion for Non-Annex I). Based on those data, any combination of per capita emissions of Annex I and Non-Annex I countries on the bottom diagonal line in Fig. 2.2 can achieve global 50% emissions reductions. For example, if Annex I countries reduce their per capita emissions by 80% to 2.2 tCO_2 in 2050, the room left for Non-Annex I countries' per capita emissions in 2050 is 1.1 tCO_2. In view of the fact that Non-Annex I countries' per capita emissions increased to 2.7 tCO_2 in 2009, this corresponds to 59% reduction from 2009. In the extreme case, even if Annex I countries emission become zero (100% reduction), Non-Annex I countries must reduce their per capita emissions to 1.5 tCO_2 (44% reduction from 2009) to halve global emissions. G8 Summit leaders ambitiously declared that developed countries intend to reduce their emissions by 80% by 2050. As the population in developed countries is expected to remain stable, this is almost the same meaning as 80% per capita emissions reduction for developed countries. In this situation, even if developed countries are successful in reducing per capita emissions by 80%, whether developing countries will be able to reduce their emissions by 59% (from 2.7 tCO_2 in 2009 to 1.1 tCO_2 in 2050) is yet to be seen. To sum up, in view of the rapid economic growth in emerging economies, and the fact that per capita emissions in China have almost reached 4 tCO_2 in 2005 and 5.2 tCO_2 in 2009, the feasibility of halving global emissions by 2050 (to achieve the 2 degree target) seems to be highly questionable, if not impossible.

In closing this Subsection (feasibility of the 2 degree target), the author would like to draw attention to the World Energy Outlook 2011 (IEA 2011). It states that "the door to 2 °C is closing." This means that if we delay further action until 2017, achieving the 2 degree target will become extremely costly. It also shows that even the IEA's New Policy Scenario (the central scenario of the Outlook) will lead to a temperature increase of more than 3.5 °C, and without the New Policies, we are on track to a temperature increase of 6 °C or more. Furthermore, Clarke et al. (2009) found it was almost infeasible to attain 2 °C target without the *immediate* full participation of *all* the countries utilizing bioenergy with CCS. In addition to the above, van Vuuren et al. (2011) argued that unless several conditions such as peaking global emissions around 2020, and mobilizing all technologies such as renewable energy, nuclear power and CCS both for fossil fuel and bioenergy will be met, stabilization at $2.6 W/m^2$, corresponding to 2 °C target, will be excessively challenging.

2.2.5 Uncertainty and 2 Degree Target

As described in Sect. 2.1.2, current scientific knowledge tells us that climate sensitivity is estimated as 2 °C–4.5 °C. This means that there are wide ranges of concentration levels to achieve the 2 degree target. Meinshausen (2006) successfully illustrated the situation. Refer to Fig. 2.3.

Generally speaking, it is said that stabilization at 450 ppm CO_2-eq is necessary to achieve the 2 degree target. As shown in Fig. 2.3, shown in the next page, the probability of exceeding the 2 degree target at such a concentration level is between 26 and 78% (mean 54%). Even if the concentration level is stabilized at 350 ppm CO_2-eq, the probability is between 0 and 31% (mean 7%).[12] Considering the uncertainty of climate sensitivity, however, it is impossible to determine the concentration level to attain the 2 degree target [for further study on uncertainty, refer to Webster et al. (2009)]. If people share the idea that a 2 degree increase above the preindustrial level is dangerous, then, even 350 ppm CO_2-eq stabilization is not enough. Most experts know this target is very costly, and therefore politically unrealistic. In view of this, recently many experts argue to keep the probability of not hitting 2 degrees at less than 50%. If so, those who adhere to the 2 degree target have to explain the reason why, because in this case there is 50% chance of exceeding 2 degrees.

[12] Note that 11 studies had been conducted when climate sensitivity had been considered as 1.5–4.5 °C.

