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A Safe Landing for the Climate - the 1C Target

W. L. Hare

W. L. Hare is a scientist in Earth System Analysis at the Potsdam Institute for Climate Impact Research.

Our climate system is in trouble. It has warmed by over 0.7 degrees Celsius in the last 100 years. Warming's impacts on human and natural systems are now being observed nearly everywhere—perhaps most obviously in the recent loss of Arctic sea ice, which in 2007 and 2008 reached record low levels at the end of the northern summer. In spite of nearly 20 years of international attention, emissions of greenhouse gases (GHGs)—principally carbon dioxide (CO2) from the burning of fossil fuels—continue to grow rapidly. As a consequence, the concentration of carbon dioxide in the atmosphere has increased faster during the last 10 years than at any time since continuous measurements began in 1960.

Unabated, current increasing trends in emissions can be expected to raise Earth's temperature by a further 4–6 degrees Celsius. (7.2–10.8 degrees fahrenheit), if not more, by the end of this century.

Table 2–1. Risks and Impacts at Different Warming Levels above Preindustrial Level

System	1.5–2.0 Degrees Celsius	2.0–2.5 Degrees Celsius	> 2.5 Degrees Celsius
Ecosystems and biodiversity	• 10–15 percent of species assessed committed to extinction, and significant risks for many biodiversity hotspots • Sharply accelerating risk of extinction for land birds, with loss of 100–500 species per degree of warming • Evidence from observed amphibian and reptile declines "portend a planetary-scale mass extinction"	• Major losses of endemic plants and animals in Southern Africa, northeastern Australia	• 20–30 percent of plant and animal species assessed at increased risk of extinction • Loss of 20–80 percent of Amazon rainforest and its biodiversity
	• Widespread damages to coral reef systems due to bleaching	• Increasing damage to coral reefs	• Widespread mortality of corals
	• Observed larger-than-expected losses of Arctic sea ice indicate increasing risk of extinction for the polar bear • High extinction risk projected for the King Penguin, with a reduction in adult survival of about 30 percent per degree of warming		• High risk of extinction for the polar bear due to projected loss of Arctic sea ice
Food Production	• Decreases in cereal production for some crops in low-latitude poor regions • Risk of highly adverse and severe impacts on food production in some African countries • Substantial risks to rice production in Java and Bali	• Significant decreases in crop production of around 5 percent for wheat and maize in India and rice in China • Agriculture losses of up 20 percent of GDP in low-lying island states • Recent review indicates that increases in productivity projected in IPCC report for warming of up to 2 degrees Celsius may not occur	• Risk of decline in crop yield globally
Coastal regions	• Increased damages from storms and floods, with up to 3 million additional people at risk of coastal flooding	• Increasing damages	• Increasing damages

System	1.5–2.0 Degrees Celsius	2.0–2.5 Degrees Celsius	>2.5 Degrees Celsius
Health	• Increasing burden from malnutrition and from diarrheal, infectious, and cardiovascular diseases, with increased mortality from heat waves, floods, and droughts	• Increasing damages	• Increasing damages
Water	• Many hundreds of millions at risk of increased water stress in Africa, Asia, and Latin America	• Increasing number at risk of water stress	• 2 billion at risk of increased water stress for warming over 2–2.5 degrees Celsius
	• Glacial area in the Himalaya and Tibetan plateau regions could be reduced by 80 percent, adversely affecting billions of people • Transition to a more arid climate in southwestern North America	• Colorado River flow reduced to unprecedented levels that cannot be compensated by increased reservoir capacity or operating policies for water supplies	
Sea level rise	• Greenland ice sheet risk of irreversible meltdown for warming of 1.9–4.6 degrees Celsius • New data from the last interglacial period, 125,000 years ago, indicates that average rates of sea level rise in this period were rapid, around 1.6 meters per century	• Increasing risk of Greenland meltdown raising sea level; rapid sea level rise from this “cannot be excluded”	• Loss of ice sheet would raise sea level by some 2–7 meters over centuries to millennia
	• Accelerating ice loss from the West Antarctic ice sheet indicates risk of significant sea level rise at low levels of warming	• Increasing risk	• Increasing likelihood of partial or complete loss of the West Antarctic ice sheet, raising sea level 1.5–5 meters over several centuries to millennia
	• Commitment to minimum sea level rise of 0.3–1.2 meters over many centuries due to thermal expansion (0.2–0.6 meters per degree Celsius of global average warming)	• New projections indicate likely well above 0.5 meters of sea level rise by 2100 • Commitment to minimum sea level rise over many centuries of 0.4–1.5 meters due to thermal expansion irrespective of loss of the ice sheets and glaciers, which would only add to this risk	• New sea level rise projections of 0.5–1.4 meters above 1990 levels

