June 11, 2011

Comments of the Competitive Enterprise Institute, Caesar Rodney Institute, Committee for a Constructive Tomorrow (CFACT), Energy and Environment Legal Institute, FreedomWorks, Heartland Institute, National Center for Public Policy Research, and 60 Plus Association

Thank you for the opportunity to comment on Acting Chair Allison Herren Lee's questions on climate change disclosures.[1] Our comments are broadly responsive to the foundational issue raised in Question 2. Please address any inquiries about this letter to Marlo Lewis, Senior Fellow, Competitive Enterprise Institute (marlo.lewis@cei.org).

Introduction: Climate Risk Quantification and Measurement

Among other queries, Question 2 asks:

"What information related to climate risks can be quantified and measured?"

That is the foundational question. ESG and climate activists believe corporations should be required to report the magnitude and probability of the financial losses they could incur due to the physical impacts of climate change. They also want companies, especially fossil-fuel companies, to report their "transition" and "liability" risks—the losses they may incur as climate policies devalue and strand their assets and courts compel them to pay compensation to climate change victims.

However, objective quantification and measurement of such risks is often impossible. Climate risk assessments typically depend on multiple assumptions fraught with uncertainties. Speculative risk guestimates are of little financial value to investors.

Boston University professor Madison Condon's "Market Myopia's Climate Bubble" (MMCB), a recent influential paper advocating mandatory disclosure and quantification of climate change risks, describes some of the epistemological challenges:

> Evaluating climate risk involves forecasting macroeconomic energy demand, guessing on the success of carbon regulation and future technologies, modeling the relationship between atmospheric gas concentrations and global temperatures, predicting how temperature rise will change the earth's climate systems, and calculating how those changes impact physical economic assets. The task requires skills beyond that of a typical financial analyst, colossal amounts of data, and models that have only begun to be built. Each step of estimation adds layers of uncertainty to risk projections. In some cases, particularly those longer-term and macroeconomic, the estimation of the economic impact of climate change may be dwarfed by this uncertainty.[2]

Another level of uncertainty arises from the vagaries of politics and litigation: "No amount of regulatory or corporate governance intervention can give shareholders and managers the ability to foresee the future—the outcomes of national elections, for example, are both largely uncertain and hugely influential in determining the strength of future climate policy."[3]

MMCB therefore cautions against an "overemphasis on false precision provided by complicated models." The author prefers the use of "fine-grained asset-level" analysis focused "on climate risks at the scale of individual corporations and investors and their horizons." She suggests companies should at least be able to report on the "climate-related impacts we have already been experiencing."[4]

In practice, however, it is often hard to distinguish what component of current risks is due to climate change rather than just plain old climate. Even when assessing current impacts, speculative modeling often comes into play. Consider *Lights Out: Climate Change Risk to Internet Infrastructure*,[5] the featured study in MMCB's introduction. MMCB summarizes:

> In 2016, a duo of computer scientists undertook the laborious task of creating a map of U.S. Internet infrastructure, indicating where cable was laid and where colocation centers were based. . . When one of the researchers showed the results of his work to his wife, a climate scientist, she immediately remarked that much of the infrastructure was located in coastal regions at risk to be inundated by sea-level rise as soon as the coming decade. All three scientists then worked together, publishing a study showing that thousands of miles of fiber optic cable, and more than a thousand nodes of key Internet infrastructure, could be underwater in the next 15 years.[6]

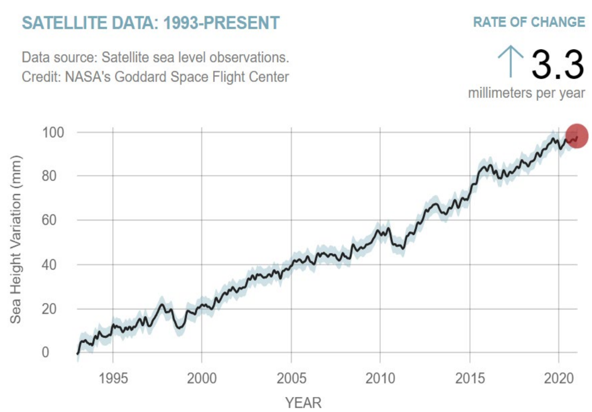
In an allusion to *Lights Out* a few pages later, MMCB criticizes "the continued neglect of assessing companies' exposure to foreseeable climate risks," describing "global sea-level rise over the next 15 years" as a phenomenon that "can be predicted with some certainty."[7]

In fact, *Lights Out* is a cautionary tale of how dubious climate risk analysis can be. The study is explicitly based on a long-term (2018-2100) sea-level rise projection, and not just any projection but the "highest"—i.e. "most extreme." The study assumes sea levels will rise 6 feet by 2100 and 1 foot by 2030:

Table 1: Timeline of projected Global Mean Sea Level Rise. Data is based off of "Highest" (*i.e.*, most extreme) projections.

Year	2030	2045	2060	2075	2090	2100
Projected rise (ft)	1	2	3	4	5	6

Global mean sea-levels have risen 8-9 inches (21-24 centimeters) since 1880.[8] The Internet infrastructure risks forecast in *Lights Out* materialize only if there is almost twice as much sea-level rise during 2018-2030 as there was in the preceding 138 years. The current annual rate of global mean sea-level rise is 3.3 millimeters, according to the National Aeronautics and Space Administration (NASA).[9] *Lights Out* assumes a 15-year rate of about 20.3 mm/year—more than six times faster.



The lesson here is the need for due diligence before citing climate impact assessments. *Lights Out* sources its "extreme" sea-level rise projection to "a collection of projected sea level rise scenarios, flood exposures, and affected coastal counties, and is amassed from a number of partner organizations." However, the accompanying footnote takes us not to sea-level rise scenarios, models, or data but to the Web sites of 827 partner organizations.[10] The study is literally non-auditable.

Despite the plea for "fine grained" analysis, nearly all assessments of the physical risks of climate change rely on speculative models and emission scenarios.

Overview

The remainder of the comment letter develops the following points. Advocates of climate risk disclosure:

- Favor assessments based on warm-biased models run with warm-biased emission scenarios.
- Often attribute to climate change damages that chiefly reflect societal factors such as increases in population and exposed wealth.
- Overlook the increasing sustainability of our chiefly fossil-fueled civilization.
- Assume away the power of adaptation to mitigate climate change damages.
- Misbrand efforts to decapitalize companies as "protecting shareholder value."
- Ignore the vast potential of climate policies to destroy jobs, growth, and, thus, shareholder value.
- Downplay the economic, environmental, and geopolitical risks of mandating a transition from a fuel-intensive to a material-intensive energy system.
- Downplay the regulatory impediments to building a "clean energy economy."
- Ignore what may become the biggest transition risk—the creation of a mandate- and subsidy-fueled "clean energy" bubble.

Warm-Biased Risk Assessments

In all model-based climate change assessments, the potential magnitude of the risks depends chiefly on two variables—the model's estimate of climate sensitivity and the forcing trajectory (emissions scenario) with which the model is run.

Climate sensitivity is typically defined as the rise in global mean annual temperature after the climate system fully adjusts to a doubling of atmospheric carbon dioxide-equivalent (CO_2e) greenhouse gas (GHG) concentration. Radiative forcing is the difference, measured in watts per square meter (W/m^2), between the amount of incoming shortwave solar radiation and the amount of outgoing longwave infrared radiation.

For its Fifth Assessment Report (AR5), the U.N. Intergovernmental Panel on Climate Change (IPCC) used an ensemble of models called CMIP5.[11] The IPCC ran the models with four representative concentration pathways (RCPs), which plot changes in emissions, concentrations, and forcing from 2000 to 2100. RCPs are called "representative" because each forcing trajectory corresponds to at least some published socio-economic development scenarios. From coolest to hottest, the four pathways are RPC2.6, RPC4.5, RPC6.0, and RCP8.5, each numbered for its W/m^2 forcing.

In such analyses, the big-scary warming projections and associated physical impacts come from running CMIP5 (or models estimating similar or higher sensitivity) with RCP8.5.[12] This methodology is doubly biased towards high-end warming and climate damage projections.

On average, CMIP5 models hindcast a warming rate of 0.44°C per decade in the tropical mid-troposphere since 1979. The average observed warming rate from satellites, weather balloons, and re-analyses[13] is 0.15°C per decade—roughly one third the model average.[14]

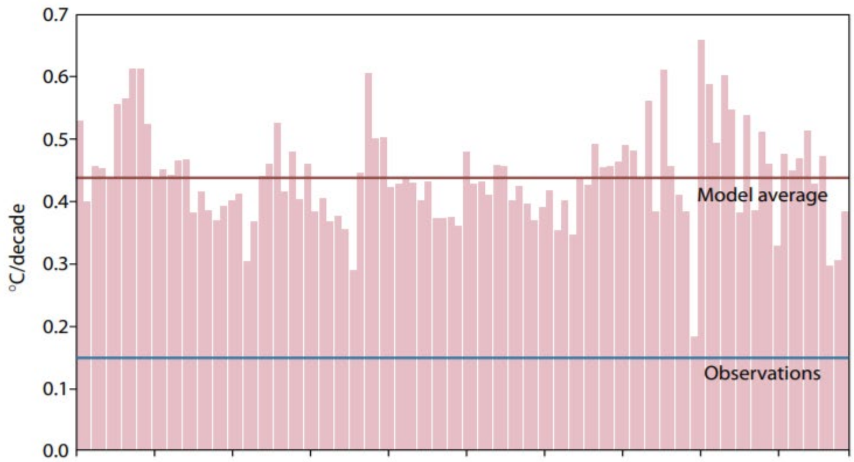


Figure 6: Tropical troposphere warming trends in 102 climate models.
CMIP5 models, trends for 1979–2017, 20°N–20°S, 300-200 hPa.

