A Copenhagen Prognosis: Towards a Safe Climate Future

A Synthesis of the Science of Climate Change, Environment and Development

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KEY MESSAGES

The 2°C limit is a not only a widely endorsed political target, it is also a scientifically meaningful one. “Temperature rises above 2°C will be difficult for contemporary societies to cope with, and are likely to cause major societal and environmental disruptions through the rest of the century and beyond” (Richardson *et al*., 2009).

This is not to say that levels of warming below 2°C would be “safe”. As global mean temperature change surpasses the current level of anthropogenic warming (~0.7°C), the world’s vulnerable populations and sensitive ecosystems are increasingly exposed to dangerous climate change.

Emerging science published since the Fourth Assessment Report of the IPCC suggests that some components of the climate system are responding more rapidly to anthropogenic forcing than had been previously anticipated. A broader analysis of tipping points and feedbacks reinforces the conclusion that greenhouse gas (GHG) emission reductions targets currently being tabled within the political realm are not consistent with the expressed political will to protect humanity against high risks of devastating climate impacts and significant risks of self-amplifying global warming.

An assessment of the available carbon budget, if we are to have a good (75 per cent) chance for warming to stay below 2°C, makes it clear that global GHG emissions would nearly certainly need to decline extremely rapidly after 2015, and reach essentially zero by midcentury.

While this clearly confronts human society with an almost overwhelming challenge, there is no evidence suggesting it is impossible. To the contrary, the growing body of analytical work examining such scenarios at the global and regional level suggest it is not only technically feasible but also economically affordable, even profitable. The challenge becomes more manageable by undertaking reductions in CO_2 emissions simultaneously with reductions in emissions of shorter-lived non- CO_2 greenhouse gases and black carbon particles from fossil fuels. The affordability of an ambitious response is even clearer when the costs of inaction are considered. These conclusions, however, only apply assuming a global transformation towards sustainability begins in the very near future and accelerates quickly.

The challenge is especially daunting in developing countries, which are currently plagued with widespread energy poverty. While the earnest engagement of some developing countries is critical to an effort to address climate change, developing country efforts to expand access to energy services cannot be eclipsed by the exigencies of rapid decarbonization.

The only way to secure the earnest commitment of developing countries to an adequately ambitious global climate accord is to ensure that they have the resources necessary to enable a decarbonization that is rapid and comprehensive, but that also allows access to energy services to expand rapidly. This calls for unprecedented levels of North-South cooperation, including flows of financial and technological resources.

The need to provide a sufficient share of the very limited remaining global carbon dioxide budget (less than 1000 billion tons) for developing countries and to ensure that sufficient financial and technological resources are made available, suggests that industrialized countries' emission allocations (e.g. within an emissions trading scheme) must decline to zero and even become negative for some nations within the timeframe 2020-2030. This conclusion is supported by recent analysis of principle-based approaches to equitable and empirically-substantiated effort-sharing in a global climate accord.

Securing a safe climate future on our planet for centuries to come is determined by just one generation today. Greenhouse gases emitted now will contribute to an energy imbalance over the long term and can trigger potentially irreversible, non-linear changes in environmental systems. The prevailing social, political, business, and economic paradigms must be recalibrated to deal in the present with unacceptable, potentially disastrous risks in the long-term future.

Analyses at the global level and in regions, both in poor and rich nations, clearly show that energy transformations towards a low-carbon future are technologically possible, even over the short term, and that they are socially desirable, and to a large extent economically profitable. Recent energy scenarios show that the EU can achieve 40 per cent emission reductions by 2020 with current technologies, and that India and China can bend their emission trajectories while increasing energy access and securing their economic and development goals over the coming decades.

One of the world's largest challenges, besides reducing fossil emissions, is to achieve a global transformation of world food production. Agricultural land use systems – today accounting for 17-30 per cent of global GHG emissions – need to rapidly shift from being a net source of emissions to potentially becoming a net global sink. This needs to occur in a situation where (1) a new green revolution is needed to lift 1 billion out of hunger and feed a world population of ~9 billion in 2050; (2) options for sustainable expansion of agricultural land are extremely limited due to current disastrous rates of biodiversity loss and ecosystem degradation; (3) unavoidable climate change will undermine the stability of freshwater availability for agriculture – the world's largest water-dependent human activity.

The climate challenge is not only a challenge of reducing emissions of greenhouse gases. As negative environmental pressures on the biosphere continue to grow, the final battle ground over avoiding human-induced warming that exceeds 2°C will shift from the current focus on reducing CO_2 emissions, to the sustainable management of land, water and biodiversity in the world's ecosystems.

Achieving the necessary "Great Transformation" to give humanity a reasonable chance to contain warming < 2°C will require major world-wide innovations in institutions, policy development and enforcement, including economic instruments at a global level such as a global climate fund and a feed-in tariff system that enables the rapid development of renewable energy world-wide. Market incentives are urgently needed to tap technological and systems innovations as well as dynamic multiplier effects when getting a desirable fossil-free snowball rolling.

