Written Testimony of

Ted Nordhaus
Founder and Executive Director, The Breakthrough Institute

To the U.S. House of Representatives
Committee on Science, Space, and Technology

Hearing Entitled:
Using Technology to Address Climate Change

May 16, 2018

It is an honor to testify before this committee. My name is Ted Nordhaus. I am the founder and executive director of the Breakthrough Institute, an environmental think tank located in Oakland, California. I have spent a fair portion of my career working with environmental NGOs and have researched and written about the issue of anthropogenic climate change for most of the last two decades. My think tank counts among its senior fellows prominent climate scientists, technologists and social scientists whose work has been widely cited in the relevant scholarly literatures, the IPCC, and other leading assessments of the risks associated with anthropogenic climate change. My testimony today will draw upon this work to present a synthesis that broadly reflects our assessment of the nature of climate risk, the uncertainties associated with both action and inaction, and the pragmatic steps that we might take today to address those risks. All of the perspectives I offer today will be broadly consistent with the assessment reports of the Intergovernmental Panel on Climate Change.

Climate Science, Risk, and Uncertainty

Let me begin with a few observations about climate science and climate risk:

- First, there is a well established scientific consensus regarding anthropogenic climate change. That consensus is as follows - global temperatures, as measured at the surface level and the upper atmosphere have risen since the industrial revolution, that increase has been caused in significant part by anthropogenic forcings, notably the emissions of carbon dioxide from the burning of fossil fuels, and these anthropogenic greenhouse gas emissions are responsible for a significant share of anthropogenic forcing.[1,2] We also know that current CO2 concentrations in the atmosphere are higher than the Earth has experienced for at least several hundred thousand years, with most of the increase occurring since the early 1950's.

- Second, to the best of my knowledge, none of the witnesses called today, by either the majority or the minority, contest these well established facts.

- Third, while the basic relationship between rising atmospheric concentrations of greenhouse gases and global temperatures is well established, much else that might inform societal responses to climate change is not, including the extent of climate impacts that will result from rising global average temperatures, the costs to human societies of those impacts, and the cost of avoiding those impacts, where they can be avoided. To wit:

    - The IPCC estimates a wide range of temperature outcomes associated with a doubling of atmospheric greenhouse gas concentrations from pre-industrial levels. In the most recent IPCC estimate, published in 2014, the estimated range of climate sensitivity was 1.5 to

[1] World Meteorological Organization, *WMO Statement on the State of the Global Climate in 2017* (2018), p. 4. https://library.wmo.int/opac/doc_num.php?explnum_id=4453
[2] Intergovernmental Panel on Climate Change. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (2015). http://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf

4.5 degrees celsius.[3] In the prior assessment, the range was 2 to 4.5 C.[4] In the next assessment, scheduled for 2022, that estimate will probably shift again.

- The estimated relationship between global temperature increases and climate impacts at the local and regional scales at which they actually affect human societies is also uncertain. While it is likely that many climate related phenomena will intensify, there is significant uncertainty as to by how much and over what timescales. This is true of most of the impacts that we worry most about, such as sea level rise, the intensity of landfalling hurricanes, the duration of droughts, or incidence of floods.

- We have limited foreknowledge as to how well human societies will adapt to climate impacts. This is due in part to uncertainties about the timescales and extent of climate impacts but arguably more so to uncertainties regarding the adaptability of human social, economic, and technological systems and the efficacy of the social and political institutions upon which they depend. Even a cursory review of the differential human and economic impacts associated with natural disasters of similar magnitude around the world should establish that the primary factor that mediates the relationship between natural disasters of various sorts and human impacts associated with those events are societal affluence, infrastructure, technology, and institutions.

- We have little certainty about the cost of climate mitigation. There have been many attempts to estimate the costs and benefits of mitigating climate change. But all are highly dependent upon assumed rates of technological change that are ultimately unknowable. Assume that technological change, with or without a helping hand from government, will be rapid, and the cost of deeply cutting greenhouse gas emissions will be very modest. Assume slower rates of technological change and costs will be prohibitive.[5]

● Fourth, given all of the uncertainties delineated above, one can find ample justification within the consensus climate science to advocate either far reaching and immediate action to mitigate climate change or no action whatsoever. Neither position is inconsistent with what we know with certainty about climate risk, as established by the IPCC and other similar assessments.