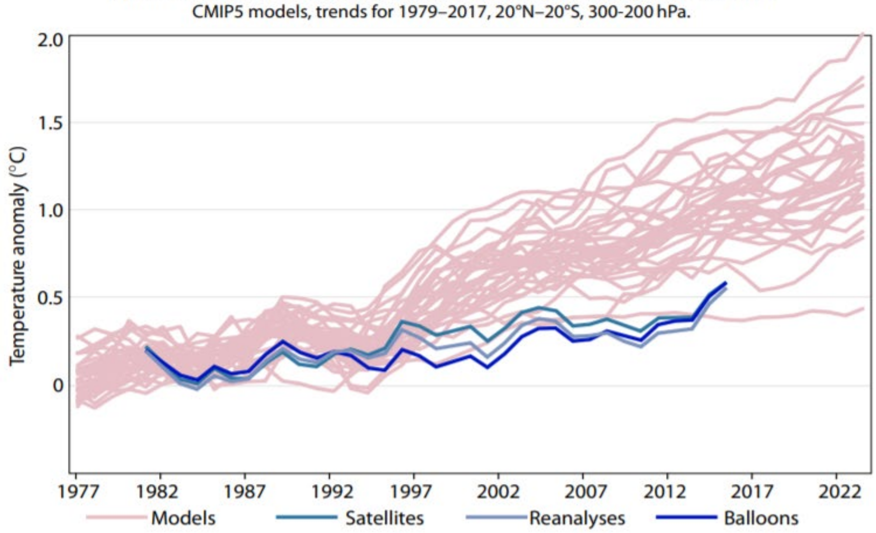
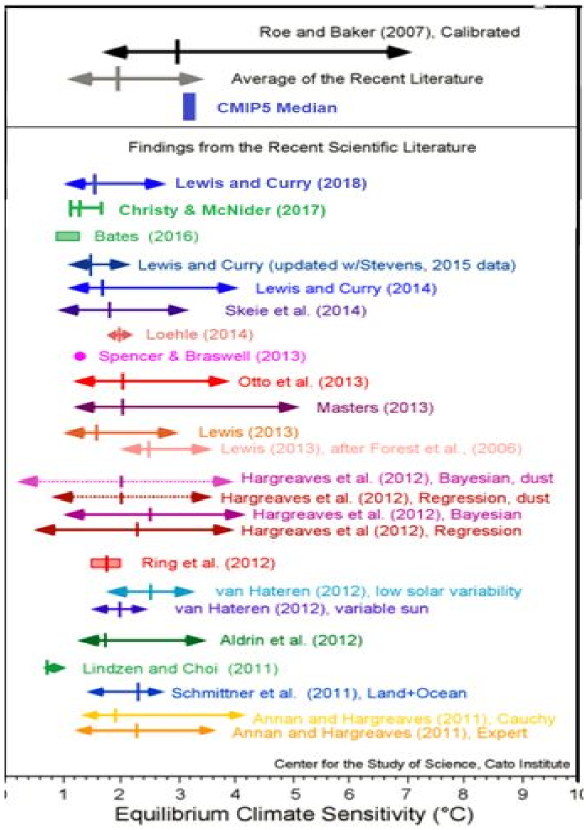


Figure 7: Tropical mid-tropospheric temperatures, models vs. observations.
Models in pink, against various observational datasets in shades of blue. Five-year averages 1979–2017. Trend lines cross zero at 1979 for all series.

A reasonable inference is that most CMIP5 models overestimate climate sensitivity and project too much warming from whatever emission scenario is fed into the models. The following chart[15] compares the sensitivity estimates of 24 empirically-constrained studies[16] with the climate sensitivity probability distribution (Roe-Baker 2007) used by federal agencies to estimate the social cost of carbon dioxide[17] and the CMIP5 mean climate sensitivity. The average sensitivity in the 24 studies (2°C) is 37.5 percent lower than the average in CMIP5 (3.2°C). Or, conversely, the CMIP5 mean sensitivity is 60 percent higher than the mean of the 24 studies.



Although often described as a "business-as-usual" scenario, RCP8.5 is actually a high-emission, worst-case scenario.[18] For RCP8.5 to be a realistic projection of future CO_2 emissions and concentrations, coal consumption would have to increase approximately tenfold during 2000-2100,[19] achieving market shares not seen since the 1940s.[20] There is no evidence the world is on the verge of a "return to coal."[21]

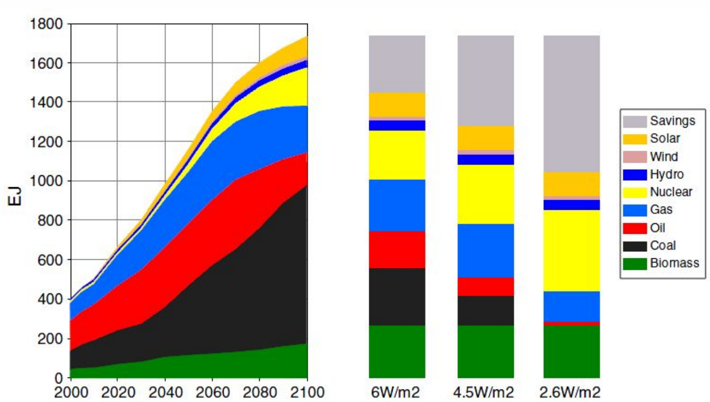


Fig. 5 Development of global primary energy supply in RCP8.5 (*left-hand panel*) and global primary energy supply in 2100 in the associated mitigation cases stabilizing radiative forcing at levels of 6, 4.5, and 2.6 W/m^2 (*right-hand bars*). Note that primary energy is accounted using the direct equivalent method

This dubious methodology taints many climate risk exposure analyses, even those with a granular, asset-specific focus. One such study, cited in MMCB, examines the impact of climate change on the structural integrity of aging U.S. bridges.[22]

The study reports that four of ten highway bridges in the National Bridge Inventory (NBI) "are 50 years or older, reaching or even exceeding their design life," and that 54,560 bridges (about 9 percent of the total NBI) are considered structurally deficient. Incidentally, this is clearly not a study of climate impacts already experienced. The study identifies only two highway bridge collapses in the past 60 years (the Silver Bridge over the Ohio River in 1967 and the Mianus River Bridge in Connecticut in 1983), and authors do not hypothesize that climate change was the straw that broke the camel's back.

Nonetheless, the unsafe condition of many bridges is widely accepted and weather obviously affects the long-term structural integrity of infrastructure. To most people, that means we have an aging bridge problem. However, the bridge study presents it as a climate change problem, and MMCB presents it as a climate risk disclosure problem.

To determine the potential impact of global warming on the expansion joints connecting bridge spans, the authors ran RCP2.6, RCP6.0, and RCP8.5 with the Geophysical Fluid Dynamics Laboratory GFDL-CM3 model. By sheer coincidence, GFDL-CM3 is among the most sensitive of the CMIP5 models.

The chart below shows the divergence of model projections and observations through the depth of the tropical atmosphere during 1979-2016. The GFDL-CM3 projection is the warmest and least accurate.[23]

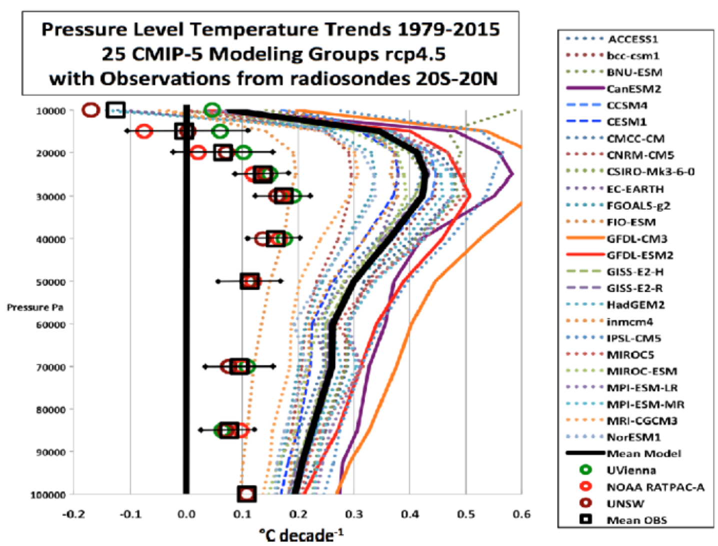


Fig. 3. Pressure-level temperature trends (1979-2016) for the tropical atmosphere as measured by four radiosonde datasets (circles with square as average, UVienna is average of two datasets) and 25 modeling groups (dotted, dashed and solid lines, mean is black line) used in the IPCC AR5.