It is hard to avoid the conclusion that even a warming of 2 degrees Celsius poses unacceptable risks to key natural and human systems. It is clearly not “safe” and would not prevent, with high certainty, dangerous interference with the climate system.

It would seem safest and most prudent to reduce emissions fast enough in the coming decades so that global warming can be stopped soon and as far below 2 degrees Celsius as possible. The warming would then also need to be reduced as rapidly as possible, aiming to get it below 1 degree Celsius above preindustrial level—in other words, to at most about one fifth of a degree Celsius from where it is today.

The approach taken here is to construct a pathway whose achievement in practice is plausible technically. It goes beyond the technically and economically feasible pathways published elsewhere so far. No pathway published to date brings warming below 1 degree Celsius. A few pathways could get warming below 1.5 degrees Celsius by the twenty-third century if the negative CO_2 emissions at the end of the twenty-first century in these scenarios were sustained for at least 100 years.[35]

Recent research has demonstrated that it is technically and economically feasible to reduce CO_2 emissions fast enough so that GHG concentrations can be limited to around 400 ppm CO_{2eq}, or to lower in the longer term. Under these scenarios it is likely that peak warming would occur close to, if not below, 2 degrees Celsius. And in some cases temperatures might slowly decline beyond the twenty-first century. All these scenarios require rapid fossil fuel CO_2 emission reductions, approaching zero emissions between 2050 and 2100, along with rapid reductions in deforestation.[36]

One very important finding is that in order to reach low stabilization levels of GHG concentrations, nearly all these scenarios require negative CO_2 emissions by the last quarter of the twenty-first century at the latest. Without this it is impossible to draw down atmospheric CO_2 concentrations, owing to the long lifetime of this gas. Without this key component, CO_2 concentrations would drop only slowly, and warming would likely remain well above 1.5 degrees Celsius for many centuries.[37]

The possible need to stabilize CO_2 at low concentration levels to avoid dangerous climate changes has been recognized for a long time, as has the need for negative CO_2 emissions if low CO_2 stabilization levels are to be reached. But evaluation of the implications of the technologies required to achieve this is only just beginning. In the low stabilization studies, models rely on the capture of CO_2 from biomass-fired power plants to essentially draw CO_2 out of the air so it can be stored underground in stable geological reservoirs (referred to often as biomass energy with carbon capture and storage, or BECS, technology). Plantations grow plants that take up CO_2 from the air as they grow, and if much of this is captured when the plants are burned, the process effectively pumps CO_2 out of the air. The environmental and sustainability consequences of such a strategy have yet to be fully evaluated. Air capture technology—taking CO_2 out of the air and storing it underground—has also been proposed as a feasible technology.[38]

While reducing emissions from deforestation is important, the scale of potential uptake of carbon in forests and agricultural soils is unlikely to be sufficient to draw atmospheric CO_2 concentrations down significantly.

