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What Should the Climate Goal Be, 1.5℃ or 2℃?

Tejal Kanitkar*

Abstract: The Paris Agreement on climate change signed by 195 countries in Paris on December 11, 2015, calls on countries to reduce greenhouse gas emissions in order to restrict temperature rise to well below 2℃ from pre-industrial levels. The target of a 1.5℃ limit on temperature rise has now explicitly been identified as a goal to be achieved. The demand to restrict temperature rise to 1.5℃ rather than 2℃ has long been articulated by the group of countries most vulnerable to the impact of climate change, since a 2℃ rise in temperatures will lead to greater risks from ocean acidification and extreme events in these countries and will very likely have a significant impact on crop production as well. At the same time, large less-developed countries such as India have been opposed to this more stringent target as it would leave very little carbon space for governments to provide basic needs to their people. This paper undertakes a comparative review of the impact of and mitigation requirements implied by the 1.5℃ and 2℃ targets and discusses the implications of the Paris Agreement in the light of this review.

Keywords: Paris Agreement, carbon budgets, 1.5℃, 2℃, climate change mitigation, climate change impact

Introduction

The Paris Agreement under the United Nations Framework Convention on Climate Change adopted on December 11, 2015, is an important step towards attempting to save the planet from dangerous and irreversible climate change. The agreement, signed by 195 countries, signals a commitment to keeping temperature rise to "well below 2℃" from pre-industrial levels and, in fact, "pursuing efforts to limit temperature rise to 1.5℃ above pre-industrial levels." The world has, in other words, committed itself to a stringent check on temperature rise, an act that translates directly to a stringent cap on global emissions. However, the sum total of the

* Assistant Professor, Centre for Climate Change and Sustainability Studies, School of Habitat Studies, Tata Institute of Social Sciences, tejal.kanitkar@tiss.edu

current "voluntary" reductions in emissions embodied in the INDCs (Intended Nationally Determined Contributions) that have now been included as part of the Agreement are not at all adequate to restrict rising temperatures. Experts suggest that the trajectories of emissions implied by the INDCs would commit the world to a temperature rise of more than 2℃ above pre-industrial levels (UNFCCC, 2015). Independent studies, such as the one done by Climate Action Tracker, suggest that even with the reductions pledged by all countries, temperature rise is likely to be approximately 2.7℃.[1] The implications of the Paris Agreement have to be evaluated with respect to three issues: (i) the feasibility of meeting the stringent temperature targets and the total carbon budget that will consequently be available to the world; (ii) the division of this carbon budget between countries on an equitable basis and the claim on the budget embodied in the INDCs submitted by all countries; and (iii) the implications of not meeting temperature targets.

Issues for Less-Developed Countries

Less-developed countries as a group must ensure the mitigation of global greenhouse gas emissions to restrict temperature rise to an acceptable level. At the same time, they must ensure that they can gain access to the global atmospheric commons to the extent necessary in order to ensure the well-being of their people. A South-South alliance in climate change negotiations would seem the best way to achieve these two objectives. However, as successive conferences, including COP 21, have shown, there are differences even among less-developed countries, depending upon national circumstances, with regard to their emphasis on mitigation and the impact of climate change. For example, countries such as China, India, Indonesia, and Brazil have tended to emphasise the aspect of equity in mitigation, arguing for their right to an equitable share of the carbon space. Given the size of their economies, these countries find it necessary to ensure that there is an adequate share of carbon space to which they can stake future claims. This demand has been viewed by many of the most vulnerable countries as asking for carbon space at the cost of accepting a higher temperature rise. The Countries of the Alliance of Small Island States (AOSIS) have always maintained their demand for more stringent constraints on total emissions, and for limiting temperature rise to 1.5℃ rather than to the present target of 2℃.

The demand for the 1.5℃ limit comes mainly from the least developed and most vulnerable countries because of the threat that they face if temperatures are allowed to rise even to 2℃. This issue of whether to accept a 1.5℃ limit or a 2℃ limit has often driven a wedge among developing countries at the negotiations, with large developing countries on one side and the most vulnerable small island states on the other.