The bridge study, which projects the thermal stress on expansion joints under the three RCPs in 2040, 2060, 2080, and 2100, argues that such research can help decisionmakers "prioritize the allocation of funds for maintenance and replacement." MMCB takes it a step further, suggesting that such information is important to investors generally: "The businesses (and their shareholders) whose supply chains rely on these bridges are likely unaware of their heightened risk exposure."[24]

However, such granular information would appear to be of more interest to companies that build and repair bridges than to shareholders of the vast number and variety of companies that ship goods via the U.S. highway system. Moreover, on-site inspections would seem to be a more accurate way to determine bridge construction priorities than extrapolations from an overheated climate model.

BlackRock's influential April 2019 report, "Getting Physical: Scenario Analysis for Assessing Climate-Related Risk," also pairs hot models with RCP8.5.[25] BlackRock's modeling was done by the Rhodium Group,[26] who supplemented CMIP5 with "simple climate models" designed to capture "tail risk." The effect is to increase the probability of warming projections beyond the CMIP5 "likely" range. Rhodium explains:

> The CMIP5 models substantially underestimate the 95th-percentile projections from the probabilistic methods. We find that by the end of the twenty-first century there is a 5 percent chance that annual CONUS temperature change could be as high as ~8°C over 1981–2010 levels—roughly 1°C warmer than the hottest CMIP5 model projection (RCP 8.5).[27]

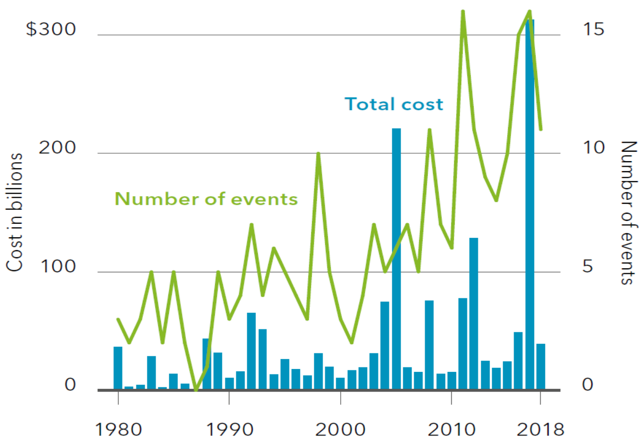
For perspective, the warming rate of the global lower troposphere since January 1979 has been 0.14°C per decade,[28] which implies an additional 1.1°C rise in global mean temperature by 2100—seven times less than Rhodium's 8°C scenario. Although the observed warming rate may increase, there has been no acceleration over the past four decades. Somehow that never factors into climate impact projections.

Misattribution of Climate-Related Damages

For some reason not explained, *Getting Physical* sticks with a central CMIP5 warming projection of 4°C from RCP8.5. It highlights the following impact projections: 5 feet of sea-level rise in Houston, annualized hurricane GDP losses of 3.9 percent in Miami, annualized agricultural GDP losses of 3.8 percent in Pine Bluff, Arkansas, and annualized energy consumption GDP losses of 1.6 percent in Tucson, Arizona.[29]

Getting Physical makes those damage projections look credible by plotting the number of recent "climate events" with losses exceeding $1 billion since 1980.

Mounting costs
U.S. billion-dollar disaster events, 1980–2018



Sources: BlackRock Investment Institute, with data from NOAA National Center for Environmental Information NCEI, October 2018. Notes: The line shows the number of climate events with losses exceeding $1 billion. The data include droughts, flooding, severe storms, tropical cyclones, wildfires, winter storms and freezes. The bars show the total cost. The data are adjusted for inflation using 2018 dollars.

Unwary readers are left to infer that the frequency and intensity of bad weather has increased dramatically over the past 40 years. Some may conclude the world must be in a "climate crisis."

The chart is misleading. It adjusts economic losses for inflation. However, to discern a climate signal, the data must also be adjusted ("normalized") for changes in population, wealth, and development patterns. More people and more stuff in harm's way produce bigger weather-related losses even if there is no overall trend in the weather.

Economist Bjorn Lomborg calls this phenomenon the "expanding bull's-eye effect." He explains:

> While the U.S. population since 1900 has more than quadrupled, coastal populations have increased far more. The population of all the coastal counties from Texas to Virginia on the Gulf of Mexico and Atlantic has increased sixteen-fold during the same period. The coastal population of Florida has increased a phenomenal sixty-seven times. There are now many more people living in Dade and Broward Counties in South Florida than lived along the entire coast from Texas to Virginia in 1940. For a hurricane in 1940 to hit the same number of people as a modern hurricane ripping through Dade and Broward today, it would have had to tear through *the entire Gulf of Mexico and Atlantic coastline*.[30]

Getting Physical's 1980-2018 comparison ignores the expanding bull's eye. Between 1980 and 2018, the U.S. population increased by 42.5 percent and U.S. GDP increased by 275 percent.[31] Moreover, substantial population growth and economic development occurred in coastal areas[32] and the fire-prone wildland-urban interface.[33]

Normalizing the damages—estimating the direct economic losses from an historic extreme weather event if the same event were to occur under present societal conditions—completely changes the picture. For example, there has been no trend in normalized U.S. hurricane damages since 1900. That result is consistent with meteorological data, which show no long-term trend in the frequency and strength of U.S. landfalling hurricanes.[34]

This is what hurricane damages look like if adjusted only for inflation:

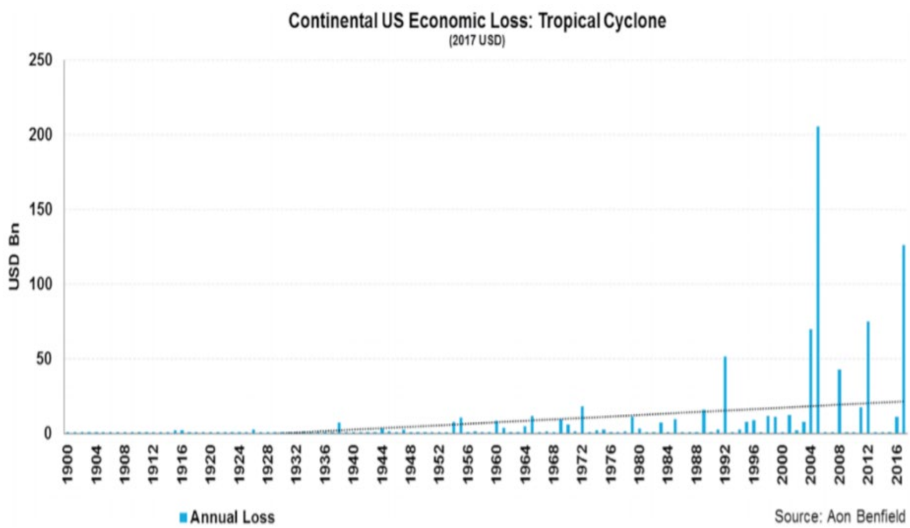


Fig. 1. CONUS total inflation-adjusted economic losses from TC landfalls (1900–2017). The dotted line represents the linear trend over the period. The *p* value for the linear trend is <0.01, indicating that the trend is significant.

Here are the same damages normalized for changes in population and exposed wealth:

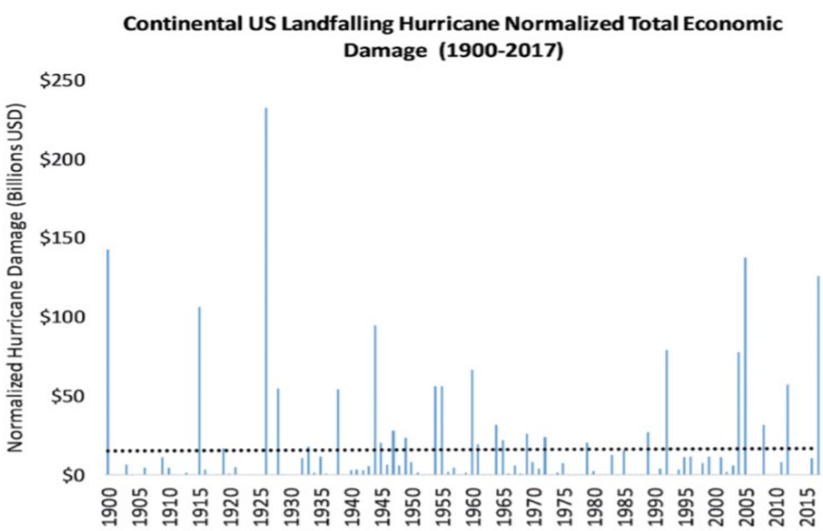


Fig. 3. Normalized CONUS landfalling hurricane damage from 1900 to 2017. The dotted line represents the linear trend in CONUS hurricane normalized damage during the period of record. The *p* value for the linear trend is 0.86, indicating that the trend is not significant.

Here are plots of total and major (Category 3-5) U.S. landfalling hurricanes during 1900-2017. No long-term trend or “climate signal” is discernible in the data.

