ATTACHMENT D. ECOLOGICAL INTEGRITY

D.1. CLIMATE CHANGE

Paragraphs 1-16 are the core summary outline. Paragraphs 17-20 cover related topics of interest.

1. In the absence of mitigation policies **anthropogenic climate change (ACC) is likely to reach ~ 2.0°C by 2050** and just below 4.0°C by turn of the century. World Bank (2012), New (2011), Parry et al. (2009) and Stern (2007) have inventoried the sorts of impacts and damages that might be expected in the run-up to a 4°C warming. These include 1–3 billion people under severe water stress; sea level rise of 0.5 to 1 meter, putting 2-15 million people at strong risk of coastal flooding; pronounced stress on cereal crops; increased malnutrition, diarrhea and infectious disease, notably in tropical countries; up to 80 million malarial exposures annually in Africa; greater heat and flood mortality; major amphibian extinctions; widespread coral reef mortality; 30% loss of coastal wetlands; loss of 50% of the Arctic tundra; substantial dieback of Amazon Rainforest; and greater risk of abrupt, large-scale, irreversible impacts of the sort noted in DN 74.

2. The December 2015 **United Nations Framework Convention on Climate Change** Conference of Parties (UNFCCC COP21) in Paris was an important step forward in the global campaign to address ACC. All countries agreed on the need to keep ACC "well below 2°C", and pledged to constrain growth of their GHG emissions. Most developed countries pledged absolute reductions of GHG emissions as well. However, the final Paris Agreement acknowledged that these country pledges ("intended nationally determined contributions", or INDCs), taken in the aggregate, were not sufficient to prevent ACC from exceeding the agreed-upon limit of 2°C. They acknowledged as well that deeper emissions reductions would thus need to be negotiated and agreed upon, ideally within the next 3-5 years.

3. How much stronger would the COP21 INDCs need to be to ensure peak ACC below 2°C? **Box D.1-1** below shows relevant data. Panel A shows "business-as-usual" ACC levels as projected by the DICE-2013R and RICE-2010 models, and by the IPCC (2013). Panel B shows the level of ACC expected in 2100 if current INDCs are all fully realized, as independently evaluated by academic, governmental and advocacy bodies. From Panel A let's posit that BAU ACC in 2100 is 3.7°C. From Panel B let's take the median value of 3.0°C as the level of ACC attained and stabilized by 2100 if all INDC pledges are fully realized. We see that 1) we will have successfully reduced ACC by 19% from its currently projected BAU value; and 2) we will still need to reduce ACC by an additional 33% to realize a 2°C warming peak.

4. Will such **further reductions** come easily or with difficulty? Informed parties differ. Those who paint an optimistic picture cite the compounding impacts of innovations in energy efficiency and in renewable energy systems; the rapidly growing global public awareness of the dangers of climate change; the growing and deepening capacity of the climate movement to mobilize on multiple fronts; and the assumption that anticipated growing climate-related harms will reinforce consumer, investor and governmental support for more rapid GHG reductions. Others paint a more sobering picture, noting that the Paris Agreement contains no sanction or enforcement provisions; that many of the current INDCs are sketchy and unconvincing; that many developing countries have made their pledges conditional upon funding and other assistance from developed countries; and that many INDCs rely upon the development and widespread adoption of technologies that today are barely beyond the conceptual stage. [cites pending]

- - - - - - - - - - - - - - - - - -

BOX D.1-1. WARMING AND THE IMPACT OF PLEDGES TO PREVENT WARMING [All values in °C]

Panel A. "Business-as-usual" Warming Projections, 2005-2200

	DICE	RICE	IPCC RCP 8.5	[5%-95% confidence range]
2050	1.9	2.0	2.0	[1.4-2.6]
2100	3.8	3.5	3.7	[2.6-4.8]
2150	5.4	4.7	5.5	[2.7-7.0]
2200	6.4	5.2	6.5	[3.5-8.4]

Panel B. Warming to be expected in 2100 if all COP21 pledges are successfully carried out.

