**STATEMENT TO THE
COMMITTEE ON NATURAL RESOURCES
OF THE UNITED STATES HOUSE OF REPRESENTATIVES**

**Hearing on
Climate Change: The Impacts and the Need to Act**

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I thank the Chairman, Ranking Member and the Committee for the opportunity to offer testimony today on 'Climate Change: The Impacts and the Need to Act.' I am President of Climate Forecast Applications Network (CFAN) and Professor Emerita and former Chair of the School of Earth and Atmospheric Sciences at the Georgia Institute of Technology. I have devoted four decades to conducting research on a variety of topics related to weather and climate.

By engaging with decision makers in both the private and public sectors on issues related to weather and climate, I have learned about the complexity of different decisions that depend, at least in part, on weather and climate information. I have learned the importance of careful determination and conveyance of the uncertainty associated with our scientific understanding and particularly for predictions. I have found that the worst outcome for decision makers is a scientific conclusion or forecast issued with a high level of confidence that turns out to be wrong.

I am increasingly concerned that both the climate change problem and its solution have been vastly oversimplified.[1] For the past decade, I have been promoting dialogue across the full spectrum of understanding and opinion on the climate debate through my blog Climate Etc. (judithcurry.com). I have learned about the complex reasons that intelligent, educated and well-informed people disagree on the subject of climate change, as well as tactics used by both sides to try to gain a political advantage in the debate.

With this perspective, my testimony focuses on the following issues of central relevance to climate change, its impacts and need to act:

- The climate knowledge gap
- The climate change response challenge
- The urgency (?) of $CO_2$ emissions reductions
- Resilience, anti-fragility and thrivability
- Moving forward with pragmatic climate change policies

[1] Curry, JA and Webster PJ 2011: Climate science and the uncertainty monster. *Bull Amer Meteorol. Soc.,* 92, 1667-1682. http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3139.1

**The climate knowledge gap**

Climate scientists have made a forceful argument for a future threat from manmade climate change. Manmade climate change is a theory in which the basic mechanism is well understood, but the potential magnitude is highly uncertain. Scientists agree that surface temperatures have increased overall since 1880, humans are adding carbon dioxide to the atmosphere, and carbon dioxide and other greenhouse gases have a warming effect on the planet.

However, there is considerable disagreement about the most consequential issues: whether the recent warming has been dominated by human causes versus natural variability, how much the planet will warm in the 21$^{st}$ century, whether warming is 'dangerous', and whether radically reducing carbon dioxide ($CO_2$) emissions will improve the climate and human well being in the 21$^{st}$ century.

The scientific conflict regarding the theory of manmade climate change is over the level of our ignorance regarding what is unknown about natural climate variability. Why do climate scientists disagree on the relative importance of natural versus manmade climate change? The historical data is sparse and inadequate. There is disagreement about the value of different classes of evidence, notably the value of global climate model simulations and paleoclimate reconstructions from geologic data. There is disagreement about the appropriate logical framework for linking and assessing the evidence in this complex problem.[2] Further, politicization of the science and the consensus building process itself can be a source of bias.

Apart from these broad sources of disagreement, there are two sources of misconception and uncertainty that are of particular relevance to climate policy making:

- Projections of 21$^{st}$ century climate change
- Linking extreme weather events to manmade climate change

With regards to projections of 21$^{st}$ century climate change, Sections 11.3.1.1 and 12.2.3 of the Intergovernmental Panel on Climate Change (IPCC) 5$^{th}$ Assessment Report (AR5) describe uncertainties in the climate model-based projections. Climate models consistently indicate that the mean global temperature of the planet will rise with increasing $CO_2$ emissions. However, these models show systematic errors in the simulated global mean temperature that are similar in magnitude to the size of the historical change we are seeking to understand.[3] The *likely*[4] range of estimates of the sensitivity of global warming to doubling of $CO_2$ as reported by the IPCC AR5 varies by a factor of 3, from 1.5 to 4.5 $^{o}$C.[5] Apart from uncertainties in climate model projections that focus primarily on the impact of increases in greenhouse gases, we do not have sufficient understanding to project future solar variations, future volcanic eruptions, and decadal to century variations in ocean circulations. Finally, existing climate models are unable to simulate realistically possible extreme outcomes, such as abrupt climate change or a rapid disintegration of the West Antarctic Ice Sheet. Hence global climate models provide little relevant information regarding very unlikely but potentially catastrophic impacts – whether caused by manmade climate forcing or natural processes or some combination.

