Not Just a Number:

Achieving A CO_2 Concentration of 350 ppm or Less To Avoid Catastrophic Climate Impacts

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Climate negotiations resume this week in Cancún against the backdrop of an unprecedented grassroots mobilization on October 10, and some of the most dramatic climate change impacts witnessed to date. Action to confront the climate crisis must be massively scaled up. This paper focuses on two critical pieces of these negotiations: (1) the necessity of reducing atmospheric concentrations of carbon dioxide (CO_2) to 350 parts per million (ppm) and limiting warming to 1.5°C; and (2) the emission reduction pathways necessary to meet these critical objectives.

Atmospheric concentrations of CO_2 must be reduced from current levels of ~389 ppm to at most 350 ppm to avoid dangerous climate change and provide a good chance of limiting future warming to 1.5°C. To date, attempts to confront the climate crisis and ensure that future generations are not consigned to irreversible catastrophe have fallen short. Even viewed in the most optimistic light, climate pledges made in Copenhagen would still lead to CO_2 concentrations of 650 ppm, or roughly a 3.2°C increase in temperature.[1]

A temperature increase of this magnitude would result in widespread catastrophic impacts that far exceed what can rationally be considered safe.

Immediate and significant emissions reductions are needed to return CO_2 to 350 ppm. A rapid reduction scenario to 350 ppm that minimizes the risk of passing tipping points calls for reductions of global CO_2 emissions of 42% below 1990 levels by 2020, net-zero emissions by 2050, and modest levels of net-negative emissions thereafter. Achieving these reductions is ambitious, necessary and obtainable. The needed investment—roughly 1 to 3 % of global Gross Domestic Product (GDP)—is a small price to ensure a livable planet for future generations. Indeed, the long-term costs of inaction will be much higher.

One thing is certain. Reductions of this scale will not be possible unless there is a huge upwelling of international cooperation. And this will only be possible within a mobilization that respects the UN principles of common but differentiated responsibilities, and equity more generally. Only then will we be able to take advantage of all available means to assist in a clean development pathway.

1. Why 350?

Sustained Atmospheric Concentrations of CO_2 At Current Levels Will Result in Severe and Irreversible Impacts

Climate change is happening much more quickly than previously predicted.[2] Based on observed impacts, future warming commitment, and paleoclimatic evidence, leading climate scientists including Dr. James Hansen have concluded that current atmospheric carbon dioxide concentrations of ~389 ppm are "already in the dangerous zone."[3]

To preserve a planet resembling the one humans have known, we must reduce atmospheric concentrations of CO_2 to less than 350 ppm.[4]

Current CO_2 concentrations of 389 ppm have already resulted in significant impacts and pose unacceptable future risks. Observed climate impacts include a 0.8°C increase in surface temperature rise, a 30% increase in ocean acidity, increased frequency of floods, droughts and other extreme weather events, tens of thousands of climate-related deaths, declines and population extirpations of numerous species, widespread coral bleaching events, a 50% decline in Arctic summer sea-ice extent and thickness since 1980, the near-global retreat of alpine glaciers and the accelerating mass loss of the Greenland and west Antarctic ice sheets.[5]

The full extent of temperature rise and associated impacts resulting from current CO_2 concentrations has yet to be experienced due to thermal inertia in the climate system and identified feedback loops. Additional warming "in the pipeline" due to this warming commitment is estimated at 0.6°C and could reach 1.6°C within this century if the cooling effect of aerosols is unmasked, and 2°C in the long-term.[6] From a paleoclimatic perspective, today's CO_2 levels were last seen 15 million to 20 million years ago when global surface temperatures were 3 to 6°C warmer than present,[7] suggesting that the upper end of warming commitment estimates are likely.

Although the observed and committed impacts are dire, we have not passed the point of no return. We still can reverse current effects and minimize future ones, provided that we can achieve and maintain an ambitious global emissions reduction trajectory. Reducing CO_2 to between 300 to 350 ppm can restore sea ice, re-establish the balance of ice sheets and glaciers to avoid runaway sea level rise and protect alpine water supplies, and avoid levels of ocean acidification that destroy coral reefs.[8]

However, Hansen and others have concluded that a 350 ppm target must be achieved within decades to prevent dangerous tipping points and “the possibility of seeding irreversible catastrophic effects.”[9] Indeed, the serious climate impacts already observed portend the likely catastrophic future scenarios if CO_2 levels are not reduced in the near future.

