Testimony of
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On
The Infrastructure Needs of the U.S. Energy Sector

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Good morning. Thank you for the opportunity to testify again before this Committee. I'm a Senior Fellow at the Manhattan Institute where I focus on science, technology, and energy issues. I am also a Faculty Fellow at the McCormick School of Engineering at Northwestern University where the focus is on future manufacturing technologies. And, for the record, I'm a strategic partner in a venture fund dedicated to energy software.

Since the purpose of this hearing is to considering draft legislation that addresses the infrastructure implications associated with shifting the nation's energy supply towards lower-carbon options, I believe it would be prudent to consider the full range of options that could achieve such goals, especially those that could do so rapidly and cost-effectively. But before outlining some options to consider, I think it's important to begin with the global framework within which we are necessarily operating. It is obvious that the United States U.S. is far from alone in aspirations to "de-carbonize" national energy systems. This has critical implications because all infrastructures have supply chains, and the U.S. will be in global competition for the resources, hardware and machines needed to build the kind of lower-carbon systems being proposed.

The International Energy Agency's (IEA) has issued a very useful, recent report that provides a sense of perspective on where policies are attempting to take the world in terms of a global "roadmap" to "net zero." Specifically, that path envisions over the coming two decades a 1,200% increase in global energy production from wind and solar machines. In the IEA's roadmap, those two energy systems alone account for about three-fourths of all forecast growth in energy supply to the world.

It bears noting that the IEA roadmap also envisions, for example, bans on the sale of cars with internal combustion engines and thus forecasts hundreds of millions of battery-only cars that will further increase demand on infrastructures for both electricity generation and battery mineral. In addition the IEA "net zero" roadmap envisions, for example, policies that will induce or force what the IEA terms "behavior changes" such as, for example, a *doubling* of the number of global households without a car of any kind.

Setting aside issues associated with achieving the kinds of "behavior changes" that the IEA—and others—propose for reducing energy use in order to implement the "net zero" path, consider instead the physical challenges for producing energy. It is a truism that's often lost in debates over different visions for energy production, but all energy systems require building physical infrastructures and machines. This reality has salience for plans to expand the use of wind, solar and battery technologies because building those energy systems, compared to conventional hydrocarbon technology, entails using roughly 1,000% <u>more</u> materials to deliver a unit of energy to society.

In addition to a radical increase in the use of the usual class of construction materials, such as concrete, steel and glass to building, there is also the separate but related matter of a radical increase in the use of critical "energy minerals" needed to build key components needed for the wind, solar and battery hardware. Relevant to this particular issue, the IEA has recently issued another massive report, one that reveals confirmatory data regarding the materials and minerals challenge for he "net zero" path. That report documents a 700% to 4,000% increase needed in mining for critical energy minerals. If such a path is in fact pursued, it will require an unprecedented expansion in the associated scale of infrastructures for mineral and materials processing, not just mining.

Without regard to the economic, environmental, and other implications of such an astounding increase in materials used to supply energy to society, there is the very practical challenge in actually building the new lower-carbon infrastructures. Start with the fact that all the world's current solar and wind hardware produces energy equivalent to 5 million barrels per day of oil. The IEA's path to "net zero" requires that energy production to increase to the equivalent of 65 million barrels within 20 years. For context, it took the world 50 years to build an oil infrastructure that went from 5 million barrels per day in 1930 to 65 million barrels per day by 1980. Thus the proposed "net zero" path will require a construction program that expands more than twice as fast and do so using 1,000% times more physical stuff. This scale of infrastructure expansion is truly breathtaking. It is also unlikely to be possible.

Consider an infrastructure analogy. The total number of lane-miles built in the United States increased by 300% in the 100 years since 1921. Imagine proposing incentives to build that many more lane-miles again but expecting to do so in less than half the time, and while using a different road 'technology' that requires 1,000% more materials per mile built. The world of mining and construction machines have certainly improved over the decades, but there is no evidence that suggests such ambitious expansions are possible for either the infrastructures of roads or energy systems.

Given all of that and, given that this Administration and many in Congress are seeking means to reduce the use of hydrocarbons in the world, one might consider five energy options that don't appear to be on the favored roadmap. These are options that are more likely to be physically possible to implement and demonstrably more cost-effective means for achieving the stated goals.