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[2] Curry, JA (2011) Reasoning about climate uncertainty https://link.springer.com/article/10.1007/s10584-011-0180-z

[3] Mauritsen et al. (2012) Tuning the climate of a global model https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2012MS000154

[4] > 66% probability

[5] IPCC AR5 WG1 Report https://www.ipcc.ch/report/ar5/wg1/

Among the greatest concerns about climate change are its impacts on extreme events such floods, droughts, heat waves, wildfires and hurricanes. However, there is little evidence that the recent warming has worsened such events. The IPCC *Special Report on Extreme Events*[6] acknowledges that there is not yet evidence of changes in the global frequency or intensity of hurricanes, droughts, floods or wildfires. The recent Climate Science Special Report from the Fourth National Climate Assessment (NCA4)[7] reported the following conclusions abut extreme events and climate change:

- "Recent droughts and associated heat waves have reached record intensity in some regions of the United States; however, the Dust Bowl era of the 1930s remains the benchmark drought and extreme heat event in the historical record." [Ch. 6]
- "Detectable changes in some classes of flood frequency have occurred in parts of the United States and are a mix of increases and decreases. Extreme precipitation is observed to have generally increased. However, formal attribution approaches have not established a significant connection of increased riverine flooding to human-induced climate change." [Ch. 8]
- "State-level fire data over the 20th century indicates that area burned in the western United States decreased from 1916 to about 1940, was at low levels until the 1970s, then increased into the more recent period." [Ch. 8]
- "[T]here is still low confidence that any reported long-term increases in [hurricane] activity are robust, after accounting for past changes in observing capabilities" [Ch 9]

With regards to the perception (and damage statistics) that severe weather events seem more frequent and more severe over the past decade, there are several factors in play. The first is the increasing vulnerability and exposure associated with increasing concentration of wealth in coastal and other disaster-prone regions. The second factor is natural climate variability. Many extreme weather events have documented relationships with natural climate variability; in the U.S., extreme weather events (e.g. droughts, heat waves and hurricanes) were significantly worse in the 1930's and 1950's.[8]

While climate models predict changes in extreme weather events with future warming, the time of emergence of any manmade signal relative to the large natural variability in extreme weather events is not expected to be evident until late in the 21st century, even for the most aggressive scenarios of future warming.

When considering the predictions of additional climate change impacts in the NCA4, pay attention to the confidence level ascribed to their conclusions. The NCA4 defines the confidence levels as follows:

- "Low: Inconclusive evidence (limited sources extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts"
- "Medium: Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought."
- "High: Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus"
- "Very high: Strong evidence (established theory, multiple sources, consistent results well documented and accepted methods, etc.), high consensus"

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6 IPCC Special Report on Extreme Events http://www.ipcc.ch/report/srex/
7 4th National Climate Assessment Vol 1 https://www.globalchange.gov/nca4
8 Curry, JA 2014 Senate EPW testimony http://judithcurry.com/2014/01/16/senate-epw-hearing-on-the-presidents-climate-action-plan/

These categories defy the common understanding of the words used to describe them.[9] The words used to describe 'High confidence' include 'Moderate evidence, medium consensus', which are more descriptive of the common understanding of medium confidence. The words used to describe 'Medium confidence' include: 'a few sources, limited consistency, models incomplete, methods emerging; competing schools of thought,' that are more descriptive of the common understanding of low confidence.

Apart from these semantic issues, there are very few conclusions of meaningful impacts in the NCA4 that are associated with 'very high' confidence or even 'high' confidence. For conclusions associated with low, medium and even high confidence, there is substantial room for scientific disagreement.