For all of these reasons, all discussions of climate change and what we ought to do about it revolve, unavoidably, around how we should orient ourselves toward uncertainty and risk. The dilemma that climate change ultimately presents us with is that we know that there is some significant possibility of catastrophic impacts *AND* that efforts to assess the appropriate response to those risks are confounded by cascading uncertainty and complexity in both the climate system and human social and technological

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[3] Ibid., p. 43.
[4] Intergovernmental Panel on Climate Change. *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2008), p. 38. https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf
[5] See Edmonds, Jae, et al. "Technology and the economics of climate change policy." *Pew Center on Global Climate Change* (2000). https://www.c2es.org/site/assets/uploads/2000/09/technology_economics.pdf

systems. In my remaining remarks, I will offer some thoughts about how then we might best navigate those uncertainties in order to take wise action in the coming years and decades to both prepare for and mitigate climate variability and change.

Climate Mitigation and Uncertainty

Given high present day uncertainty, in which the consequences of inaction are potentially catastrophic and the costs of mitigation are potentially large, how should policymakers respond? Faced with many competing national and global priorities, what level of resources should we invest today to mitigate impacts that will unfold over the course of decades and centuries and whose consequences are highly uncertain and may not be knowable within the timeframes in which policy-makers have to act?

Let me first dispense with a common objection to asking the question in this way. Many suggest that we are already facing the consequences of anthropogenic climate change, in the form of increasingly severe climate related natural disasters. I will not attempt to parse for you the evidence for and against this claim. Rather I will simply observe two things that can be found in the consensus view of both the IPCC and the US National Climate Assessment.

- First, insofar as various studies have suggested that a climate signal can be found in recent disasters, the signal is relatively modest in the context of both known variability and projected future changes.[6,7] To take a prominent recent example, one recent study estimated that rainfall associated with Hurricane Harvey was 15% greater than would otherwise have been the case due to anthropogenic climate change. To put that finding in context, Hurricane Harvey produced an extreme rainfall event that resulted in approximately 40” of rainfall in some locations. The 15% increase associated with global warming according to this analysis would mean that Hurricane Harvey produced 40” of rainfall in these locations over three days rather than 34”. I will let this committee draw its own conclusions as to whether 40” of rainfall rather than 34” of rainfall during this period materially contributed to the human and economic costs associated with this event. Suffice to say that the 34” of rainfall that the authors recognize was due to natural climate variability was an extreme event, outside of the observed climatic record for the region and would have brought extraordinary impacts without regard to additional anthropogenic forcings.[8]

- Second, even assuming that climate change is here today, intensifying natural disasters in some meaningful fashion, measures to mitigate emissions undertaken today will not appreciably influence the trajectory of either global temperatures or climate impacts for many decades to

[6] For example, this study suggests that warming will increase the area scorched by wildfires in Southern California: Jin, Yufang, et al.. "Identification of two distinct fire regimes in Southern California: implications for economic impact and future change." Environmental Research Letters 10, no. 9 (2015): 094005. http://iopscience.iop.org/article/10.1088/1748-9326/10/9/094005
[7] NASA. *The Impact of Climate Change on Natural Disasters*. https://earthobservatory.nasa.gov/Features/RisingCost/rising_cost5.php
[8] Geert Jan van Oldenborgh, et. al. “Attribution of extreme rainfall from Hurricane Harvey,” Environmental Research Letters 12 no 12 (2018) 019501 http://iopscience.iop.org/article/10.1088/1748-9326/aa9ef2

come.[9] To cite two prominent examples, when comparing low and high emissions scenarios produced by the IPCC, neither global average temperatures nor sea level rise see significant divergence for decades or perhaps until late in this century or early in the 22nd century.[10]