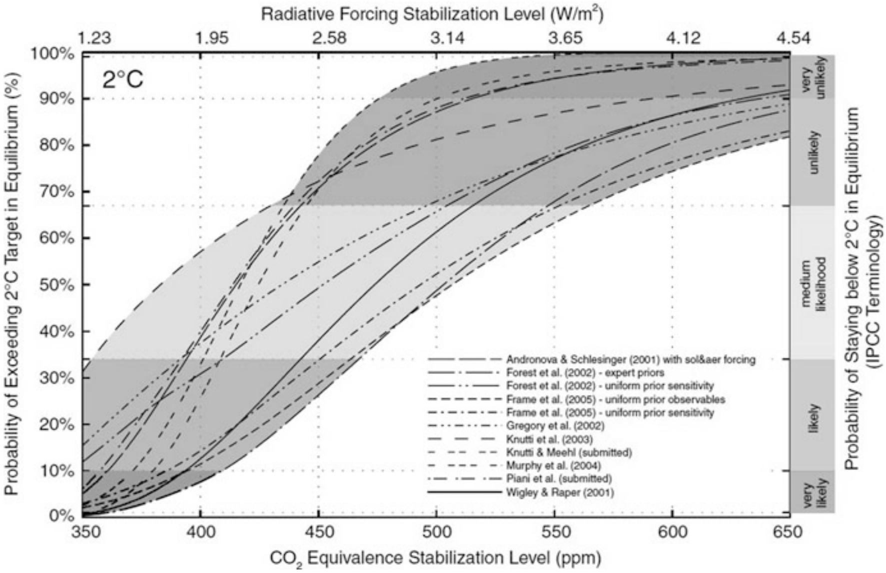

Fig. 2.3 Relationship between CO_2-eq stabilization levels and probabilities of exceeding 2 degree target. The *X*-axis shows the CO_2-eq stabilization level (*bottom*) and Radiative Forcing Stabilization Level (*top*). The *Y*-axis shows the probability of reaching the 2 degree target in equilibrium. The outcome of 11 studies is shown here. The probabilities to hit 2 degrees at 450 ppm CO_2-eq, the concentration level that is generally thought to limit temperature increase less than 2 degrees since preindustrialization, are between 26% (lower boundary) and 78% (upper boundary). *Source:* Figure 28.5 in Meinshausen (2006). What does a 2 °C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates. In Schellnhuber HJ, Cramer W, Nakicenovic N, Wigley T, Yohe G (Eds) Avoiding dangerous climate change (pp. 265–279). Cambridge: Cambridge University Press. This figure is published with permission of Cambridge University Press.

2.2.6 2 Degree Target from a Cost and Benefit Perspective

As described in Sect. 2.1.2, the IPCC 4th assessment report construed Article 2 not only from just a dangerous level of concentration but also as a balance of insufficient response measures against excessive response measures. The underlining idea is that the cost of response measures should be well-balanced with the damage avoided (benefits). In that sense, the author examines the ultimate objective of response measures from the standpoint of CBA.

As already touched upon in Sect. 2.1.2.3, the basic concept of CBA is that the "marginal costs of reducing CO_2 and other GHGs should be equalized in each sector and country; furthermore, in every year the marginal cost should be equal to the marginal benefit in lower future damages from climate change" (Nordhaus 2008, p. 14). The calculation of optimal policy is based on the assumption that the same level of carbon tax is introduced to all the countries in the world. This is rather unrealistic, but can be a benchmark to evaluate the efficiency of alternative policies. In this subsection, the author introduces two different studies of CBA, one by Nordhaus and the other by Stern,[13] although the latter is not CBA in the strict sense of the word.

2.2.6.1 Nordhaus' a Question of Balance

William Nordhaus of Yale University, having made several amendments to his previous DICE model, compared the optimal policy case with the BAU case from the standpoint of CBA (Nordhaus 2008). Thereafter, he examined more than ten alternative policies such as to limit temperature increase or concentration to a certain extent, etc. The differences from previous models include decreasing the pure rate of time preference (PRTP) from 3% to 1.5%[14] (Refer to Sect. 2.2.6.2 where *The Stern Review* applied 0.1%).

According to Nordhaus (2008), in a BAU scenario, CO_2 emissions will increase from 7.4 billion tons in 2005 to 19 billion tons in 2100, the concentration level will increase from 380 ppm in 2005 to 685 ppm, while temperature already increased by 0.7 °C in 2005 and will increase by 3.1 °C in 2100 relative to the 1990 level. After 2100, the uncertainty increases, but the model forecasts a 5.3 °C increase by 2200. Damage will be 3% of GWP, and will increase to 8% in 2200 accordingly.

In the optimal policy, by reducing 25% and 45% from BAU emissions in 2050 and 2100, respectively, the discounted present value of benefit will increase by $3 trillion (although the abatement cost will increase by $2 trillion, the damage avoided, i.e., benefit, will increase by $5 trillion). What is important here is that even in this case, a climate damage of $17 trillion cannot be avoided. The reason is that cost for further abatement surpasses benefit (damage avoided). This is the essence of the CBA. Nordhaus assumes the introduction of a carbon tax to reduce emissions. The level of tax deserves careful attention in that it is useful information for decision-making. According to Nordhaus, optimal levels of carbon tax are $25/tCO_2$ and $55/tCO_2$ in 2050 and 2100, respectively. The temperature increase since 1990 will be 2.6 °C in 2100 in contrast to 3.1 °C in a BAU scenario.

As pointed out before, Nordhaus compared more than ten alternative policies with his optimal policy. One of them is a policy to limit the temperature increase within 1.5 °C above the 1990 level. This is almost equivalent to limiting the temperature increase within 2 °C above preindustrial level (the so-called 2 degree target). In this case, while the benefit will be more than 2.4 times in comparison to the optimal policy, the cost will be 12.5 times higher than the optimal policy. As a

[13] Pizer (2007, p. 290) challenged environmental advocates on why economic mitigation benefits have not been used to justify action. Stern (2006) was one of the few who tried to do this.