First, far greater, faster and more certain reductions in carbon dioxide emissions would happen if the U.S. were to ensure that liquified natural gas (LNG) exports increased as much in the future as happened (without subsidies) in the past. It is indisputable that global electrification will continue, regardless of policies to accelerate that century-long trend, and consequently nations will necessarily seek means to meet that demand

While the IEA's aspirational "net zero" path projects a ten-fold drop in coal use over the next two decades, it bears noting what is in fact happening. There are some 300 GW of new coal-fired power plants on the global drawing boards or under construction; that represents more new capacity than the entire current U.S. fleet of coal plants. Similarly, an early 2021 survey found that the new coal mines planned, or under construction, will add over two billion tons per year of new coal production – that's double the peak U.S. coal production of a decade ago. And the data also show that global coal use increased in the first quarter of 2021 as economies fired back up and as global LNG prices increased. The fact that global gas prices had earlier in the decade been trending down, thereby increasing its use for electricity generation, was almost entirely a consequence of the unexpected and enormous increase in U.S. gas production.

U.S. shale technology was responsible for nearly one-third of all the world's increased production of natural gas over the past decade. Middle East production growth was only slightly ahead. More than a dozen states are significant producers of natural gas, with Pennsylvania, Ohio, and West Virginia collectively accounting for nearly two-thirds of the increased supply in the past decade. America's Appalachian region is one of the world's biggest producers of natural gas and could be far bigger yet. Absent the epic increase in global natural gas supply, and the drop in prices—again driven in large part by America's increased production—the world today would almost certainly be burning about two billion tons more coal per year.

Increasing U.S. LNG exports to the world would not only help displace existing and increased coal use on a purely economic basis, but it would also benefit consumers everywhere as the American abundance holds global prices down. No incentives are needed to convince America's natural gas producers to supply more to the world. The key to facilitating export of that gas rests in the infrastructures of pipelines and ports. Here Congress can certainly play an important role in ensuring that there aren't regulatory impediments, never mind incentives, for permits to build that infrastructure.

A second, obvious, energy option for a lower-carbon future would be to accelerate next generation nuclear energy deployment. Nuclear fission offers a foundationally superior advantage in terms of its infrastructure. That advantage rests on the simple fact that fission-based energy requires a trivial amount of land and material. The energy in one pound of nuclear fuel matches 60,000 pounds of oil or 100,000 pounds of coal. Or consider a comparison with batteries, which are now frequently proposed as means to fix the unreliability of wind and solar: it would take 1 million pounds of Tesla-class batteries to hold the energy in 1 pound of nuclear fuel.

But despite its astounding promise, today barely 10% of the world's electricity comes from uranium on this the 65th anniversary of the world's first commercial nuclear plant. (That was England's Calder Hall, inaugurated in 1956 by Queen Elizabeth II.) The impediments to building more grid-scale nuclear power plants have been well-documented and are, in the main, associated with precisely the same regulatory impediments that kept "shovel ready" infrastructure from expanding quickly a decade ago the last time Congress enacted "recovery" spending.

There are now some exciting technology options for expanding the use of nuclear energy beyond gigawatt-class grid-scale power plants. More than a dozen companies are at various stages in developing innovative designs for very small nuclear power plants offering inherently safe features, and are at a scale appropriate for powering a small city or even a town. A key challenge with unlocking the technology of this new class of mini-reactors is in providing both commercial validation and scale of production. Congress can play a role. Much as the administration proposes to convert the federal vehicle fleet to battery-power, we should consider converting a large share of federal government electric supply to microgrids powered by mini-reactors, perhaps focused on military bases. No government R&D funding is required. Instead, a program could be modeled on the military's well-tested competition and procurement process used to stimulate access to a new generation of aircraft, for example, wherein the one or two winners are awarded multi-year multi-billion-dollar production contracts.

A third option for reducing future oil use is a simple even if unpopular one; encourage greater use of next generation internal combustion engines. Again, to the extent that the goal is to find cost-effective and rapid means to reduce oil use, the data show that a dollar spent on subsidizing more efficient engine choices would save far more oil than the same dollar subsidizing batteries. Innovative designs for internal combustion engines continue to emerge, some with as few moving parts as an electric motor, and many with the potential for as much as a five to 10-fold gain in power-to-weight ratio.[1] That is a far greater level of improvement than is possible with batteries, for example. The IEA has also noted in another, earlier, analysis that advanced combustion engines could yield far more oil savings over the coming decade than the expansion of electric vehicles. Even the most optimistic scenario for EV growth leaves the world with hundreds of millions of conventional cars for many decades. Here again, aside from subsidy and tax issues, the government, perhaps the Department of Energy's advanced manufacturing program, can play a constructive role in building and facilitating the infrastructures needed to fabricate such advanced engines.