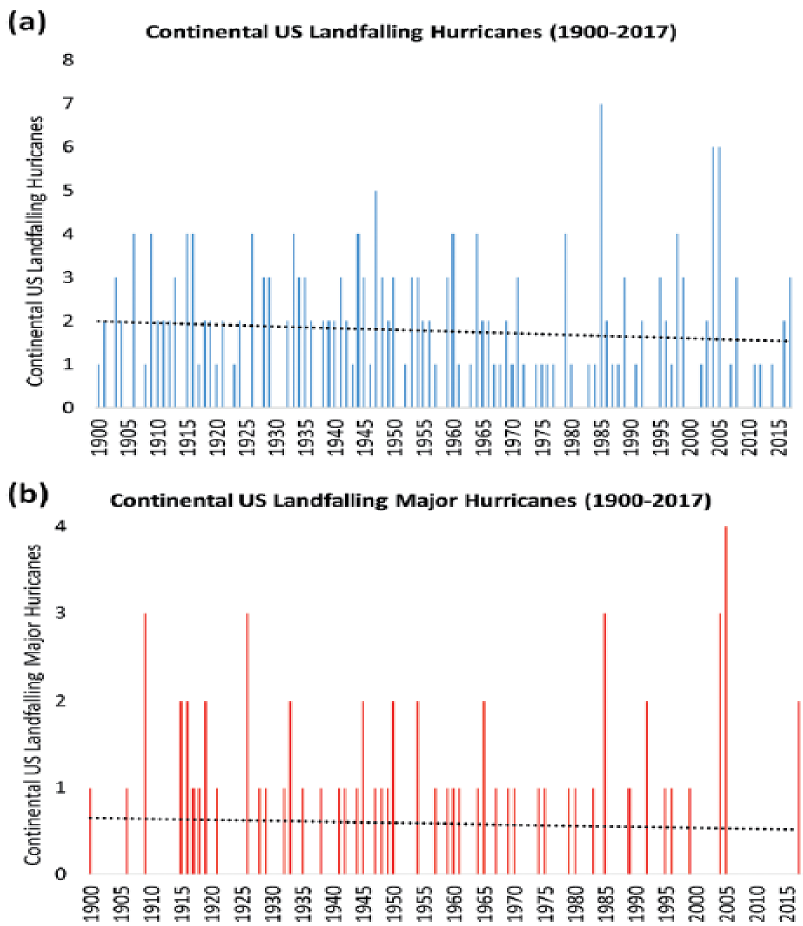


FIG. 2. (a) CONUS landfalling hurricanes by year from 1900 to 2017, and (b) CONUS landfalling major hurricanes by year from 1900 to 2017. The dotted lines represent linear trends over the period. The *p* values for the linear trends are 0.33 for landfalling hurricanes and 0.61 for landfalling major hurricanes, indicating that neither of these trends are significant.

Sustainability Perspective

People under the spell of the "existential threat" narrative can easily overlook the increasing wealth, health, and safety achieved by our mostly fossil-fueled civilization during the age of global warming. The past 70 years have been marked by unprecedented improvements in life expectancy,[35] per capita income,[36] food security,[37] and various health-related metrics.[38] Yields of all major food crops keep increasing,[39] nearly 3 billion people gained access to improved water sources since 1990,[40] and deaths from malaria (the most consequential climate-sensitive disease) declined by 52 percent during 2000-2015.[41]

Taking a somewhat longer view, since the 1920s, global CO_2 concentrations increased from about 305 parts per million to more than 410 ppm, and average global temperatures increased by about 1°C.[42] Yet, globally, the individual risk of dying from weather-related disasters such as hurricanes, floods, and drought decreased by 99 percent.[43] If we are in a "climate crisis" today, what words can adequately describe the climate regime of the 1920s?[44]

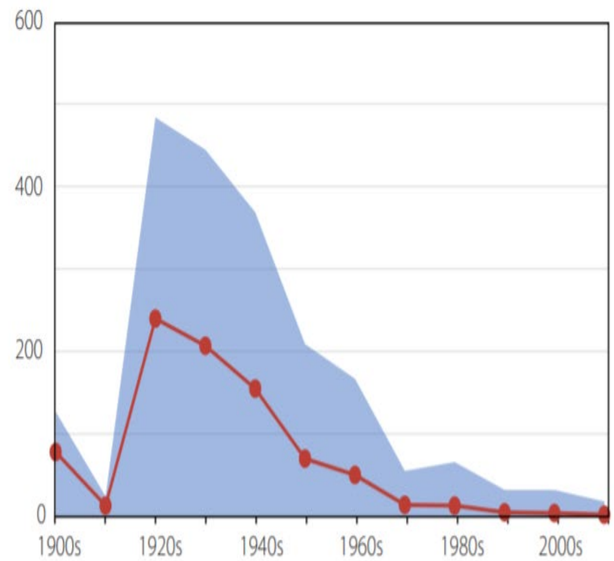
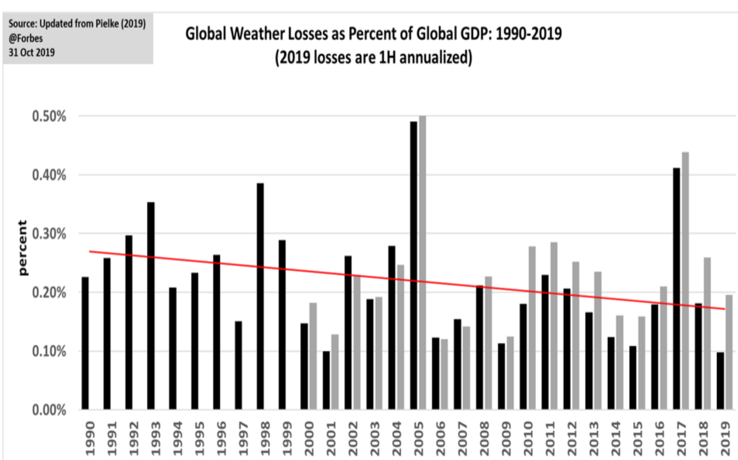


Figure 8: Average annual deaths and death rates from all EWEs, 1900–2018.
Source: Updated from Goklany (2009b), using WDI (2019) and EM-DAT (2019).

Even in recent decades, the warmest in the instrumental record, mortality and economic loss data point to an increasingly sustainable civilization. A recent peer-reviewed study finds that climate-related hazards show a “clear decreasing trend in both human and economic vulnerability, with global average mortality and economic loss rates that have dropped by 6.5 and nearly 5 times, respectively, from 1980–1989 to 2007–2016.”[45]

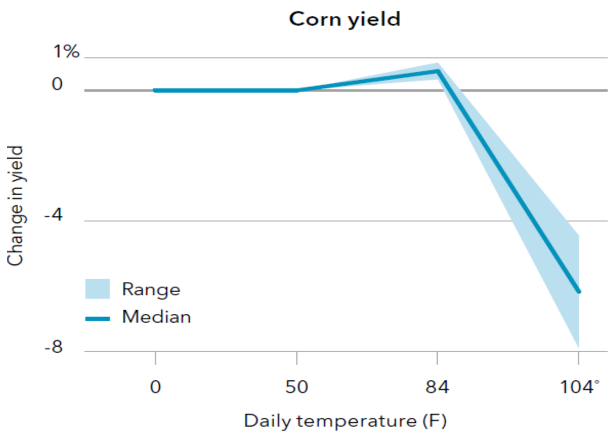
Data from Munich Re and Aon, two companies that track natural disaster losses for the global reinsurance industry, indicate that the economic impact of weather-related losses declined from about 0.3 percent of global GDP in 1990 to about 0.25 percent in 2019.[46] In other words, the relative burden of climate-related damages on the global economy declined.



Those results should give the Commission pause. If the state of the world is improving, including in regard to climate-related risks, why now compel publicly-traded companies to quantify climate-related risks as though their financial lives depend on it?

Underestimating Adaptation

Getting Physical warns that "many effects of climate change are non-linear," noting that corn yields "start to drop sharply when daily high temperatures exceed 84°F (29°C)."[47] It illustrates the point with the following chart:



The imminent decline of corn yields has been predicted for some time.[48] A few quick points.

