The world beyond two degrees: where do we stand?

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The 1992 UN Framework Convention on Climate Change (Rio de Janeiro) commits signatories to prevent 'dangerous anthropogenic interference with the climate system', leaving unspecified the level of global warming that is to be considered dangerous. But keeping the average rise in global temperature below 2°C has become the focus of international efforts crystallized first in the Copenhagen climate change conference (2009) and reaffirmed in Cancun (2010). However, recent evidence shows that, there are slim chances that we can stay below this target and it is likely that temperature will rise above 4 degrees. It will have severe implications for societies around the world. The Durban conference (2011) recognized the need to limit the global warming to below 2°C, above pre-industrial levels. However, as the agreements in Durban do not propose remedial action before 2020, the risk of exceeding 2°C remains very high. The current pledges will require very high annual reduction rates after 2020, increasing the risk of not being able to restrict warming to less than 2 degrees. In other words, slow mitigation process at present will have to be hastened after 2020. Limiting warming to 2°C is critical for avoiding dangerous consequences and adaptive actions are needed to limit damage from climate change.

Keywords: Adaptation, dangerous climate change, 2 degrees, India.

THE 1992 United Nations Framework Convention on Climate Change (Rio de Janeiro) commits signatories to achieving a 'stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. However, there was no specified level of global warming which can be called dangerous[1,2]. Defining dangerous climate change has proven to be a difficult task. This is partly because of the uncertainty about how much the climate warms in response to emissions and the subjective nature of the definition of 'dangerous level' itself. However, despite these difficulties, limiting global average temperature rise below 2°C has become the focus of international efforts crystallized first in Copenhagen in 2009 and reaffirmed in Cancun. But, with the current weak mitigation efforts, scientists are skeptical of achieving the target of limiting global temperature below 2°C, above pre-industrial levels (in 1750).

Even if it is feasible to achieve the target, the probability that all the countries will meet the emission reduction targets is very less. For example, Rogelj *et al.*[3] have reported that there is 'virtually no chance of limiting warming to 2°C above pre-industrial temperatures'. They have argued that having a 50 : 50 chance of constraining warming to 2°C would require developed countries to cut emissions by up to 80% below 1990 levels by 2050. Such new scientific evidences have led many scientists to believe in the likelihood of global temperature rising above 3°C or 4°C within this century[4–6].

In a scenario, where it is likely that the world will experience global warming of 4°C or more, adapting to such changes will be difficult and complex. The scale of change and interconnectedness of impacts may be such that the window of opportunity for adaptation is smaller than previously imagined[7]. While adapting to climate change has already been an essential component of the international climate change policy, with new evidences showing possibility of global temperature crossing 2°C, rethinking the nature and scope of actions towards mitigating climate change and adapting to it seems imperative. In this context, this paper discusses, first, the current status of scientific evidence on the debate of crossing 2 degrees. Second, it discusses the implications of such a change on different sectors around the world in general, and India in particular. Third, it discusses different adaptation frameworks that have been proposed to deal with it. Lastly, it suggests shifting from ad hoc or short-term adaptive measures to transformative or long-term adaptive measures to deal with such changes.

Threshold number of 2 degrees

The debate on defining the level of climate change which can be called dangerous[1,8–10] can be regarded as the pre-

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cursor for the 2°C target which has emerged as the most prominent interpretation[11]. Perhaps, the first suggestion to use 2°C as a critical limit for climate policy was made by the economist, W. D. Nordhaus[12]. Later in 1996, the European Council adopted it as a driving climate policy. The council states that: '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 pre-industrial level and that therefore concentration levels lower than 550 ppm CO_2 should guide global limitation and reduction efforts.'[13]

The level of danger caused by climate change has generally been measured in terms of emissions, model projections and concentrations or temperature changes that can be linked to impacts of concern. The focus has been on the level of threshold of global average temperature rise beyond which climate there is a disproportionate increase in adverse impacts of climate change. The IPCC Second Assessment Report[14] projected a mid-range emission scenario associated with a global temperature increase of 2°C by 2100 and identified 'potentially serious changes' of increases in the incidence of extreme high-temperature events, floods and droughts, with consequences for fires and pest outbreaks. Since the Third Assessment Report of the IPCC (2001), considerable effort has gone into trying to estimate the level of GHG concentrations that would avoid dangerous climate change. One important attempt in the Third Assessment Report by the Working Group II of the IPCC has been to define and communicate dangerous climate change, underpinned by a large number of scientific analyses. 'Burning Embers' is the term which was used to summarize the risks of climate change to the planet.