THE STATE OF CLIMATE SCIENCE

Amidst the complex negotiations now taking place, the fundamental scientific reality of our climate predicament has drifted into the background. This is extremely serious, as humanity is facing a problem like no other. We cannot negotiate with the physics of the planet, and we cannot solve the anthropogenic climate crisis without a systems-based scientific understanding of the human and biophysical dimensions of the challenge. We, along with much of the scientific community, are deeply concerned that an adequate climate protection agreement cannot emerge under such circumstances. We issue this memorandum as a joint effort to reinject a systems-based scientific rigour and a commensurate sense of urgency into the negotiations.

It has become increasingly evident that human society is testing the earth's basic bio-geophysical limits. We are approaching critical thresholds beyond which abrupt, irreversible, and potentially catastrophic environmental disruption may occur, and thereby threatening to transgress boundaries and leaving the safe space in which the Earth system can continue to function in the remarkably stable, Holocene-like mode that has seen human civilizations arise, develop, and thrive (Rockstrom *et al*., 2009).

The vulnerability of the Earth's climate system to anthropogenic interference has become overwhelmingly clear. The atmospheric concentration of carbon dioxide is now already close to 390 ppm and keeps climbing faster and faster as emissions rise and as the CO_2 absorbing capacities of natural sinks decline. Current CO_2 concentrations exceed pre-industrial levels by more than 100 ppm, and are higher than at any time in the past 800,000 years, and possibly the last 3 - 20 million years. In total consistency with theoretical expectations and modelling exercises, a long-term cooling trend caused by astronomical forcing has been reversed, and the earth is now approximately 0.7°C warmer than its pre-industrial temperature. The warming has proceeded at a rate of 0.19°C per decade over the past twenty-five years (Allison *et al*., 2009) and current emission trends in GHGs are increasing the heat addition to the planet at unprecedented rates (IPCC AR4 and Ramanathan and Feng, 2008).

The consequences of this unprecedented warming are widespread, severe, and occurring more rapidly than anticipated. Some indicators of global change are not only moving beyond the patterns of natural variability, they are exceeding even very recent projections of anthropogenic disturbance. Arctic sea-ice has declined at a rate far exceeding projections, with the ice extent remaining over the past three summers about 40 per cent less than the average IPCC AR4 model prediction. Both Greenland and Antarctica are losing mass at an increasing rate, contributing to a rise in sea-level that is progressing at a rate about 80 per cent above IPCC predictions and is closely correlated with temperature.

These observations are, to be sure, only a subset of the many manifestations of anthropogenic climate change. Even more importantly, they are only a mild forewarning of the potential impacts to come, absent a concerted societal effort to curb greenhouse gas emissions. The figure below, (Smith *et al*., 2007) illustrates the extent of the threats posed by progressively higher levels of warming. It also conveys – by juxtaposing an appraisal presented in the IPCC TAR in 2001 (left) with a 2007 update based on subsequent science (right) – the extent to which reasons for concern have grown more serious. And now, a mere two years later, even the more recent version can be interpreted as conservative, in that it has already been superseded in various respects by more

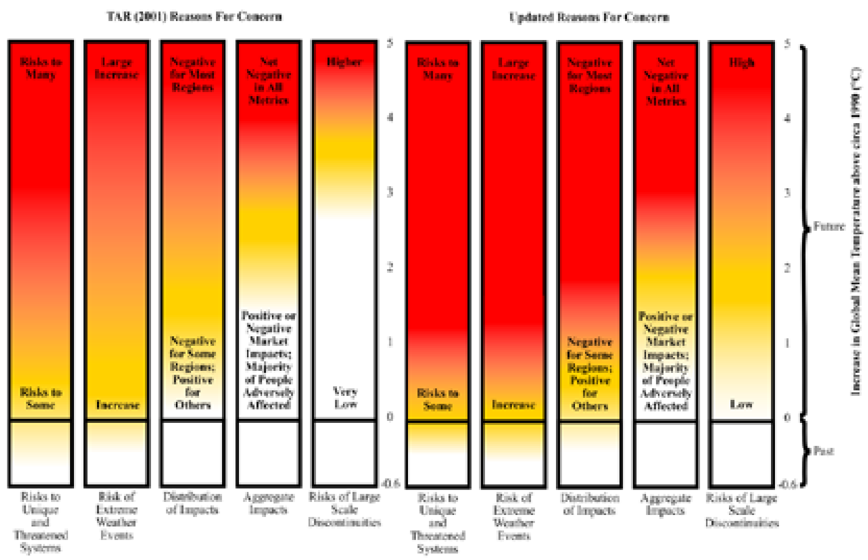

Figure 1: Reasons for concern.

recent research. Notably, current expectations of future sea level rise are at least double the IPCC AR4 projections from 2007 (Richardson *et al*., 2009).

Accordingly, systemic reviews of the evolving climate science has led many scientists to the conclusion that "Temperature rises above 2°C will be difficult for contemporary societies to cope with, and are likely to cause major societal and environmental disruptions through the rest of the century and beyond" (Richardson *et al*., 2009). This should not, by any means, be taken as a statement that warming below 2°C is "safe". Indeed, even while political support for a 2°C definition of climate protection has become more mainstream, it is also becoming increasingly clear that even 2°C of warming will bring devastating impacts on particularly vulnerable communities and sensitive ecosystems. With this understanding, eighty nations representing the nearly 800 million people have taken the position that a global target be set "as far below 1.5°C as possible."