First, as noted, *Getting Physical* assumes a 4°C warming under a "no climate action" scenario. Of all the CMIP5 models, the only one that accurately tracks observed warming in the tropical troposphere over the past 40 years is the Russian INM-CM4.[49] Running that model with a realistic emission scenario (perhaps something between RCP4.5 and RCP6.0) would project far less warming.[50]

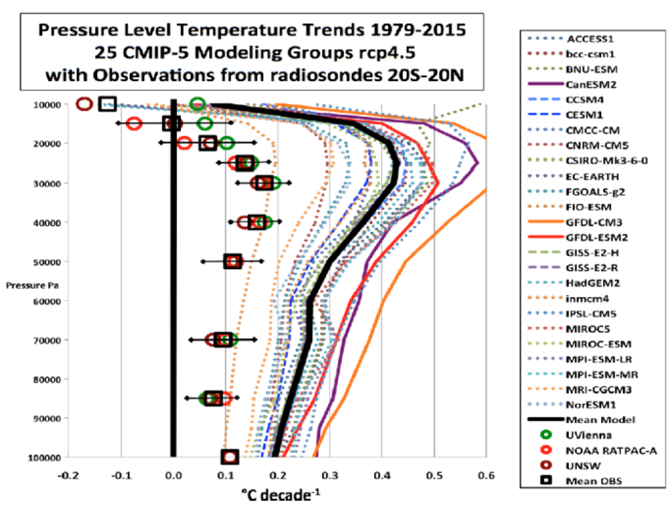
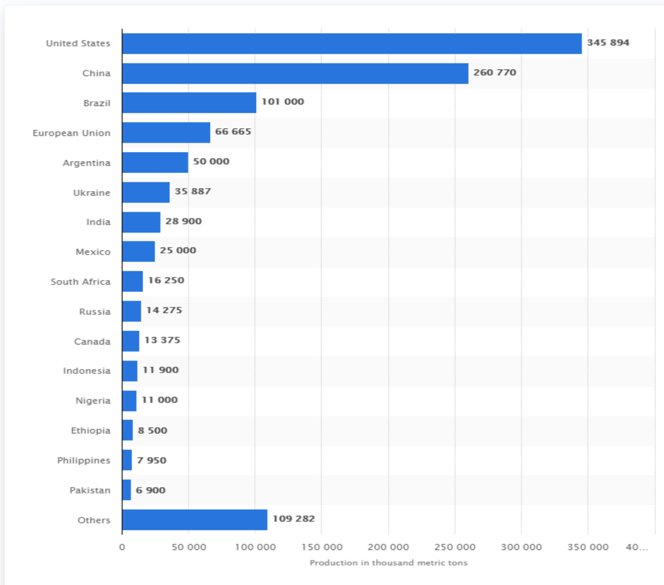


Fig. 3. Pressure-level temperature trends (1979-2016) for the tropical atmosphere as measured by four radiosonde datasets (circles with square as average, UVienna is average of two datasets) and 25 modeling groups (dotted, dashed and solid lines, mean is black line) used in the IPCC AR5.

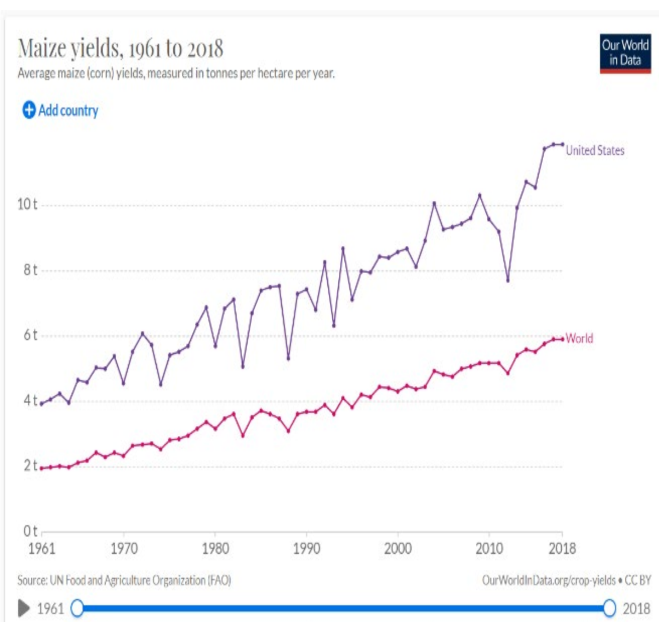
Second, in Iowa, the No. 1 corn producing state, maximum daily temperatures in July (the warmest month) often exceed 84°F. The same holds for No. 2 corn producer Illinois, and No. 3 producer Nebraska.[51] The United States remains by far the world's leading corn producer.[52]

Global corn production in 2019/2020, by country
(in 1,000 metric tons)



Third, CO_2 emissions have positive as well as negative externalities. In 60 experiments, a 300 ppm increase in CO_2 concentration increased average corn plant dry weight (biomass) by 32.1 percent. In 28 experiments, a 300 ppm increase in CO_2 concentration increased average corn plant photosynthetic activity by 23.7 percent.[53]

Fourth, whatever negative impacts climate change may be having on corn production, farmers continue to increase yields both in the United States and globally.[54]



Climate impact assessments often assume away mankind's remarkable capacity for adaptation.[55] For example, the Fourth National Climate Assessment's estimates of U.S. climate damages in the 2090s "only capture adaptation to the extent that populations employed them in the historical period," i.e., during 1980-2010. Similarly, the Assessment's $505 billion estimate of annual RCP8.5 economic damages in 2090 "assume limited or no adaptation."[56]

A 2014 study published in *Proceedings of the National Academy of Sciences* (PNAS) is relevant here. An international team of 20 researchers used satellite-based spectroscopy to monitor sun-induced chlorophyll fluorescence (SIF), an electromagnetic signal emitted as a byproduct of photosynthesis. They found that the region with the highest gross primary production (GPP) from photosynthesis is the U.S. corn belt (the red area in the map).

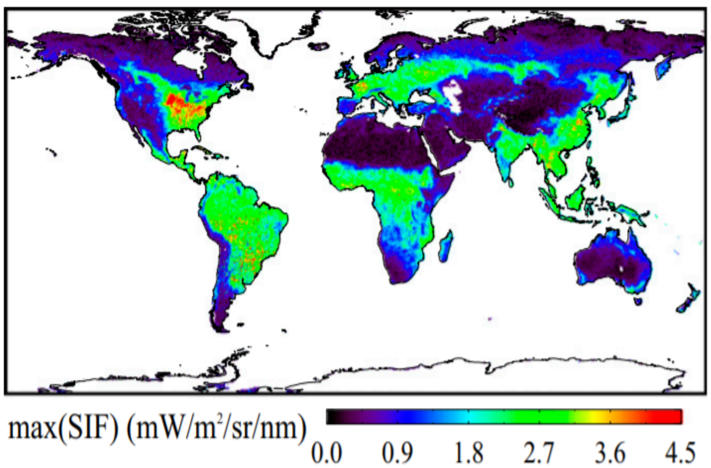
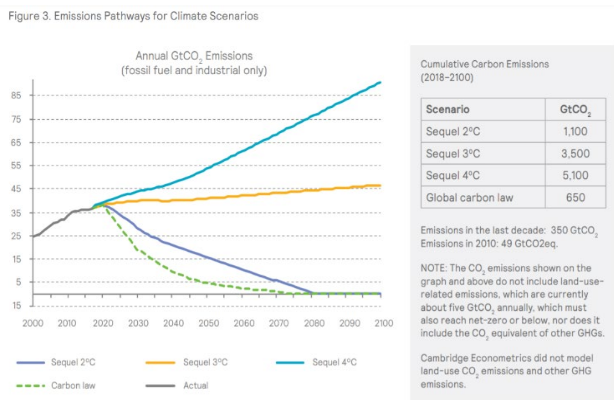


Fig. 1. Global map of maximum monthly sun-induced chlorophyll fluorescence (SIF) per 0.5° grid box for 2009. SIF retrievals are performed in a spectral window centered at 740 nm (see *Materials and Methods* and *SI Appendix, SIF Retrievals*). This maps illustrates the outstanding SIF signal detected at the US CB, which shows the highest SIF return of all terrestrial ecosystems. The maximum SIF over the largest part of the US CB region is detected in July.

Pertinently, the researchers report that the satellite-based crop GPP estimates are "50–75 percent higher than results from state-of-the-art carbon cycle models over, for example, the U.S. Corn Belt and the Indo-Gangetic Plain, *implying that current models severely underestimate the role of management*."[57]

Decapitalizing Companies to "Protect Shareholder Value"

Mercer's *Investing in a Time of Climate Change: The Sequel* estimates the physical and transition risks businesses would experience in 2°C, 3°C, and 4°C warming scenarios (relative to pre-industrial levels).[58] Although *Investing* does not use the term "RCP," the 4°C scenario is clearly a variant of RCP8.5, as can be seen by comparing it to the original in Riahi et al. (2011):



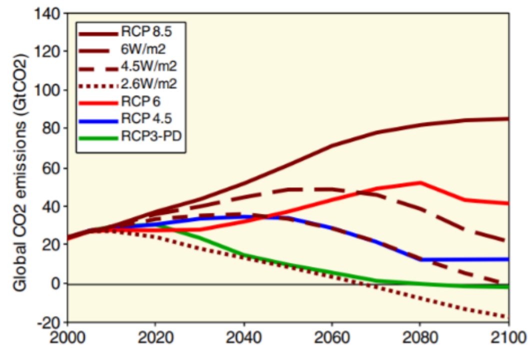


Figure Source: Mercer (2019)

Figure Source: Riahi et al. (2011)[59]

To estimate climate change impacts, *Investing* ran its RCP8.5-equivalent scenario with a model called GENIE (Grid-Enabled Integrated Earth). For a description of GENIE, Mercer refers readers to a *Nature Climate Change* study. There we find that GENIE has a climate sensitivity range of 2.6°C-4.5°C, compared to 1.9°C-4.5°C in CMIP5.[60] An earlier study by the same lead author reports that GENIE's "peak probability" climate sensitivity is 3.6°C, which is also the mean of the range.[61] GENIE's mean sensitivity is 12.5 percent higher than that of CMIP5 (3.2°C) and 80 percent higher than that of the 24 recent empirically-constrained studies (2°C).