[1] See http://climateactiontracker.org/news/224/indcs-lower-projected-warming-to-2.7c-significant-progress-but-still-above-2c-.html.

Reaching a Consensus on the 1.5℃ Temperature Target

A detailed discussion of the process through which the 2℃ target was arrived at and first used at the Copenhagen Climate Change Conference (COP 15), held in 2009 and subsequent events relevant to the consideration of 1.5℃ as the better long term goal can be found in Tshackert (2015). A brief overview is given here to contextualise the discussion on the feasibility of the 1.5℃ target as opposed to the 2℃ target. At COP 16 in Cancun, Parties to the convention recognised the need to consider the possible adoption of the 1.5℃ target (UNFCCC 2011). As a result, at COP 18 in Doha in 2012, a structured expert dialogue (SED) was established under the guidance of the convention's Subsidiary Body for Scientific and Technological Advice. The purpose of the SED was to ensure scientific integrity of the review process. The final report of the SED was officially a summary of

> face-to-face dialogue between over 70 experts and Parties on: the adequacy of the long-term global goal in the light of the ultimate objective of the Convention; and the overall progress made towards achieving the long-term global goal, including a consideration of the commitments under the Convention.

In addition to the summary of the discussions that took place in each of the four SEDs, the final report also discussed the implications of shifting the temperature target from 2℃ to 1.5℃.

The demand for a reduction in the temperature limit was thus building up even before the Paris Conference was under way. In November 2015, prominent academicians from around the world, in an open letter, called on world leaders to limit temperatures to 1.5℃.[2] In the opening session of COP 21, leaders from the Association of Small Island States reiterated this demand, and were joined by large countries from the Climate Vulnerable Forum (CVF) such as Bangladesh and the Philippines, who broke ranks with the G77+China group to do so.

Developed countries that were earlier opposed to a target of 1.5℃ also promoted acceptance of this target at the Paris Conference. The result was that countries such as India were isolated in their concerns regarding the implications of a 1.5℃ target. The aspirational goal of a limit on temperature rise to 1.5℃ was included in the final accepted draft of the agreement.

The achievement of the 1.5℃ limit is virtually impossible with the mitigation efforts currently implied by the Intended Nationally Determined Contributions. It can only be assumed that signatories to the agreement believe that large-scale deployment of carbon capture technologies will be possible in the future, enabling countries to emit carbon in the short term. In the absence of technologies that can effectively remove carbon dioxide (CO_2) from the atmosphere – and technologies that can do this at

[2] The full text of the letter and the list of signatories can be found at www.globalclimatechangeweek.com/open-letter.

the scale required are not yet available – the acceptance of a temperature target of 1.5℃ implies severe restrictions on all future emissions. This means that irrespective of who has emitted CO_2 in the past, everyone has to undertake strong mitigation action in the future. For less-developed countries as a whole, the implication is that they have to meet the vast challenges of poverty eradication and find ways of ensuring the well-being of their people without the use of the fossil fuels to which developed countries have had unrestricted access thus far. Even if we assume the accelerated development of alternative technologies, it is not evident that such a shift out of fossil fuels is possible.

The next section of this paper reviews the projected impact of climate change when the threshold value is 1.5℃ and when it is 2℃. The subsequent section discusses the impact in terms of the allowable carbon dioxide emissions in order to meet each of the targets, particularly with respect to the impact on less-developed countries. The final section presents a summary of the arguments and discusses the possibility of combining both goals – avoiding dangerous climate change by limiting temperature rise to acceptable limits and securing carbon space for less-developed countries to meet their development requirements.