More recently, Hansen *et al.*[15] have adopted a similar approach and define 1°C above the global mean temperature for the year 2000 as the dangerous threshold value. However, it is now recognized that dangerous level must involve a range of threshold values of global and regional surface temperature change depending on the elements of the climate system that are being impacted by the warming[16]. For example, the notion of climate tipping elements[17], some of which are hypothesized to be triggered by global warming in the 1–2°C range and many others when global warming is in the 3–5°C range. The concept of 'tipping points' is a phenomenon where at a particular point of time, a small change can have large, long-term consequences for a system[18]. Such distributed level of threshold is also consistent with the findings reported by the Fourth Assessment Report of the IPCC (2007) which specifies 1–3°C global warming as the range with various risks such as loss of biodiversity, widespread deglaciation of the Greenland Ice Sheet and a major reduction of area and volume of Hindu Kush Himalaya Tibetan glaciers. Despite different estimates, many studies on the corresponding aggregate risk of 'dangerous anthropogenic interference with the climate system' specifically on the crossing of large-scale thresholds lie mostly in the 1–4°C range of global warming[15,19,20].

The seriousness of undesirable changes in the Earth system has been reinforced by the recent argument on *planetary boundaries*[21]. The study identified important Earth-system processes and their associated thresholds which, if crossed, could generate unacceptable environmental change. The study found nine such processes to define planetary boundaries: climate change; rate of bio-diversity loss (terrestrial, land and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution and atmospheric aerosol loading. The study shows that humanity has already crossed the planetary thresholds, for example, of climate change in terms of CO_2 concentration in the atmosphere with a proposed threshold of 350 parts per million (ppm) by volume which has already been crossed to 387 ppm. The rate of bio-diversity loss in terms of species extinction and the amount of nitrogen that could be replenished in the environment for human use have also been crossed. Apart from these, the thresholds of global freshwater use, change in land use, ocean acidification and interference with the global phosphorus cycle may soon be crossed.

However, despite evidence and the Copenhagen Accord having a stated aim of keeping global warming below 2°C and reviewing the 1.5°C goal by 2015, there is no conclusion whether this is a safe level to be considered as a policy target or we need less than 2 degrees as a policy target. For example, in deference to the Maldives and other small island states, which had pushed for a 1.5°C limit on global temperature change, the Copenhagen Accord provides for consideration of a stronger long-term goal as part of the assessment of the Accord's implementation that will be completed by 2015. Although the debate is not settled, many countries have taken this target as a benchmark for climate policy. More than 100 countries have adopted a global warming limit of 2°C or below (relative to pre-industrial levels) as a guiding principle for mitigation efforts to reduce climate change risks, impacts and damages[22,23].

Where do we stand?

The Kyoto Protocol adopted in 1997 has been the most comprehensive binding multinational agreement to mitigate climate change. Enforced in February 2005, the protocol commits industrialized countries, i.e. Annex I countries, to curb domestic emissions by about 5% relative to 1990 levels by the first commitment period 2008–2012 including USA, and a target of reducing their GHG emissions by 4.2% on average for the period 2008–2012 relative to the base year of 1990, excluding USA.

However, the Kyoto Protocol has limited impact in its potential to curb emissions. As the inclusion of the 2°C and 1.5°C targets in the Copenhagen Accord is important, response from the countries has been inadequate. Parties were invited to communicate voluntary targets or actions for 2020 and their base year to the Secretariat by 31 January 2010. But, this did not result in any stronger reduction pledges, bringing into question the feasibility and will of large emitters to seriously aim for the 2°C target, let alone 1.5°C.