350 ppm Provides a Reasonable Chance of Limiting Warming to 1.5°C Above Pre-Industrial Levels

Unlike higher targets, pathways to 350 ppm provide a reasonable chance of limiting temperature rise to 1.5°C above pre-industrial levels. Limiting warming to 1.5°C is called for by the Alliance of Small Island States, the Least Developed Countries, and Climate Action Network as the maximum level beyond which climate change must be considered dangerous. While limiting warming to 2°C may have seemed acceptable when first proposed by the European Union in 1996, the best available science now indicates that much smaller increases in global mean temperature will result in substantial environmental and socio-economic consequences.[10]

A 2°C temperature rise is simply no longer an acceptable target for climate policy.

Pathways that reduce CO_2 to 350 ppm in the near-term (i.e. by 2100) provide the best chance of limiting warming to 1.5°C compared to prolonged pathways. The 350-ppm-by-2100 pathway outlined by Hansen and colleagues that relies on net-negative emissions after 2050 would lead to a peak temperature rise of 1.6°C, assuming a climate sensitivity of 6°C.[11]

Similarly, an analysis of low emissions pathways found that only those that approach 350 ppm by 2100 have a reasonable probability (40–60%) of limiting warming to 1.5°C.[12] In comparison, higher stabilization targets of 400 and 450 ppm CO_2 provide only a 22% and 9% chance, respectively, of limiting warming to 1.5°C.[13]

2. Reaching 350 ppm

All of the proposals for reaching 350 ppm CO_2 call for global CO_2 emissions to peak in the near future and then rapidly decline. For any stabilization target, the later the emissions peak, the steeper the annual reductions that must follow.[14]

In other words, the longer emissions reductions are delayed, the more difficult it will be to reach a particular target. Achieving 350 ppm is most feasible if emissions peak in 2011. While it could happen slightly later, the difference between a 2011 and 2015 peak equates to a necessary doubling of annual emission reductions thereafter.[15]

If the emissions peak was further delayed until 2020, the entire emissions budget for a 350 ppm target would be exhausted along with any chance of reaching this goal.[16]

The various pathways for reaching 350 ppm involve different trade-offs between how much emissions must be reduced in the near-term versus how much carbon must be sequestered from the atmosphere in the second half of the century. The pathways requiring the most stringent emissions reductions by 2020 do not rely on sequestering carbon down the road to create net-negative emissions (i.e. the removal of more carbon from the atmosphere than is produced). Pathways permitting less stringent emissions reductions by 2020 can do so only by assuming large amounts of net-negative emissions after 2050 through reliance on extensive use of largely undeveloped and unproven technologies for carbon sequestration (i.e. large-scale biomass energy combined with carbon capture and storage). Three pathways that assume differing levels of stringency in near-term emissions reductions and net-negative emissions requirements are illustrated here.

Pathway 1: Stringent near-term reductions, modest net-negative emissions after 2050

Hansen and colleagues outlined a 350-ppm-by-2100 pathway that could be achieved by reducing global emissions to 42% below 1990 levels by 2020 and net-zero emissions by 2050.[17] Emissions peak in 2011 with an annual rate of subsequent decline soon reaching 10% per year.[18] Over the course of the second half of the century, this pathway relies on achieving modest net-negative emissions totalling about 150 $GtCO_2$ for the 2050-2100 period. Net-negative emissions are achieved via very low fossil fuel emissions and sequestration through existing removal methods such as reforestation.[19]

Pathway 2: Less stringent near-term reductions, high net-negative emissions after 2050

Pathways with assumptions of high future net-negative emissions require less stringent reductions in the near-term. One such scenario requires that global emissions peak in 2012, reach 40 gigatonnes (40 Gt CO_2eq) by 2020 (equivalent to 14% above 1990 levels in 2020), and fall to 84% below 1990 levels by 2050.[20] Emissions from the energy/industrial sector would drop to zero shortly thereafter and reach a value of -3.5 GtC/yr (-12.8 GtCO_2/yr) by the 2070s and stay constant thereafter.[21] This high level of negative emissions would only be possible though extensive use of biomass energy combined with carbon capture and storage (BECCS).[22] Making available the significant amount of land needed to supply this scale of biomass energy may not be feasible and has serious implications for biodiversity and food security.[23] This pathway also envisions halting of deforestation by 2020, creating a large recovery sink that reaches -0.5 GtC/yr (-1.8 GtCO_2/yr) by the 2070s.

Reaching the 40 Gt CO_2eq objective by 2020 could be achieved through a combination of measures by 2020 that could include reducing developed country emissions to 45% below 1990, reducing developing country emissions to 30% below business as usual by 2020, halving projected emissions from international aviation and shipping, halting deforestation, removing crediting for forest and other land-use management activities and closing loopholes in Kyoto Protocol rules.[24] Adoption of all of these measures would reduce 2020 emissions to below 40 gigatonnes and temper the need for the extremely high levels of net-negative required for the second half of the century under this scenario.

