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Risky Business: How Climate Change is Changing Insurance Markets

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I thank the Chairman, Ranking Member and the Committee for the opportunity to offer testimony today on "Risky Business: How Climate Change is Changing Insurance Markets." 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 climate dynamics and severe weather, particularly hurricanes.

For the past 15 years, through my company CFAN, I have engaged with decision makers in both the private and public sectors on issues extreme weather and climate change. CFAN's primary objective is to translate cutting-edge weather and climate research into forecast products that support the mitigation of weather and climate risks. 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.

Since 2017, CFAN has been engaging with clients in the insurance sector: insurance, reinsurance, and asset management companies with Insurance Linked Securities (ILS) funds. Of specific relevance to this Hearing, I have authored a book titled *Climate Uncertainty and Risk* that has been extensively peer reviewed and is in press at Anthem Press (an academic press).

With this perspective, my testimony focuses on the following issues of central relevance to climate change and insurance markets:

- The "climate crisis" isn't what it used to be
- Mischaracterization of climate risk
- The insurance sector and climate change
- Global warming and hurricanes
- Adaptation to extreme weather events
- Risks from a rapid transition of electric power systems
- Ways forward to manage climate-related insurance risk

The "climate crisis"

The insurance market is influenced by our perceptions of risk. Risk perception is our subjective judgment or appraisal of risk, which can involve social, cultural, political and psychological factors. Referring to climate change as a "crisis" is at odds with professional judgments of climate risk.[1]

The "climate crisis" isn't what it used to be. Circa 2013 with publication of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the extreme emissions scenario RCP8.5 was regarded as a baseline business-as-usual emissions scenario, with expected warming of 4 to 5^oC (7 to 9^oF) by 2100.

Now, there is general acceptance that the RCP8.5 scenario is implausible. The Conference of Parties (COP) to the UNFCCC Agreement dropped consideration of the RCP8.5 scenario in COP26 (2021) and COP27 (2022). COP27 is working from a baseline temperature projection based on RCP4.5 (SSP2-4.5) of 2.5^oC by 2100, relative to temperatures in the late 19th century (note: 1.1^oC of warming has already occurred). Only a few years ago, an emissions trajectory that followed RCP4.5 with 2 to 3^oC (4 to 5^oF) warming was regarded as climate policy success.

An additional factor in reducing the magnitude of risk from human-caused warming is that our understanding of the sensitivity of the climate to atmospheric CO_2 has increased. The IPCC Sixth Assessment Report (AR6) reduced the upper bound of the likely range of equilibrium climate sensitivity from 4.5 to 4.0^oC.[2] A recent paper challenged the main analysis used by the IPCC AR6 by identifying errors, outdated input values, and concerns about the statistical analysis method. This paper found that climate sensitivity is considerably more likely to be below 2^oC than above 2.5^oC.[3]

The IPCC AR6 recognized that a substantial number of climate models are running "too hot." Therefore, the AR6 adopted a new approach to make 21st century temperature projections that combined the climate model projections with observational constraints on simulated past warming and best estimates of the climate sensitivity.[4] These constraints reduced the climate model projections of warming by up to 20% for the higher emissions scenarios. This new constrained procedure used by the AR6 is significant because it breaks the hegemony of the global climate models in dominating the IPCC's conclusions about twenty-first century climate change.

There are additional reasons to expect less warming than indicated by the COP27 projections. Plausible scenarios of natural climate variability in the mid-21st century (not included in the climate model simulations) point to a slowdown in the rate of global warming driven by: an expected solar minimum,[5,6] the possibility of explosive volcanic eruptions,[7,8] and a projected shift in multi-decadal ocean circulation patterns.[9,10]

The mainstream media is currently awash with articles from prominent journalists on how the global warming threat is less than we thought.[11] However, the rationale for continuing to sound the alarm is that the *impacts* are worse than we thought, specifically with regards to extreme weather. Climate crisis rhetoric is now linked to extreme weather events, most of which are difficult to identify any role for human-caused climate change in increasing either their intensity or frequency against the large natural variations in weather and climate variability.