After the UN Climate Conference in Copenhagen, all major governments pledged on emission reductions and limitations. Analysis of emission reduction pledges by the countries after the Copenhagen conference shows that the chances of achieving the target of limiting the Earth's temperature below 2°C are low[24–30]. Most Annex I countries have submitted an unconditional pledge and a more ambitious pledge, that is mainly conditional on other countries pledging comparable reductions. The unconditional ('low') pledges would result in a total Annex I emission reduction target of 12% below 1990 levels by 2020; the conditional ('high') pledges in a reduction of 18% (ref. 31). *Bridging the Emissions Gap*, a report by United Nations Environment Programme (UNEP, November 2011)[32] synthesized major studies on this subject. The report shows that for the year 2020, there is an emission gap of approximately 12 Gt CO_2 eq between business-as-usual development and pathways compatible with a maximum temperature rise of 2°C. Further, it concluded that altogether these pledges from national governments will lead to at the most an emission reduction of 6 Gt CO_2 eq.

If the current reduction offers of Annex I and non-Annex I countries are fully implemented, global GHG emissions could amount to 48.6–49.7 Gt CO_2 eq by 2020. Recent literature suggests that the emission levels should be between 42 and 46 Gt CO_2 eq by 2020 to maintain a 'medium' chance (50–66%) of meeting the 2°C target. The emission gap is therefore 2.6–7.7 Gt CO_2 eq (ref. 31). Rogelj *et al.*[33] provide the latest and most robust analysis of the mitigation efforts needed to achieve that goal. They have analysed 193 'feasible' emission scenarios from earlier literature – two-thirds of which are mitigation scenarios. Their analysis reveals that to stay below 2°C throughout this century, annual emissions will have to come down by about 4 Gt CO_2 eq from the present-day level to about 44 Gt CO_2 eq in 2020. Even then, there is just a 66% probability of staying within the 2°C threshold by 2100. Out of the nearly 200 scenarios studied, only three give a 90% probability of staying below 2°C in this century and all of them rely on commercially unproven technologies to capture and store carbon-based GHGs. Even with the use of these technologies, there is at best a 50% probability of staying below 1.5°C in this century. Further, if we wait until 2030 for emissions to peak, we would be lucky to avoid 3°C in this century. In short, the 2°C threshold is steadily slipping out of reach and 1.5°C already seems unachievable.

The international climate negotiations in Durban showed that there has been progress in several areas, but not on the ambitious level of emission reductions by 2020. The conference decided to include all the major emitters such as USA, India and China in the legally binding emission reduction targets in the new agreement. However, those targets probably will not be operational before 2020. Although the document recognized the need to limit the global warming below 2°C, above the pre-industrial level, as the agreements in Durban do not propose additional action before 2020, the risk of exceeding 2°C remains very high. Global mean warming would reach about 3.5°C by 2100 with the reduction proposals being considered currently[34]. However, an important achievement on the Durban platform was the agreement for enhanced action. A new ad hoc working group will work to agree by 2015 at the latest on 'a protocol, another legal instrument or an agreed outcome with legal force to come into effect and be implemented from 2020'. However, Durban decisions essentially postpone a discussion on ambitions.

Despite the concern on this seemingly impossible target, many solutions have been proposed. Some important suggestions include: increasing domestic mitigation efforts in developing countries such as China and India where there is potential to decrease the carbon emissions; reducing deforestation by 50% by 2020 (ref. 31); implementing conditional pledges, laying down groundwork for faster emission reduction after 2020 (ref. 32); focusing on non-nation-state actors such as regional city and local governments, private sector, non-profit organizations and individuals in limiting GHG. One important suggestion in this regard is the role of cities in reducing GHGs, as cities now host the majority of the world's population and may produce somewhere between 30% and 75% of global GHG emissions[35]. However, the contribution of these actions to reducing GHGs is difficult to calculate at this stage. A recent study has proposed a new approach consisting of 21 coherent major initiatives in addition to the pledges and actions from national government under the UNFCCC, called 'wedging the gap', that together would trigger GHG emission reductions of around 10 Gt CO_2 eq by 2020. They argued that the approach would play a significant part in bridging the gap between current emission trends and what is necessary to put the world on a path that would limit global temperature increase to 2°C, above pre-industrial levels[36].