For these reasons, climate change has been a relatively low priority on the public agenda and is likely to remain so, despite longstanding efforts on the part of some to increase the salience of the issue. The asymmetry in timescales, between mitigation measures with present day costs and very long-term benefits is the reason that policies demanding high mitigation costs in the present to avoid unquantifiable risks far into the future have reliably failed politically, not only here in the United States[11] but almost everywhere else.[12,13] Explicit climate policies have not much affected the trajectory of emissions anywhere.[14,15] That fact has been obfuscated by both advocates of climate action, who have exaggerated the scope of the policies that have been proposed and initiated and opponents, who have exaggerated the cost of those policies.

To put a finer point on that observation, almost a decade after the US Senate failed to bring climate legislation to a vote, US carbon emissions today remain lower than the level that would have been mandated by the Waxman Markey legislation that passed this house in 2009.[16] The Waxman Markey proposal is not an isolated case. Similar efforts to cap emissions in Europe and California have established emissions caps that have proven with the benefit of hindsight to be consistently above the actual trajectory of observed emissions. For these reasons, it is difficult to take very seriously claims that these measures would have led to economic catastrophe, for the simple reason that they would have changed much less than either proponents or opponents claimed.

As such, policies to cap, price, or regulate greenhouse gas emissions, where they are established and well conceived, will likely very modestly tip the scales toward lower carbon fuels and technologies. The success or failure of efforts to substantially drive decarbonization to levels that diverge significantly from business as usual trajectories will depend primarily upon the availability of low carbon technologies that are cheap and scalable.[17] Reasonable pricing and regulatory strategies will have a role to play, but will be

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9 Moss, Richard H., et al. "The next generation of scenarios for climate change research and assessment." *Nature* 463, no. 7282 (2010): fig 5b, pg 753. http://cmaps.cmappers.net/rid=1KJHRBBS9-X1Y02G-RJT/nature08823.pdf
10 IPCC. *The Global Climate of the 21st Century,* 2001. https://www.ipcc.ch/ipccreports/tar/wg1/figspm-5.htm
11 Center for Climate and Energy Solutions. *Congress Climate History*. https://www.c2es.org/content/congress-climate-history/
12 Sengupta, Somini. *The New York Times*. "Why China Wants to Lead on Climate, but Clings to Coal (for Now)," Nov 14, 2017. https://www.nytimes.com/2017/11/14/climate/china-coal.html?
13 Neslen, Arthur. *The Guardian*. "Secret UK push to weaken EU climate laws 'completely mad'", May 9, 2018. https://www.theguardian.com/environment/2018/may/09/secret-uk-push-to-weaken-eu-climate-laws-completely-mad
14 van Renssen, Sonja. "The inconvenient truth of failed climate policies," *Nature Climate Change* 8 (2018), 355–358.
15 Nordhaus, Ted and Jessica Lovering. *Breakthrough Institute.* "Does Climate Policy Matter?" Nov 28, 2016. http://thebreakthrough.org/issues/Climate-Policy/does-climate-policy-matter
16 The Waxman-Markey legislation required a 3% emission cut from 2005 levels by 2012 and a 17% emission cut by 2020. This requires a 1.75% reduction per year from 2012 to 2016, so emissions should be at 10% below 2005 levels in 2016. As it happened, they were at an 11% cut from 2005. See https://grist.org/article/2009-06-03-waxman-markey-bill-breakdown/ and https://www.epa.gov/sites/production/files/2018-01/documents/2018_chapter_2_trends_in_greenhouse_gas_emissions.pdf
17 International Energy Agency. *The Way Forward,* 2014. https://www.iea.org/publications/freepublications/publication/The_Way_forward.pdf

limited both by political limits to the short term costs that can be imposed in pursuit of uncertain climate benefits and the cost and availability of low carbon substitutes.