The IPCC AR6 Summary for Policy Makers highlights the following changes in extreme weather: increased intensity and frequency of heat waves plus reduced intensity and frequency of cold waves since 1950; increased frequency and intensity of heavy precipitation events since 1950; and a *likely* increase in the global proportion of major (Category 3–5) tropical cyclone (hurricane) occurrence over the last four decades.[12] It is significant what is *not* mentioned in the Summary for Policy Makers. Chapters Eleven and Twelve in the IPCC AR6 identify the following event types for which there is either no change or low confidence in any change: meteorological and hydrological droughts; extratropical storms; total number of tropical cyclones; and tornadoes, hail, and lightning associated with severe convective storms.[13,14]

Examination of historical data records of extreme weather events in the U.S. shows that, in nearly all regions of the U.S., conditions during the 1930s were worse than what we've seen in the early 21st century: the most intense landfalling hurricane, greatest magnitude and frequency of heat waves, worst droughts, and worst wildfires.[15] The magnitude and frequency of extreme weather events do not scale simply with an increase in global temperature; natural weather and climate variability dominate the occurrence of these events.

Despite the moderate and equivocal conclusions of the IPCC, every extreme weather event now gets associated in the media with human-caused global warming, distorting our perception of climate risk. Any change in the intensity or frequency of extreme weather events is incremental at most; even if a change in the event type has been detected, attributing any change to emissions-driven warming is not at all straightforward. Quantitative forward projection of any changes is highly uncertain.[16]

With regard to the perception that severe weather events seem more frequent and more severe over the past decade, there are several factors in play. The first factor is increasing vulnerability and exposure associated with increasing population and 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. A recent analysis summarizing many studies finds no evidence to support claims that any part of the overall increase in global economic losses (when scaled by GDP) from weather and climate disasters can be attributed to global warming.[17]

And finally, it is difficult to overstate the importance of the shift in expectations for extreme weather events that is represented by the rejection of the RCP8.5 emissions scenario as implausible.[18,19] The IPCC, the U.S. National Climate Assessment, and a majority of published papers have centered their analyses on RCP8.5 as a reference scenario against which climate impacts and policies are evaluated.[20] Rejection of the RCP8.5 emissions scenario has rendered obsolete much of the climate impacts literature of the past decade, which have focused on RCP8.5. It is now clear that climate impact assessments have been biased in an alarming direction by continued inclusion, and even sole reliance, on RCP8.5 in most studies.

Mischaracterization of climate risk

What has been cast as a global "crisis" is for the most part thousands of local vulnerability emergencies that are revealed by extreme weather events. The misidentification of climate change as a "crisis" and the ensuing precautionary mandate to urgently and rapidly eliminate the use of fossil fuels is creating new risks, while failing to address the current risks associated with extreme weather events.

Climate change risk includes elements of both incremental risk and emergency risk. Incremental risk displays creeping characteristics and the "fat tail" effect. Since changes take place slowly, the adverse consequences take a long time to emerge as impacts accumulate and worsen over time. The slow creep of sea level rise is an example of incremental climate risk. By contrast, emergency risks are associated with extreme weather events.

The rationale for the rapid transition away from fossil fuels conflates incremental and emergency risk. The proposed management strategy for both risk categories is to eliminate CO_2 emissions. This strategy may have some incremental benefits in the 22nd century, but will not help with the emergency risks associated with extreme weather events in the 21st century. The urgency of addressing emergency risk is being used to motivate the urgency of reducing emissions. Ironically, costly and suboptimal attempts to rapidly reduce emissions are exacerbating energy unreliability, which is increasing emergency risk through increased vulnerability.