The world beyond 2 degrees

The 'Burning Embers' is a diagram often used to summarize the key concerns about dangerous climate change provided by the IPCC report[37]. The diagram shows five reasons for concern of the impacts of climate change. On the left-hand side of the diagram are the projections of temperature changes associated with a variety of emission scenarios suggesting that global temperatures could rise by 1–6°C by 2100, depending on GHG emission trajectories and on their climate impact simulated by various climate models. The right-hand side of the diagram shows the level of danger associated with these temperature changes for each of the five areas of concern, with red associated with larger or more widespread impacts. The first column shows that there are serious risks to unique and threatened systems and the second column shows risks from extreme climate events at even moderate temperature increases. At 2-degree global warming, there are risks associated with unequal impacts and damages to the aggregate economy. At higher temperatures, there are greater risks of large-scale climate discontinuities. The yellow to deep red shading gave rise to the label 'burning embers'. This diagram used by IPCC shows that five reasons for concern become critical as global mean temperature increases beyond 2°C of average global warming. In the diagram, the first two reasons for concern, i.e. risks to unique and threatened ecosystems and the risks of extreme weather events were judged to imply substantial impacts or risks between 1°C and 2°C above the 1990 level of global mean temperature. The third and fourth reasons for concern – distribution of impact and aggregate impacts reflected substantial risks beginning in the range between 2°C and 3°C. The fifth reason for concern – risks of large-scale discontinuities – was not judged to be a source of substantial risk until global mean temperature climbed more than 4°C and 5°C above the 1990 mean[19].

These reasons were later updated by Smith *et al.*[19] using new studies and literature on the impact of climate change. The authors show that the sensitivity of systems at risk is now greater and so the risk from large-scale disruptions is higher than before for any given level of mean temperature rise. For example, the transition from moderately significant risks to substantial or severe risks for all of the reasons for concern is at lower global mean temperature increases above 1990 level of global mean temperature compared with the location of the transitions in the Third Assessment Report of IPCC. In addition, for three reasons for concerns: (i) distribution of impacts; (ii) aggregate impacts and (iii) large-scale discontinuities – the transition from no/little risk to moderately significant risk also occurs at a lower global mean temperature increase. This means that, even a small increase in the mean global temperature is likely to have significant or substantial consequences on the five reasons for concern.

A rise in temperature beyond two degrees will pose greater challenges to impacts and adaptation across the sectors of agriculture, ecosystems, migration and coastal cities. Precipitation changes from models have shown that global precipitation in most models increases linearly with increasing temperature[38]. Sanderson *et al.*[39] use 40 global climate A2 scenarios from the IPCC Fourth Assessment Report and a number of simulations that project a high-end warming of 4°C or more by the 2090s (relative to the pre-industrial period) and have analysed the precipitation and temperature changes. The results show that precipitation in December, January and February (DJF) is projected to decrease over Central America, the Mediterranean, Northern Africa, India and parts of Southeast Asia. Other regions experiencing a decrease in rainfall are the southernmost parts of South America and much of Chile. Precipitation has been projected to increase over most of the remainder of South America, the Horn of Africa and much of Australia. Precipitation is still projected to decrease over Central America and also to decrease over large parts of Brazil, Southern Africa and Australia. Increase in June–July–August (JJA) precipitation has been projected over India and Southeast Asia. There is poor model agreement over much of the USA and Australia during JJA. The areas most at risk due to high-end temperature changes and decrease in precipitation are Northern Africa, Southern Europe and Central Asia.

Apart from the precipitation and temperature changes, water resources are going to be significantly affected by the increase in the temperature beyond two degrees. Fung *et al.*[40] have evaluated the differences in impacts and adaptation issues for water resources in the world corresponding to the policy objective (+2°C) and possible reality (+4°C). Their model ensembles for the +2°C world indicate that water stress will increase in all river basins in Africa, India, Eastern USA and Southern Europe. One of the interesting findings in this study is that it shows decrease in water stress for a +4°C world under population scenarios for the 2030s and 2060s in the Ganges. Thus, as one moves from +2°C to +4°C, the effects of climate change become large enough to offset the large increases in demand expected in the Ganges basin. This model implies that water stress in the Ganges will decrease as we move from a 2-degree towards a 4-degree warming world. This is because in this case, the effects of climate change become large enough to offset the large increases in demand in a +4°C world. However, there are chances that the wet seasons could get wetter and dry seasons get drier in the Ganges river basin. However, the authors have also pointed out that most global circulation models find it notoriously difficult to model the Indian monsoon, so the results for the Ganges should be treated with particular caution.