Climate Action Tracker	- 2.7	[2.2 - 3.4]
International Energy Agency	- 2.7	
MILES Project Consortium	- 2.9	
European Commission Joint Research Centre	- 3.0	
Climate Interactive	- 3.5	[2.0 - 4.6]
United Nations Environmental Program	- 3.5	
Massachusetts Institute of Technology	- 3.7	

Most values shown were assigned a 50% confidence level, meaning that there is a 50-50 chance that actual warming in 2100 will be above or below the given value.

Sources: DICE-2013R and RICE-2010 figures are from models made available at http://aida.wss.yale.edu/~nordhaus/homepage. IPCC is from IPCC (2014). Values shown in Panel B are from Levin and Fransen (2015.)

- - - - - - - - - - - - - - - - - -

5. A comprehensive post-Paris assessment concluded that while achieving a 2°C peak ACC is still theoretically possible, numerous technical, economic, social and political factors would need to fall into place at a pace and scale unprecedented in human affairs; see Rogelj et al (2016). Some analysts explicitly argue that it is no longer realistic to expect that even ambitious conventional mitigation strategies can prevent ACC from exceeding 2°C. See Roberts (2016b, 2015a) Geden (2015), Smil (2015, 2014, 2011), Victor and Kennel (2014), New et al. (2011), Nichols et al. (2011), Plummer (2013), Jordon et al. (2013), Mora et al. (2013), PricewaterhouseCoopers (2012), Anderson and Bows (2011), and Betts (2011). For the case that the 2°C limit is still conventionally attainable see United Nations Sustainable Development Solutions Network (2014).

6. In the face of these sobering assessments some scientists propose that we undertake an initiative of **climate engineering,** the deliberate, large-scale modification of terrestrial, oceanic and atmospheric systems to influence the Earth's climate. They argue that climate engineering holds the possibility of suppressing ACC quickly and at comparatively low cost. Proposals for climate engineering are mostly of two sorts. *Solar geoengineering* seeks to block sunlight from warming the atmosphere. Methods include stratospheric sulfate aerosols inserted via rockets, tropospheric marine cloud brightening via massive sea-water spray cannons, and orbital mirrors or dust particles that deflect incoming radiation. *Greenhouse gas removal* seeks to remove existing GHGs directly from the atmosphere and/or keep newly produced GHGs from entering the atmosphere. Methods include encouraging large oceanic phytoplankton blooms via iron fertilization, bio-energy plantations combined with carbon-capture-and-storage (BECCS), biota genetically modified to absorb large quantities of GHGs, and mechanical/chemical GHG scrubbing. [cites pending]

7. Until recently proposals for climate engineering were actively discouraged by most climate policy activists and scientists, for fear that even discussion of such options could create a moral hazard and undermine resolve on the part of the public and political leaders in support of GHG mitigation. Some climate advocates strongly reject solar radiation management but see certain forms of GHG removal as potentially valuable and benign. The most general objections to solar radiation management are that suppression of ACC while GHG concentrations continue to build leaves us at risk of abrupt and truly catastrophic climate change if anything goes wrong with the suppression process, and that oceanic acidification would continue apace. Some proponents reply that they'd only recommend climate engineering as last-ditch emergency interventions to buy time while stronger, deeper and more durable mitigation measures are agreed upon, implemented and take effect. In January 2017 top U.S. government scientists for the first time recommended that research bearing on the practicability of certain forms of climate engineering be undertaken. See Kintisch (2017), Walters (2017). The debate is unresolved.