That should not, however, be the end of the story with regard to policy efforts to mitigate climate change. There is much beyond pricing or regulating emissions that policymakers can do to move us more rapidly in a cost-effective manner toward a lower carbon economy. Despite the industry's recent struggles, almost twenty percent of America's electricity still comes from nuclear energy,[18] a technology that was developed and commercialized through a range of federal policies and initiatives. America's world leading decline in emissions over the last decade has been achieved in large part due to the shale gas revolution,[19] which was made possible by decades of federal research, development, and demonstration efforts in partnership with the private sector.[20] Decades of policy support for wind and solar energy have begun to pay off as well, with costs falling rapidly and electricity penetration rising.[21]

There is much that federal policy makers can do to support continuing reductions in US emissions in the short term.

- This includes, most especially, keeping America's nuclear power plants open. Continuing plant closures threaten to undo much of the progress that America has made over the last decade due to both the transition from coal to gas and growing renewable energy shares. Whether through state and federal clean energy standards, intervention at the Federal Energy Regulatory Commission, or other measures, it is imperative that we keep America's zero carbon nuclear power plants operating.
- Natural gas, meanwhile, continues to displace coal-fired electricity generation.[22,23,24] Efforts to resuscitate the coal industry are misguided and doomed to fail due to the realities of energy economics. Coal is being displaced by a cleaner, cheaper, and more useful fuel due to market forces and we should let that transition run its course.[25]
- Finally, we should put claims that wind and solar energy are now economically competitive with fossil fuels to the test. I have long supported generous federal support for those technologies but it is clearly time to ramp those subsidies down and let existing wind and solar technologies stand on

[18] U.S. Energy Information Administration. *U.S. Nuclear Industry,* May 1, 2018. https://www.eia.gov/energyexplained/index.php?page=nuclear_use

[19] Middleton, Richard S., et al. "The shale gas revolution: Barriers, sustainability, and emerging opportunities." *Applied Energy* 199 (2017): 88-95. https://www.sciencedirect.com/science/article/pii/S0306261917304312

[20] Jenkins, Jesse, et al. *Breakthrough Institute*. "US Government History in Shale Gas Fracking History: An Overview," March 2, 2012. https://thebreakthrough.org/archive/shale_gas_fracking_history_and

[21] Cusick, Daniel. *Scientific American.* "Wind and Solar Growth Outpace Gas," Jan 12, 2017. https://www.scientificamerican.com/article/wind-and-solar-growth-outpace-gas/

[22] Nuccitelli, Daniel. *The Guardian.* "The war on coal is over. Coal lost," Oct 16, 2017. https://www.theguardian.com/environment/climate-consensus-97-per-cent/2017/oct/16/the-war-on-coal-is-over-coal-lost

[23] Goff, Michael. *Breakthrough Institute.* "How Natural Gas and Wind Decarbonize the Grid," July 13, 2017. https://thebreakthrough.org/index.php/issues/decarbonization/how-natural-gas-and-wind-decarbonize-the-grid

[24] Nordhaus, Ted, et al. *Breakthrough Institute.* "Natural Gas Overwhelmingly Replaces Coal," Dec 14, 2015. https://thebreakthrough.org/index.php/issues/natural-gas/natural-gas-overwhelmingly-replaces-coal

[25] McBride, Jameson. *Breakthrough Institute.* "Clean Energy Advocates Should Oppose Subsidizing Coal," Dec 7, 2017. https://thebreakthrough.org/index.php/voices/clean-energy-advocates-should-oppose-subsidizing-coal

their own so that they might survive the market test necessary to penetrate even further into the economy.

There will clearly be limits, however, to how far we are going to get with present low carbon technology. Even if wind and solar energy gets much cheaper, their variable nature means that without new and very low cost technologies capable of storing vast quantities of electricity for weeks and months, not days at a time, there will be both technical and economic limitations to how much electricity we can count on[26] from those sources. Nuclear energy still represents our largest source of zero carbon power,[27] but large conventional nuclear power plants are enormous public works projects that like many other similar endeavors have proven extremely costly to build.[28] Any nuclear renaissance worth speaking of in the United States will require a new generation of nuclear reactors that are much smaller and can be manufactured offsite. And because natural gas still has significant carbon intensity, the environmental benefits of the coal to gas transition are ultimately limited.[29] If natural gas is to fulfill its promise as a sustainable fossil fuel, we will need to develop and deploy at scale technologies of carbon capture and storage.