A key to securing meaningful action to reduce climate change risk is to clearly separate the incremental, emerging risks associated with long-term changes in average conditions from the emergency risks associated with extreme weather and climate events. Governance of climate risk needs to approach these two kinds of risk differently. Emergency risks need to be addressed in both the present and future climate.

One would logically think that if warming is less than we thought but impacts are worse, then the priorities would shift away from CO_2 mitigation towards adaptation. However, that hasn't been the case. Once the incremental risks are separated from the emergency risks, the perception of urgency in reducing emissions is diminished. It becomes far more important to develop strategies for managing atmospheric greenhouse gases in ways that do not have an adverse impact on security, the economy, industry or agriculture. At this point, assessing the transition risks associated with rapidly eliminating fossil fuels is arguably more important than attempting to refine our assessments of the incremental risks associated with continuing fossil fuel emissions.

The insurance sector and climate change

My company CFAN has ten clients in the insurance sector, most of which are related to Insurance Linked Securities (ILS) funds and catastrophe bonds. My specific engagement with this sector is to provide seasonal forecasts of hurricane activity, advanced hurricane forecast products to support live trading of catastrophe bonds, analyses of post landfall impacts, and general educational materials regarding climate change and weather/climate hazards. CFAN actively participates in insurance sector conferences and subscribes to numerous newsletters related to ILS, catastrophe bonds and reinsurance. CFAN also interacts with startup companies in the sector that are working to develop new risk transfer tools, as well as working with companies in Africa and South Asia with regards to agricultural insurance. With this context, I provide the following remarks.

There is a lot of discussion at insurance conferences and in newsletters about taking climate change into account in calculating insurance risk. Privately, insurance industry leaders state that climate change isn't taken into account since 90% of property and casualty policies last 12 months. Any change in climate related impacts can't be effectively measured on the time scale of a year. However, the industry is under pressure from investors that are reacting to an exaggerated public narrative surrounding climate change, as well as confusing weather with climate.

Catastrophe bonds, or "cat bonds," have been developed over the past 25 years as an alternative to property and casualty reinsurance. A cat bond is a contract to cover risk that provides payouts triggered by specific events. Losses due to Atlantic hurricanes were the impetus for the creation of cat bonds and remain the primary market driver.[21] There are now 51 funds that specialize in cat bonds, some of which are affiliated with reinsurance companies and others associated with capital and asset management companies. Cat bonds have lowered the costs of diversifying insurers' exposure to natural disaster risk by attracting alternative sources of capital and increasing the total capital available for the transfer of insurance risks. For investors, the appeal of cat bonds is that they are largely uncorrelated with the returns of other financial market instruments. Cat bond investment returns are at their highest levels ever, and a substantial amount of money is moving into these funds (ILS funds currently exceed $100B.)[22]

However, because cat bonds are uniquely tailored, the bonds are thinly traded in private markets. Hence, current markets lack efficiency and the ability to attract additional capital that standardized bonds could bring, possibly through public markets.

Climate change is viewed as stimulating the cat bond market as new investible risks become available.[23] Some insurance thought leaders see climate change and its perceived threats as providing an opportunity to broaden the relevance of the insurance sector to risk mitigation. Efforts to move forward with climate adaptation are creating new opportunities to underwrite climate-exposed risk. Shifting business models could focus on preventing customers from incurring damage and having to make claims by better managing and avoiding risk. Insurers could also work with the public sector to improve building standards and land use policies.[24]

Global warming and hurricanes

Landfalling hurricanes incur the greatest property and casualty losses in the U.S. among extreme weather events.

The IPCC AR6 (Chapter Eleven) summarizes the expected impacts of future warming on global hurricane activity:

- "Peak wind speeds of the most intense tropical cyclones (hurricanes) are projected to increase at the global scale with increasing global warming (high confidence). The increase in global TC maximum surface wind speeds is about 5 percent for a 2°C global warming across a number of high-resolution multi-decadal studies"
- "It is *very likely* that heavy precipitation events will intensify and become more frequent in most regions with additional global warming. At the global scale, extreme daily precipitation events are projected to intensify by about 7 percent for each 1°C of global warming (high confidence)."