8. What happens if a) it becomes clear that even ambitious conventional mitigation strategies will be insufficient to keep us below 2.0°C ACC and b) we judge climate engineering to be too risky or otherwise unacceptable? With that scenario in mind, climate activists have begun calling for an **emergency global climate mobilization** analogous in scope and scale to the 1939-1945 mobilization of the Allies during World War II. Proposals call for establishment of national and international commands with authority for "restructuring the existing socio-economic system." Fossil fuel power plants would be closed and new ones disallowed; industrial production would be redirected from proscribed output (internal combustion engines, jetliners, cruise ships, luxuries) to essential new infrastructure (solar and wind power systems, mass transit, gigaton-scale BECSS facilities); a 2-year universal youth service would be established for retrofitting, recycling and reforestation campaigns; domestic, commercial and industrial power would be rationed to encourage efficiency innovation; legal and price controls would restrict production and consumption of "climate unfriendly red meat" and other GHG-intensive output; a strong global carbon or energy tax would be established and the proceeds equitably redistributed; and more. A mobilization of this sort might involve a very intense 10-20 year "combat" phase, followed by pacification and civil administration phases over the following 40-80 years. See McKibben (2016), Randers and Gilding (2010), Delina and Diesendorf (2013a, 2013b), and Bartels (2001). The 2016 U.S. Democratic Party Platform contains language evoking the spirit and urgency of wartime mobilization to fight climate change (p. 45, *Global Climate Leadership*). For detailed proposals regarding very rapid production and deployment of 100% renewable energy systems at U.S. and global scale see Jacobson et al. (2016, 2015, 2011a, 2011b). For critique of Jacobson et al. see Trainer (2013). Some commentators find the wartime mobilization proposals overwrought and unrealistic, but acknowledge the need for both a heightened sense of collective urgency and, eventually, some sort of centralized, authoritative capacity, if humanity is to keep to the 2°C Paris Agreement target. See Roberts (2016a, 2013) and Rao (2015).

9. If it becomes widely accepted over the next few years that even ambitious conventional mitigation efforts are unlikely to keep ACC from exceeding 2°C, and if we judge climate engineering to be too risky or otherwise unacceptable, and if "wartime mobilization" is socially, politically and logistically a non-starter, what happens then? One possibility is that such conditions might motivate the human community to entertain, and then to embark upon, an intentional, secular reduction in per capita consumption. In ATTACHMENT D.2 (following) I show preliminary results of exercises using Nordhaus' DICE and RICE models to explore this option. The results suggest that this option is unlikely to be of great help. A change in lifeways significant enough to reduce consumption significantly enough to significantly impact climate change would likely require a minimum of two or three generations over which to evolve, and if we include equity constraints such that developing and developed countries converge to near equivalent per capital consumption levels, the period required for such a transition stretches to ~ 150-200 years. But if we are to avoid a 2°C warming we'll need to have reduced global GHG emissions to near zero within the next 50-70 years. Lifeways transformations involving significant reductions in per capita consumption may be an important part of a just, sustainable and technologically responsible human future – indeed, this working paper seeks to makes that case – but it's unrealistic to expect them to be a major component of the immediate program needed to avoid a 2°C warming.

10. It's worth noting here that while **peak 3°C warming by 2100** (i.e., the warming expected under current INDC pledges) is likely to cause great ecological harm and great economic loss, it's not obvious at this time that it would necessarily precipitate *global catastrophic* loss, although the risk would certainly be greater. [See DNs 72-76, and Attachment D.4, for definition and discussion of global catastrophic risk and loss.] Noting this is not meant to suggest that constraining peak ACC to levels significantly below 3°C wouldn't be highly preferable, nor is it meant to suggest complacency; quite the opposite. The technological, social and political challenges of reaching zero global net GHG emissions are so great and so unprecedented that we may very well need every one of the 80+ years between now and 2100 to successfully complete a full, safe, equitable and lasting transition to a GHG-Zero world.

11. Beyond the centerpiece 2°C ACC limit, the Paris Agreement provided that the Parties would "… pursue efforts to **limit the temperature increase to 1.5°C** above pre-industrial levels…". This aspirational ceiling was added after an extended campaign by the Alliance of Small Island States (AOSIS), the Least Developed Country Group (LDCs) and allies. It is widely acknowledged that although technically still achievable, a 1.5°C limit will be next to impossible to achieve in practice. However, inclusion of this goal in the Paris Agreement gives its sponsors a strong moral bargaining chip. They are, after all, among the most vulnerable to climate change and among the least responsible *for* climate change. When the developed countries confess that they will be unable to reduce emissions rapidly enough to avoid exceeding 1.5°C, what happens then? Very likely, negotiations on the nature and level of recompense.

12. The extent to which a proposed climate regime is considered to be fair or unfair is enormously important. **Fairness, justice and equity** (hereafter "equity," unless otherwise) are necessary if the degree of consensus and commitment needed for such a regime to succeed is to be realized. The failure of the 2009 UN climate negotiations in Copenhagen had little to do with disagreements about the need to prevent ACC from rising to dangerous levels, and almost everything to do with the fact that the equity implications of proposed regimes had not been given the necessary attention before or during the negotiations. The 2015 Paris negotiations gave greater attention to equity concerns before and throughout the proceedings, and in the final text of the Paris Agreement itself. However, as noted, the Paris Agreement is only a preliminary and partial step toward creation of the desired climate regime, and it remains the case that the equity questions that will need to be resolved have not as yet been grappled with.