Studies based on quantitative estimates of climate change impacts at 4°C above pre-industrial levels under the A1B scenario in the 2080s show that 15% of the world population will be exposed to water stress increasing from present-day 1% only[40–42]. In case of agriculture, 50% of the currently cultivated land and 15% of the globe's dry land currently suitable for cultivation will become unsuitable if the temperature rises beyond 4°C; and farmers of the sub-Saharan Africa would be severely affected due to loss in agriculture[41,43]. Different types of ecosystems will also be in danger due to a high-temperature rise beyond two degrees. For example, a temperature rise of more than 4°C risks extinction of approximately 40% species studied globally, including losses of iconic species and associated ecotourism. Further, flood-affected population would rise to 544 million annually (as defined by those experiencing a present-day one in 100-year flood)[44].

Rise in the sea level due to global warming and its impacts on coastal areas have received considerable attention in the recent years. Due to high concentration of people along the sea coast, the potential negative impacts will be higher in these areas. This has important and direct implications for the coastal society and more widespread indirect effects in terms of potential disruption and displacement of people and economic activities. Rise in the sea level causes a range of impacts for coastal areas, including submergence/increased flooding, increased erosion, ecosystems changes and increased salinization. According to a recent estimate, global rise in sea level of 0.5–2.0 m by 2100 is consistent with a beyond 4°C world[45]. Many people are displaced by sea-level rise owing to a combination of erosion and increased flooding. Their model suggests that in the absence of any adaptations such as coastal protection, submergence is a much larger contribution to the loss than erosion. Under these conditions, land loss amounts to a total of 877,000–1,789,000 sq. km for a 0.5 and 2.0 m rise in sea level respectively. This amounts to approximately 0.6–1.2% of the global land area. The net population displaced by this rise is more significant, being estimated at 72 million and 187 million people over the century respectively (roughly 0.9–2.4% of the global population). Most of the threatened people are concentrated in three regions of Asia: east, southeast and south Asia. Given a 0.5–2 m rise in sea level, a total of 53–125 million people are estimated to be displaced over the century from these three regions alone. In the three small-island regions (Caribbean, Indian Ocean and Pacific Ocean), 1.2–2.2 million people are displaced over the century. However, an important finding from this study is that, assuming protection with dykes and nourishment, the number of displaced people will fall dramatically to comparatively minor levels of 41,000–305,000 over the twenty-first century. Hence, in contrast to the no-protection scenario, the problem of environmental refugees almost disappears[46].

Adaptation to the new degrees

With very high chances that climate change may occur sooner brings the need to rethink adaptation in a new perspective beyond the ‘business as usual’ scenario. Although many adaptations are taking place around the world, the applicability of current adaptation practices is questionable in a beyond 2-degree world. To deal with this situation, there will have to be a major turnaround in policy, planning and behaviour, to avoid an atmospheric concentration that poses a significant risk of mean global warming of 2°C or beyond[47]. With a warming of more than 2 degrees, the scale of change and interconnectedness of impacts may be such that the window of opportunity for adaptation is smaller than previously imagined. In this new situation, adaptive capacity will not necessarily translate into action and until now, adaptation has not been embedded into planning systems despite changes in extreme weather events. In some cases, the current adaptation practices may not be sustainable and turns out to be a maladaptation in the long run[7].