Shortly before publication of the IPCC AR6, two assessment reports were published by a distinguished international group of scientists who serve on the World Meteorological Organization (WMO) Task Team on Tropical Cyclones.[25,26] Apart from detecting poleward migration of the latitude of maximum intensity in the northwest Pacific basin, the majority of the author team had only low confidence that any other observed tropical cyclone changes represented either detectable changes or attributable anthropogenic changes. The relatively low confidence in tropical cyclone change detection results from observational limitations and the smallness of the expected human-caused change (signal) relative to the expected natural variability (noise).

With regards to future changes, the WMO Report relied on model results and expert judgment for a 2°C warming:

1. For hurricane intensity (maximum wind speed), there is medium-to-high confidence that the global average will increase. The median projected increase in lifetime maximum surface wind speeds is about 5% (range 1–10%).
2. For the global *proportion* of hurricanes that reach Category 4–5 levels, there is at least medium-to-high confidence in an increase, with a median projected change of +13%.

Author opinion was more mixed and confidence levels lower for the following projections:

1. A *decrease* of global hurricane frequency, as projected in most modeling studies
2. An increase in the global *number* of very intense hurricanes (Category 4–5).

The insurance industry's perception of a substantial increase in damage from U.S. landfall hurricanes is influenced by three recent reports:

- AIR Worldwide (2020): *Quantifying the Impact from Climate Change on U.S. Hurricane Risk*[27]
- Twelve Capital (2022): *Managing U.S. Hurricane Landfall Risk in a Changing Climate*[28]
- First Street Foundation (2023): *The 7th National Risk Assessment: Worsening Winds*[29]

These three studies focusing on U.S. hurricane risk circa 2050 use comparable approaches, albeit with some different assumptions. My analysis here focuses on the AIR Report, which is the most comprehensive. The headline conclusion from the AIR Report is:

> "The growth in the number of stronger storms, and landfalling storms overall, increases modeled losses by approximately 20%, with slightly larger changes in areas such as the Gulf and Southeast coasts"[30]

My critique focuses solely on the hazard component of AIR's analysis:

1. The driver for AIR's assessment is warming associated with the emissions scenario RCP8.5, which AIR refers to as a "business as usual scenario." This scenario has been judged as implausible by energy economists and is no longer used in international policy making.

The projected incremental temperature change between 2020 and 2050 for the RCP4.6 scenario (as per the IPCC AR6, Table SPM.1) is 0.9^{o}C (compared to 1.4^{o}C for RCP8.5).[31] I have argued previously in this Report that the IPCC temperature projections for 2050 may be too high, when plausible lower values of climate sensitivity and natural climate variability are considered.

2. Their assumed changes in the numbers of Category 3,4,5 hurricanes are inconsistent with recent IPCC and WMO assessment reports.

AIR assumes an increase by 2050 of the frequency increased frequency of Category 3, 4, and 5 storms of 15%, 25%, and 35%, respectively, with frequencies of Category 1,2 storms held at today's values. This implies an *increase* of >20% in the total number of hurricanes. By contrast, a *decrease* of global hurricane frequency is projected in most modelling studies (WMO Report)[32], although there is relatively low confidence in these projections. The WMO Report cites low confidence in an increase in the global number of very intense hurricanes (Categories 4–5). The WMO Report also cites medium-to-high confidence in a median increase of +13% in the global proportion of hurricanes that reach Category 4–5 levels, reflecting a small shift in the distribution of hurricane intensities.

3. The AIR Report ignores the "elephant in the room" that is of relevance to their target period to 2050: the Atlantic Multi-decadal Oscillation (AMO). An expected shift to the cool phase of the AMO would arguably portend fewer major hurricanes striking the U.S., particularly Florida.

