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The Factual Context for Climate and Energy Policy

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Virtually all climate policy discussions assume that climate science compels us to make large and rapid reductions in greenhouse gas emissions. But any realistic policy must balance the hazards, risks, and benefits of a changing climate against the world's growing demand for reliable, affordable, and clean energy. To strike that balance, climate policymakers will consider society's values and priorities, its tolerance for risk, equities among generations and geographies, and the efficacy, costs, and collateral impacts of any policy. This paper reviews some of the scientific, techno-economic, and societal facts and circumstances that should inform those policy decisions and draws some straightforward conclusions from them.

CLIMATE IMPACTS

Projections of the impacts of future climate changes rely on assumptions about future greenhouse gas emissions fed into large computer models of the ocean and atmosphere. Although those models can give a hazy picture of what lies before us at the global scale, their deficiencies on smaller scales are legion. For example, two senior climate researchers firmly within the scientific mainstream have said this:

> For many key applications that require regional climate model output or for assessing large-scale changes from small-scale processes, we believe that the current generation of models is not fit for purpose.[1]

That's particularly important because adaptation measures depend upon regional model projections. One of the same senior researchers noted the following:

> It is difficult, and in many places impossible, to scientifically advise societal efforts to adapt in the face of unavoidable warming. Our knowledge gaps are frightful because they make it impossible to assess the extent to which a given degree of warming poses existential threats.[2]

A Hoover Institution Essay

September 2024

Users of the model output similarly caution about being overly credulous:

> The use of these [climate] models to guide local, practical adaptation actions is unwarranted. Climate models are unable to represent future conditions at the degree of spatial, temporal, and probabilistic precision with which projections are often provided, which gives a false impression of confidence to users of climate change information.[3]

Even if we can't rely on unvalidated climate models, we can get some sense of how the world has fared under a changing climate by looking back to 1900. Since that time, the globe warmed 1.3°C, about as much as the Intergovernmental Panel on Climate Change (IPCC) predicts will occur in the next century under moderate future emissions. But even as the globe warmed and the population quintupled, humanity prospered as never before. For example, global average lifespan went from thirty-two years to seventy-two years, economic activity per capita grew by a factor of seven, and the death rate from extreme weather events plummeted by a factor of fifty! Any assertion that a similar warming over the next century will be catastrophic is implausible and finds little support in either IPCC science assessments or the underlying scientific literature and data.

Although climate varies a lot on its own, many still allege that we've broken the climate in the past few decades. Yet table 12.12 of the most recent IPCC report (AR6 WG1) shows it's hard to find long-term global trends in most types of extreme weather events, including storms, droughts, and floods. And economic loss rates have *declined* slightly over the past thirty years, averaging about 0.2 percent of global GDP.[4] A wealthier world is a more resilient world.

Perhaps future climates will be a lot worse. But the United Nations (UN) projects substantial economic growth, even for an emissions-heavy future. The IPCC's 2014 Fifth Assessment Report said the following in chapter 10:

> For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (medium evidence, high agreement). Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change.[5]

Subsequent research has confirmed that warming is expected to be a minor hinderance to growth—a few degrees of warming by the end of the century would make the growing economy a few percent smaller than it might have been.[6] For example, if the US economy were to grow at an average annual rate of 2 percent, it would be four times larger seventy years from now. A climate impact of, say, 4 percent would reduce the growth from 400 percent to 384 percent, a change much smaller than our ability to project that quantity. Of course, there are uncertainties in these projections, GDP is not the only measure of well-being, and the rich will fare better than the poor. But the term "existential crisis" is hardly justified.[7]

Another form of "climate impact" is the disruption caused by large and rapid reductions in greenhouse gas emissions. William Nordhaus's work showed that there is an optimal pace to reduce emissions: moving too quickly causes turmoil and deploys immature technologies. His 2018 Nobel lecture stated that an economically optimal decarbonization could let the global temperature rise in 2100 exceed 6°C (quadruple the Paris Accord guardrail of 1.5°C!). Of course, that's based on assumptions that can be, and have been, challenged, but Nordhaus's main takeaway is "don't panic"—take the time to reduce emissions gracefully.[8]

MORAL CONSIDERATIONS

To paraphrase the best climate science can tell us, *Something very bad might happen—but we do not know exactly what, or precisely when, or just how bad it is going to be*. Developed countries fret about that "climate threat" and therefore urge prompt, large-scale action to reduce global emissions. But that vague, uncertain, and distant threat is hardly compelling for most of the world, which has many more certain, immediate, and soluble problems.

The 1.5 billion people in the developed world enjoy abundant and affordable energy. But the globe's other 6.5 billion don't have enough energy. The inequalities are astounding: Americans consume thirty times more energy per capita than Nigerians. And 3 billion of the world's 8 billion people use less electricity every year than does the average US refrigerator. Energy poverty also means cooking with wood and dung, and smoke in the kitchen kills some 2 million people each year.