GUIDANCE FOR THE FUTURE

The implications of various climate protection targets with respect to the available CO_2 emissions budget are understood sufficiently well to provide policy-relevant guidance on a global emission budget for the coming decades. Figure 2 presents an "emission band" that would provide a reasonable chance of holding warming below 2°C. The emission pathway defining the lower edge of the band requires a CO_2 budget of 650 $GtCO_2$ for the period 2010 to 2050. The recent analysis by Meinshausen *et al*. (2008) concludes that such a pathway would have a 1 in 4 risk (25 per cent) that warming would exceed 2°C. The emission pathway defining the upper edge of the band requires a CO_2 budget of 800 $GtCO_2$, and has a correspondingly greater risk (1 in 3, or 33 per cent) of exceeding 2°C.

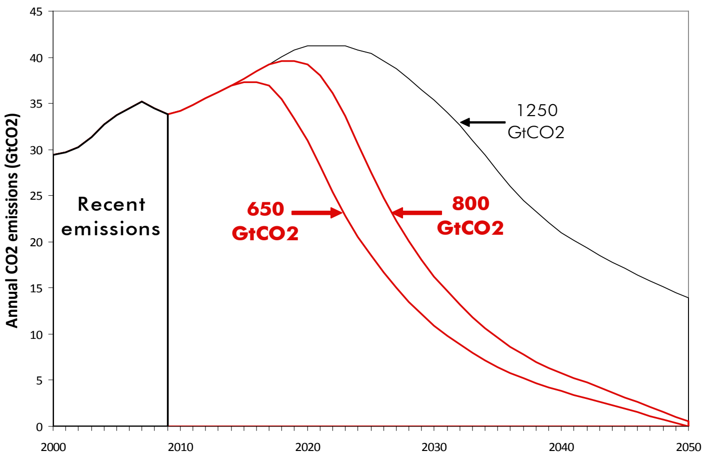

Figure 2: Emission pathways and risk.

The 650 $GtCO_2$ emission pathway (the bottom of the red band) would limit the risk of exceeding 2°C to approximately 1 in 4 (25 per cent), and the 800 $GtCO_2$ pathway (the top of the red band) would limit the risk to approximately 1 in 3 (33 per cent). The 1250 $GtCO_2$ pathway, which reduces emissions to 50 per cent below 1990 levels by 2050, would pose a risk significantly greater than 1 in 2 (> 50 per cent) that warming would exceed 2°C.

Figure 2 also shows a pathway in which emissions peak in 2020, and decline to 50 per cent below 1990 levels by 2050. While this pathway has frequently been referred to as being consistent with a 2°C limit, it actually poses a risk significantly greater than 1 in 2 (50 per cent) that warming will exceed 2°C. It cannot reasonably be considered a strategy for keeping warming below 2°C.

An honest scientific appraisal, however, must acknowledge that even the red band defines a highly risky course. Emission pathways in this band still pose a significant risk (25 – 33 per cent) of exceeding 2°C . Using the terminology adopted by the IPCC to describe probabilistic assessments, these pathways would be termed "likely", but not "very likely", to keep warming below 2°C. Moreover, the risk could be considerably greater. These estimates are based on the default parameters of Meinshausen *et al*., who point out that less optimistic assumptions that are also scientifically defensible raise the estimated risk of exceeding 2°C to more than 40 – 50 per cent. Also, it is not clear whether these more pessimistic estimates fully account for the slow feedback mechanisms such as albedo change due to diminishing ice sheets or shifts in vegetation. Another important consideration is the role of air pollution in climate change. IPCC-AR4 estimates that reflection of solar radiation by particles (also referred to as aerosols) such as sulphates, nitrates and others have masked about 40 per cent of the warming. Because of health and agriculture impacts of air pollution, stringent air pollution laws are needed, but will lead to unmasking of this cooling effect, with further acceleration in the warming (Ramanathan and Feng, 2008). Given this formidable situation, we need to complement CO_2 reduction strategies with reductions in non-CO_2 agents of climate change.

CO_2 accounts for about 55 per cent of climate forcing and its long-term damage to the climate system makes it critical to take aggressive reductions now. But the other 45 per cent of climate forcing must be targeted as well. Recent articles (Ramanathan and Feng, 2008 and Molina *et al*, 2009) describe the importance of reducing key non-CO_2 greenhouse gases (methane; HFCs; ozone in the lower atmosphere) and black carbon aerosols. Technologies are available to achieve reductions of the order of 30 per cent to 50 per cent in their emissions (Molina *et al*, 2009) and such aggressive actions now on the non-CO_2 forcers that make up the other 45 per cent will help forestall abrupt climate change in the near term (Ramanathan and Feng, 2008).