Moreover, roughly 70% of US carbon emissions arise from outside the power sector.[30] We have made some progress in the transportation sector, due to fuel efficiency and the commercialization of hybrid electric engines. We are just beginning to see the entry of electric vehicles into the light duty transportation market. But both hybrid and fully electric vehicles still require significant cost premiums and, for the latter, a huge build-out of charging infrastructure. As a result, it will likely be decades before we see the end of the internal combustion engine, if at all.

Outside of light duty transportation, the path to decarbonization is harder still. We have few viable low carbon substitutes for industrial heat and power, cement production, fertilizer, and heavy transportation. Carbon capture technologies could offer us a way to avoid emissions from fossil energy uses that we can't displace, but the path to economically viable carbon capture technologies for many applications is far from clear as well.

All of these new and improved technologies will require a significant and sustained commitment to mission-driven innovation in collaborative fashion between the public and private sectors to offer viable alternatives to fossil fuels in the United States and globally, and most are likely decades away from commercialization.

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[26] Beaudin, Marc, et al. "Energy storage for mitigating the variability of renewable electricity sources: An updated review." *Energy for sustainable development* 14, no. 4 (2010): 302-314.
[27] Center for Climate and Energy Solutions. *Climate Solutions: The Role of Nuclear Power*, April 2014. https://www.c2es.org/site/assets/uploads/2014/04/climate-solutions-role-nuclear-power.pdf
[28] Synapse Energy Economics. *Nuclear Power Plant Construction Costs*, July 2008. https://www.synapse-energy.com/sites/default/files/SynapsePaper.2008-07.0.Nuclear-Plant-Construction-Costs.A0022_0.pdf
[29] U.S. Energy Information Administration. How much carbon dioxide is produced when different fuels are burned? https://www.eia.gov/tools/faqs/faq.php?id=73&t=11
[30] EPA. *Sources of Greenhouse Gas Emissions.* https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

For this reason, the prospects for stabilizing atmospheric concentrations of greenhouse gases to levels consistent with limiting global warming to two degrees or less, the long-standing international target for climate stabilization, are extremely unlikely. Fossil fuels still constitute over 80% of primary energy consumption globally and in the United States and that share has hardly fallen since the oil shocks of the 1970's.[31] Most IPCC scenarios for stabilizing temperatures at 2 degrees celsius assume that the world removes enormous quantities of carbon from the atmosphere in the latter half of this century, something that we have no idea how to do at the scale that would be required.[32]

The likelihood, however, that in the next several decades atmospheric concentrations of greenhouse gases will rise to levels inconsistent with limiting global temperature increase to less than two degrees, should not be taken as reason to abandon mitigation efforts. The two degree target represents a political convention, not a particularly well established biophysical boundary.[33] There is no particularly strong empirical basis for the view that catastrophic climate impacts might be avoided should we succeed at stabilizing temperature below the two degree threshold nor that catastrophe is assured should we fail. Irrespective of the international two degree convention, the basic relationship between emissions and climate risk remains. Lower emissions bring lower long-term climate risk.[34] That includes both impacts whose relationships to global temperatures are relatively linear and climate tipping points that could bring non-linear impacts. Lower emissions bring lower risk of crossing tipping points that may or may not exist and whose precise location with regard to global temperatures is highly uncertain.

That basic relationship, between emissions and risk, is true today, when we have not yet surpassed two degrees of warming, and it will still be true several decades hence, when we have. All else being equal, cost-effective mitigation brings lower climate risk even recognizing that global mitigation efforts are highly unlikely to result in stabilization of atmospheric concentration of greenhouse gases at levels consistent with limiting the temperature increase to two degrees. Developing and deploying cost-effective technologies that reduce carbon emissions can also bring a range of further benefits, including improved public health from cleaner energy, lower energy costs, global competitiveness, and access to global export markets.