**The climate change response challenge**

In response to the threat of manmade climate change, the United Nations Framework Convention on Climate Change (UNFCCC) has established an international goal of stabilization of the concentrations of greenhouse gases in the atmosphere.

This framing of the climate change problem and its solution has led to the dilemma of climate response policy that is aptly described by Obersteiner et al:[10]

> The key issue is whether "betting big today" with a comprehensive global climate policy targeted at stabilization "will fundamentally reshape our common future on a global scale to our advantage, or quickly produce losses that can throw mankind into economic, social, and environmental bankruptcy."

In their 'Wrong Trousers' essay,[11] Prins and Rayner argue that we have made the wrong choices in our attempts to define the problem of climate change and its solution, by relying on strategies that worked previously for 'tame' problems. A tame problem is well defined, well understood, and the appropriate solutions are agreed upon. Cost-benefit analyses are appropriate for tame problems, and the potential harm from miscalculation is bounded.

By contrast, climate change is better characterized as a 'wicked' problem, which is a complex tangle characterized by multiple problem definitions, methods of understanding that are open to contention, 'unknown unknowns' that suggest chronic conditions of ignorance, and lack of capacity to imagine future eventualities of both the problem and the proposed solutions. The complex web of causality may result in surprising unintended consequences to attempted solutions, that generate new vulnerabilities or exacerbate the original harm. Further, the wickedness of the climate change problem makes it difficult to identify points of irrefutable failure or success in either the scientific predictions or the policies.

Overreaction to a possible catastrophic threat may cause more harm than benefits and introduce new systemic risks, which are difficult to foresee for a wicked problem. The known risks to human well being associated with constraining fossil fuels may be worse than the eventual risks from climate change, and there are undoubtedly some risks from both that we currently do not foresee.

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[9] https://judithcurry.com/2019/01/02/national-climate-assessment-a-crisis-of-epistemic-overconfidence/

[10] Obersteiner,et al. (2001) Managing Climate Riskhttp://www.iiasa.ac.at/Admin/PUB/Documents/IR-01-051.pdf

[11] Prins and Rayner, 2007. The wrong trousers: radically rethinking climate policy http://eureka.bodleian.ox.ac.uk/66/

The wickedness of the climate change problem is further manifested in the regional variability of the risks. Balancing the risks of climate change and the policy response is very difficult across different regions and countries that face varying risks from climate change, energy poverty and challenges to economic development. Some regions may actually benefit from a warmer climate. Regional perceptions of a preferred climate or 'dangerous' climate change depend on societal values and vulnerability/resilience, which vary regionally and culturally. Climate has always changed, independently of human activity, so climate change is nothing new. Further, our current preferences for avoiding a particular climate of the future fail to account for human creativity and ingenuity in creating new technologies and social and political structures that will condition our perceptions and the consequences of climate change.

Climate-related decisions involve incomplete information from a fast-moving and irreducibly uncertain science. There are many different interests and values in play, the relevant time scales are long and there is near certainty of surprise. In the context of decision making, 'deep uncertainty'[12] refers to:

- situations in which the phenomena are still only poorly understood and experts do not know or cannot agree on models that relate key forces that shape the future;
- modeling and subjective judgments are used rather than estimates based upon previous experience of actual events and outcomes; and
- experts cannot agree on the value of alternative outcomes.

The climate change problem arguably meets all three of these criteria for 'deep uncertainty.[13] Acknowledgement of deep uncertainty surrounding a problem and its solutions does not imply that 'no action' is needed. Rather, it implies that decision-analytic frameworks should be selected that are consistent with deep uncertainty.

Robust and flexible policy strategies can be designed that account for uncertainty, ignorance and dissent. Robust strategies formally consider uncertainty, whereby decision makers seek to reduce the range of possible scenarios over which the strategy performs poorly. Flexible strategies can be quickly adjusted to advancing scientific insights and new conditions that arise.