A PATH FORWARD

These assessments are bracing. In order to have reasonable confidence that warming would stay below 2°C, extraordinarily ambitious emission reductions are clearly necessary. In the band of pathways shown, global emissions peak in the next few years (between 2015 and 2018), reach a sustained rate of decline of 10 per cent per year for several decades, and fall essentially to zero by 2050.

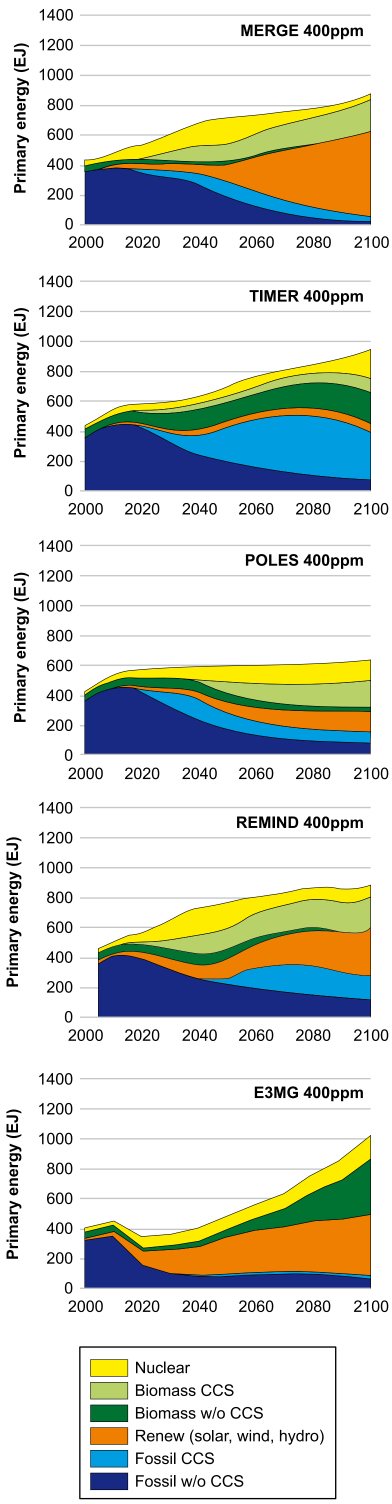

Figure 3: 400ppm energy scenarios.

Several energy-environment-economy modelling analyses concluded that energy demand can be satisfied under extremely stringent emission pathway, at costs of less than 2.5% of GWP (Knopf and Edenhofer, 2009).

Still, there is very good reason to believe that such pathways are attainable. A recently completed *Regional Modelling Comparison Project* employed five distinct energy-environment-economy modelling approaches to assess the feasibility of reaching an extremely ambitious emission pathway, broadly consistent with the red band shown in figure 2, designed to stabilize atmospheric concentrations of greenhouse gases at 400 ppm-equivalent (Knopf and Edenhofer, 2009). Each of the modelling analyses conducted for this project concluded that such a path was feasible. Moreover, they each concluded that the path was feasible at quite modest cost, with aggregate losses for this century being below 2.5 per cent of Gross World Product.

These results have been reinforced by several detailed studies for individual regions. In the same report by Knopf and Edenhofer, and also in another study by Stockholm Environment Institute (SEI) examining the viability of a 40 per cent cut in emissions by 2020 (Heaps *et al*, 2009), detailed energy scenarios have been constructed for the EU-27 showing that deep reduction scenarios consistent with the red band in Figure 1 are feasible. According to a scenario prepared by SEI using the Long-range Energy Alternatives Planning system (LEAP), Europe can reduce greenhouse gas emissions by 40 per cent solely through domestic action, without resorting to international carbon offsetting schemes. Emission reductions of this magnitude require radical improvements in energy efficiency, the accelerated retirement of fossil fuel and a dramatic shift towards renewable energy. Cuts beyond 90 per cent in 2050 might be possible with technologies and measures not yet commercialised today. The initial cost of this domestic action to tackle the climate challenge in Europe (between 2010 and 2020) is likely to be within the range of 1 per cent to 3 per cent of EU GDP.

Going Clean, a report that describes the techno-economic and policy features of deep emission reductions in China (Gang *et al*, 2009), has concluded that China can cut carbon emissions dramatically and still grow its economy over the next 40 years.

Within the tight constraints of a global 2ºC target, there are strong mitigation potentials in Chinese building, industry, transport and electricity generation sectors. Advancing technology and innovation need to be fundamental policy objectives, as early investment reduces costs and paves the way for large-scale abatement. Consumption and production patterns must also be steered in a more resource sustainable direction. But with today's low price on carbon emissions, the incentives for a low-carbon transition are not sufficiently strong. In addition to a carbon price, there needs to be a substantial, stable and predictable source of international finance, accompanied by market reform and regulatory mechanisms that can recognise, support and deepen Chinese mitigation and adaptation efforts.