Adaptation for A Hotter World

Given the likely trajectory of emissions and global temperature, even presupposing much more far-reaching mitigation success than the global community has thus far made, climate adaptation will play a large role in determining how well human societies weather a changing climate over the coming decades and centuries. Adaptation in the context of anthropogenic climate change is, in most of its particulars, not much different than the steps that human societies reliably undertake as they modernize and develop. As societies become wealthier, their populations have become more resilient to climate

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[31] The World Bank, *Fossil fuel energy consumption*, 2014. https://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS
[32] Peters, Glen P., and Oliver Geden. "Catalysing a political shift from low to negative carbon." *Nature Climate Change* 7, no. 9 (2017): 619.
[33] Jaeger, Carlo C., and Julia Jaeger. "Three views of two degrees." *Regional Environmental Change* 11, no. 1 (2011): 15-26.
[34] Majkut, Joseph, *Reducing Emission, Reducing Climate Risk*, March 2016. https://niskanencenter.org/blog/reducing-emissions-reducing-climate-risks/

variability and extreme weather.[35,36] Modern, affluent societies are able to deploy infrastructure and technology to keep the weather at bay - sea walls and flood channels, modern housing and transportation networks, water and sewage systems, air conditioning to offer a few examples. Those measures are further amplified by modern institutions and practices - weather forecasts, emergency response systems, public health measures and the like.[37]

Citizens of wealthy economies are also much more mobile and integrated into national and global networks of trade and commerce that make them much less vulnerable to local and regional climatic disruptions. There has been a heavy focus among many concerned about climate adaptation upon increasing local resilience, mostly focused on localized food and energy production in the event that connections to regional and national networks are lost. And while there is clearly some utility in having backup power generation and water resources available in the immediate aftermath of a natural disaster, it is precisely our integration into global and national networks that make developed world populations so resilient to climate variability and disruption. The ability, for instance, to purchase food produced halfway across the country, or the world, in the midst of a drought, makes us much more resilient to that sort of climate variability, especially if it is sustained, as may become increasingly frequent.

Wealthy societies are able to abandon areas that become indefensible in the face of a changing climate and citizens of those societies are able to leave in search of better climates. Over the last fifty years, about 20% of the United States population has shifted from the northeast and midwest to the southeast and southwest, much of that due to voluntarily migration in search of better climates.[38] Those climates were not always so. Much of the southeast was historically malarial wetlands. Much of the southwest was inhospitable desert. Infrastructure and technologies have transformed those regions to desirable places to live. Climate change over the course of the next century may occasion migrations and transformations of similar scale. Good infrastructure and good institutions will greatly minimize the disruption and dislocation that could result from those shifts.

So the first critical thing to understand about climate adaptation is that we in the developed world are already very well adapted to climate change and, in many cases, also to the variability and change that we might experience in coming decades. The greatest risks to our continuing ability to be so will be our failure to invest in infrastructure and to tend to the institutions that we depend on to keep us safe. Hurricane Katrina was an extreme but otherwise ordinary hurricane that we should expect to see every so often along the Gulf Coast. But decades of neglected infrastructure exacerbated by neglect and incompetence on the part of state and federal emergency response officials turned it into a national tragedy.[39] We are watching a similar tragedy unfold in Puerto Rico today.

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[35] The World Bank, *Turn Down the Heat*, November 2012. http://documents.worldbank.org/curated/en/865571468149107611/pdf/NonAsciiFileName0.pdf

[36] Fankhauser, Samuel, and Thomas KJ McDermott. "Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries?" *Global Environmental Change* 27 (2014): 9-18.

[37] Noble, I.R., et al. "Adaptation needs and options." In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (2014) pp. 833-868.