What Climate Science Says About Increased Risk

The Structured Expert Dialogue (SED) provides a summary of the science with respect to the implications of the 1.5℃ temperature target. The key findings of the Structured Expert Dialogue on this issue are summarised here. The SED says, in essence, that there is still uncertainty in the scientific finding in this regard. The findings with regard to the impact of a 1.5℃ rise in temperature are less clearly delineated than the findings regarding the impact of a 2℃ rise. However, there is some estimation of differential risk that experts have made by developing a concept of "one unit of risk." This is an estimate of the transition of a risk from one level to the next – from, for example, "very low" to "low" or from "medium-high" to "high." Using this concept, the SED notes that for each key risk – of a list of 25 key risks identified by the Synthesis Report - an average of 0.5 additional risk units are estimated for the difference between 1.5℃ and 2℃ of warming above pre-industrial levels.[3] This includes mainly the increased risk from ocean acidification and extreme events. The report of the SED also emphasises that the

> difference in projected risks between 1.5℃ and 2℃ of warming is significant for highly temperature-sensitive systems, such as the polar regions, high mountains and the tropics, as well as for some other regions, in particular low-lying coastal regions.

The SED also mentions that regional differences are expected to be large in terms of the additional risks from food insecurity, since crop yields are projected to be more

[3] This is derived from a more exhaustive list of 102 key risks identified by Working Group–II of the Intergovernmental Panel on Climate Change.

affected for every degree change in temperature in some regions than in others. The Fifth Assessment Report (AR5) of Working Group-II of the IPCC states that climate change poses a severe threat to food security, and that less-developed countries such as India are especially vulnerable to global warming. The findings of AR5 are that an increase in temperature of 2℃ will cause a significant reduction in yields by 2050, thus posing substantial risks to global food production and security (IPCC 2014). Tropical countries face higher risks because the reduction in yields as a result of climate change is expected to be higher in the tropics than elsewhere. For India, it is estimated that an increase of 1℃ in annual temperature can reduce rice yields by 6 per cent (Saseendran *et al.* 2000) and that an increase of 0.5℃ in winter temperature would result in a loss of 0.45 tons per hectare of wheat (Sinha and Swaminathan 1991). The predicted impact of a 1.5℃ rise in global temperatures has not, however, been measured or quantified in as great detail as has the impact of a 2℃ rise.

Although the assessment of specific risks is not very robust, the report of Working Group-II of the Intergovernmental Panel on Climate Change is clear about the fact that increasing temperatures are directly related to increasing risks. This is shown by an image from the report of Working Group-II that has been reproduced in many subsequent reports and papers (see figure 1).

The most vulnerable to a 2℃ temperature rise are the "unique and threatened systems" for which additional risk is very high. While risks of extreme weather events and large-scale singular events are moderate for a temperature rise of 1.5℃, these range from moderate-high to high for a temperature rise of 2℃. Although this illustration provides an overview of the potential impact of increasing the temperature threshold to 2℃, both the report of Working Group-II and the report on the Structured Expert Dialogue (SED) repeatedly advise caution in using these estimates of differential impact for policy prescriptions, as there is still substantial scientific uncertainty regarding the issue. However, it is interesting to note that, despite this uncertainty, the experts who were part of the SED advised that "taking a precautionary approach and adopting a more stringent target (viz. the 1.5℃ temperature target)" may be of value. While they acknowledged that meeting a temperature target of 1.5℃ would be extremely difficult, as such an outcome required negative emissions in the future, they nevertheless considered this target to be a more effective "guardrail" for limiting the impact of climate change. For less-developed countries it is also very important to evaluate the impact of the 1.5℃ limit in terms of the mitigation action they would be required to undertake whether or not developed countries do so as well.

Carbon Space for Development

A 1.5℃ target carries with it very stringent mitigation requirements. An analysis of these requirements helps explain the reluctance of large less-developed countries such as India to accept the 1.5℃ target, despite being among the group of nations most vulnerable to climate change.