Recent results using the LPJ (Lund-Potsdam- Jena) land biosphere model—with scenarios of population increase, deforestation, land use change, and agriculture from the Dutch IMAGE 2.2 integrated assessment model—indicate that under high environmental sustainability assumptions (taking into account the effects of increased CO_2 and climatic changes) the net uptake of carbon over the twenty-first century would not increase the additional carbon stored in terrestrial human activities enough to outweigh the need for negative emissions from the energy sector.[39]

Recent scenarios that keep warming below 2 degrees Celsius and get to concentrations of around 400 ppm CO_{2eq} or lower reduce CO_2 emissions 60–70 percent below 1990 levels and cut total GHGs around 40–60 percent by 2050. And they have negative CO_2 emissions in the range of 1 billon to 8 billion tons of carbon per year in 2100. All would require BECS.[40]

The emission pathway required to limit warming to below 2 degrees Celsius with higher confidence and at the same time reduce warming rapidly to below 1 degree Celsius (see Figure 2–1) would require a more rapid reduction in emissions by 2050 than in the most recent scenarios, which have already been at the limits of what models indicate is feasible based on present technological assessments.

Plausible additional measures to achieve this include a more rapid reduction in fossil fuel emissions.

Getting fossil CO_2 emissions down to close to zero in 2050—which would be 25 years earlier than in most low-stabilization scenarios— would require an earlier and more massive global deployment of renewable energy systems, accelerated energy efficiency measures, and a limit to the lifetime of coal power plants.

Deploying as-yet unproven carbon capture and storage (CCS) technology after the mid-2020s may also help. However, the expected large life-cycle energy and emissions costs of CCS technology indicate that it cannot be relied on to reduce fossil CO_2 emission to zero.

The faster that renewable energy systems can be scaled up and deployed, the less will be needed of CCS coal and gas power plants.[41]

In addition to action on fossil fuels, deforestation would need to be halted well before 2030, and there would need to be large scale efforts to store carbon in soils through progress toward sustainable agriculture and regrowing forests.

The reductions assumed here for emissions of methane and nitrous oxide, two powerful greenhouse gases, from agriculture and industry are not taken significantly further than can be found in the literature for low scenarios. And the emission pathway is relatively insensitive to the phase out schedules for emissions of ozone-depleting substances, hydrofluorocarbons, perfluorcarbons, and sulfur hexafluoride.[42]

The resulting pathway has Kyoto GHG reductions of around 85 percent from 1990 levels by 2050 after peaking before 2020. (See Figure 2–2.) GHG atmospheric concentrations drop below today's levels by the mid twenty-second century and toward the preindustrial level by the twenty-fourth century.

Figure 2–1. CO_2 Emissions from Fossil Fuels through 2100, IPCC SRES (High) Scenario and the Below 1 Degree Celsius Scenario

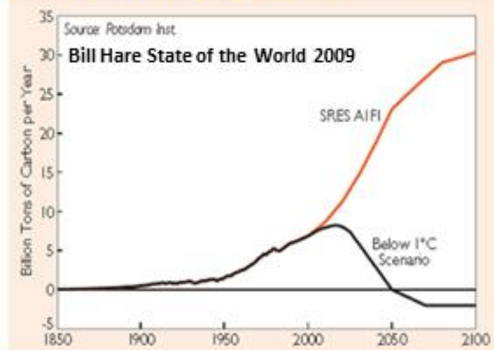
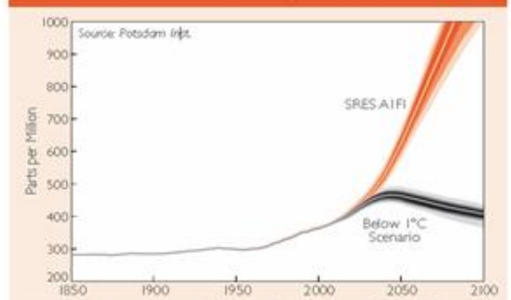
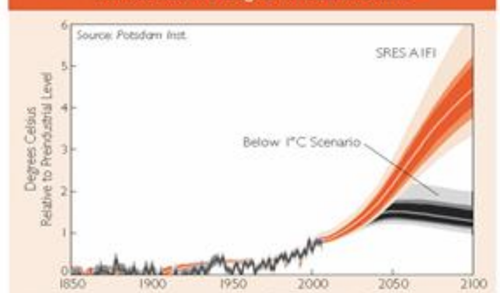


Figure 2–2. Greenhouse Gas Atmospheric Concentration through 2100, IPCC SRES (High) Scenario and the Below 1 Degree Celsius Scenario



Note: The darker parts show the higher confidence range of changes for the emission pathway shown.