Justification for addressing the climate change problem is transitioning away from precaution to a risk management approach that addresses the economics of preventing losses from climate change. The World Bank has a recent paper entitled *Investment decision making under deep uncertainty – application to climate change*[14] that summarizes decision-making methodologies that are able to deal with the deep uncertainty associated with climate change, including robust decision making and Climate Informed Decision Analysis.

The Hartwell Paper,[15] published by the London School of Economics in cooperation with the University of Oxford, argues that: "decarbonisation will only be achieved successfully as a benefit contingent upon other goals which are politically attractive and relentlessly pragmatic." The Hartwell Paper analyzes many alternative policy approaches to decarbonization. The authors remind us that: "it is not just that science does not dictate climate policy; it is that climate policy alone does not dictate environmental or development or energy policies."

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12 Walker et al. (2016): Deep Uncertainty. doi:10.1007/978-1-4419-1153-7_1140.
13 Curry (2018) Climate uncertainty and risk. https://indd.adobe.com/view/da3d0bde-1848-474d-b080-f07200293f91
14 http://elibrary.worldbank.org/content/workingpaper/10.1596/1813-9450-6193
15 Hartwell Paper http://eprints.lse.ac.uk/27939/

The Breakthrough Institute has proposed Climate Pragmatism,[16] a pluralistic approach based on innovation, resilience and no regrets. This pragmatic strategy centers on efforts to accelerate energy innovation, build resilience to extreme weather, and pursue no regrets pollution reduction measures. Each of these three efforts has justifications independent of their benefits for climate mitigation and adaptation. Further, this framework does not depend on any agreement about climate science or the risks posed by $CO_2$ emissions.

**The urgency (?) of $CO_2$ emissions reductions**

In the decades since the 1992 UNFCCC Treaty, global $CO_2$ emissions have continued to increase, especially in developing countries. In 2010, the world's governments agreed that emissions need to be reduced so that global temperature increases are limited to below 2 degrees Celsius.[17] The target of 2°C (and increasingly 1.5°C)[18] remains the focal point of international climate agreements and negotiations.

The original rationale for the 2°C target is the idea that 'tipping points' – abrupt or nonlinear transition to a different climate state – become likely to occur once this threshold has been crossed, with consequences that are largely uncontrollable and beyond our management. The IPCC AR5 considered a number of potential tipping points, including ice sheet collapse, collapse of the Atlantic overturning circulation, and permafrost carbon release. Every single catastrophic scenario considered by the IPCC AR5 (WGII, Table 12.4) has a rating of *very unlikely* or *exceptionally unlikely* and/or has *low confidence*. The only tipping point that the IPCC considers *likely* in the 21st century is disappearance of Arctic summer sea ice (which is fairly reversible, since sea ice freezes every winter).

In the absence of tipping points on the timescale of the 21st century, the 2°C limit is more usefully considered by analogy to a highway speed limit:[19] driving at 10 mph under the speed limit is not automatically safe, and exceeding the limit by 10 mph is not automatically dangerous, although the faster one travels the greater the danger from an accident. Analogously, the 2°C (or 1.5°C) limit should not be taken literally as a real danger threshold. An analogy for considering the urgency of emissions reductions is your 401K account: if you begin making contributions early, it will be easier to meet your retirement goals.

Nevertheless, the 2°C and 1.5°C limits are used to motivate the urgency of action to reduce $CO_2$ emissions. At a recent UN Climate Summit, (former) Secretary-General Ban Ki-moon warned that: "Without significant cuts in emissions by all countries, and in key sectors, the window of opportunity to stay within less than 2 degrees [of warming] will soon close forever."[20] Actually, this window of opportunity may remain open for quite some time. The implications of the lower values of climate sensitivity found by Lewis and Curry[21] and other recent studies is that human-caused warming is not expected to exceed the 2°C 'danger' level in the 21st century. Further, there is growing evidence that the RCP8.5 scenario for future greenhouse gas concentrations, which drives the largest amount of warming in climate model simulations, is impossibly high, requiring a combination of numerous borderline impossible socioeconomic scenarios.[22] A slower rate of