[14] A 3% PRTR has continuously been criticized by "green" economists as too high. In order to keep consistency with real return of capital observed in the market, Nordhaus set the elasticity of the marginal utility of consumption as 2, and made the real return on capital (discount rate) 5.5% for the first 50 years.

result, cost will be twice as much as benefit.[15] This suggests that, if we follow the Nordhaus model, the 2 degree target cannot be justified from the view point of CBA.

The above is just an example of CBA. Although catastrophic damage is included, Nordhaus admits that the model does not take account of a "genuinely catastrophic outcome that would wipe out the human species or destroy the fabric of human civilizations" (Nordhaus 2008, p. 28).

Weitzman (2009) raised concern on this point. The point here is how to deal with a low probability but high impact catastrophe. More specifically, how to deal with the risk of extinction of human-beings or destruction of civilizations? Although climate sensitivity is presumed at 2–4.5 °C, this does not exclude the case that it will be more than that figure. This is called the *fat tail* issue. How to cope with this case? Is the CBA appropriate approach?

Weitzman argues that climate science seems to be saying that the probability of a disastrous collapse of planetary welfare is not negligible, even if this tiny probability is not objectively knowable. Therefore traditional CBA, such as Nordhaus', should take fat tail issues into consideration. This may be true. But the immediate question is to what extent the optimal policy should reflect fat tail in a standard CBA. Although Weitzman does not have any quantitative answer to this question, he argues "the qualitative direction of the policy advice is nevertheless quite clear," and the author appreciates this point. This does not justify, however, that the ultimate objective is to limit the temperature increase to 2 degrees above preindustrial level.

2.2.6.2 The Stern Review

Next, the author would like to introduce the Stern Review (Stern 2006), as this is quite well-known but drew a completely different outcome from the one by Nordhaus.

The Stern Review (hereinafter called the Review) was based on the PAGE2002 Integrated Assessment Model, and, in assessing climate damage, it used the A2 scenario[16] of the IPCC Special Report on Emission Scenarios (SRES) as a baseline (Stern 2006, p. 175). Note that the A2 marker scenario assumes the highest population (11 billion in 2050 and 15 billion in 2100 that may lead to higher future

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[15] As explained previously, the optimal policy assumes participation by all countries. This is quite unlikely. If participants are limited to major economies such as OECD countries, China and India that cover around 75% global emissions, the cost will be 68% higher (Nordhaus 2008, p. 122). Even this case will not be realistic in the near future. This suggests that if major economies agree to the 2 degree target and take necessary policies and measures, the cost would be enormously high.

[16] There are six SRES scenarios. Among them, the A2 scenario is explained as a scenario describing a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in a continuously increasing global population. Economic development is primarily region-oriented, and per capita economic growth and technological change are more fragmented and slower than in other storylines (IPCC 2000, p. 5).

damage), and highest cumulative CO_2 emissions since 1990 of 738 GtC in 2050 and 1,862 GtC in 2100 (IPCC 2000, p. 363). The Review also ran the model at two different levels of climate response scenario; one is baseline climate scenario and the other is high climate scenario.[17] The Review estimated a direct market economic loss, including catastrophic losses such as collapse of the THC and disintegration of the WAIS, of 0.9% in 2100 and 5.3% in 2200 in a baseline climate scenario (7.3% in 2200 in a high climate scenario, p. 177). Furthermore, it added nonmarket impacts of climate change. The outcome, under high climate scenario, is that the total damage will be 2.9% in 2100 and 13.8% in 2200. In this case, the temperature will increase by 4.3 °C in 2100 and 8.6 °C in 2200 relative to the 1990 level. The Review goes further. By adopting a pure rate of time preference of 0.1% (near zero), the discounted *present* value of per capita losses including catastrophe is calculated as 6.9%, and by adding nonmarket impacts, it increases to 14.4% now and forever in a high climate scenario.[18] Then, if regional costs are weighted, damage will be almost equivalent to 20% now and forever (pp. 186–187).

The Review estimated the cost of mitigation using a technology-based bottom-up as well as a model-based top-down approach, and concluded that "the annual cost of cutting total GHG to about three quarters of current levels by 2050, consistent with a 550 ppm CO_2-eq stabilization level, will be in the range of −1.0 to +3.5% of GDP, with an average of approximately 1%" (p. 239).