[38] Frey, William, *U.S. growth rate hits new low as migration to the Sun Belt continues*, December 2016. https://www.brookings.edu/blog/the-avenue/2016/12/23/u-s-growth-rate-hits-new-low-as-migration-to-the-sun-belt-continues

[39] Griffis, F. H. "Engineering failures exposed by Hurricane Katrina." *Technology in Society* 29, no. 2 (2007): 189-195.

Neither of these disasters can be laid at the feet of a rapidly changing climate. They are what we should expect in these regions and storms like those will, with certainty, occur again. Both disasters resulted from neglecting infrastructure, institutions, and the people who depend upon them. Even as it may continue to debate the merits of various climate mitigation measures, this Congress would substantially improve our long term prospects of adapting to climate change well if it agreed on a bipartisan basis to dramatically raise national investment in infrastructure and recommitted itself to ensuring a comprehensive federal response to all natural disasters for all of America's citizens.

What is true in the rich world is even more so in developing countries. Modern infrastructure is what makes us resilient to climate variability and natural disasters. The faster developing countries are able to build that infrastructure, the more resilient they will be to a changing climate. It is here that difficult tradeoffs between mitigation and adaptation are most problematic. Institutions can make a big difference and they can't really be disentangled from infrastructure. But the existence of hard infrastructure - steel and cement for housing, roads, hospitals, water and sewage systems - is the critical physical fact that makes societies more resilient to climatic extremes. Building that infrastructure is energy intensive and, as noted above, there are few viable low carbon alternatives presently available for many of the activities entailed in doing so.

This presents a quandary of sorts. Fossil fueled development globally increases climate risk. But it also makes developing world populations much more resilient to that risk. Infrastructure is an obvious example. But the basic dynamic is broadly applicable. Social and economic modernization is an energy intensive business and while there are some cases where that energy can be produced without carbon emissions, global development is, for at least the next several decades, almost certain to remain an enterprise that is primarily powered by fossil fuels.

There have been a number efforts through US funded global development institutions to establish sweeping restrictions on fossil fuel development, including at the World Bank, USAID, and the Overseas Private Development Corporation. While there may be some limited cases where this has been wise, trading off present day development for the poorest people in the world for uncertain climate mitigation benefits many decades hence is indefensible in my view. Development today makes poor populations much more resilient to both present day climate extremes and long term climate change. The United States should not stand in the way of poor nations around the world availing themselves of the same development and infrastructure that has made us so much more resilient to climate change, even if that development entails greater fossil fuel consumption.

Conclusion

In closing, I would like to suggest that America and the world would be better served by a bit more moderation in this body from both sides of the aisle. Climate change is real, its origins are primarily anthropogenic, and it presents real risks to human societies. Whether those risks will prove catastrophic, much less apocalyptic, simply cannot be foretold.

Lest anything I have said lead this committee to conclude that climate change does not constitute a significant threat to the American people, let me return to the question of uncertainty. An increasingly wealthy world faced with impacts that unfold gradually, over century timescales, should be able to adapt to them reasonably well. But there are unquantifiable risks of significant impacts that could unfold over decadal, not century timescales, and these are the sorts of impacts that even wealthy nations may not weather well. These risks, I will note, exist even if one is more inclined towards the low end of estimates of climate sensitivity. I am skeptical of calls to stabilize temperature at 1.5 degrees celsius and atmospheric concentrations of carbon at 350ppm.[40] But those demands are based in part upon studies of various climate impacts and tipping points that, while far from convincing in my view, cannot be dismissed out of hand either.

If the impacts associated with rising emissions unfold slowly and in linear fashion, then there is good reason to think that the United States and much of the rest of the world will manage those changes relatively well. The gradual migration of large populations from the Rust Belt to the Sun Belt took place over many decades and brought faster economic growth and improvements to overall well being. A large and sudden migration necessitated by rapidly unfolding climate impacts would not be so benign and would almost certainly bring very significant costs and disruption.

There are also important potential interactive effects between climate change and social and political institutions that should not be dismissed. I am skeptical of various claims that assert a causal link between civil strife in various parts of the world and climate change. But it is certainly plausible to suggest that worsening climate impacts in various parts of the nation and the world, in complex interactions with various other dynamics, might undermine the institutional capacities that allow us to establish and maintain resilience.