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[16] http://thebreakthrough.org/blog/Climate_Pragmatism_web.pdf
[17] http://unfccc.int/essential_background/items/6031.php
[18] https://www.ipcc.ch/sr15/
[19] http://www.carbonbrief.org/blog/2014/12/two-degrees-a-selected-history-of-climate-change-speed-limit/
[20] http://unfccc.int/un-climate-summit-ban-ki-moon-final-summary/
[21] Lewis and Curry (2018) https://journals.ametsoc.org/doi/10.1175/JCLI-D-17-0667.1
[22] https://www.sciencedirect.com/science/article/abs/pii/S0360544217314597

warming means there is less urgency to phase out greenhouse gas emissions now, and more time to find ways to decarbonize the economy affordably and with a minimum of unintended consequences. It also allows for the flexibility to revise our policies as further information becomes available.

Is it possible that something truly dangerous and unforeseen could happen to Earth's climate during the 21st century? Yes it is possible, but natural climate variability (including geologic processes) may be a more likely source of possible undesirable change than manmade warming. In any event, attempting to avoid such a dangerous and unforeseen climate by reducing fossil fuel emissions will be futile if natural climate and geologic processes are dominant factors. Geologic processes are an important factor in the potential instability of the West Antarctic ice sheet that could contribute to substantial sea level rise in the 21st century.[23]

Under the Paris Agreement, individual countries have submitted to the UNFCCC their Nationally Determined Contributions (NDCs). Under the Obama Administration, the U.S. NDC had a goal of reducing emissions by 28% below 2005 levels by 2025. Apart from considerations of feasibility and cost, it has been estimated[24] using the EPA MAGICC model that this commitment will prevent 0.03°C in warming by 2100. When combined with current commitments from other nations, only a small fraction of the projected future warming will be ameliorated by these commitments. If climate models are indeed running too hot,[25] then the amount of warming prevented would be even smaller. Even if emissions immediately went to zero and the projections of climate models are to be believed, the impact on the climate would not be noticeable until the 2nd half of the 21st century. Most of the expected benefits to the climate from the UNFCCC emissions reductions policy will be realized in the 22nd century and beyond.

Attempting to use carbon dioxide as a control knob to regulate climate on decadal to century timescales is arguably futile. The UNFCCC emissions reductions policies have brought us to a point between a rock and a hard place, whereby the emissions reduction policy with its extensive costs and questions of feasibility are inadequate for making a meaningful dent in slowing down the expected warming in the 21st century. And the real societal consequences of climate change and extreme weather events (whether caused by manmade climate change or natural variability) remain largely unaddressed.

This is not to say that a transition away from burning fossil fuels doesn't make sense over the course of the 21st century. People prefer 'clean' over 'dirty' energy – provided that all other things are equal, such as reliability, security, and economy. However, assuming that current wind and solar technologies are adequate for providing the required amount and density of electric power for an advanced economy is misguided.[26]

The recent record-breaking cold outbreak in the Midwest is a stark reminder of the challenges of providing a reliable power supply in the face of extreme weather events, where an inadequate power supply not only harms the economy, but jeopardizes lives and public safety. Last week, central Minnesota experienced a natural gas 'brownout,' as Xcel Energy advised customers to

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https://www.researchgate.net/publication/303621100_The_implications_of_fossil_fuel_supply_constraints_on_climate_change_projetions-A_supply-side_analysis/download

23 Curry (2018) Sea level and climate change. https://curryja.files.wordpress.com/2018/11/special-report-sea-level-rise3.pdf (section 4.2.2)
Whitehouse et al. (2019) https://www.nature.com/articles/s41467-018-08068-y

24 Lomborg (2015) https://onlinelibrary.wiley.com/doi/full/10.1111/1758-5899.12295

25 Curry (2017) Climate models for laypersons https://www.thegwpf.org/content/uploads/2017/02/Curry-2017.pdf

26 Clack et al. (2017) https://www.pnas.org/content/114/26/6722

turn thermostats down to 60 degrees and avoid using hot water.[27] Why? Because the wind wasn't blowing during an exceptionally cold period. Utilities pair natural gas plants with wind farms, where the gas plants can be ramped up and down quickly when the wind isn't blowing. With bitter cold temperatures and no wind, there wasn't enough natural gas.