In view of the above, the Review concludes that the benefits of strong, early action outweigh the costs (pp. 191 and 347). And as to the stabilization level, the Review describes "[t]he evidence on the benefits and costs of mitigation at different atmospheric concentrations . . . suggests that the stabilization goal should lie within the range 450–550 ppm CO_2-eq." On the other hand, it also stresses that "stabilization at 450 ppm CO_2-eq or below is likely to be very difficult and costly" (p. 338)[19]. Note that stabilization at 450 ppm CO_2-eq leads to around a 2 degree temperature increase above preindustrial level.

There appeared several criticisms against the Review. Tol and Yohe (2006b) raised 6 points where they disagree with it. One of them is the use of a 0.1% (near zero) discount rate (more correctly, pure rate of time preference). As a result, the damage is calculated to be dramatically high in comparison with the case where a

[17] The high climate scenario includes estimates of a weakening of natural carbon absorption, and increased natural methane releases from, for example, thawing permafrost (Stern 2006, p. 175).

[18] The reason that a 14.4% (discounted present value) loss now and forever is bigger than a damage of 13.8% in 2200 is that the damage after 2201 has been integrated, and the total amount has been discounted with a very low discount rate to the present value.

[19] When the Review became first available through the Stern Review Web site, there was an Executive Summary. In the page 15 of the Summary, there were the following sentences: "Stabilization at 450 ppm CO_2-eq is already almost out of reach, given that we are likely to reach this level within 10 years and that there are real difficulties of making the sharp reductions required with current and foreseeable technologies." Instead there are following sentences in the printed version, i.e., "It would already be very difficult and costly to aim to stabilize at 450 ppm CO_2-eq. If we delay, the opportunity to stabilize at 500–550 ppm CO_2-eq may slip away."

standard discount rate is used. The lower the discount rate is, the higher the discounted present value of future climate damage. Nordhaus (2008) argues that *now and forever* used in the Review does not mean *today,* but it means, with zero discounting, the equivalent of the average annual consumption loss over the indefinite future. It continues that if we use the Stern Review's methodology, more than half the estimated damage *now and forever* occurs after the year 2800 (p. 182). Even the Review admitted that if it used 1.5% PRTP instead of 0.1%, 14.4% loss would be reduced to 4.2% (p. 668).

Another critical point raised by Tol and Yohe (2006b) is that the Review did not perform a cost–benefit analysis. The author of this book shares the same view. The damage has been calculated by the model (PAGE2002). Cost has been estimated not by the same model, but by comparing various existing studies. There is no such description in the Review where the marginal abatement cost would be equalized to marginal damage. In other words, it did not perform an optimization exercise.

The author would like to add two points. One is that the Review estimated the damage based on the SRES A2 scenario as described above, but there is no description of the SRES scenario on which costs have been based. Another point is the lack of transparency. For example, it is very hard for readers to know how a 6.9% damage, under a high climate scenario, will increase to 14.4% when nonmarket losses are added, and will become 20% when regional damages are weighted.

The purpose of this subsection is to explore how to use CBA in order to operationalize Article 2 of the UNFCCC. It is important to know that even the Review, though it did not conduct the standard CBA analysis as described earlier, concluded that the 450 ppm CO_2-eq stabilization (corresponding to roughly 2 degree target) as being too costly (though it is not clearly written, this may mean cost outweigh benefit). CBA seems to be appropriate in that it can take account of balancing too little against too many response measures. We should note, however, that the criticism raised by Azar (1998) in Sect. 2.1.2.3 that any CBA must be subject to a value judgment, applies.

From the above discussions through Sects. 2.2.1 to 2.2.6, it became clear that the 2 degree target is unfounded. In closing this subsection, the author would like to cite several words from Victor (2011). “Two degree is attractive because it is a simple number, but it bears no relationship to emission controls that most governments will actually adopt. And it isn't based on much science either” (p. 6).

2.3 2 Degree Target from the Viewpoint of Horizontal Balance: Efficient Allocation of Scarce Resources

So far, discussions on ultimate objective have focused solely on the aspect of climate change (vertical balance). The conclusion was that there was no solid ground for a 2 degree target. This section focuses on horizontal balance, i.e., efficient allocation of scarce resources among globally urgent issues including climate change. Policy makers are surrounded by various urgent issues without having sufficient resources to cope with all of them. Even if the 2 degree target is relevant from the vertical point of view (although it is not), policy makers would have to weigh the priority of such a target among other urgent issues, internationally and domestically.

The MDGs were worked out based on the United Nations Millennium Declaration in September 2000. Eight goals, including eradication of extreme poverty and hunger, reduction of child mortality, combating HIV/AIDS, malaria and other diseases, and eighteen targets, were set. The seventh goal is ensuring environmental sustainability, and there are four targets under the goal. “Integrating the principle of sustainable development into country policies and programs and reverse the loss of environmental resources” is one of four targets, under which response to climate change is included.[20] MDGs are, no doubt, the urgent issues human beings should cope with globally.