Given the dominant influence on Atlantic hurricane activity of the Atlantic Multidecadal Oscillation (AMO), arguably the single most important factor determining Atlantic hurricane activity for the next 30 years would be a shift to the cold phase of the AMO. Analysis of historical and paleoclimatic records suggest that a transition to the next cold phase is expected is expected in the next few decades. The AMO not only influences the number of major Atlantic hurricanes, but also the preferred location of U.S. landfalls. Florida and North Carolina showed markedly fewer hurricane landfalls during the previous cool phase of the AMO. The timing of a future shift to the cold phase of the AMO remains uncertain. Whether a future cold phase would have a comparable distribution of landfalls also remains uncertain. A scenario of reduced U.S. landfalling hurricanes between 2020 and 2050 is justified by empirical evidence from the historical record in context of a possible (or even likely) shift to the cold phase of the AMO in the next few decades.[33]

The net impact of such Reports of implausibly high projections of U.S. landfalling hurricanes by 2050 is to provide unjustified confidence in a future of substantially elevated hurricane damage. Overconfidence in such projections can result in inappropriate notions of insurability, inappropriate pricing of insurance, and the misguided confidence levels of investors.

Adaptation to extreme weather

We are not passive victims in the face of climate variability and change. The success of human adaptation to weather and climate extremes is reflected by the fact that global deaths and economic damage from weather and climate disasters dropped 80–90 percent during the last four decades, when scaled for population and gross domestic product (GDP) changes.[34]

The extreme damages from recent hurricanes plus 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 1930s and 1950s. Possible scenarios of incremental worsening of weather and climate extremes over the course of the 21st century don't change the fundamental fact 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 century and could be expected to occur in the future.

Disaster risk and impacts can be reduced by tackling fundamental issues that cause vulnerability, no matter what the evolution of the future weather and climate. Synergy among land use policies, technological innovation, infrastructure, and operational plans can reduce vulnerability to weather and climate extremes. Risk management, risk sharing, and warning strategies are also key for adapting to extreme weather events and climate change. To the extent that vulnerabilities can be reduced across regions in the U.S. and various economic sectors, insurance losses will likely be reduced.

Microeconomics of adaptation

The microeconomic approach for climate change adaptation addresses the role of market mechanisms in increasing local resilience. Environmental economist Matthew Kahn posits that owing to free markets, we are growing increasingly resilient and suffering less from the "punches that Mother Nature is throwing."[35]

Climate resilience is an increasingly valued public good. Cities and geographic areas that develop an edge in being resilient in the face of climate risks will experience greater economic growth. This resilience edge can be built up either due to natural advantage (physical location and topography) or local collective action in figuring out how to protect themselves against the threats of extreme heat and cold, droughts and floods, sea level rise and wildfire risk. Property owners in locations that are particularly susceptible to risks from extreme events have strong incentives to seek out solutions both through private markets and local government policies.

Banks and insurers can nudge real estate buyers to reduce their demand in risk-prone locations and increase their demand for housing and real estate in safer places. Changes to zoning codes to up-zone in safer places featuring less weather- and climate-related risk will result in increased housing supply in safer places. The end result is not to completely desert fire- and flood-prone areas, because these are often desirable and productive locations. Civil engineers can design productive real estate assets that are acclimated to the risks. An alternative approach to building resilient real estate is to build less durable structures that are meant to have a lifetime of less than 20 years. The owner of the property would have less capital at risk and holds an option to rebuild or not in the future.

Kahn argues that the key to this smooth adaptation dynamic is for government to retreat. Government is currently taxing people on higher ground to subsidize people taking risks on lower ground – politically, this may not be a sustainable situation. When the government subsidizes insurance in flood zones and fire zones, this creates a moral hazard effect of reducing the likelihood that owners of at-risk property take appropriate precautions. As the federal government crowds out private insurance sector investment in addressing climate-related risk, adaptation efforts may be slowed.