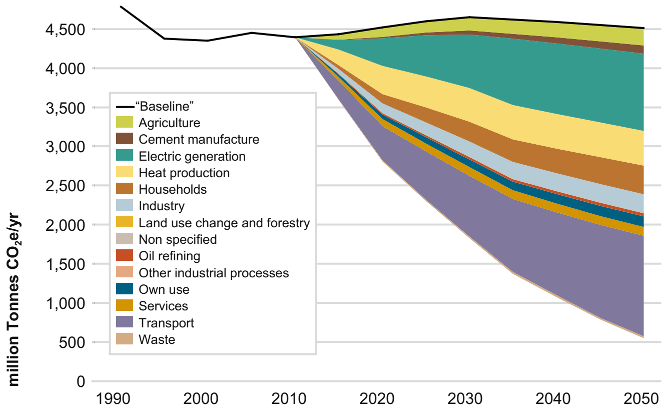

Figure 4: GHG mitigation wedges.

The top line of this chart shows baseline scenario GHG emissions. Below that is displayed a series of "wedges"that show the contribution of each the various sectors to reducing the baseline emissions down to the final levelseen in the mitigation scenario. Each sector plays an important part in the reduction but the largest reductionscome from measures in the transport and electric generation sectors (Heaps *et al.*, 2009).

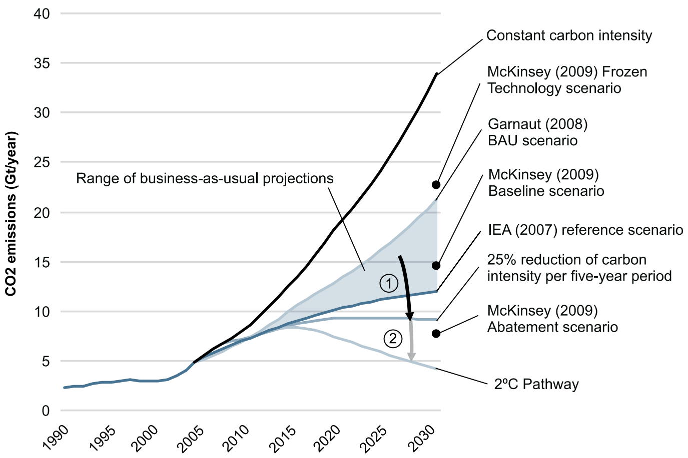

Figure 5: Schematic overview of possible future emission pathways for China.

The first arrow ① illustrates the considerable curb of carbon emissions that China's current ambition to reduce energy intensity and switch to non-fossil fuel would imply if it were extended to 2030. The second arrow ② shows how much more would be needed for China to reach a low-carbon emission trajectory in line with what would be needed for the world to meet the 2°C target (Gang *et al.*, 2009).

In Africa, a study of the economics of climate change for Kenya (Downing *et al*, 2009) has concluded that low carbon development combined with adaptation would significantly benefit the economy, avoid emissions and improve social conditions. The study has investigated a low carbon alternative pathway. This finds that a large number of 'no regrets' options that would enhance economic growth, as well as allowing further access to international carbon credits. These also have economic benefits from greater energy security and diversity, reduced air pollution, reduced environmental impacts. The study estimates energy related emission savings of 22 per cent could be achieved by 2020, relative to the baseline, even for a small selection of

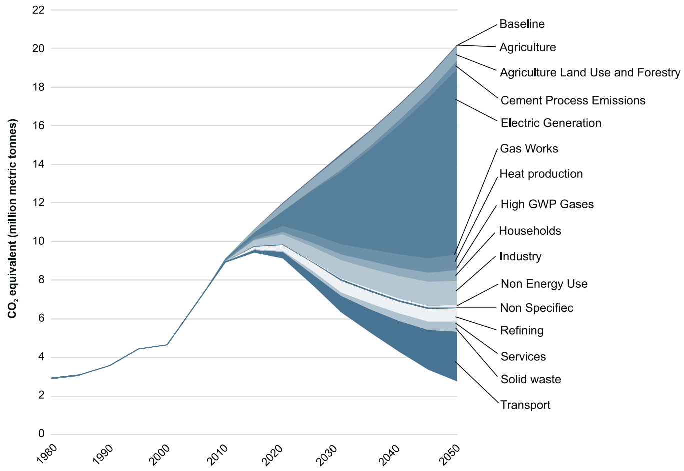

Figure 6: CO_2 emissions in baseline and deep carbon reduction scenarios. (Gang *et al.*, 2009)

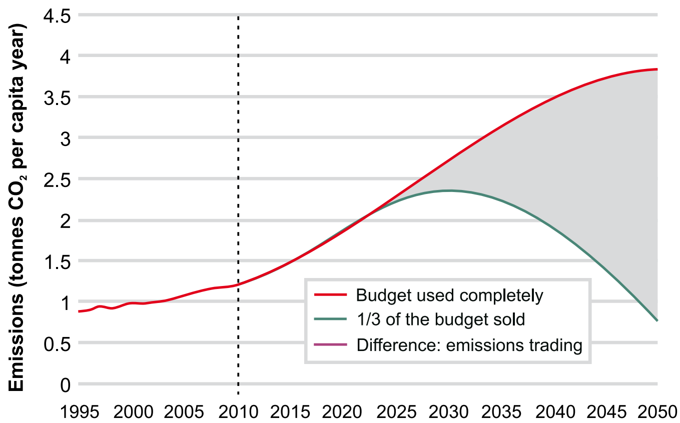

Figure 7: Examples of budget compatible CO_2 emissions trajectories per capita for India.