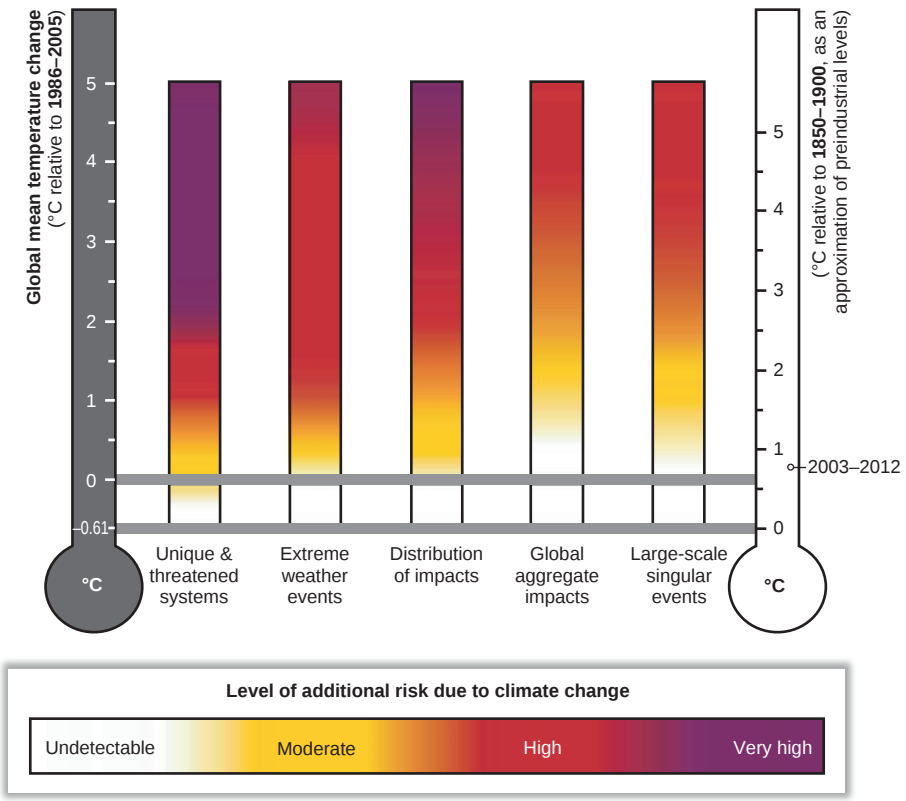

Figure 1 *Five measures of climate-related risks*
Source: IPCC (2014a)

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) signals a decisive shift by scientists towards cumulative emissions as the appropriate indicator for global reduction in emissions in order that the maximum temperature increase be kept below a specified level (IPCC 2013). The basic scientific idea is that the global temperature increase over a specified period is approximately proportional to the cumulative global emissions of greenhouse gases in this period (IPCC 2013; Caldeira and Kasting 1993; Matthews and Caldeira 2008; Allen *et al.* 2009).[4] The global carbon budget is defined as the cumulative emissions allowed that will keep maximum temperature increase below the specified target. Thus, the target of limiting temperature rise to, say, 2℃, will correspond to a carbon budget that will meet this target with a certain level of probability. For a higher probability of limiting temperature rise to 2℃, the carbon budget available will be relatively low, and, for a lower probability, the carbon budget will be correspondingly higher. For a target of limiting temperature rise to 1.5℃, a similar corresponding range of carbon

[4] At the end of the period, the annual emissions must reach a virtually carbon neutral state. Otherwise, if the emissions continue, temperature increase will also continue.

Table 1 *Carbon budgets corresponding to different probabilities of restricting temperature rise to 1.5 or 2℃* in GtC

Probability of limiting temperature rise[5]	Carbon budget values for the period 1870-2100 corresponding to the 1.5℃ target (in GtC)	Carbon budget values for the period 1870-2100 corresponding to the 2℃ target (in GtC)
80%	635	846
67%	744	992
50%	909	1212
33%	1168	1557

Note: GtC=billion metric tonnes of carbon emissions
Source: Computed from data in IPCC (2014b).

budgets (budgets that are more stringent) are available. Based on the methodology specified in the report of Working Group-I of the Fifth Assessment Report of the IPCC, which correlates an increase of 1℃ in temperature to cumulative emissions of 1000 GtC (billion tonnes of carbon emissions), a range of carbon budgets for different probabilities of exceeding both 1.5℃ and 2℃ are calculated and presented in Table 1.