13. The eventual climate accord will need to address a multitude of equity concerns, as most of its elements will independently impact some parties differently that they will other parties, either positively or negatively. The trick will be to cobble together a package that gets the job done and that all parties consider fair. For a concise but thorough discussion of the many dimensions of climate equity see Dryzek et al (2013 Ch 5). For a thorough analysis of the equity dimensions of the Paris Agreement and of the necessary provisions of any eventual equity framework, see Climate Equity Reference Project (2015). For a proposal for near-term action on the part of civil society and others to ensure that the eventual accord includes such provisions, see Athanasiou et al. (2016).

14. Three major provisions of any eventual climate accord will be those addressing *mitigation*, *adaptation,* and *loss and damage.* ***Mitigation*** involves actions that countries take to reduce their GHG emissions (example: close a coal-fired power plant and build a wind farm). ***Adaptations*** are actions taken to minimize damages from whatever ACC takes place despite mitigation efforts (example: relocate a threatened coastal village inland). ***Loss and damage*** refers to losses and damages caused by ACC despite both mitigation and adaptation efforts (example: Medical and relief efforts for a region experiencing heat and drought of historically unprecedented severity and duration). All three can be extraordinarily costly, these costs will vary greatly among countries and over time, and in many instances those who suffer the greatest consequences of ACC will be among those least able to take preventative or adaptive action.

15. What do we do with this? Three important principles widely applied to questions involving equity and public policy were incorporated into the 1992 UN Climate Convention. These principles are grounded in understandings of *responsibility*, *capacity* and *need.* ***Responsibility*** refers to the principle that those who play greater roles in creating a given problem in the first place should play greater roles in addressing it. ***Capacity*** refers to the principle that those in a better position to help address a problem should play greater roles in addressing it (the widely affirmed principle of *progressivity* in tax policies is an example of this). And ***Need*** refers to the principle that there exist basic human rights or conditions that all are entitled to and that humanity as a whole has an interest and an obligation in helping ensure.

16. The Climate Equity Reference Project (2015) applies the three principles noted in Para 15 to the three substantive treaty provisions noted in Para 14 to construct a **Fair Shares Framework** that could serve as the core of the equity structure of an eventual climate treaty and a climate regime. A key element of this framework involves the calculation of a **Responsibility and Capacity Index (RCI).** This index can be used to determine each country's fair share of the carbon budget available at any point in time consistent with a desired emissions trajectory, as well as the share of total mitigation, adaptation and (possibly) loss and damage costs for which that country is responsible. The RCI algorithm includes features that allow varying degrees of progressivity to be built into the fair share allocations. Long-time developed countries will in general have little remaining normative leeway for continued carbon emissions, and in many cases may already be operating beyond their fair share carbon allowance. Conversely, many developing countries will show carbon budget *surpluses.* They have normative leeway for continued GHG emissions growth, and in addition are currently emitting *less* GHGs than their fair shares allow. Under the CERP framework these imbalances offer a set of mutually beneficial trade-offs: developed countries can agree to cover a portion of the costs of mitigation, adaptation and (possibly) loss and damage incurred by a developing country, in exchange for a negotiated quantity of emissions allowances from the developing country's surplus. Detailed description of the CERP Fair Shares Framework and the Responsibility and Capacity Index, along with worked-out examples for sample countries, can be found in Climate Equity Reference Project (2015).