Per-capita emissions shown are based on the 2010 population and do not take account of population growth. The figure shows a theoretical pathway with full utilization of the budget (red), and a pathway along which India sells one-third of its budget to other countries and thus retains a smaller budget for itself (green). Up to 2030, the red emission pathway continues along the projected business-as-usual pathway (IEA, 2007). (Source: WBGU)

options. Over 80 per cent of these options can be realized at net negative cost. When carbon credits are included, this amount is likely to be even higher.

India remains an "energy starved" country, which needs to rapidly expand energy access to meet current and future development needs. A recent energy analysis by TERI (TERI, 2008), highlighted India's energy pathways under alternative scenarios (until 2031/32). This analysis indicates that India could meet development needs while following ambitious CO_2 mitigation scenarios (resolution and the ambition scenarios), which would allow India's emissions to follow the required pathway for a stringent 2°C pathway.

How close to overshooting this "safe" pathway would obviously be a function of the resources it is able to invest in energy transformations.

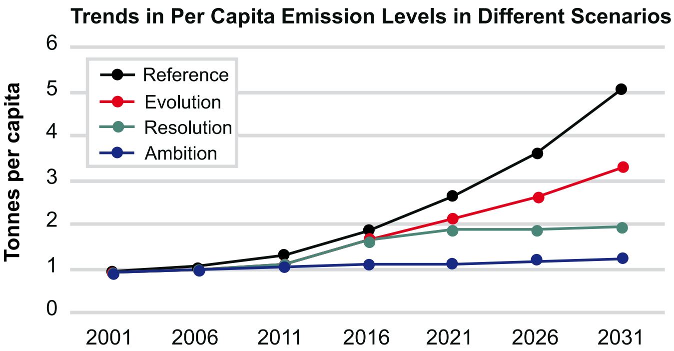

Figure 8: Per capita CO_2 emission trajectories for India under different energy & technology development pathways. (Source: TERI)

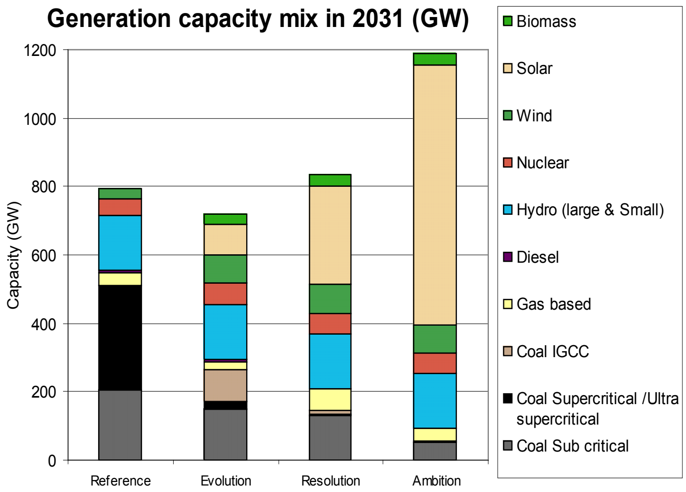

Figure 9b: Transformations in electricity generation capacity mix across alternative energy development pathways in India in 2031. (Source: TERI)

The relative share of renewable energy in India's total energy mix will have to increase rapidly. Solar energy would need to play a key role, and policy making is already responding: India's solar capacity targets are in line with the numbers indicated by TERI's modeling outputs.

Moving towards a low-carbon trajectory would obviously not be without costs. However, the increase in actual energy system cost would be somewhat lower than the capital cost because of the shift to renewable energy technologies and the consequent lower fuel costs. Taking into account the likely evolution of renewable energy and energy efficiency markets and the economies of scale that may then accrue, the financial support needed to move to a low carbon pathway would be even lower than the estimated increase in the energy system cost. An initial Fund of approximately USD 200 billion for a period of ten years has been proposed for facilitating the shift to the low carbon path (the Resolution scenario).

The global food and freshwater nexus constitutes a particularly large challenge for humanity over the coming decades. Only five years from the 2015 target year of the UN Millennium Development Goals of halving hunger in the world, new reports indicate that the absolute number of starving human beings is on the rise, exceeding 1 billion people. With another 2.5-3 billion world citizens by 2050, essentially all born in currently poor countries, nothing less than a new green revolution is needed to provide food for a world population of ~9 billion people by 2050. As shown by the UN Millennium Ecosystem Assessment (2005) the options to expand agricultural land without undermining ecosystem functions and services is very limited. Agriculture is the world's largest freshwater consuming human activity thereby facing major challenges due to unavoidable freshwater impacts from climate change. Finally, agriculture is a major source of GHG emissions, accounting for ~ 17 per cent of emissions from current agricultural land, or an estimated 30 per cent if all land use transformations into agriculture (e.g. deforestation) are included. Recent analyses (Rockström *et al* 2009) show that agriculture will have to go through a major sustainability transformation in order to contribute to solve the climate change crisis while at the same time achieve a sustainable green revolution. Research indicates that it is possible through innovations in water and land management to shift agricultural systems from a source to sink (Lal *et al*, 2008).