MMCB summarizes the big takeaway of *Investing* as follows: "In a 2°C scenario, which models a world with aggressive regulation of emissions that reaches net zero emissions by 2070, certain sectors suffer a severe decline in returns in the short run. Assets in the oil and gas industry, for example, lose 42.1 percent of their value by 2030."[62]

Several responses are in order. First, if CMIP5 and RCP8.5 overestimate climate sensitivity and emissions, the 2°C goal is achievable with less emission reduction and, therefore, less risk of stranding fossil fuel investments, especially over the next two decades.

Second, the idea that any warming beyond 2°C must be avoided at all costs underestimates human adaptive capabilities. For example, the Policy Analysis of the Greenhouse Effect (PAGE) model—one of the three integrated assessment models (IAMs) used by the U.S. government to estimate the social cost of greenhouse gases (SC-GHG)—assumes that, beyond 2°C, no adaptation is available to mitigate climate change impacts.[63] Perhaps the scariest climate impact scenarios are the high-end sea-level rise estimates associated with high-end warming projections.

In his recent book *False Alarm*, Bjorn Lomborg discusses Hinkel et al. (2014), a sea-level rise study published in *Proceedings of the National Academy of Sciences*. The study includes a worst-case scenario in which rising sea levels flood up to 350 million people every year by century's end, with costs reaching $100 trillion or 11 percent of global GDP annually.[64] However, those extraordinary damages are projected to occur only if people do nothing more than maintain current sea walls.

If "enhanced" adaptive measures are taken, annual flood costs increase from $11 billion in 2000 to $38 billion in 2100. Similarly, annual dike costs increase from $13 billion to $48 billion.

However, Lomborg notes, "the total cost to the economy will actually decline, from 0.05 percent of GDP to 0.008 percent." Moreover, the number of people experiencing flood damages drops from 3.4 million in 2000 to 15,000 in 2100—a 99.6 percent reduction in flood victims! In other words, with reasonable adaptation, people are projected to be much safer, and the global economy much less affected by sea-level rise in 2100, despite high-end warming. [65]

Notice how "enhanced adaptation" (adaptation that keeps pace with sea level rise) decreases by orders of magnitude the number of people exposed to flood risks and the GDP losses even under RCP8.5.

Fig. S4. Global expected annual number of people flooded. The lines show the average impacts across the range of DEMs, population datasets, GCMs, and land-ice scenarios used. The shaded areas show the respective uncertainty ranges defined by the maximum and minimum impacts.

Fig. S5. Global expected annual flood cost. The lines show the average impacts across the range of DEMs, population datasets, GCMs, and land-ice scenarios used. The shaded areas show the respective uncertainty ranges defined by the maximum and minimum impacts.

The point here is that a broader appreciation of adaptation should also alleviate the transition risk facing fossil fuel companies. Adaptation's proven power is evident in the dramatic long-term reduction in climate-related mortality. However, adaptation requires wealth, and mitigation targets that strand 42.1 percent fossil fuel industry assets by 2030 would destroy trillions of dollars of wealth. Even from a climate protection perspective, aggressive mitigation targets could do more harm than good.

To be sure, some politicians and activists seem ambitious to punish fossil fuel companies. The NetZero agenda is the political equivalent of war on the fossil fuel industry. A bewildering number of local, state, federal, and international tax, regulatory, and litigation initiatives target the fossil fuel industry, creating the risk of death by a thousand cuts.

The climate risk disclosure movement is no mere chronicler of transition and liability risks but an active contributor. Politically, the function of climate risk disclosure is to extract confessions from fossil fuel companies that their business models are unsustainable in a carbon-constrained world. Such confessions could to some degree decapitalize and defund the companies, as investors and banks tend to shun businesses perceived to lack assets of durable value.

The confessions could also invite litigation by shareholder groups claiming the companies committed fraud by overpricing asset values in the past. Such litigation could further spook investors and lenders, causing additional capital flight. As capital and credit ratings decline, so would the companies' ability to fend off legal and political predation. A death spiral is easily imagined in which pension funds, retirement accounts, and other owners of fossil-fuel company stock lose their shirts. In Climatespeak, this strategy is called "protecting shareholder value."

Ignoring Climate Policy Risks to Consumers and the Economy

The death-by-a-thousand-cuts strategy is unlikely to succeed. To begin with, abundant, reliable, and scalable energy is a valuable societal asset, and even a far more efficient decarbonization path than the current hodgepodge of mandates, subsidies, and litigation could prove prohibitively costly and politically unsustainable.

A July 2019 Heritage Foundation study shows why. The study uses a clone of the U.S. Energy Information Administration's National Energy Modeling System (NEMS) to analyze the economic impacts of revenue-neutral CO_2 taxes enacted in 2020 and set alternatively at $35, $54, $75, $100, $150, $200, and $300 per ton.

The aim of the study is to assess the economic impacts of the Green New Deal using a CO_2 tax high enough to achieve net-zero emissions by 2050. The Heritage analysts found that the $300 per ton tax achieves only a 58 percent reduction in U.S. CO_2 emissions by 2050. To their surprise, raising the tax to $450 per ton did not produce additional emission cuts. Instead, it caused the model to crash. Apparently, many households and firms are willing to pay almost any price for dense, scalable, reliable energy, and products made therefrom.

Note that a revenue-neutral carbon tax is arguably the most efficient (least costly) way to reduce CO_2 emissions. Unlike prescriptive regulations or massive spending programs, taxing CO_2 emissions incentivizes all economic actors to find and exploit economical emission-reduction opportunities. In addition, the revenues can be used to cut other taxes. Nonetheless, the $300 per ton CO_2 tax has severe economic impacts, including:

- Cause an average annual shortfall of 1.2 million jobs through 2040, with a peak of more than 5.3 million jobs lost in 2023.
- Reduce a typical family of four's income by nearly $8,000 every year, or a total of more than $165,000 through 2040.
- Reduce cumulative GDP by more than $15 trillion.
- Increase household electricity expenditures by well over 30 percent.[66]

Those formidable economic sacrifices would achieve no discernible climate benefits. By 2100, the tax would avert 0.1°C of global warming and 2 centimeters of sea-level rise, according to standard EPA climate modeling.[67] Any associated mitigation of climate change impacts on weather patterns, crop yields, polar bear populations, or any other environmental condition people care about would be too small to detect.

An agenda so costly with such an abysmal benefit-cost ratio is a political loser. Consider that most Americans are unwilling to spend $20 or $10 a month in higher electric bills to combat climate change.[68] In a recent poll, more than one third of registered voters were unwilling to spend $1 per month on climate policies.[69]

Clearly, transition risks are not limited to the fossil-fuel companies in the crosshairs of climate campaigners. Long-term investors in general will suffer if, as the Heritage analysis suggests, climate policies squash growth, job creation, and household incomes.

Downplaying the Economic, Environmental, and Geopolitical Risks of Mandating a Material-Intensive Energy System

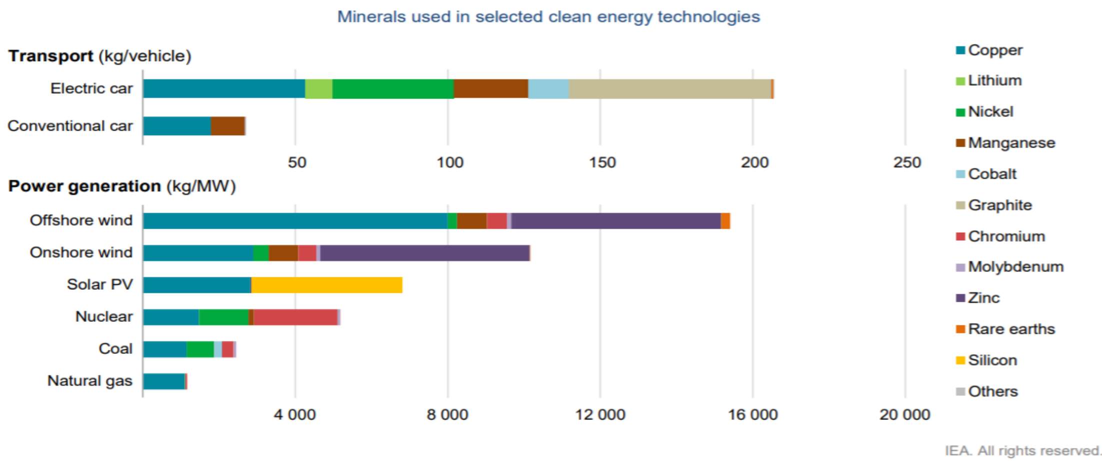
In May 2021, the International Energy Agency (IEA) released *The Role of Critical Minerals in Clean Energy Transitions*.[70] The IEA is perhaps the first agency to clarify the nature of "clean energy transitions." What the Paris treaty and NetZero agendas aim at most fundamentally is a "shift from a fuel-intensive to a material-intensive energy system."[71] Such a project creates substantial economic, environmental, and geopolitical risks seldom discussed by proponents. Moreover, the shift to a material-intensive energy system may not even be feasible. As Manhattan Institute scholar Mark Mills explains in a review of the IEA report:

> [The "clean energy" transition] requires mining industries and infrastructure that don't exist. Wind, solar and battery technologies are built from an array of "energy transition minerals," or ETMs, that must be mined and processed. The IEA finds that with a global energy transition like the one President Biden envisions, demand for key minerals such as lithium, graphite, nickel and rare-earth metals would explode, rising by 4,200 percent, 2,500 percent, 1,900 percent and 700 percent, respectively, by 2040.
>
> The world doesn't have the capacity to meet such demand. As the IEA observes, albeit in cautious bureaucratese, there are no plans to fund and build the necessary mines and refineries. The supply of ETMs is entirely aspirational. And if it were pursued at the quantities dictated by the goals of the energy transition, the world would face daunting environmental, economic and social challenges, along with geopolitical risks.
>
> The IEA stipulates up front one underlying fact that advocates of a transition never mention: Green-energy machines use far more critical minerals than conventional-energy machines do. "A typical electric car requires six times the mineral inputs of a conventional car, and an onshore wind plant requires nine times more mineral resources than a gas-fired power plant," the report says. "Since 2010, the average amount of minerals needed for a new unit of power generation capacity has increased by 50 percent

> as the share of renewables has risen." That was merely to bring wind and solar to a 10 percent share of the world's electricity.[72]

The chart below compares the tons of critical minerals required to build conventional automobiles and fossil-fuel power plants to the tons required to build electric vehicles and renewable power plants.

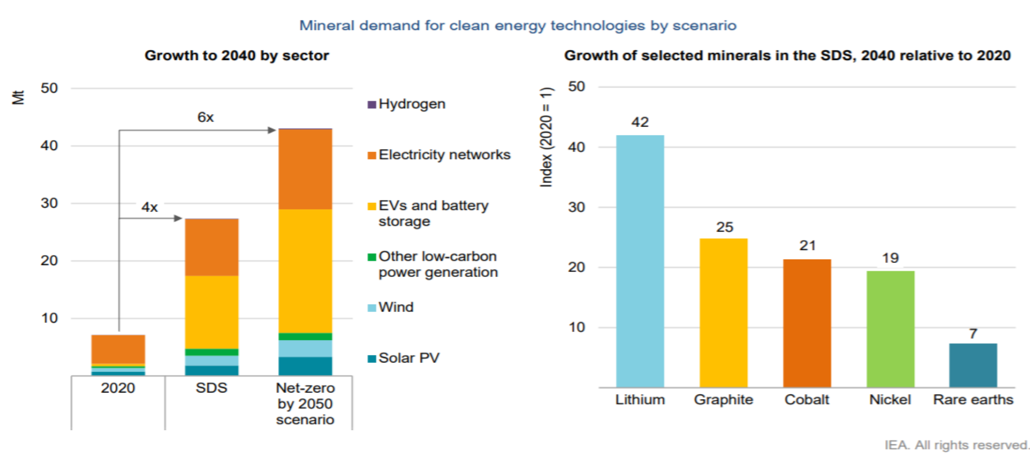
The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals



Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

The IEA estimates that reaching Paris climate treaty goals would increase mineral demand by at least 400 percent by 2040. Seven times more rare earths will be needed by 2040; 19 times more nickel; 21 times more cobalt; 25 times more graphite; and 42 times more lithium.[73] "An even faster transition, to hit net-zero *globally* by 2050, would require six times more mineral inputs in 2040 than today."[74]

Mineral demand for clean energy technologies would rise by at least four times by 2040 to meet climate goals, with particularly high growth for EV-related minerals



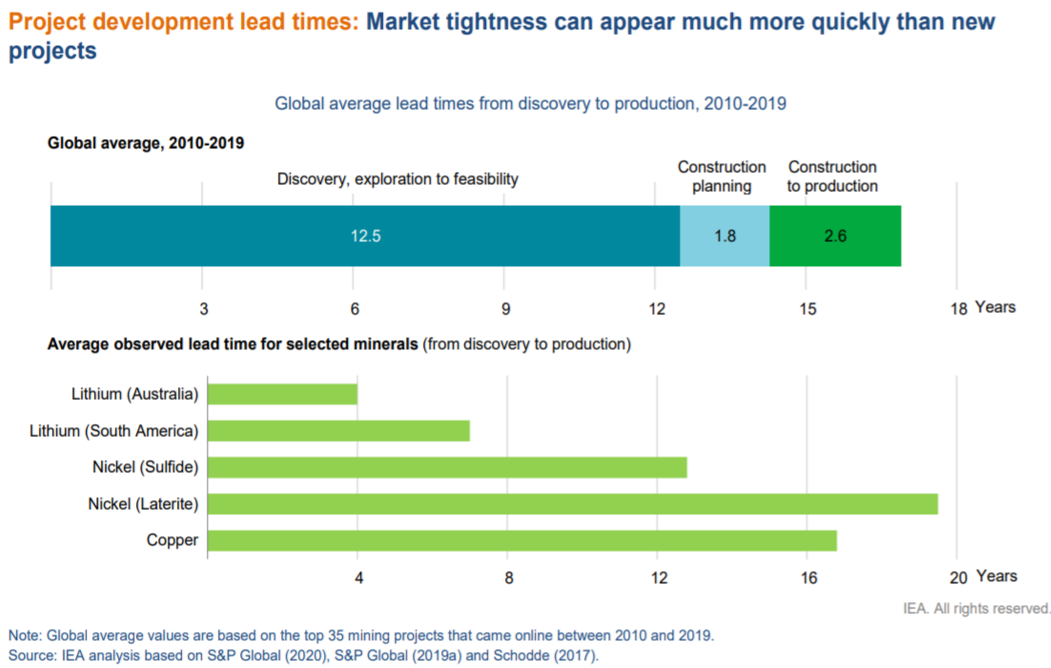
Notes: Mt = million tonnes. Includes all minerals in the scope of this report, but does not include steel and aluminium. See Annex for a full list of minerals.

The IEA oddly projects "moderate growth" (10-20 percent) in mineral prices even though implementing Paris treaty goals would "supercharge demand for critical minerals."[75] However, the IEA also identifies several factors that may constrain future supplies,[76] which could cause mineral prices to spike. Such factors include:

- "Today's supply and investment plans are geared to a world of more gradual, insufficient action on climate change. . . They are not ready to support accelerated energy transitions."
- "Long project development lead times: Our analysis suggests that it has taken on average over 16 years to move mining projects from discovery to first production. These long lead times raise questions about the ability of suppliers to ramp up output if demand were to pick up rapidly."
- "Declining resource quality: Concerns about resources relate to quality rather than quantity. In recent years, ore quality has continued to fall across a range of commodities."
- "High geographical concentration of production: Production of many energy transition minerals is more concentrated than that of oil and natural gas. . . The level of concentration is even higher for processing operations, where China has a strong presence across the board. China's share of refining is around 35 percent for nickel, 50-70 percent for lithium and cobalt, and nearly 90 percent for rare earth elements."
- "Growing scrutiny of environmental and social performance: Production and processing of mineral resources gives rise to a variety of environmental and social issues that, if poorly managed, can harm local communities and disrupt supply. Consumers and investors are increasingly calling for companies to source minerals that are sustainably and responsibly produced."

Mills cautions that "radical increases in demand will raise commodity prices, which reverberate throughout the global economy." He quotes the IEA's acknowledgement that increases in EV battery costs could "eat up the anticipated learning effects associated with a doubling of capacity."[77] The IEA also acknowledges that "Market tightness can appear much more quickly than new projects."[78] Precisely. Centrally planned production quota could easily increase demand beyond the capability of mining and processing infrastructure to deliver adequate supplies. Mills describes the potential train wreck this way:

> Spooling up production can't happen overnight. The IEA observes something every miner knows: "It has taken on average over 16 years to move mining projects from discovery to first production." Start tomorrow and new ETM production will begin only after 2035. This is a considerable problem for the Biden administration's plan to achieve 100 percent carbon-free electricity by 2035.