A transition to an electric power system driven solely by wind and solar would require a massive amount of energy storage. While energy storage technologies are advancing, massive deployment of cost effective energy storage technologies is well beyond current capabilities.[28] An unintended consequence of rapid deployment of wind and solar energy farms may be that natural gas power plants become increasingly entrenched in the power supply system.

Apart from energy policy, there are a number of land use practices related to croplands, grazing lands, forests and wetlands that could increase the natural sequestration of carbon and have ancillary economic and ecosystem benefits.[29] These co-benefits include improved biodiversity, soil quality, agricultural productivity and wildfire behavior modification.

In evaluating the urgency of $CO_2$ emissions reductions, we need to be realistic about what reducing emissions will actually accomplish. Drastic reductions of emissions in the U.S. will not reduce global $CO_2$ concentrations if emissions in the developing world, particularly China and India, continue to increase. If we believe the climate model simulations, we would not expect to see any changes in extreme weather/climate events until late in the 21st century. The greatest impacts will be felt in the 22nd century and beyond, in terms of reducing sea level rise and ocean acidification.

**Resilience, anti-fragility and thrivability**

Given that emissions reductions policies are very costly, politically contentious and are not expected to change the climate in a meaningful way in the 21st century, adaptation strategies are receiving increasing attention in formulating responses to climate change.

The extreme damages from recent hurricanes plus the recent billion dollar disasters from floods, droughts and wildfires, emphasize that the U.S. is highly vulnerable to current weather and climate disasters. Even worse disasters were encountered in the U.S. during the 1930's and 1950's. Possible scenarios of incremental worsening of weather and climate extremes over the course of the 21st century don't change the fundamental storyline that many regions of the U.S. are not well adapted to the current weather and climate variability, let alone the range that has been experienced over the past two centuries.

As a practical matter, adaptation has been driven by local crises associated with extreme weather and climate events, emphasizing the role of 'surprises' in shaping responses. Advocates of adaptation to climate change are not arguing for simply responding to events and changes after they occur; they are arguing for anticipatory adaptation. However, in adapting to climate change, we need to acknowledge that we cannot know how the climate will evolve in the 21st century, we are certain to be surprised and we will make mistakes along the way.

'Resilience' is the ability to 'bounce back' in the face of unexpected events. Resilience carries a connotation of returning to the original state as quickly as possible. The difference in impact and

[27] https://www.powerlineblog.com/archives/2019/01/why-green-energy-is-futile-in-one-lesson.php
[28] https://webstore.iea.org/technology-roadmap-energy-storage
[29] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf

recovery from Hurricane Sandy striking New York City in 2012 versus the impact of Tropical Cyclone Nargis striking Myanmar in 2008[30] reflects very different vulnerabilities and capacities for bouncing back.

To increase our resilience to extreme weather and climate events, we can 'bounce forward' to reduce future vulnerability by evolving our infrastructures, institutions and practices. Nicholas Taleb's concept of antifragility[31] focuses on learning from adversity, and developing approaches that enable us to thrive from high levels of volatility, particularly unexpected extreme events. Anti-fragility goes beyond 'bouncing back' to becoming even better as a result of encountering and overcoming challenges. Anti-fragile systems are dynamic rather than static, thriving and growing in new directions rather than simply maintaining the *status quo*.

Strategies to increase antifragility include: economic development, reducing the downside from volatility, developing a range of options, tinkering with small experiments, and developing and testing transformative ideas. Antifragility is consistent with decentralized models of policy innovation that create flexibility and redundance in the face of volatility. This 'innovation dividend' is analogous to biodiversity in the natural world, enhancing resilience in the face of future shocks.[32]

Similar to anti-fragility, the concept of 'thrivability' has been articulated by Jean Russell:[33]

> "It isn't enough to repair the damage our progress has brought. It is also not enough to manage our risks and be more shock-resistant. Now is not only the time to course correct and be more resilient. It is a time to imagine what we can generate for the world. Not only can we work to minimize our footprint but we can also create positive handprints. It is time to strive for a world that thrives."