The carbon budget available to the world if it wants to restrict temperature rise to 1.5℃ is about 33 per cent lower than the corresponding budget for a target of 2℃. To take an example from Table 1, when the probability of exceeding a global warming limit of 2℃ is 67 per cent, the entire carbon budget available to the world is 992 GtC. The corresponding figure for a global warming limit of 1.5℃ is 744 GtC.

The world as a whole emitted about 667 Gt of carbon between 1870 and 2011.[6] This estimate includes all emissions – carbon dioxide (CO_2) emissions from burning fossil fuels, CO_2 emissions from land use change, and forestry and non-carbon dioxide (CO_2) greenhouse gas emissions. Therefore, if we want to restrict temperature rise to 2℃, the carbon space left for the future is about 325 GtC. If we want to restrict

[5] *Technical note:* The values for carbon space used in the UNFCCC Synthesis Report on the aggregate effect of the intended nationally determined contributions for probabilities of 33 per cent and 50 per cent of exceeding 2℃ temperature rise are lower as they consider emissions including the effect of non-carbon dioxide (CO_2) forcing for the future. The carbon space values specified in the Synthesis Report for the period between 2012 and 2100 are 273 GtC and 355 GtC for probabilities of 33 per cent and 50 per cent of exceeding a 2℃ temperature increase respectively. These numbers are calculated in the IPCC report based on a range of models that provide estimates for future emissions using radiative forcing that is consistent with RCP 8.5 (Representative Concentration Pathway). RCP 8.5 is a scenario that uses a very high value of radiative forcing from both carbon dioxide (CO_2) and non-carbon dioxide greenhouse gases and it is not clear why estimates from this RCP are used to calculate the effects of non-greenhouse gas forcings. In the analysis done in this paper, the carbon budget is estimated for the period between 1870 and 2100 without adding the effect of non-carbon dioxide (CO_2) radiative forcings for the future. However, the effect of past non-carbon dioxide (CO_2) greenhouse gas emissions is included.

[6] This estimate is obtained from the sum of carbon dioxide (CO_2) emissions from fossil fuel use and from land use change (approximately 515 GtC) given in the Report of Working Group-I of IPCC's AR5 and non-carbon dioxide (CO_2) greenhouse gas emissions (approximately 152 GtC) obtained from trends for past carbon dioxide (CO_2) emissions used in constructing the Representative Concentration Pathways.

temperature rise to 1.5℃ (with a 67 per cent probability), the carbon space left is about 77 GtC. *It is evident that the target of 1.5℃ leaves virtually no carbon space for the future.* Thus, those countries that have not already occupied substantial carbon space in the past, i.e., the less-developed countries, would have to accomplish their development tasks without the benefit of fossil fuels.

Table 2 shows past emissions and the carbon space left for the future for a few countries. These values are compared to the total entitlement of each country. "Entitlement" here is defined in terms of a per capita allocation of the total carbon budget, i.e., the sum of cumulative emissions in the past (1870-2011) and those allowed in the future (2012-2100), for all countries.