Pathway 3: Very stringent near-term reductions, no net-negative emissions

A pathway that reaches 350 ppm by 2100 without negative emissions, assuming a 6ºC climate sensitivity, requires global emissions reductions of 97% below 1990 levels by 2020 and 100% below 1990 levels by 2030; temperature peaks at 1.9°C and falls to 1.5°C by 2220.[25] When the time horizon for reaching 350 ppm is lengthened to 2200, global reductions of 47% below

1990 by 2020, 79% below 1990 by 2030, and 97% below 1990 by 2050 are required.[26] However, extending the time horizon to reach 350 ppm increases peak temperature and with it the risk of experiencing severe and irreversible climate impacts.[27] Were returning to 350 ppm delayed until 2200, temperature would peak at 2.1°C and fall to 1.5°C by 2300.[28]

Some proposed scenarios do not articulate the deeper reductions expected from developed countries under the UNFCCC's "common but differentiated responsibilities and respective capabilities." Because the emission reduction pathways for 350 ppm are extremely ambitious, even with additional action by developed countries, there is still limited carbon space for developing countries and growth along a business-as-usual trajectory. One way to protect development rights in a severely carbon constrained world is through a Greenhouse Development Rights (GDRs) framework, which examines the capacity and responsibility of individual countries to establish differentiated emissions reductions obligations and international finance obligations.[29]

A Cumulative Emissions Budget for Reaching 350 ppm

Another approach for defining what quantity of emissions is allowable to achieve desired temperature targets and avoid dangerous climate impacts emphasizes cumulative emissions since specific quantities of cumulative emissions are thought to linearly correspond to likely ranges of temperature rise.[30] The cumulative emissions approach is complementary to the 350 ppm target-setting approach because it informs the allowable emissions budget and reductions needed to reach a CO_2 concentration of 350 ppm or less. For example, the Hansen et al. 350-ppm-by-2100 pathway requires that cumulative emissions be confined to 750 to 824 $GtCO_2$ during the first half of the century (2000-2050), and that cumulative emissions decline after 2050 based on the implementation of carbon removal initiatives.[31] Achieving this 750 to 824 $GtCO_2$ budget would require stringent, rapid global emissions reductions (i.e. 42% below 1990 levels by 2020 and net-zero emissions by 2050 as described above), but would limit temperature rise to 1.6 to 1.7ºC based on more conservative estimates of temperature change in response to cumulative emissions.[32]

3. Achieving 350 ppm: Feasible Costs and Technologies

Even accounting for the more stringent emission reduction pathways, 350 ppm remains an attainable goal. Cost estimates for reaching this target are estimated at one to three percent of world GDP per year.[33] Achieving 350 ppm will require a moratorium on coal-fired power plants that do not capture and store CO_2 in the near future and the phase out of existing coal-fired power plants in the next 20 years.[34]

Existing technologies already exist to phase-out coal in the United States by 2030, a vital step in achieving 350 ppm.[35] Reforestation and the end of deforestation are also key components in achieving 350 ppm CO_2 by the end of the century.

4. Conclusion

The devastating effects of climate change are already evident throughout the world. The science is now clear: in order to avoid further catastrophic effects, carbon dioxide levels in the Earth's atmosphere must be reduced to 350 ppm or less. There are viable options now to begin achieving this ambitious goal but enacting them will require bold, willful steps from world leaders. Delay only increases the danger and puts future generations at increased risk. Meaningful actions—those that target 350 and are aimed at avoiding irreversible, uncontrollable catastrophic impacts—will ensure a livable planet for generations to come.

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Endnotes

1. Niklas Höhne et al., Climate Analytics & Ecofys, Copenhagen Climate Deal—How to Close the Gap? Briefing Paper 1 (Dec. 15, 2009).

2. Hans-Martin Füssel, *An Updated Assessment of the Risks from Climate Change Based on Research Published Since the IPCC Fourth Assessment Report*, 97 Climatic Change 469, 471 (2009).