A focus on policies that support resilience, anti-fragility and thrivability avoids the hubris of thinking we can predict the future climate. The relevant questions then become:

- How can we best promote the development of transformative ideas and technologies?
- How much resilience can we afford?

The threats from climate change (whether natural or human caused) are fundamentally regional, associated not only with regional changes to the weather/climate, but with local vulnerabilities and cultural values and perceptions. In the least developed countries, energy poverty and survivability is of overwhelming concern, where there are severe challenges to meeting basic needs and their idea of clean energy is something other than burning dung inside their dwelling for cooking and heating. In many less developed countries, particularly in South Asia, an overwhelming concern is vulnerability to extreme weather events such as floods and hurricanes that can set back the local economies for a generation. In the developed world, countries are relatively less vulnerable to climate change and extreme weather events and have the luxury of experimenting with new ideas: entrepreneurs not only want to make money, but also to strive for greatness and transform the infrastructure for society.

Extreme weather/climate events such as landfalling major hurricanes, floods, extreme heat waves and droughts become catastrophes through a combination of large populations, large and exposed infrastructure in vulnerable locations, and human modification of natural systems that can provide

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[30] Webster, (2008) Myanmar's Deadly Daffodil. http://webster.eas.gatech.edu/Papers/Webster2008c.pdf
[31] Taleb, (2012) Antifragile: Things That Gain From Disorder. Random House.
[32] Lynch: Policy Diversity: Creative Potential or Wasteful Redundancy? https://slideplayer.com/slide/6265255/
[33] Russell (2013) https://www.amazon.com/Thrivability-Breaking-through-World-Works/dp/1909470287

a natural safety barrier (e.g. deforestation, draining wetlands). Addressing current adaptive deficits and planning for climate compatible development will increase societal resilience to future extreme events that may possibly be more frequent or severe in the future.

**Ways forward**

Climate scientists have made a forceful argument for a future threat from manmade climate change. Based upon our current assessment of the science, the threat does not seem to be an existential one on the time scale of the 21$^{st}$ century, even in its most alarming incarnation. However, the perception of manmade climate change as a near-term apocalypse and alignment with range of other social objectives has narrowed the policy options that we're willing to consider.

Effectively responding to the possible threats from a warmer climate is challenging because of the deep uncertainties surrounding the risks both from the problem and the proposed solutions. The wickedness of the climate change problem provides much scope for disagreement among reasonable and intelligent people.

With regards to energy policy and its role in reducing emissions, consider the following three options:

1. Do nothing, continue with the status quo
2. Rapidly deploy wind and solar power plants, with the goal of eliminating fossil fuels on the timescale of 1-2 decades
3. Re-imagine 21$^{st}$ century electric power generation and transmission systems with new technologies that improve energy security, reliability and cost while at the same time minimizing environmental impacts.

The current climate/energy policy debate seems to be #1 versus #2; in my opinion, neither of these options gets us where we want to be in terms of thriving economically and minimizing the environmental impact of energy generation. #3 in principle can usher in a new era of abundant, clean energy, but we can't put an arbitrary timetable/deadline on this; it will require substantial research, development and experimentation. In the meantime, muddling along with some combination of #1 and #2 can improve the situation somewhat. Ironically, acting urgently on emissions reduction by massively deploying solar and wind power could entrench natural gas in the power system and turn out to be the enemy of a better long-term solution. Focusing on #3 has the potential to eliminate the current gridlock of debating #1 versus #2, and provides the best option for a long-term solution.