The issue here is that global resources are finite. How should limited resources be allocated to urgent global issues? There were such attempts in the past: The Copenhagen Consensus Projects in 2004 and 2008 (Lomborg 2004, 2008). In 2004, eight members of a panel consisting of the world’s most distinguished economists were invited to Copenhagen to prioritize 17 selected policies on 10 urgent global issues based on CBA, on the assumption that an additional $50 billion of resources were at governments’ disposal for the coming 4 years. The urgent global issues included disease, hunger, poverty, and climate change etc. While top priorities were given to control of HIV/AIDS (disease), providing micro nutrients (poverty), trade liberalization and control of malaria (disease), three climate policies including an optimal carbon tax, however, were given the lowest priority.

The same project was repeated in 2008. Three out of eight panel members were replaced. This time, the resource limitation was increased to $75 billion. But the outcome was basically the same. Climate policies were not given higher priorities.

When the outcome of the 2004 project was released, most environmental NGOs, many climate community experts and environmental negotiators fiercely criticized the result. Jeffrey Sachs of Columbia University joined the camp. His argument consisted of the wrong question, the wrong participants, and the wrong conclusions. Firstly, he complained that $50 billion was too small, and that the huge and complex challenge of long-term climate change was ranked low. Secondly, Sachs argued that no natural scientist or public health specialists were involved in the panel, and except for one, those members were not real experts on the particular issues. Under these circumstances, he believed, it would be difficult to evaluate the proposed policies accurately. The third argument of Sachs was the lack of transparency. According to his view and expertise, such policies as climate change and basic health proposals should have been given much higher priorities, but they were not, and the reasons were not convincing (Sachs 2004). While Sachs criticized the

[20] http://www.un.org/millenniumgoals/environ.shtml.

outcome, he admitted the core concept of the Copenhagen Consensus was a good one, but needed improvement in several points.

Lawrence Summers, once the President of Harvard University and also used to be the Secretary of the Treasury of the United States, commented on the Copenhagen Consensus that “[t]he greatest acts of statesmanship . . . have been motivated by a concern for posterity not by benefit–cost analyses. How best to recognize this obligation in carrying out policy analysis, while at the same time maintaining some rigor in recognizing that resources are scarce and become increasingly so . . . is a question that deserves much more analysis . . . ” (Summers 2007). It should be noted that, though he does not think CBA should be the primary tool dealing with long-term issues such as climate change, he, as an economist, still pays serious attention to the efficient allocation of scarce resources.

The purpose of the introduction or the outcomes of the Copenhagen Consensus does not mean that the author shares the same view on priorities. Rather, as Sachs pointed out, it is the author’s belief that this kind of concept is quite important as global resources are limited and the world needs to allocate the scarce resources efficiently and effectively to various urgent global issues including climate change. Especially, in the recent world economic situation, much more attention should be given to prioritization issues, as once we allocate a certain amount of resources to some particular issue, that portion of the resources cannot be used for other issues. And in doing so, CBA still remains one of the important tools.

The same thing applies to domestic policies. Developing countries, including China, recognize that most of the future emission increase will come from them, and therefore in order to reduce global emissions, for example, by 50% in 2050, it is imperative that both developed and developing countries reduce their emissions by absolute levels. It may be very difficult for them to do so immediately, however, because there are other urgent issues for those countries to tackle. Among them, promoting (sustainable) economic growth should be the first step to cope with climate change.

Developed countries are no exceptions. The United States, European Union, and Japan are all in the midst of economic recessions. Unemployment is a common concern among them. In addition, all suffer serious budget deficits, and credit ratings of national bonds of several governments were actually downgraded. Decision makers have to cope with various issues such as economic recovery, unemployment, the aging society, health care, and pensions. Britain can have clean energy or cheap energy, but not both (The Economist, 9 December 2010). As described in Chap. 10, the urgent priority in Japan after the Fukushima nuclear accident has been securing a power supply by any means (this means to switch from nuclear to fossil fuel for the time being). In this situation, OECD countries are trying to search for a way to have mutually supportive economic development and climate change under the flag of Green Growth. This strategy seems to become a global agenda now. Whether it will be effective and efficient, however, is yet to be seen (refer to Sect. 7.1.7).

The author has never seen any other academic and political discussion as to whether the 2 degree target is relevant or not from the viewpoint of efficient allocation of global resources (horizontal balance). If world leaders are really convinced that the stabilization of temperature within 2 degrees since preindustrialization is the first priority, why they do not start regulating emissions from military activities, such as emissions from warplanes and warships?