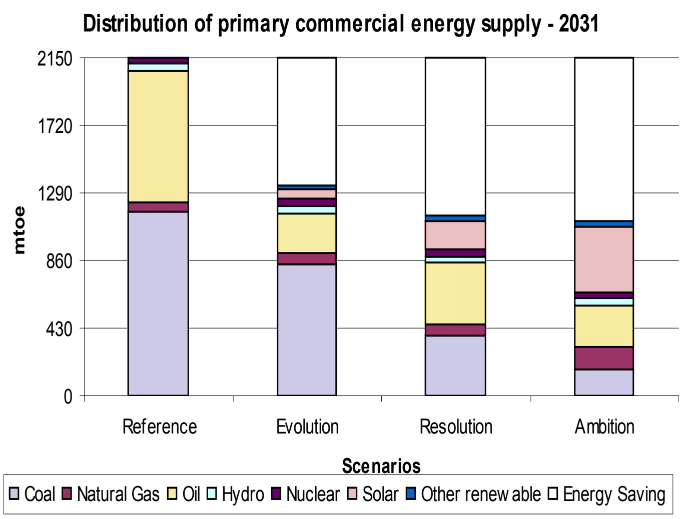

Figure 9a: Primary commercial energy requirements across alternative energy development pathways for India in 2031. (Source: TERI)

CLIMATE PROTECTION *WITH* HUMAN DEVELOPMENT

While a sufficiently ambitious societal response may be techno-economically feasible, there are far greater difficulties in establishing its political viability. Without a doubt, such a response will imply a momentous transformation. Such transformations will be a challenge even for the most financially endowed and technologically advanced of nations. It will be orders of magnitude more challenging for the less developed countries given that our world is starkly divided between rich and poor.

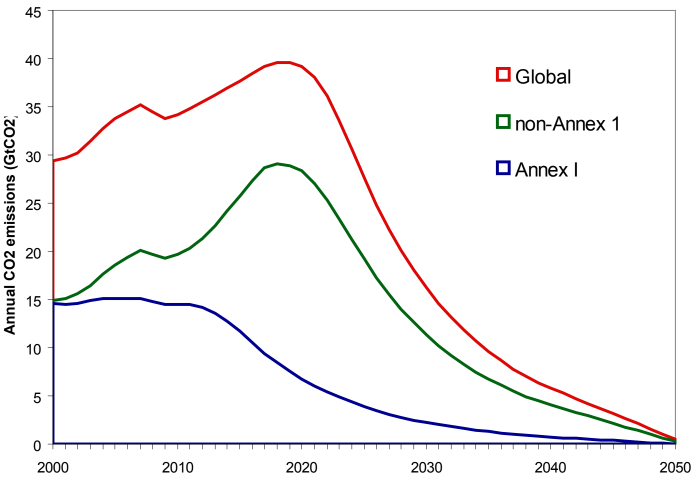

Figure 10: The climate and development dilemma.

The red line shows a global 800 $GtCO_2$ pathway, the blue line shows industrialized (Annex 1) countries' emissions declining more than 50 per cent below 1990 levels by 2020, and to zero by 2050. The green line shows, by subtraction, the severely restricted emissions path that would remain for the developing countries. (Source: GDRs)

To highlight the profundity of that divide, consider figure 10, which shows (the red emission path) the same 800 $GtCO_2$ pathway that is the upper bound of the red band in figure 2. It also shows the portion of that budget that industrialized (Annex 1) countries would consume (the blue emissions path) – assuming strenuous mitigation efforts, sufficient to cut emissions to 40 per cent below 1990 levels by 2020, reduce by 10 per cent annually in the ensuing decades, and then wholly eliminate emissions by 2050. This pathway shows the industrialized world undertaking mitigation efforts well beyond the Annex 1 reduction pledges currently on the negotiating table[1].

Simple subtraction[2] yields the emission pathway (the green line) that would be available to the developing world (non-Annex 1 countries). As for the industrialized world, this path shows emissions in the developing world peaking in 2018, dropping by 10 per cent per year in the decades following, and being eliminated altogether by 2050. But, in contrast to the industrialized world, these reductions have to happen while, at the same time, most of the developing world's citizens were struggling out of poverty and desperately seeking a meaningful improvement in their living standards.

The crux of the challenge, as seen from the developing world, is that the only proven routes out of poverty involve an expanded use of energy and, consequently, a seemingly inevitable increase in fossil fuel use and thus carbon emissions. In the absence of environmental constraints, emissions in the developing world are foreseen by all energy analyses to rise much more rapidly than in the industrialized countries, as its citizens finally gain access to energy services and build the infrastructure that has long been lacking, and, hopefully, moved toward some sort of lifestyle/development parity with the citizens of the industrialized world. This is the reason why, in the absence of an alternative route to development that has been proven to be technologically feasible and financially viable, it is extremely difficult for the developing world to imagine an equitable future in which its emissions decline so precipitously. It is, indeed, the reason why the developing world is deeply and justifiably concerned that an inequitable climate regime will force a choice between development and climate protection.