Then, a fourth category of actions that could be directed at energy options intended to reduce future carbon dioxide emissions entails a domain I've offered in earlier testimony relating to the U.S mining industry. The increased use of wind, solar and batteries technologies in America will increase imports of critical minerals and materials with negative implications for the balance of trade, the economy, and geopolitics. This is not news, even if it is often ignored. There have been over the decades many studies, congressional hearings, and bipartisan policy analyses, pointing to the same two facts.[2] The United States contain vast mineral reserves including all the elements relevant to green energy machines, not to mention those critical for computers and the military.[3] But America's share of domestic and global mineral supply continues to shrink.

We've seen decades of bipartisan proposals reaching back to the Strategic Materials Act of 1939 regarding action needed in this area. Every single one has included the same central and obvious

[1] Sara Toth Stub, "The Car Engine of Tomorrow: Cleaner, Lighter, With One Moving Part." *The Wall Street Journal*, June 20, 2019.
Jack Stewart, "A Powerful Yet Tiny Engine Inches Closer to Powering EVs and Drones." *Wired*, June 3, 2017.
Juan Plaza, "LiquidPiston Enters the UAV Arena with a Revolutionary Rotary Engine." Commercial UAV News, April 2, 2018.
[2] Philip Wegmann, "Murkowski: U.S. Made Vulnerable by Lag in Key Mineral Extraction," *RealClearPolitics*, Nov. 13, 2019.
[3] DOI and USGS, "Mineral Commodity Summaries 2020."

conclusion: the primary means for decreasing import dependencies is to increase domestic mining.[4] As the National Academies of Sciences pointed out in a 1999 report on mining: "lack of early, consistent cooperation and participation by all the federal, state and local agencies involved in the NEPA process results in excessive costs, delays and inefficiencies."[5] The U.S. has one of longest permitting processes for mines in the world.[6] It can take up to three decades to get a new mine into production.[7] At the same time, policymakers and U.S. presidents over the years have substantially decreased access to federal lands for mineral exploration. The U.S. has regulated its way into far greater mineral import dependencies.[8]

Congress enacted legislation more than 40 years ago, on a bipartisan basis, signed by President Carter—the National Materials and Minerals Policy, Research and Development Act of 1980—specifically directed at the coequal pursuit of mineral production and environmental protection.[9] If we are to have a path to "net zero" energy production, that path passes directly through the critical infrastructure of a mining and minerals processing industry. It's being left out of the equation.

Finally, a fifth policy action to consider, in the spirit of the goal to pursue foundationally more efficient and lower-carbon energy technologies, emerges from the fact that many of the capabilities and technologies imagined for a "net zero" path do not yet exist. This reality is acknowledged in numerous serious analyses including from the IEA. And Microsoft, for example, in its lengthy and candid 2020 climate-policy position, specifically notes that "net zero" energy plans "will require technology that does not exist today." This means we need truly radical inventions or, in effect, we need what could be termed "new science." Such a goal of course can only be addressed through foundational discoveries in the sciences, in physics, chemistry and biology, a domain where Congress can certainly play a role. Increased support for fundamental research, rather than just subsidizing or mandating existing technologies, will be essential.

In summary, regarding the $100 billion or so contemplated in the legislation under consideration, the scale and long-lead times inherent in all of civilization's energy infrastructures essentially demands a long-term vision. It also suggests caution is in order regarding the risk of putting into place short-term incentives that would not only fail to achieve the stated goals, but also damage the U.S. economy and geopolitical status.

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[4] Ned Mamula and Ann Bridges, *Groundbreaking! America's New Quest for Mineral Independence* (Round Rock, TX: Terra Dynamics, 2018).
[5] National Research Council, *Hardrock Mining on Federal Lands* (Washington, DC: National Academies Press, 1999).
[6] Matthew Kandrach, "America's Dangerous Foreign Mineral Dependence," RealClearEnergy, Feb. 21, 2018.
[7] Peter Coy, "Why the Periodic Table of Elements Is More Important than Ever," *Bloomberg Businessweek*, Aug. 28, 2019.
[8] USGS, "Risk and Reliance: The U.S. Economy and Mineral Resources," Apr. 12, 2017.
[9] Ned Mamula, "Balancing America's Environment, Mining, and the Green New Deal," *The Hill*, Mar. 1, 2019.