Figure 2–3. Global Mean Surface Temperature through 2100, with Uncertainty, IPCC SRES (High) Scenario and the Below 1 Degree Celsius Scenario



Note: The darker parts show the higher confidence range of changes for the emission pathway shown.

After the 2050s this pathway also would require the capture from the atmosphere and permanent storage of initially around 2.5 billion tons of carbon a year (about 9 billion tons of CO_2 per year) for more than 200 years in order to draw total GHG concentrations down to below 300 ppm CO_{2eq}. Global temperatures should peak below 2 degrees Celsius around midcentury and begin a slow decline, dropping to present levels by the last half of the twenty-third century and to 1990s levels by the end of the twenty fourth century. (See Figure 2–3.) In Figures 2–2 and 2–3, there are bands of projected levels due to uncertainties in the science.

The amount of carbon that would need to be captured and stored to achieve all this would be on the same order as that emitted since the nineteenth century. As the amount of additional carbon that can be taken up and stored by the terrestrial biosphere due to human activities is limited—assumed here to be about 0.5 billion tons a year during much of the latter part of the twenty-first century and dropping to zero by 2200—the extraction of CO_2 from the atmosphere would have to be largely done using technologies similar to those just mentioned.

Just as the effects of climate change pose enormous long-term problems, a safe resolution of the problem will require a commitment to action that spans centuries. Returning to warming levels significantly below 2 degrees Celsius implies the need for large long-term extraction of CO_2 from the air and the storage of the captured carbon in secure underground reservoirs, which will need to be watched and managed over many centuries, perhaps millennia. Extracting CO_2 from the air appears to be a necessity that must be confronted within the next 50 years.

From any perspective the consequences of following an emissions pathway that keeps the temperature increase below 1 degree Celsius are quite radical and may be seen as technologically, economically, and politically close to impossible. But this needs to placed against the also quite radical risks that global warming poses if emissions are not reduced to low levels.[43]

As difficult as this emissions pathway seems, it is important to note that the low emissions scenarios reviewed by the IPCC (all consistent with limiting warming to about 2 degrees Celsius) start out much like this one. In the lowest scenarios, global emissions need to peak before 2020. After that it may not be possible for technologies to be introduced fast enough to lower emissions at the rate required to keep warming below 2 degrees Celsius.

Delay in acting entails faster rates of emissions reduction and significantly increased costs to reach the goal. And it might totally foreclose the ability to reduce GHG concentrations to low levels once societies are locked into emission-intensive energy sources and other infrastructure as well as development pathways that are carbon-intensive. Delay obviously also increases the risk of more-severe climate change impacts.[44]

An indication of the required reductions can be seen from the IPCC Fourth Assessment Report, where the reductions for different regions from a range of models are reviewed for different GHG stabilization scenarios.
The lowest scenario was for stabilization at 450 ppm CO2eq, far higher than the CO2eq stabilization levels that would provide a higher probability of keeping warming below 2 degrees Celsius.

Critical Priorities for the Next 10 Years

Halting the increase in global warming at far below 2 degrees Celsius is possible, and lowering global warming as rapidly as possible to below an increase of 1 degree Celsius appears critical if there is to be a high probability of preventing dangerous climate change. The emissions reduction actions required to achieve this are massive and appear to be at the outer edge of what is technically and economically feasible. Scenarios that can start to get within reach of these temperature goals require GHG emissions to peak before 2020 and then to drop toward 85 percent below 1990 levels by 2050, with further reductions beyond this time.

As for climate policy, the vital preparation for a safe landing—whether the final safe landing place is a 2 degrees Celsius runway or a below 1 degree Celsius runway—is to halt the rise in global emissions by 2020 and to start to put in place the policies that can lower emissions.