A strong case can be made that an alternative set of emissions pathways, one in which industrialized world emissions declined even more quickly than is shown here, would be more plausible, in raw technical and developmental terms, for it would allow a larger share of the very limited remaining emissions budget to be consumed in the developing world, where it would contribute to meeting more fundamental human needs.

Such an apportionment would help. But the underlying problem is that so small a portion of the global carbon budget remains; most of the cumulative budget has already been expended, predominantly in the process of development for the world's relatively wealthy minority. There is no future scenario – regardless of how the remaining diminished carbon budget is apportioned among nations - in which the developing world has sufficient space to avoid a decarbonization transition so rapid that, without a shift away from familiar modes of development, it threatens prospects for development for the world's poor. It is for this reason that the only way to secure the earnest engagement of the developing world in a global climate accord is for the developed world to exhibit a rapid transformation in its emission trajectory along the lines represented in the analysis, while ensuring that the developing countries are provided with the support necessary to enable a decarbonization transition that is rapid and comprehensive, but that also allows human development to continue unimpeded.

This has been clearly expressed by various principle-based approaches to defining equitable effort-sharing in a global climate regime (see figure 11). For example, the WBGU analysis of equal cumulative per capita emission rights (building off the approaches of China and others) concludes that industrialized countries will have entirely depleted their emission entitlements in the next decade or two, and will have zero allocations remaining (WBGU, 2009) (see figure 11). A similar conclusion is drawn by the Greenhouse Development Rights approach, which assesses national

1 For example, the UNFCCC Secretariat (2009) has estimated that reduction pledges by Annex 1 countries sum to a patently inadequate 17-24 per cent reduction below 1990 levels by 2020. A second technical analysis (AOSIS, 2009) estimates the combined Annex 1 pledge to be 10-16 per cent. Both of these estimates date from August 2009, three months before the milestone Copenhagen Conference of Parties to the UNFCCC, and will soon be superseded by more definitive numbers.

2 By consuming 200 $GtCO_2$ between now and 2050 out of a total global budget of 800 $GtCO_2$, the remaining budget is 600 $GtCO_2$ for the South.

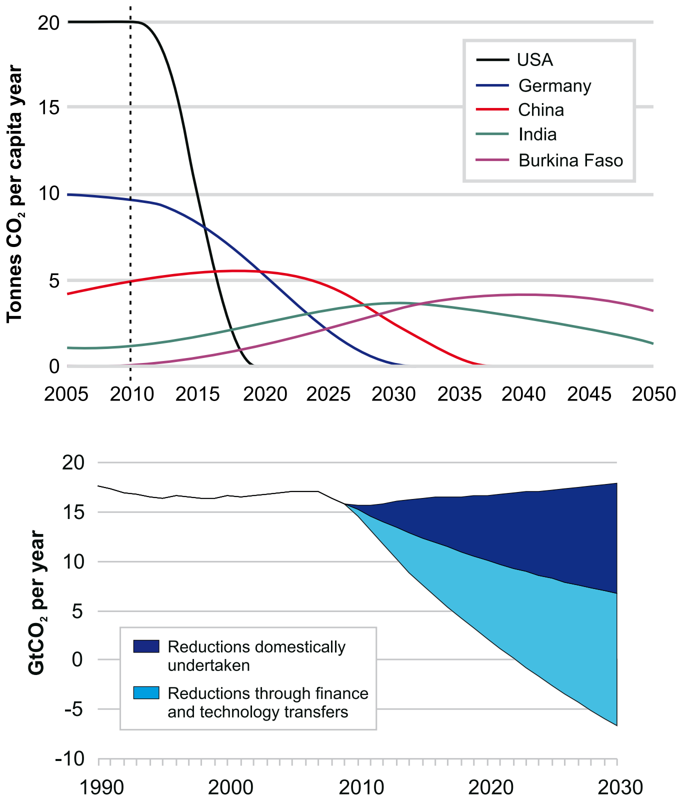

Figure 11: Emission allocations.

Emission allocation for Annex 1 countries/regions. Derived from the WBGU (upper) and GDR (lower) frameworks for principle-based effort-sharing frameworks in a climate regime.

climate obligations in terms of capacity (income) and responsibility (emissions) for all individuals who are above a "development threshold" that corresponds to a basic level of human welfare. It demonstrates that if shielding the poor from the costs of a climate transition is accepted as a basic element of an effort sharing regime, the emissions allocations to wealthier countries would rapidly decline to zero and, in the near future, become negative.

Though it is starkly expressed, this is not actually a novel conclusion, unique to this memorandum. Indeed, it underlies the long-standing UNFCCC commitment by industrialized countries to provide finance and technological support to developing countries. It does, however, underscore the point that, just as negotiations relating to national emissions targets are in desperate need of a tremendous amplification of ambition, so too are negotiations regarding the financial, technological, and institutional basis for cooperation between the industrialized world and the developing world.

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