3. James Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 Open Atmospheric Sci. J. 217, 218 (2008). Other scientists have similarly cautioned that there is a "high probability that the [Dangerous Anthropogenic Interference] threshold is already in our rearview mirror" based on our current warming commitment of 1.6ºC. V. Ramanathan & Y. Feng, *On Avoiding Dangerous Anthropogenic Interference with the Climate System*, 105 Proc. of the Nat'l Acad. Sci. 14245, 14249 (2008). Coral scientists have determined that reducing CO_2 below 350 ppm is needed to prevent the irreversible decline of reefs worldwide and protect the livelihoods of the nearly half billion people world wide that depend on them. J.E.N. Veron, *The Coral Reef Crisis: The Critical Importance of <350 ppm CO_2*, 58 Marine Pollution Bulletin 1428 (2009).

4. This paper focuses specifically on CO_2 reductions because long term climate change is largely controlled by CO_2 due to its persistence in the atmosphere. Rapid reduction of short-lived global warming pollutants, including black carbon and methane, is critical to limiting peak-warming. National Research Council, Stabilization Targets for Atmospheric Greenhouse Gas Concentrations 59-60 (2010).

5. Rachel Warren, *Impacts of Global Climate Change at Different Annual Mean Global Temperature Increases, in* Avoiding Dangerous Climate Change 93 (2006); C. Parmesan, *Ecological and Evolutionary Responses to Recent Climate Change*, 37 Annual Review of Ecology Evolution & Systematics 637 (2006); J. Stroeve et al, *Arctic Sea Ice Extent Plummets in 2007,* 89 EOS Transactions 13 (2008); R. Kwok & D. A. Rothrock, *Decline in Arctic sea Ice Thickness from Submarine and ICESat Records*: 1958-2008, 36 Geophysical Res. Letters L15501 (2009); Hansen, *supra* note 3.

6. G.A. Meehl et al., *Global Warming Projections, in* Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 763 (2007); Ramanathan and Feng, *supra* note, at 14247; Hansen, *supra* note 3, at 225.

7. A. Tripati et al, *Coupling of CO_2 and Ice Sheet Stability Over Major Climate Transitions of the Last 20 Million Years,* 326 Sci. 1394, 1396 (2009).

8. Hansen, *supra* note 3; Veron, *supra* note 3.

9. Hansen, *supra* note 3, at 217.

10. As reflected in an update of the IPCC's Reasons for Concern, a 2°C temperature increase from pre-industrial levels (or 1.4°C increase from 1990 levels) is well past the point where severe and irreversible impacts will occur). J.B. Smith et al., *Assessing Dangerous Climate Change Though an Update of the Intergovernmental Panel on Climate Change (IPCC) "Reasons for Concern,"* 106 Proc. of the Nat'l Acad. Sci. 4133 (Feb. 26, 2009). *See also* Warren, *supra* note 5, at

96, 109 (impacts from 2°C temperature rise including complete loss of Arctic summer sea ice and corresponding ecosystem disruption and increase in water stress for approximately one billion to three billion people).

11. Frank Ackerman et al., Economics for Equity & the Env't, The Economics of 350: The Benefits and Costs of Climate Stabilization 41 (2009) (change in temperature translated from 1990 levels to change from pre-industrial levels by adding 0.6°C).

12. Of 9 low emissions pathways, three (AZAR 350 FC, NC, MERGE 2.6) that resulted in CO_2-eq concentrations of 405 and 410 (equivalent to ~350 ppm CO_2) had the lowest probabilities of exceeding 1.5ºC. Bill Hare et al., *Low Mitigation Scenarios Since the AR4—Global Emission Pathways and Climate Consequences*, UNFCCC AWG LCA Bonn, at 14, 21 (Mar. 30 2009). http://unfccc.int/files/kyoto_protocol/application/pdf/low_mitigation_scenarios_since_the_ar4.pdf

13. Malte Meinshausen, *What Does a 2°C Target Mean for Greenhouse Gas Concentrations?, in* Avoiding Dangerous Climate Change 266, 272 (2006) (mean probabilities for 400 and 450 ppm CO_2 which are equivalent to 450 ppm and 520 ppm CO_2 eq were estimated and averaged from Figure 28.6(a)).

14. Malte Meinshausen & Bill Hare, *Q&A: Twenty-Six Questions and Answers in Regard to the Study "Greenhouse Gas Emission Targets for Limiting Global Warming to 2°C" by Meinshausen et al. 2009, in 30th April issue of Nature,* at 6 (Apr. 30, 2009).

15. P. Baer et al., 350 ppm Emergency Pathway, A Greenhouse Development Rights Brief 4 (2009), available at http://gdrights.org/wp-content/uploads/2009/11/a-350-ppm-emergency-pathway-v2.pdf. The authors' analysis is based off of Hansen et al., *supra* note 3. A 2011 emissions peak requires emissions to soon reach an annual decline of 10% and remain at this rate for several decades.