Global energy demand is predicted to increase 50 percent by midcentury as most of the world develops. Fossil fuels are the most reliable and convenient way for developing nations to get that energy, as they long have been for everyone; coal, oil, and natural gas provide about 80 percent of the word's energy today. So global emissions will persist in coming decades, even as the developed world's emissions decline slowly. Just to stabilize, let alone reduce, humanity's warming influences at an allegedly safe level, emissions must vanish in the latter half of this century.

Reliable and affordable energy is the overwhelming priority for developing nations. So when they're told that *The science compels us*, their clear response is *What do you mean "us"?* We hear the Indian prime minister protest that the path for development is being closed to developing nations, while Niger's former president says Africa is being punished by Western decisions and will fight to exploit the fossil fuels it has.[9]

There are moral issues when the developed world seeks to deny developing nations the energy they need, restraining economic progress by mandating costly and ineffective energy systems, particularly if the developed countries are not going to pay a "green premium" for low-emission technology from their already stretched budgets.

A very different immorality arises from continued exaggerations like *science compels*, which induce eco-anxiety. Some 60 percent of young people globally are very worried about climate change, and many are reluctant to have children.[10]

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The facts and figures about climate and energy that I have laid out show that the world will not get to net zero emissions by midcentury and that net zero by 2100 would be a heroic achievement. But they also show that the world isn't facing climate catastrophe. If advocates continue to exaggerate the importance and urgency of reducing emissions at the expense of more immediate and tangible societal needs, what will the public think as the world continues to fall short of its emissions goals yet continues to prosper?

TECHNO-ECONOMIC REALITIES

Energy systems are recalcitrant for good reasons. These systems involve massive investments in assets that last decades, their parts need to work together (for example, cars, fuel, and the fueling infrastructure must all be compatible), and there are many stakeholders whose interests don't often align. It also takes time to refine the hardware and operating procedures that ensure high reliability. So energy systems are best changed slowly and steadily over decades—more like orthodontics than the tooth extraction implied by large and rapid reductions.

Reducing emissions from energy systems will involve electrifying most transportation and heat while transitioning to a zero-emissions electrical grid. Although electric vehicles and industrial heat pose their own challenges, this paper focuses on the linchpin of the strategy, decarbonizing the grid.

The electrical grid must reliably deliver electricity. The wind turbines and solar panels so much in vogue are indeed today's cheapest ways of producing electricity. Unfortunately, they are unreliable: solar panels don't produce at night, and the wind comes and goes hourly. So there has to be a reliable backup system for when the renewables fail—technologies such as natural gas with carbon capture or nuclear power or some form of storage (like giant batteries).

Reliable backup isn't too expensive in day-to-day operations. But there are infrequent occasions, up to two weeks long, when neither wind nor solar will generate much. Those times are so important the Germans coined a word for them: *dunkelflaute*—a dark stillness. *Dunkelflauten* are documented in all locales with significant deployment of renewables, including the UK, Germany, Texas, and California.

To ride through those long *dunkelflauten*, the backup grid must be at least as capable as the wind and solar alone, and hence at least as expensive. In other words, the most expensive part of a renewables-heavy grid is reliability, and it becomes more and more expensive as the reliability requirement becomes more stringent.

The cost of reliability can be estimated by models that subject different grids (i.e., mixes of storage, gas, nuclear, wind and solar generation) to historical hour-by-hour weather and demand data. One such study of the US grid demanding >99.99 percent reliability (roughly today's federal standard) showed that natural gas with or without carbon capture would be the cheapest, and that grids with only wind and solar generation and various forms of storage would be at least two or three times more costly.[11]

So it is incorrect, and entirely misleading, to assert that a renewables-heavy grid will be cheap—unless you're okay with poor reliability. And it's reasonable to ask, *If the backup system needs to be so capable, why have renewables at all?* In short, wind and solar can never be more than an ornament to more reliable technologies.

Solar and wind generation have other drawbacks. They need a lot more land because sunlight and wind are much less concentrated than fossil or nuclear energy.[12] To produce the same electricity, wind takes four times as much land as gas, seven times as much as coal, and thirty times as much as nuclear. And you need to cover that land with enormous structures. To produce the same amount of electricity, wind takes ten times as much concrete and steel as nuclear.[13]

Renewable energy technologies also use a lot more high-value materials, such as copper, molybdenum, and dysprosium, because they need to be very efficient.[14] An electric car uses almost seven times as much high-value materials as a conventional car, while onshore wind generation uses almost nine times as much as natural gas.