Many types of adaptation frameworks have been suggested to deal with the adverse impacts of climate change on societies. However, the problem under the new circumstance is that there is much uncertainty involved in the predicted impacts of climate change; and societies and governments have to confront the problem of decision-making under uncertainty[7,45]. It involves the formulation of expectations of future impacts while adaptation actions can turn out to be efficient, redundant or maladaptive depending on the foresight and timeliness of the decisions. Uncertainty arises both from the social uncertainty about whether and when mitigation efforts will be agreed and achieved, as well as from the scientific uncertainty about how the many feedbacks in the Earth system operate, arising from imperfect climate modelling, the role of tipping points and other limits to our understanding of the system[5]. Hallegate[45] has emphasized that the speed and magnitude of potential changes create major adaptation challenges and there is a need for decision-makers today to modify their practices and decision-making frameworks to account for these realities. He proposes five approaches to reduce the risks of climate change in the face of uncertainty. These are: (i) selecting ‘no-regret’ strategies that yield benefits even in absence of climate change; (ii) favouring reversible and flexible options; (iii) buying ‘safety margins’ (strategies that reduce vulnerability at null or low costs) in new investments; (iv) promoting soft adaptation strategies, including (a) long-term (perspective) and (v) reducing decision time horizons.

However, due to differential vulnerability and adaptive capacity between countries, their adaptations will differ. For example, low-income countries are characterized by reactive adaptations in response to short-term motivations, particularly changing market conditions. Adaptation mechanisms are more likely to include community-level mobilization rather than institutional, governmental or policy tools. On the other hand, adaptation in developed countries has been characterized by more proactive or anticipatory adaptations stimulated by longer-term climatic changes such as temperature and rise in sea level. Adaptations are more likely to include governmental participation and involve non-resource sectors such as infrastructure and transportation[48]. This implies that adaptation will be different for both developed and developing countries, 'a one size fits all' adaptation framework will not work for all the countries. In relation to climate change adaptation, the key issue is the total decision lifetime. In general, decisions with a short lifetime, such as which cultivar of rice to plant, need not take account of climate change until it is experienced, whereas decisions with a long lifetime, such as the location of suburbs, need to consider climate change risks now, regardless of whether the long lifetime is a result of lead time or consequence time or both. Adaptation needs to be reconceptualized away from the incremental handling of residual risk to preparing for continuous (and potentially transformational) adaptation[5].

The road ahead for India

India is one of the countries highly vulnerable to the impacts of climate change. Many sectors such as agriculture, water resources and coastal areas are already affected by climate change[49]. Studies have been conducted over the years to assess the impacts of climate change on India. However, till now, no comprehensive studies have been made on the nature and extent of impact of climate change where the temperature rise is more than 2 degrees and associated adaptation responses in India. There is a need for studies on the impacts of climate change on different sectors in India beyond 2 degrees of global mean temperature. India has initiated the National Action Plan on climate change outlining the adaptation options and planning for climate change mitigation and adaptation through its eight national missions. Apart from that, several states such as Delhi, Odisha, Karnataka and Madhya Pradesh have already come out with their action plans on climate change. However, according to a recent report on climate legislations[50], legislations in India have mainly covered the energy efficiency aspect of climate change mitigation and the legislation covering adaptation to climate change is detailed, but it is not the main focus of attention in climate change legislations in India. This points towards a more robust planning and legislation in different sectors relating to climate change adaptation in India.

To deal with such a level of global warming in India, adaptation cannot be a mere extension of the present adaptation practices; it should be a more continuous and transformative process. We need to make adaptation practices more flexible and transformative to deal with the changes in the climate. There is a need for more studies on the current adaptation actions on the basis of long-term climate change and how these policies on adaptation can cope with future uncertainties. As the agreements in Durban do not propose additional action before 2020 on emission reductions, climate change planning at the national and sub-national levels can complement the slow progress at the international level on climate change mitigation. Domestic actions can help in mitigating the impacts of climate change and may accelerate adaptation actions. Given that adaptation to climate change is local, local-level policies and bottom-up approach to adaptation has the potential to accelerate the current adaptation efforts to deal with a warmer world.

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ACKNOWLEDGEMENTS. I thank Joeri Rojelj, ETH Zurich, Switzerland and Kanna Kumar Siripurapu, University of Maryland, College Park, USA for their initial suggestions and help, and the anonymous referees for their valuable comments and suggestions. The usual disclaimer applies.

Received 12 December 2011; revised accepted 4 July 2012