16. *Id.*

17. *Id.*

18. *Id.*

19. James Hansen et al., *Supplemental Material, Target Atmospheric CO_2: Where Should Humanity Aim?* 2 Open Atmospheric Sci. J. i, xvi (2008); *Baer* et al., *supra* note 15, at 11. "Natural" sequestration, such as ending deforestation, reforestation and aforestation, can be utilized by improving agricultural and forestry practices. Soil draw down could be achieved by biochar sequestration, the process in which plant material is converted into charcoal and then buried. Assuming the uptake from reforestation increases linearly to peak in 2030 (at -5.9 Gt CO_2/year) and from 2010-2030 waste-derived biochar is phased in (-0.6 Gt CO_2/year), these two sequestration practices more than balance out low fossil fuel emissions (175 Gt CO_2 2050 to 2100).

20. Höhne, *supra* note 1. The target of 81% below 1990 by 2050 is not stated explicitly in Hohne et al. and was derived from their 350 ppm/1.5°C pathway shown in Figure 1 at 3 (i.e. 7 $GtCO_2$eq at 2050 is ~81% below the 1990 level of 36 $GtCO_2$eq). Although Hohne et al. do not provide details about their 350 ppm/1.5°C pathway, similar pathways outlined by Ranger et al. appear to use the IPCC AR4 range of climate sensitivities (based on a medium climate sensitivity of 3°C) and result in peak atmospheric concentrations between 470 and 480 ppm CO_2eq by 2025-2030 before falling back to below 375 ppm by 2200. Nicola Ranger et al, *Policy Brief: Mitigating Climate Change Threats*

Through Reductions in Greenhouse Gas Emissions: Is It Possible to Limit Global Warming to No More Than 1.5°C? at 11 (Aug. 2010), *available at* http://searca.webfactional.com/publications/PB-Mitigating-climate-change.pdf/view.

21. Email from Dr. Michiel Shaeffer, Climate Analytics, dated Sept. 22, 2010 (on file with author).

22. *Id*.

23. C. Azar et al., *The Feasibility of Low CO_2 Concentration Targets and the Role of Bio-Energy with Carbon Capture and Storage* (BECCS), 100 Climatic Change 195, 200 (2010).

24. Höhne, *supra* note 1, at 5-6.

25. Ackerman et al., *supra* note 11, Table C1at 44; Fig. C3 at 45 (change in temperature translated from 1990 levels to change from pre-industrial levels by adding 0.6°C).

26. *Id*. Table C1at 44.

27. There are increased potential dangers of irreversible climate change and catastrophic events associated with sustained overshoots, Hansen et al., *supra* note 4, at 217.

28. Ackerman et al., *supra* note 11, Table C1at 44, Fig. C3 at 45.

29. Paul Baer et al., *The Greenhouse Development Rights Framework, Second Edition*, (Nov. 2008), http://gdrights.org/wp-content/uploads/2009/01/thegdrsframework.pdf. Responsibility is calculated as individual cumulative emissions (excluding from those below a specified development threshold) since 1990. Capacity is calculated as individual total income (excluding from those below the development threshold).

30. Cumulative emissions of 3670 $GtCO_2$ (1000 GtC) are estimated to correspond to a "very likely" range of 1 to 2.5ºC temperature rise. NRC, *supra* note 4, at 81.

31. Baer et al., *supra* note 15, at 2, 4; Meinshausen et al., *supra* note 14, at 15, 2000-2049 budget. Ackerman et al., *supra* note 11, at 17, calculate a slightly larger budget for 2000 to 2050 of 824 Gt CO_2 for the Hansen et al. *supra* note 3 pathway.

32. Given that 1615 $GtCO_2$ have already been emitted through 2000 (1945 $GtCO_2$ emitted through 2009, NRC, *supra* note 5, at 82, less the 330 $GtCO_2$ emitted from 2000-2009, Baer et al., *supra* note 18, at 2), the Hansen *et al*. budget of 750 to 831 $GtCO_2$ through 2050 (2365 to 2446 $GtCO_2$ total budget through 2050) would limit temperature rise to 1.6ºC and 1.7ºC based on the more conservative estimate that 3670 $GtCO_2$ leads to a 2.5ºC rise, NRC, *supra* note 4, at 81.

33. Ackerman, *supra* note 11, at 35.

34. Hansen et al., *Supplemental Material*, *supra* note 19, at xv.

35. Pushker Knarecha et al., *Options for Near-Term Phaseout of CO_2 Emissions From Coal Use in the United States,* 44 Environ. Sci. Technol. 4050 (2010).