The values in the first column in Table 2 show the entitlements of each country and region to the total carbon budget of 992 GtC (for a 67 per cent probability of limiting temperature rise to 2℃). Developing countries are entitled to about 81 per cent (808 GtC) of the total budget whereas developed countries, which account for a lower share of global population, are entitled to about 19 per cent. However, 67 per cent of this total 992 GtC has already been emitted between 1870 and 2011. Against their entitlement of 184 GtC, the developed countries have emitted 492 GtC, which is about 50 per cent of the total budget already. The developed countries therefore have already claimed more than can be termed their fair share of the global atmospheric space. Developing countries are entitled to 808 GtC. However, they have emitted only 175 GtC so far, which means that they should, in principle, have about 633 GtC of their entitlements left, or in other words, they should technically be entitled to emit 633 Gt of carbon in the atmosphere between 2012 and 2100. However, the world has only 325 GtC of physical space left for the future if it wants to limit temperature rise to 2℃ with at least a 67 per cent probability of achieving that target. The carbon space left for developing countries is therefore not only significantly lower than the space to which the developed countries had access in the past, it is also much lower than what can be considered a fair share based on an equitable distribution of the global commons. So assuming that there are only 325 GtC to be shared physically among all countries (since the carbon already in the atmosphere cannot be removed, at least not at the rates and scales required using currently available technology) it would mean that the space within which countries such as India have to plan their economic and energy future is severely constrained.

As shown in the last column in Table 2, if developed countries reduce their emissions sharply and immediately at the rates recommended by the Fourth Assessment Report of the IPCC, they still will emit about 40 GtC in the future, that is, between 2012 and 2100.[7] This would mean that, instead of the 633 GtC that should ideally be available to the less-developed countries, only about 285 GtC would be available. For

[7] Reduction of 40-45 per cent of 1990 levels by 2020 and of 80-95 per cent of 1990 levels by 2050 by developed countries. These rates are much higher than the rates of reduction pledged by all the developed countries as part of the INDCs (Intended Nationally Determined Contributions).

Table 2 *Entitlements, past emissions, and future shares of carbon space for a few select countries for a total carbon budget of 992 GtC between 1870 and 2100, with a 67 per cent probability of limiting temperature rise to 2°C* in GtC

Selected countries/ region	Entitlement to the total Carbon Budget (1870-2100) based on a per capita division of the budget (in GtC)	Past emissions (1870-2011) (in GtC)	Remaining entitlement for the future (2012-2100) (in GtC)	Share for 2012 to 2100, if only future carbon space is divided on a per capita basis (in GtC)	Share if developed countries reduce emissions immediately and sharply in the future — 2012-2100 — as recommended by IPCC AR4 (in GtC)
USA	46	192	-147	15	11
European Union (28)	71	173	-103	23	11
Other developed countries	68	126	-59	22	18
China	194	70	123	63	67
India	175	18	156	57	63
Rest of the world	440	87	354	144	154
Total	**992**	**667**	**325**	**325**	**325**

Notes: GtC= billion metric tonnes
IPCC AR4 = Fourth Annual Report of the Intergovernmental Panel on Climate Change
Source: Computed from data in IPCC (2007 and 2014b) and WRI (2014).

Table 3 *Comparison of the two targets in terms of their implications for the carbon space available to countries, 2012-2100* in GtC

	Remaining future per capita entitlement (2012-2100) (in GtC)		Per capita entitlement if developed countries reduce emissions immediately and sharply from 2012 to 2100, as recommended by IPCC AR4 (in GtC)	
	2℃	1.5℃	2℃	1.5℃
USA	-147	-158	11	11
European Union (28)	-103	-120	11	11
Other developed countries	-59	-76	18	18
China	123	75	67	10
India	156	113	63	6
Rest of the world	354	244	154	21
Total	325	77	325	77

Note: Irrespective of the size of the global carbon budget, there will be a physical limit on the rate at which even developed countries can reduce their emissions. They cannot, for example, decommission all their fossil-fuel-using technologies overnight.
Source: Computed from data in IPCC (2007 and 2013).

India this would mean a future carbon space of about 63 GtC between 2012 and 2100. It is necessary to emphasise here that the actual reductions pledged by developed countries as part of their Intended Nationally Determined Contributions (INDCs) translate to about 61 GtC by 2030 itself.

Three conclusions emerge. First, developed countries have already emitted more than their fair share of emissions. Secondly, they will continue to emit in the future and claim a share of the future carbon space as well. Thirdly, the INDCs specified by developed countries translate to 53 per cent more than the fair share specified by IPCC recommendations, and even more than the fair share if only the future available space is divided on a per capita basis.