Planning to fail safely

Extreme weather events will continue to challenge the ability of infrastructure systems to supply critical services. Critical infrastructure systems include electric power systems, oil and gas networks, water networks, transportation networks, telecommunications and computer systems. These complex systems are increasingly interdependent on each other, at scales ranging from the local to global. For example, operation of water and telecommunications systems requires a steady supply of electricity. The generation and delivery of electric power requires the availability of fuel and water plus telecommunication and computer services. These interdependencies can turn a local disturbance in a single system into a large-scale systemic failure, with catastrophic impacts that include property loss and casualties.[36]

Power outages associated with extreme weather events are estimated to cost U.S. businesses tens of billions of dollars per year, and the cost trend is increasing.[37] Failure of electric power systems during events such as a hurricane are unavoidable; the challenge is to restore power as quickly as possible to avoid cascading disasters. Extended power outages during Hurricane Sandy resulted in additional property damage and casualties.[38] Power outages or brownouts during extreme heat and cold events are avoidable with adequate electric power infrastructure and grid management. With both inadequate infrastructure and grid management, the extreme cold event in Texas during February 2021 resulted in power outages that caused $11.2 B in property damage[39] and 246 deaths.[40]

Designing systems so they are safe-to-fail includes operational plans to minimize the consequences of failure.[41] Safe-to-fail strategies can minimize the damage to electric utilities from an extreme event even if the physical electric power infrastructure is inadequate and unavoidably damaged.

An exemplary example of safe-to-fail is provided by the manner in which Florida Power & Light (FPL) manages to quickly restore electric power following a hurricane. Following Hurricane Wilma, FPL embarked on a program called Storm Secure. Significant investments have been made to harden the grid, and they have implemented strategies to make the grid smarter. FPL uses advanced weather forecast products to anticipate power outages. They have also implemented protocols to rapidly restore power following a hurricane. Continued efforts to strengthen energy grid, coupled with innovative smart grid technology and rapid restoration of power outages, have led to national recognition of FPL for best-in-nation service reliability.[42] The property and casualty losses avoided by FPL's actions prior to, during and following a hurricane are incalculable, but almost certainly substantial.

Resilience traps

Resilience is the ability to bounce back in the face of unexpected events. Resilience carries a connotation of returning to the original state, or "bouncing back," as quickly as possible. To increase our resilience to extreme weather and climate events, we need to "bounce forward" by evolving our infrastructures, institutions and practices.

A substantial concern about adaptation is the potential for creating resilience traps. An overemphasis on recovery without transformation entrenches resilience traps if recovery acts to inhibit positive transformation and perpetuate maladaptive states. Distorted incentives and government policies can create resilience traps. Current federal government policies distort incentives in a way that increases vulnerability to extreme weather events, resulting in public investment that protects unwise private investments. These policies include subsidized flood insurance and federal funding for reconstruction after a disaster, which encourages people to build in areas known to be vulnerable. Providing aid to rebuild in the areas that were damaged reinforces the incentive to downplay risks.

The most politically important hurricane that you have probably never heard of is Hurricane Frederic, a Category 3 hurricane that struck Alabama and Mississippi in 1979. This landfall occurred shortly after FEMA was established, and it was the focal point for nearly $250 million in federal aid for recovery. In 1992, following the catastrophic damage to Miami from Hurricane Andrew, Robert Sheets (then Director of the National Hurricane Center) stated in Congressional testimony that he credited the aid for Frederic's recovery with spurring development in hurricane prone regions.[43]

Also of concern is FEMA's National Flood Insurance Program, which provides coverage at subsidized rates for homes deemed too risky for commercial insurers. The Program's artificially low cost encourages residents to repeatedly rebuild their homes rather than move away. Efforts to reform the program have stalled because the resulting rate hikes would disadvantage low-income policyholders. As of 2012, repetitive loss properties that have been rebuilt multiple times using federal flood insurance payouts had cost U.S. taxpayers more than $12 billion.[44]

The emphasis on restoring the status quo engenders norms and policies that inhibit the ability of communities to transform. Changing the motivations to build back better or to locate in places with lower risk is far more cost-effective than continuing to defend unwise investments.