Unfortunately, those high-value materials and their processing are concentrated in inconvenient countries. The Democratic Republic of the Congo produces 75 percent of the world's cobalt, while China is a major player in extracting rare earths and graphite and in processing an array of critical minerals.

And although China uses less than 40 percent of the world's solar panels, it makes 75 percent of all panels, 97 percent of the wafers, 85 percent of the cells, and 79 percent of the polysilicon.[15] Chinese manufacturing costs are lower due to cheap (coal-fired) electricity, loose environmental standards, and forced labor.[16] The US government has imposed sanctions on some Chinese material for solar panels, which has driven up costs.[17] And the Inflation Reduction Act begins an effort to onshore or "friend shore" the supply chains for critical minerals.[18]

But some of the drawbacks of fossil fuels that disturb many people would still be there in a high-renewables world—there will still be international trade to lower commodities costs. And there will still be pollution from extracting and processing the enormous quantities of materials that renewables require. However, since critical minerals are input to the manufacture of energy equipment, disruption of one of those supply chains would not have the immediate impact that disruption of a fossil fuel would entail.

In addition, renewables may not remain the cheapest form of generation. If wind, solar, electric vehicles (EVs), and the like are deployed at the envisioned pace, mineral supplies will have a hard time keeping up. For example, by the middle of the next decade, copper demand is expected to double, but the supply will be 20–25 percent short because new mines will have lower quality ore and take sixteen years to start up.[19]

SUMMARY

A dispassionate look at trends in demographics, development, and energy technology shows that global net zero by 2050 is a fantasy and that it's quite unlikely even by 2100. But also, the consequences of missing that goal will hardly be catastrophic. That doesn't mean the world, or we in the United States, shouldn't do anything. But it does undermine claims of urgency. Here's what I think we should do.

Sustain and improve climate science. Our knowledge of the climate system is not what it should be. Paleoclimate studies tell us how and why climate has changed in the past; current observations with improved coverage, precision, and continuity tell us what the climate system is doing today; and models give a sense of what might happen in the future. There is a particular need for greater statistical rigor in the analyses and for more focused modeling efforts to reduce uncertainties.

Improve communications to the public. We need to cancel the alleged climate crisis even as we acknowledge that human influences on the climate are growing and that we should be working to reduce them. The public must have an accurate view of both climate and energy that gets beyond sound bites like *We are on a highway to climate hell with our foot still on the accelerator*.[20] Such alarmism is counterproductive, since many people are savvy enough to dismiss unsupported scare stories.

Acknowledge that energy reliability and affordability take precedence over emissions reductions. A good start was President Joe Biden's recent admission that oil and gas will be necessary in the United States for at least a decade. (Actually, it will be far longer than that.) Europe's current energy crisis is self-inflected: fossil fuel investments and domestic production were abandoned in favor of unreliable import partners and unreliable wind and solar generation. It was easy to see that this would lead to trouble, but mitigation was deemed more important than reliability and affordability.

Pursue thoughtful decarbonization. Governments should embark on programs that aim to reduce emissions by productively coordinating technology development, private sector activity, regulation, and behavior change. It will also be important to estimate costs, timescales, and any actual impacts on the climate (i.e., will it make a difference?). An essential element is research, development, and demonstration (RD&D) of emissions-lite technologies to reduce the so-called green premium. Small fission reactors, grid storage and management, batteries, noncarbon chemical fuels, and carbon capture and storage should be high on the list of today's most promising early-stage technologies.

But programs that go beyond RD&D to meaningful deployment should not scattershot mandates and incentives currently popular. Energy is delivered by complex systems that touch—to borrow from a recent movie title—"everything, everywhere, all the time." Those systems are recalcitrant for fundamental reasons, so they are best changed slowly. Precipitous climate action is far more disruptive than any plausible impact of climate change. Recent events in Germany, the UK, and the Netherlands show how overly severe emissions regulations can destabilize the political landscape.

Acknowledge developing world energy needs. Most of the world today is energy starved, and fossil fuels are currently the most convenient and reliable way of meeting that demand. Without costly backup systems, weather-dependent wind and solar generation cannot provide appropriate energy access for the people of developing countries. Most advocates of rapid global decarbonization never say what they would do to meet the developing world's energy needs. And for those who do say, I have yet to hear an answer that respects technical, economic, demographic, and political realities.

Place a greater focus on alternative strategies for dealing with a changing climate. The most important is adaptation. It's autonomous—adaptation is what humans do, it is effective, it is proportional, and it is local and hence achievable. If nothing else, governments should work to facilitate adaptation.

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Policymakers need to realize that large and rapid reductions in emissions are overkill—they risk far more damage to humanity than any conceivable impact from climate change itself. But there is a sensible path forward that will moderate human influences on the climate while responding to the growing demand for reliable and affordable energy. The policy challenge is to identify that path and begin to follow it.

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