In closing the discussion of the 2 degree target, the author would like to cite an extract from Robert Watson's speech. Dr. Watson used to be Chairman of IPCC. In his Commemorative Lecture for the 2010 Blue Planet Prize awarded to him on October 27, Dr. Watson said "[t]he goal, . . . to limit global temperature changes to 2 °C above preindustrial levels is appropriate if the most severe consequences of human-induced climate change are to be avoided, but it must be recognized to be a stretch target and, unless political will changes drastically in the near future, it will not be met. Therefore, we should be prepared to adapt to global temperature changes of 4–5 °C" (Watson 2010).[21]

2.4 What Kind of International Framework Will Be Desirable and Feasible[22]?

2.4.1 Current Situation

The EU-led top-down international framework has failed at COP 15 held in Copenhagen in December 2009. The Copenhagen Accord adopted there is a typical example of pledge and review. Although global leaders appeared to have agreed with the 2 degree target, the wordings *above preindustrial level* was missing. In reality, they have simply *recognized* but not really *agreed* to the target, as discussed in Sect. 2.1.3. Furthermore, the aggregation of the pledged emission reduction and limitation targets for 2020 was not on track to achieve the 2 degree target (den Elzen et al. 2011; UNEP 2010). This is why member countries of the UNFCCC noted at COP 17 that there is a gap between pledges and the 2 degree target. The current situation is as follows:

The United States submitted its reduction pledge in 2020 as "[i]n the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in the light of enacted legislation." Thereafter, it became clear that the anticipated cap and trade

[21] For the sake of fairness, the author would like to introduce the lecture of Dr. James Hansen. Hansen, also a winner of the same prize emphasized, "for policy purposes all we need to know for the foreseeable future is that the CO_2 target must be <350 ppm, if we wish to preserve creation, the planet on which civilization developed". http://www.af-info.or.jp/en/blueplanet/doc/list/2010lect-hansen.pdf.

[22] The author would like to draw the readers' attention to the Government Committee's Interim Report on Sustainable Future Framework on Climate Change published in December 2004 (METI 2004). The author was a member of the Committee. Almost all the issues discussed there are still hot issues now.

legislation would have no possibility to become law at least for several years. The US administration still tries to achieve its goal by utilizing the existing Clean Air Act. Several studies revealed, however, that it will be difficult to do so (Bianco and Litz 2010; Burtraw et al. 2011). Japan's pledge of a 25% reduction is also "premised on the establishment of a fair and effective international framework in which all major economies participate, and on agreement by those economies on ambitious targets." Since it is unlikely that these preconditions have been met, Japan may propose an alternative target. This is quite likely especially in view of the Fukushima nuclear accident on 11 March 2011. Since then, the priority of their climate policy has, at least in the short term, been replaced by the securing of electricity supply by fossil fuels (refer to Chap. 10). Not only in United States and Japan, but also in major economies, economic growth and securing employment are gaining higher priority than climate change. As a matter of fact, without a strong economy, even in developed countries, it is very hard for political leaders to devote resources to climate change. In this situation, it would be a better strategy to deal with climate change issues in the context of sustainable economic development.

2.4.2 Does a Legally Binding Treaty Work Well?

The author would like to focus on the nature of a top-down, legally binding treaty. The Kyoto Protocol is an example under which Annex I countries have legally binding numerical targets.[23] It is the author's view that this type of international treaty does not work effectively. Take Canada's case for example. Legally speaking, Canada should have purchased credits, say, from Russia and by doing so, it could comply with its reduction target. It did not. Instead, it simply announced 1 year before the Kyoto period started that it would be impossible for Canada to comply with the target. In the Protocol, there were no penalty provisions. A legally binding international agreement without any penalty provision will be toothless. On the other hand, if it has a penalty provision, the United States is unlikely to join. Lawrence Summers, recalling his experience as US Secretary of Treasury, writes on international emissions trading as follows:

> As one who has sought, with mixed success, to induce the US Congress to support transfers in low hundreds of millions of dollars to international financial organizations at a time when the US economy was imperiled by international financial instability, I am skeptical that US policy would ever contemplate transfers in the billions of dollars. I fear this kind of political constraint may be every bit as real as the various natural constraints imposed by the laws of chemistry and physics (Summers 2007).

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[23] Victor (2007) summarizes the key elements of the Kyoto Protocol as follows: universal participation, binding targets and timetables for GHG emissions, integrated international emission trading, and compensation to encourage participation by developing countries. He continues to argue that these four elements are the bedrock of the Kyoto system.

This means that the US Government would not spend taxpayers' money to comply with its target under the treaty.[24] To sum up, any legally binding treaty without a penalty would not work effectively, but the United States would not join any legally binding treaty with a penalty, making the treaty ineffective. In this connection, what kind of agreement will be reached to reflect "a protocol, legal instrument or an agreed outcome with legal force" decided at COP 17 in Durban is yet to be seen.