Risks from a rapid transition of electric power systems

When insurers refer to "climate transition risk," they are generally referring to risks from contracts with the fossil fuel industry associated with expected losses in asset values as government policies and private actions shift toward a low-carbon economy.

There is another critical element to transition risk that impacts the U.S. economy, the U.S. government budget and the insurance industry. The unfortunate reality is that efforts to rapidly move to a low-carbon economy are creating systemic risks through increasing the cost and decreasing the reliability of electric power—this is far more dangerous in the short term than incremental climate risk. The social and economic costs of unreliable power and outages are of primarily relevance to this Hearing, particularly as they increase property losses and casualties.

Because of the role of electricity as the backbone of our economy and societal support systems, risks to the electric power system are systemic risks, with implications for property loss and casualties. Focusing on one set of risks—CO_2 emissions—can create other, potentially more dangerous risks. If efforts to reduce CO_2 emissions result in electric power that is less abundant, less reliable, and/or less secure, then the transition will make people worse off now and very possibly in the future. If people are worse off, vulnerability to extreme weather events and insurance losses will increase.

By relaxing the time horizon for the energy transition to be consistent with the incremental risk from climate change, the transition risk can be reduced while maintaining energy abundance, reliability, and security through the energy transition.

Ironically, Environmental, Social and Governance (ESG) objectives that are increasingly being met by divesting from fossil fuel companies may turn out to be counterproductive to a rapid and robust energy transition. The perceived urgency and priority of eliminating fossil fuels is having two adverse impacts on the transition:

- Strategies to reduce fossil fuel production and use in the near term are slowing down the transition, during a period when substantial additional energy is needed to implement new clean technologies, as well as to support the additional electricity required by growing numbers of electric vehicles and heat pumps.
- The perceived urgency demands that we use existing technologies, primarily wind and solar power. However, some of the technologies required to robustly integrate wind and solar power into the grid do not exist or are exceedingly expensive. Further, land use requirements for wind/solar farms and additional transmission lines are engendering conflicts with other desired uses of the land. The net result is to downplay the role of more advanced energy technologies that are under development.

In my own household, the amount of electricity used has more than doubled following installation of heat pump furnaces, electric water heaters, an induction stovetop and the purchase of an electric vehicle. Solar panels that were installed in 2020 to cover more than our annual electric power usage now cover significantly less than half of our electricity usage. While the transition of households to electric power is a step in the right direction as part of a learning curve, we need to acknowledge that substantially more electric power will be needed to fuel this particular element of the transition; in the near term, this is predominantly fossil fuels.

The transition is not just about replacing our current generating capacity with cleaner energy. We need to acknowledge that the world will need much more energy in the future than it is currently consuming. More electricity can help reduce our vulnerability to weather and climate extremes: air conditioners and cleaners, water desalination plants, irrigation, vertical farming operations, water pumps, and environmental monitoring systems. Further, abundant electricity is key to innovations that will support our future prosperity and wealth.

Countries that have achieved greater than 80% of their energy supplies from renewable energy rely on hydropower and geothermal energy, not solar and wind. These countries include Iceland, Paraguay, Costa Rica, Norway and Brazil. The advantage of hydropower and geothermal power is that they are dispatchable and available on demand. Wind and solar resources are highly intermittent and asynchronous, resulting in mismatches between electricity supply and demand. As the grid penetration of wind and solar power increases, these challenges become increasingly difficult to overcome.