There are also significant environmental risks. The transition to material-intensive energy "means a shift away from liquids and gases whose extraction and transport leave a very light footprint on the land and are transported easily, cheaply and efficiently, and toward big-footprint mines, the energy-intensive transport of massive amounts of rocks and other solid materials, and subsequent chemical processing and refining," Mills explains. Here is one of the environmental risks described in the IEA report: "Mining and mineral processing require large volumes of water for their operations and pose contamination risks through acid mine drainage, wastewater discharge and the disposal of tailings," and "around half of global lithium and copper production are concentrated in areas of high water stress."[79]

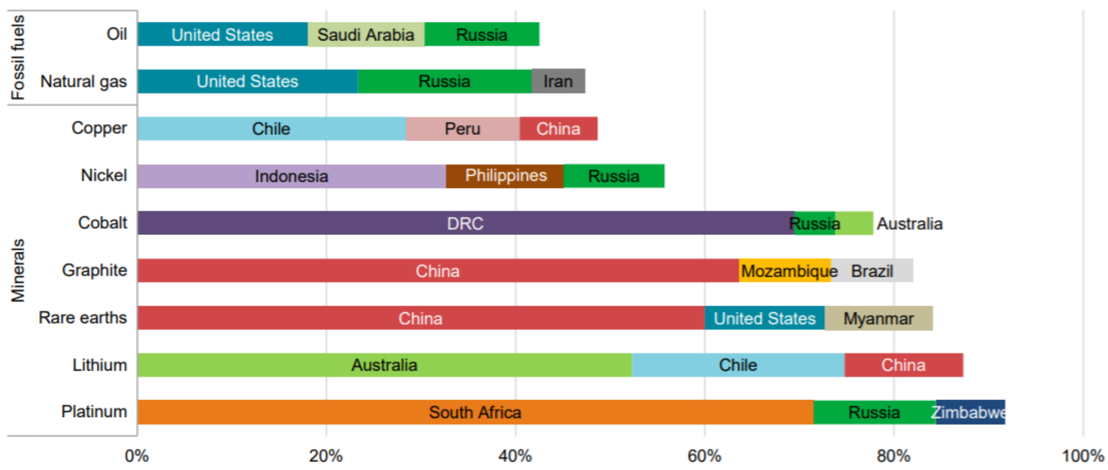
Finally, the shift to material-intensive energy entails geopolitical risks. In effect, the Paris treaty and NetZero agendas require America to exchange its hard-won global leadership in oil and gas production[80] and recent net energy-exporter status[81] for a future of increasing dependence on OPEC and Russia for hydrocarbons and on China for energy transition minerals. As the IEA reports, China is the dominant supplier of graphite and rare earths, and is the largest processor of copper, lithium, nickel, cobalt, and rare earth elements.[82]

The U.S. has vast stores of minerals but that will do us little good between now and 2035 given the long lead times between discovery and production. Decades of anti-mining activism have driven most multi-billion-dollar investments in mining projects out of the United States. Activist pressure has also caused policymakers to withdraw millions of acres of federal lands in the West and Alaska from potential mineral production. Those policies will not easily be reversed.

The charts below show where most energy transition minerals and processing industries are concentrated. Whereas America's geopolitical influence is set to increase in a global economy powered by gas and oil, China's is set to increase in a global economy powered by energy transition minerals. Note that the United States is not a significant producer or processor of ETMs.

Current production of many energy transition minerals is more geographically concentrated than that of oil or natural gas

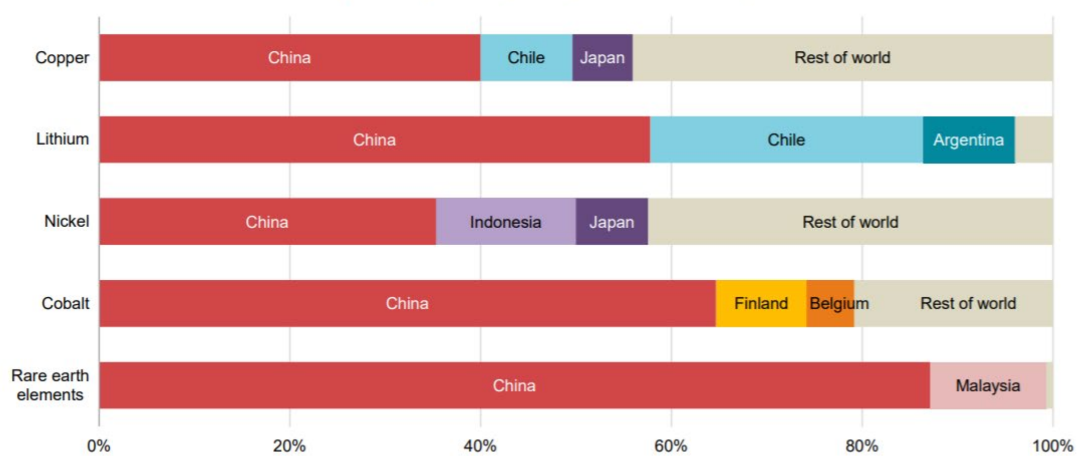
Share of top three producing countries in total production for selected minerals and fossil fuels, 2019



Sources: IEA (2020b); USGS (2021).

The level of concentration is similarly high for processing operations, with China's significant presence across the board

Share of processing volume by country for selected minerals, 2019



Note: The values for copper are for refining operations.
Sources: World Bureau of Metal Statistics (2020); Adamas Intelligence (2020) for rare earth elements.

An America increasingly dependent on geopolitical rivals for both hydrocarbons and critical minerals would be a riskier place to build businesses and invest. A rather important transition risk. Yet most climate risk disclosure advocates say little or nothing about it.

Downplaying Regulatory Impediments

University of Colorado professor Roger Pielke, Jr. recently outlined a simple way to keep track of the Biden-Harris administration's progress in achieving a zero-emission electric power sector:

> In January 2021, according to the U.S. Energy Information Administration, in the United States there were 1,852 coal and natural gas power plants that generated electricity.[83] By 2035, to hit President Biden's target all of these power plants will have to be either shut down or converted into zero-emissions power plants (using carbon capture and storage technologies that presently do not exist).
>
> There are 164 months until 2035. That means that more than 11 of the fossil fuel power plants operational in January 2021 will need to be closed every month, on average, starting today until 2035.[84]

Commenting on Pielke, Jr.'s metric, Florida International University professor Mario Loyola explains the scope of the challenge confronting the Biden-Harris administration:

> Hundreds of those plants produce several multiples as much electricity as the largest solar-power plant in the United States, which means that as those coal and natural-gas plants close, they will have to be replaced by dozens of new renewable-energy plants *every month*. Meanwhile, back in the real world, the federal government can barely manage to issue permits for a small handful of renewable-energy projects *every year*.[85]

The sheer number of renewable energy projects required to achieve NetZero electricity by 2035 and the land surface area affected are staggering. Loyola explains:

> Focusing just on the solar part, consider that each new solar project might have a total footprint of 10,000 acres. Multiply that by 1,000 projects, and you've already covered an area twice the size of New Jersey with solar panels. Because of intermittency and other issues, you can multiply that area by maybe two. Now add thousands of utility-scale batteries (just to extend the power output of solar plants through evening hours and cover increasingly frequent shortfalls), and hundreds of thousands of miles of transmission lines.[86]

The problem, Loyola contends, is that the federal permitting program established by the National Environmental Policy Act (NEPA) only has the bandwidth to complete about 70 environmental impact statements (EISs) per year. A major project cannot move forward until its EIS is completed and the responsible agency or agencies have granted project developers a permit. The average time to complete an EIS is 4.5 years. For transmission projects, the average is 7 years. "In a typical year, federal agencies issue permits to, at most, a few dozen solar and wind projects across the entire country. Individual federal agencies get totally overwhelmed by just a handful of permit applications," Loyola contends.

Granting a permit is seldom the end of the story. The risk of litigation is almost 100 percent, and litigation can drag on for years. The result is that many "shovel-ready" renewable energy projects are never built.[87]

In a recent Webinar, prof. Loyola acknowledged that Congress could in theory exempt renewable energy projects from NEPA review. Politically, however, that is a non-starter. A major purpose of NEPA is to empower local communities to raise environmental concerns about federal agency actions, including permitting decisions. "What those congressmen would be voting for is to cut their local constituents out of voicing their concerns about a local project."[88]

Carbon Bubble or Green Bubble?

A forced march towards a material-intensive energy system could culminate in a "perfect storm." In this scenario, Congress and the White House authorize regulations to phase out fossil-electric generation, the market for new internal combustion engine vehicles, hydraulic fracturing on federal land, and so on. They also pump trillion-dollar subsidies into the "clean energy" sector. However, due to permitting process bottlenecks and the long lead times required to scale up mining and processing infrastructure, the supply of fossil energy decreases faster than the supply of zero-emission energy increases. The supposed transition from fossil fuels to renewables is instead mostly a transition from abundant and affordable fossil fuels to scarce and unaffordable fossil fuels.

Disclosure advocates warn of a carbon bubble but the Paris treaty and NetZero agendas may be setting the stage for a green bubble. Unsustainable levels of deficit spending combined with unprecedented levels of regulatory coercion may incentive many otherwise sober investors to chase windfall profits. Beguiled by the false security of government favor, many investors may buy stock in companies based on the latter's alignment with an ideological echo chamber in Washington, D.C. That seems to us like a prescription for disaster.

In his remarks for the September 2009 Solyndra groundbreaking ceremony, then-Vice President Biden boasted that the Department of Energy's $535 million loan guarantee would create "1,000 permanent new jobs," "jobs of the future," "jobs that cannot be exported." Energy Secretary Steven Chu agreed: "And here's the best part, none of these jobs can be outsourced."[89] Almost two years later to the day, all the Solyndra jobs disappeared and the company filed for bankruptcy protection.

The Solyndra loan guarantee was part of a $30 billion program administered by one agency. The Biden-Harris administration now engages all agencies in a multi-trillion dollar "clean energy transition." The stage is set for hundreds of Solyndras and worse. Somebody should warn the public of the risks to investors. If not the Commission, then who?

Respectfully Submitted,

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