2.4.3 Pledge and Review Is the Best Way for the First Step

From the above discussions and in view of various uncertainties surrounding climate change, the first thing we have to do is review of the 2 degree target from scratch. Moreover, once we agree to the target, that target should be under regular review to reflect the most recent scientific findings. An alternative way is to make the 2 degree target aspirational. In this case, however, there is a risk that any cumulative figures of each country's pledge would always be compared to the 2 degree target and evaluated as insufficient. What would be the level of a desirable target will be discussed from various aspects in Chap. 3.

The best workable framework to achieve the newly agreed target is pledge and review.[25] Each country pledges its target, and receives a review by experts from either other countries or international organizations after a certain time period. A country not complying with the pledge must explain the reason, and re-develop measures for the future. What a country commits to do is to implement policies and measures domestically. The numerical target itself is not the commitment. One advantage of this scheme is that this will allow us to start with a small number of countries. There is no need for international agreement. If major economies agree, this framework can start immediately. Among pledging countries or regions, they can co-operate, if they so wish, to achieve targets by introducing a harmonized tax or cap and trade. Each country's socioeconomic situation and policy priority can be reflected in its pledge. Because of the concern for international competitiveness, a country may wish to see another country's target, and may change its pledges accordingly. In this case, a country can propose an unilateral target as well as a more stringent target premised with several conditions as seen in the EU and Australia. A rapidly developing country can choose an intensity target. This means each country does its best under given

[24] Schmalensee (2010) has the same idea. He writes that "[t]he task of developing and enacting the necessary legislation is likely to be sufficiently intellectually and politically complex that it will necessarily be 'unilateral'—i.e., only loosely coupled to the international negotiation process" (p. 896).

[25] Schmalensee also tends to return to what used to be called the "pledge and review" approach (Schmalensee 2010, p. 897). Pizer also writes "it suggests that rather than a centrally planned global solution of one flavor or another, we are likely to see a suite of domestic (or sub-domestic) responses that are gradually prodded and caroused into rough harmonization. And that is what we do see" (Pizer 2007, p. 284).

conditions. After several years if the scheme proved to be ineffective than expected, it may be one idea to introduce a *pledge (with review) and review*. In this case, each country's pledge will be reviewed before it becomes registered (for a detailed explanation, refer to Yamaguchi and Sekine 2006, p. 107).

In any case, once major economies agree to the pledge and review framework, and actually they did in Copenhagen, it is the author's belief that this framework is more effective than the mere extension of the Kyoto Protocol. The reason is very simple. At the time of the adoption of the Protocol, it covered 58% of global emissions. Because of US withdrawal and rapid increase of emissions from emerging economies, coverage has shrunk to only 27% in 2008 (figures are based on energy-related CO_2 by IEA statistics). And at COP 17 in 2010, Japan, Russia, and Canada made it clear that they do not commit any numerical figure for the second commitment period of the Kyoto Protocol. This has led to the outcome that the protocol covers less than 15% of global CO_2 emissions in 2009 No treaty without the United States and emerging economies is effective. The Copenhagen Accord is quite welcome in that it adopted the pledge and review approach, and almost all countries agreed to submit their pledges.

2.4.4 Common but Differentiated Responsibilities

The principle of Common but Differentiated Responsibilities (CBDRs) is one of the basic principles in climate change. Both developed and developing countries have accepted the principle, and it was included in the Rio Declaration on Environment and Development, which was adopted at the United Nations Conference on Environment and Development (UNCED) in 1992, as well as in the UNFCCC and the Kyoto Protocol. The author shares the same view.[26]

It is true that in 1990 the portion of GHG emissions from developed countries was around 60% and their cumulative emissions should have been much larger. Under the Kyoto Protocol, only developed countries assumed a legally binding numerical target, reflecting this principle. Nobody, however, was able to forecast the dramatic change taking place in the world today: the significant growth of emerging economies. In 2010, China's emission was the biggest and its economy became the second biggest in the world. According to RITE (2011), the portion of developing countries' emissions will be as big as 70%, and India's emission volume will be side by side with that of the United States in 2050. Also, China's GDP may surpass that of the United States by the mid-2040s, although per capita GDP will be around 30% of that in the United States (RITE's medium technological progress scenario). In this situation, although CBDR still remains an important principle, classification of current Annex I and Non-Annex I countries will become

[26] One recent notable exception can be seen in the international maritime transport sector (refer to Sect. 7.1.4 of Chap. 7).

meaningless in the near future. It is indispensable that all major economies, measured by GHG, GDP, and some other indices, act collectively to cope with climate change now. In this regard, agreement to have some kind of treaty under which all major economies (emitters) assume responsibility to reduce or limit their emissions is the first step in this direction.

If the leaders of The Group of Twenty (G20) countries, with their share of GHG emissions around three-fourths of the world in 2010, can agree to pledge their targets and start implementing them, this may become a breakthrough in current UN-based negotiations. Professor S. Murase of Sophia University argues that all the major emitters, 15 or 20 countries, must become parties to the club in order that the club system is effective. He continues that a nuclear disarmament treaty would be meaningless if it was not ratified by those States with nuclear weapons, even if it was ratified by 180 non-nuclear States (Murase 2011).