A regional focus on adapting to the risks of climate change allows for a range of bottom-up strategies to be integrated with other societal challenges, including growing population, environmental degradation, poorly planned land-use and over-exploitation of natural resources. Even if the threat from global warming turns out to be small, near-term benefits to the region can be realized in terms of reduced vulnerability to a broad range of threats, improved resource management, and improved environmental quality. Securing the common interest on local and regional scales provides a basis for the successful implementation of climate adaptation strategies and addressing near-term social justice objectives.

Bipartisan support seems feasible for pragmatic efforts to:

- accelerate energy innovation
- build resilience to extreme events
- pursue no regrets pollution reduction measures

Each of these three efforts has justifications independent of their benefits for climate mitigation and adaptation. These three efforts provide the basis for a climate policy that addresses near-term economic and social justice concerns and the longer-term goals of mitigation.

The role for climate science and climate scientists in the policy process has been complex. In the past 20 years, dominated by the IPCC/UNFCCC paradigm, scientists have become entangled in an acrimonious scientific and political debate, where the issues in each have become confounded. This has generated much polarization in the scientific community and has resulted in political attacks on scientists on both sides of the debate. A scientist's 'side' is often defined by factors that are exogenous to the actual scientific debate. Debates over relatively arcane aspects of the scientific argument have become a substitute for what should be a real debate about politics and values.

Scientific progress is driven by uncertainty and disagreement; working to resolve these uncertainties and disagreements drives the knowledge frontier forward. Attempts by government policy makers to intimidate climate scientists[34] whose research or public statements are perceived to be in opposition to a preferred policy narrative are enormously detrimental to scientific progress.

I am making one 'ask' today: please allow climate science and the research process to proceed unfettered by political attacks on scientists. We need to acknowledge that climate-related decisions involve incomplete information from a fast-moving and irreducibly uncertain science. Uncertainty and disagreement is what drives the knowledge frontier forward; please help that process to flourish. Only in the most simple-minded policy making frameworks does scientific uncertainty and disagreement prescribe 'no action.'

It is up to the political process (international, national, and local) to decide how to contend with the climate problem, with all of its uncertainties, complexity and wickedness. The challenge is to open up the decision making processes in a way that is more honestly political and economic, while giving proper weight to scientific reason, evidence and uncertainty.

[34] http://www.hillheat.com/articles/2015/02/24/rep-grijalva-asks-for-conflict-of-interest-disclosures-from-gops-go-to-climate-science-witnesses

**Short Biography**

Dr. Judith Curry is President of Climate Forecast Applications Network (CFAN) and Professor Emerita of Earth and Atmospheric Sciences at the Georgia Institute of Technology. Dr. Curry received a Ph.D. in atmospheric science from the University of Chicago in 1982. Prior to joining the faculty at Georgia Tech as Chair of the School of Earth and Atmospheric Sciences, she held faculty positions at the University of Colorado, Penn State University and Purdue University. Dr. Curry's research interests span a range of topics in weather and climate. She has authored over 190 scientific papers and is author of the textbooks *Thermodynamics of Atmospheres and Oceans* and *Thermodynamics, Kinetics and Microphysics of Clouds*. She is a prominent public spokesperson on issues associated with the integrity of climate science, and is proprietor the weblog Climate Etc. judithcurry.com. Dr. Curry has recently served on the NASA Advisory Council Earth Science Subcommittee, the DOE Biological and Environmental Research Advisory Committee, and the National Academies Climate Research Committee and the Space Studies Board and the NOAA Climate Working Group. Dr. Curry is a Fellow of the American Meteorological Society, the American Association for the Advancement of Science, and the American Geophysical Union.

**Financial declaration**

Funding sources for Curry's research have included NSF, NASA, NOAA, DOD and DOE. Recent contracts for CFAN include a NOAA contract to improve subseasonal weather forecasts, a DOE contract to develop extended-range regional wind power forecasts, and a DOD contract to predict extreme events associated with climate variability/change having implications for regional stability. CFAN's clients include other weather service providers, energy and power companies, reinsurance and asset management companies, nongovernmental organizations and development banks.

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For more information:

http://curry.eas.gatech.edu/
http://www.cfanclimate.net/
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