It is for this reason that continuing decarbonization efforts should remain an important priority, nationally and globally – with an urgent effort to push the cost and technical envelope for low carbon technology in order to hasten and reduce the costs of mitigation. It is also for this reason that we should explore other means to mitigate climate impacts beyond decarbonization, including carbon removal and geoengineering. Neither of these latter strategies represents an existing mitigation pathway today. But clearly, a reasonable assessment of the many uncertain futures that climate change could bring suggests that further research into these mitigation strategies is wise, not out of any certainty that they will be necessary but in recognition of the possibility that they might be needed.

The absence of much serious discussion among policy-makers regarding carbon removal and geo-engineering point to a broader challenge. Climate policy discussions have been overly dominated by a heavy focus on decarbonization and discussions of decarbonization have been further constrained by an overly narrow focus upon efforts to regulate or price emissions and promote renewable energy. Those measures will certainly have a role to play moving forward but mitigation efforts will need to take a range of other steps much more seriously, including the coal to gas transition, advanced nuclear energy,

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[40] Nordhaus, Ted. *Foreign Affairs.* "The Truth About the Two-Degree Target," March 2018. https://www.foreignaffairs.com/articles/world/2018-03-07/truth-about-two-degree-target

advanced renewable energy technologies, carbon capture and removal, electrification, and geoengineering. Climate policy discussions will also be much better served to remember that adaptation to climate change is, in most cases, not appreciably different than the myriad measures we have already taken to make us more resilient to climate variability and extremes already. A broadening of the sorts of policies, technologies, and measures that we include in climate policy discussions might also bring the not inconsiderable benefit of substantially broadening the political coalition supporting climate action.

However we respond, climate change will under the best of circumstances be a chronic condition faced by human societies for many centuries to come. Accepting that reality, in non-apocalyptic terms, will allow us to mitigate, plan for, and adapt to that future most effectively and at the least cost to both present and future generations.

Thank you for considering my testimony.

THE BREAKTHROUGH

TED NORDHAUS
EXECUTIVE DIRECTOR

Ted Nordhaus is a leading global thinker on energy, environment, climate, human development, and politics. He is the co-founder and executive director of the Breakthrough Institute and a co-author of "An Ecomodernist Manifesto."

Over the last decade, he has helped lead a paradigm shift in climate, energy, and environmental policy. He was among the first to emphasize the imperative to "make clean energy cheap" in *The Harvard Law and Policy Review*, explained why efforts to establish legally binding international limits on greenhouse gas emissions would fail in the Washington Post and Democracy Journal, made the case for nuclear energy as a critical global warming solution in the Wall Street Journal, has written on the limits to energy efficiency and the need to prepare for climate change in the New York Times, and has argued for the importance of intensifying agricultural production in order to spare land for forests and biodiversity in Scientific American and the Guardian.

His 2007 book *Break Through*, co-authored with Michael Shellenberger, was called "prescient" by *Time* and "the best thing to happen to environmentalism since Rachel Carson's *Silent Spring*" by *Wired*. (An excerpt in *The New Republic* can be read here.) Their 2004 essay, "The Death of Environmentalism," was featured on the front page of the Sunday *New York Times*, sparked a national debate, and inspired a generation of young environmentalists.

Over the years, Nordhaus been profiled in the *New York Times*, *Wired*, the *San Francisco Chronicle*, the *National Review*, *The New Republic*, and on *NPR*. In 2007, he received the Green Book Award and *Time* magazine's 2008 "Heroes of the Environment" award.

Nordhaus is executive editor of the *Breakthrough Journal*, which *The New Republic* called "among the most complete efforts to provide a fresh answer" to the question of how to modernize liberal thought, and the *National Review* called "The most promising effort at self-criticism by our liberal cousins in a long time."

436 14th Street, Suite 820, Oakland • CA 94612 • 510-550-8800
info@thebreakthrough.org • www.thebreakthrough.org