If the world wants to restrict temperature rise to 1.5℃ instead of 2℃, with a 67 per cent probability of success, the carbon space available to the world in the future is 77 GtC. Of this the developed country INDCs translate to a claim of 61 GtC, leaving a meagre 16 GtC for the rest of the world. The 1.5℃ target therefore is quite clearly scientifically impossible to achieve with current technologies.

Table 3 shows a comparison of the carbon space available to key countries and regions for both cases, restricting temperature rise to 2℃ and to 1.5℃, both with a 67 per cent probability of success.

In order to achieve the 1.5℃ target India can get (in the best-case scenario) about 6 GtC, and China 10 GtC. The current INDCs of these two countries translate to about

18-24 GtC and 60-65 GtC respectively by 2030.[8] These emissions are below what can be called the fair shares of these countries. For smaller developing countries, with relatively smaller economies, the absolute level of permitted emissions becomes, in this context, very small. For all developing countries it is very important to secure carbon space in order to provide for industrial development and the provision of basic services to the people. Given the severe curtailment of carbon space availability (illustrated in Table 3), it is clear why some large developing nations were opposed to the 1.5℃ limit.

Can the World Bridge the Gap Between the 1.5℃ and 2℃ Targets?

The 2℃ target requires more adaptation to climate change than mitigation, while a 1.5℃ target requires more mitigation than adaptation. That formula encompasses a complicated reality. Restricting temperature rise to 1.5℃ may be desirable, especially for the group of least-developed countries that are most vulnerable to rising sea levels and increasing frequency and intensity of extreme events. A temperature rise of 2℃ is likely to result in a significant reduction in crop yields by 2050, with large negative effects on agricultural production and substantial risks to food security. On the other hand, more mitigation means not only sharp and immediate reductions in emissions, but also a substantial removal of CO_2 from the atmosphere sometime in the future, when the necessary technology becomes available. While the 1.5℃ target can be a goal to which the world as a whole may aspire, it cannot be the basis on which mitigation responsibilities are decided in the here and now.

To summarise,

- If the world restricts cumulative emissions between 1870 and 2100 to 992 GtC, then there is a 67 per cent probability of limiting temperature rise to 2℃. This means that only 325 GtC can be emitted between 2012 and 2100.
- Using this same carbon budget, the probability of limiting temperature to 1.5℃ is only 33 per cent. If we were to increase the probability of limiting temperature rise to 1.5℃ to 50 per cent, then the world can emit only 242 GtC between 2012 and 2100.
- An aggregation of the self-allotted carbon emissions (implied by the Intended Nationally Determined Contributions, or INDCs), amounts to 204 GtC between 2012 and 2030 alone. Therefore, at current levels of technology, the target of 1.5℃ leaves virtually no carbon space for the future. Those who have not already occupied a considerable amount of the carbon space in the past, i.e., the less-developed countries, will have to accomplish their development without the benefit of fossil fuels.

[8] A range is used here because the estimate for emissions depends upon assumptions regarding growth rates of national income.

Developed countries have already emitted more than their fair share of emissions in the past. They will continue to emit in the future and to claim a share of the future carbon space as well. Even so, it is possible to limit their claim on the future carbon space if they undertake ambitious and immediate mitigation action. However, the INDCs submitted by the developed countries translate to much more than their fair share even if only the future available space is divided on a per capita basis.

In order for the world to limit dangerous climate change *and* achieve sustainable development goals, four conditions are necessary:

1. enhanced ambition and action by developed countries to mitigate climate change with an explicit acknowledgement of their historical responsibility in causing climate change;
2. a recognition of the need for less-developed countries to gain greater proportionate access to the remaining carbon space in order to ensure the well-being of their people;
3. investment in the development of new technologies for carbon capture and to generate low-carbon energy; and
4. a strong commitment to financial and technology transfers from the developed to less-developed countries in order to assist low carbon development where possible.

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