2.4.5 Taking Various Factors—Adaptation, Technology Innovation and Diffusion, and Funding—into Account

So far, the focus has been solely on mitigation efforts. As explained in Sect. 2.2.2, adaptation has never been taken into account in evaluating climate damage (another reason may be that it was so complicated to do so). Adaptation, however, deserves full attention (see Chap. 6). By promoting adaptation strategies, the damage will be substantially reduced for the same degree of temperature increase. Because of the inertia of the climate system, it is inevitable that the temperature will increase to some extent, even if stringent policies are introduced globally. Adaptation, especially in the most vulnerable areas including small island states with assistance from developed countries, would surely be more cost effective than mitigation, and must be promoted strongly. In this sense, an international scheme to evaluate adaptation activities, including an evaluation of the assistance of developed and emerging economies in human, technological, and financial resources,[27] deserves attention. One idea is to develop indices to integrate these activities with mitigation activities.

Another important factor is technology. First, the author would like to stress the importance of diffusion of technologies both for mitigation and adaptation.[28] Just take, for example, reduction potential through diffusion of the best available technologies (BAT). As discussed in detail in Chap. 8, the reduction potential in the power sector, in case the best energy efficient technologies are introduced throughout the world, will be as large as 2.1 $GtCO_2$ per year. In view of the huge differences of marginal abatement cost (MAC) by country, emissions can be reduced more cost-effectively in regions where the MAC is rather low. A sectoral

[27] As to the detailed description of technology diffusion and development, refer to Chap. 9.

[28] In this regard, it is important to pay careful attention to the protection of Intellectual Property Right (IPR).

approach may be relevant for diffusion of BATs as shown in Chap. 9. The contribution to emission reductions in other countries through diffusion of BATs should also be counted and integrated with mitigation activities.

The second aspect of technology is, no doubt, technology development. The emergence of innovative technologies in the field of renewable energy that leads to the drastic reduction of cost, will contribute to reform our society toward de-carbonization. If CCS technology becomes commercially available, we can reduce our emissions substantially by continuously relying on a relatively cheap and stable fuel, coal, especially in the power generation sectors. Technology development of the nuclear generation can contribute to ease the huge dependence on fossil fuels, and to enhance energy security. Without technology innovation and diffusion, it is almost impossible to reduce emissions substantially as shown in Sect. 2.2.4.1. Integrating technology contribution with mitigation activities is another theme for the international society to tackle.

The same thing can be applied to financial assistance. In February 2010, the High-level Advisory Group on Climate Change Financing (AGF) was established by the Secretary General of the United Nations. After several discussions, AGF issued a report urging countries to provide $100 billion a year to developing countries by 2020. This is a huge amount of money. It includes several ideas which, from the author's viewpoint, may be quite difficult to implement. Regardless of whether this plan will be carried out as proposed or not, financial assistance to developing countries may help these countries to promote response measures. It is desirable that this kind of financial assistance is counted as a contribution by donor countries, and is integrated with mitigation activities.

2.4.6 Geo-engineering as an Insurance

Through the discussions in Sect. 2.2 and 2.3 above, it has become clear that the 2 degree target will be unachievable. This means that the temperature will continue to increase and the damage expand accordingly. Although still very low, the probability of catastrophic loss may increase also. When it comes to climate-related damage, we are living in an unknown world. Summers states that "it cannot be responsible public policy to ignore risks until it is conclusively established that they will play out. On the other hand, . . . economists are right to have great difficulty with the so-called *precautionary principle* favored by many environmentalists, which essentially calls for always assuming the worst." We have to manage the risks.

Geo-engineering is a tool for risk management. Now that society cannot spend so much money on invisible threats, we have to be prepared for the worst case. Of course, we should be very cautious in actually implementing this tool. That may invite other unknown risks. On the other hand promoting R&D and preparing for the worst case scenario may be the second best thing we can do for future generations.

2.5 Concluding Remarks

The author would like to sum up the discussions. Firstly, global leaders should revisit the target, as the 2 degree target has proved to be not based on science and not feasible both from the vertical and horizontal viewpoints. Secondly, global leaders should admit that a top-down approach has failed, and immediately start implementing what they have pledged based on the Copenhagen Accord. There may be several cases where the situation has changed since then, such as those in the United States and Japan. Those countries need to re-examine their pledges and submit revised pledges. So far, the pledges only focus on mitigation. Pledges on adaptation, technology development and diffusion, and financing should be integrated with those of mitigation.

In closing the chapter, the author would like to cite a sentence that appeared in an Economist article dated 29 November 1997, just a week before the Kyoto negotiations. “Better a strong weak agreement than a weak strong agreement that may collapse.”

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