Related climate change topics of interest

17. It's been proposed that metrics other than peak atmospheric warming be adopted as our climate policy goal. This wouldn't necessarily mean dropping 2°C as our red line; it would mean using a different indicator and different units. One alternative measure is the concentration of atmospheric CO2, measured in ppm. The Paris Agreement ACC ceiling of 2°C is consistent with ~ 450 ppm CO2. The NGO 350.org chose as their advocacy goal, and as their name, a value of CO2 concentration that would generate ACC of ~ 1°C. Roberts (2015b) suggests that a goal of "Carbon Zero," i.e., zero net global carbon *emissions*, measured in billions of tons of carbon (GTC) would lend itself to public understanding and advocacy. To make "Carbon Zero" operational we'd have to choose a target date for its realization as well, e.g., 2050, 2100 or some other. The DICE-2013R model suggests that if we get to Carbon Zero by 2060, ACC will peak at ~2°C by 2100 and then slowly decline to 1.8°C by 2220, and if we reach Carbon Zero by 2120, ACC will peak at 3.1°C in that year and then slowly decline to 2.8°C by 2220. [NB: These decline rates presume no use of scrubbing or CCS. If such technologies are developed and employed widely, the decline could be faster and deeper.]

18. Climate advocates and journalists commonly report that the 2°C ACC policy threshold is "based on science," or is "what scientists have determined is needed to avoid catastrophic harm," but this is not quite the case. An early paper by Nordhaus (1977) states that "… it seems reasonable to argue that the climatic effects of carbon dioxide should be kept well within the normal range of long-term climatic variation" and an accompanying diagram shows 2°C as the "Estimated maximum experienced over last 100,000 years". In the early 1990s German scientists chose 2°C as a benchmark for harmonizing research on the impacts of climate change. Projections suggested that under BAU conditions 2°C would be realized in the mid-21st century, a time near enough to elicit motivating concern yet far enough off to allow some confidence that meaningful policy action could be taken. As discussion of policy action spread internationally, the existence of research results pegged to 2°C allowed policy proponents to reference that particular figure with enhanced confidence and authority. As policy proponents increasingly referenced the 2°C figure researchers increasingly converged on that figure for their research. The European Union formally adopted a ceiling of 2°C as a policy goal in the mid-1990s and began urging that that level be agreed upon as a universal policy goal. In 2010 the 2°C target was officially affirmed at COP16 in Cancun. Note that other constituencies and academic studies have called for other ACC target levels. At Copenhagen 2009 over half the States Parties supported the Alliance of Small Island States (AOSIS) proposal for a 1.5°C limit. Nordhaus' (1994) DICE model generates an optimal trajectory showing ACC of 3.5°C by 2120, 4.0°C by 2150, and further increases beyond that. More recently Nordhaus (2013) argues for a 2.5° C limit. See Geden (2013) and Plummer (2013) for more on the history of the 2°C policy target.

19. The INDC evaluations displayed in Panel B of Box D.1-1 show a difference of 37% between the lowest and highest central estimates of the impact of the INDCs in 2100, and more than 100% difference between outlier values. What accounts for these significant differences? Countries were asked by the FCCC to tell what mitigation measures they will employ, and what targets they have set, through 2030. Some evaluators made the assumption that comparable effort would continue to 2100, while other evaluators did not. Some evaluators counted conditional pledges and others did not. Many INDCs were ambiguous regarding what they actually pledged, and evaluators resolved these in different ways. After aggregating all pledges, evaluators used different models to calculate emission trajectories, concentrations and warming. Discussions are underway among the parties to the Paris Agreement about harmonizing the presentation and evaluation of INDCs. For reviews of the methods used by different evaluators to evaluate country INDCs see Levin & Fransen (2015) and UNFCCC (Oct 2015).

20. Notes are in progress on the **strengths and limits of integrated assessment models** and other approaches to understanding complex dynamic relationships over long periods and large, diverse populations. Pindyck (2015, 2013) and Rosem and Guenther (2014) are highly skeptical of the value of most of these models, and in particular of integrated assessment climate/economy models. Pindyck argues strongly that such models not be used, and recommends instead the use of expert assessment panels. Darmstadter and Krupnick (2013), and Nordhaus (2014), strongly differ, arguing that despite their limitations these models can at a minimum suggest boundary values for policy outcomes, and that their utility and accuracy improves over time. Others hold that such models are problematic if intended to generate optimal policies, as that involves numerous and contested normative judgements, but can be used to generate descriptive scenarios that can then be compared and judged using other, explicitly and transparently normative, procedures. See Ackerman et al. (2009), Stanton et al. (2009), and Metcalf and Stock (2015) for a range of such middle-ground assessments and proposals.