Stringent renewable energy standards are mandated in a number of states, focused on wind and solar energy. Unfortunately, insufficient attention is being paid to the perspectives of engineers that actually plan and operate electric power systems to insure a reliable and secure supply of power. At my blog *Climate Etc*. (judithcurry.com), I am providing a forum for power system engineers and operators to present their concerns about increasing penetration of wind and solar into the grid. They are providing assessments of proposed solutions from power systems around the world, including a recent series on Australia's aggressive renewable energy transition to wind and solar.[45,46,47] The conclusions from these analyses are that known solutions to integrating large amounts of wind and solar into the grid are expensive, and there are a number of problems that are currently without solutions. The substantial extra costs of supporting renewable energy have the end result of contributing to a deteriorating quality of electricity supply. These issues do not appear to have been considered in state mandates for renewable energy based on wind and solar.

Variability of wind and solar power ranges from intermittency on time scales of minutes, to diurnal variations, variations from weather systems, seasonal cycles, interannual variability and even decadal-scale variability. Brownouts and electricity curtailments have become more frequent during both cold and heat extremes. The worst problems are associated with continental-scale high pressure systems during winter, which produce very cold temperatures and still winds—demand is exceptionally high and supply from renewables is very low. The duration of these extreme heat and cold events can extend to weeks. Apart from lack of generation by wind and solar, natural gas supplies can be compromised during extreme cold events. Now that many coal and nuclear power plants have shut down, a lack of onsite fuel storage contributed to the Texas outages in 2022 and the Christmas 2022 blackouts in areas served by the Tennessee Valley Authority.[48]

The push for weather-based renewable energy (wind, solar, hydro) seems rather contradictory. One of the main motivations for urgently transitioning away from fossil fuels is to avoid the extreme weather that is alleged to be associated with increasing CO_2 levels. So why subject our energy production to the vagaries of water droughts and wind droughts, cold temperature extremes, icing and snow, cloudiness and forest fires? The rapid transition towards weather-sensitive renewable energy is introducing systemic risk into our economy, including insurance risk.

Ways forward to manage climate-related insurance risk

The near-term risks from human-caused climate change have been exaggerated and confused by conflating the slow incremental risk from warming with emergency risk associated with extreme weather events that has little if anything to do with warming. The dominance of implausible emissions scenarios in climate assessment reports has misled our perceptions of climate risk and our policies. Of greatest relevance to the insurance sector, there is little justification to expect a noticeable change in U.S. hurricane landfalls over the next several decades beyond what has been encountered over the past century.

Climate change and its perceived threats provide opportunities to broaden the relevance of the insurance sector to risk mitigation. Climate adaptation provides new opportunities to underwrite climate-exposed risk. Insurance companies have the opportunity to expand their role by helping prevent customers from incurring damage and having to make claims and working with the public sector to improve building standards and land use policies. Both insurance companies and the government can work towards avoiding the moral hazards of resilience traps, by subsidizing risky behavior that reduces the likelihood that owners of at-risk property take appropriate precautions.

Climate variability and change, with the attendant extreme weather events, is best regarded as an ongoing predicament. Even if human-caused climate change is somehow eliminated, natural climate variability and inevitable surprises will provide ongoing challenges that require continuing adaptation by communities and mechanisms to transfer risk.

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,* and *Climate Uncertainty and Risk* (Anthem Press, forthcoming). She is a prominent public spokesperson on issues associated with the integrity of climate research and assessments, and is proprietor the weblog *Climate Etc.* judithcurry.com. Dr. Curry has 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.

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Specifically with regards to CFAN's energy-related clients: CFAN has clients in the emergency preparedness division of several electric utilities, for which CFAN provides forecasts of hurricanes and severe convective weather to helps them anticipate and minimize the duration of power outages. CFAN also provides forecasts of temperature extremes and wind/solar power to energy trading companies, to support cost-effective backup of wind/solar power with natural gas. CFAN has provided climate-related analyses to energy companies related to: power plant siting and vulnerability to storm surge and sea level rise; future profitability of wind farms; and vulnerability of solar farms in the southeast U.S. to hurricanes.

None of Curry's published research has been supported by funding from energy companies.

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