Testimony of
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Before
U.S. Senate Committee on Energy and Natural Resources
On
Sources And Uses Of Minerals For A Clean Energy Economy

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Good morning. Thank you for the opportunity to testify before this Committee. I'm a Senior Fellow at the Manhattan Institute where I focus on the policy implications of technologies, especially at the intersections with energy, and where I have advocated for years that America's energy policies should emerge from both the realities of the underlying physics of technologies, as well the unavoidable realities of geopolitics.

I am also a Faculty Fellow at the McCormick School of Engineering at Northwestern University where my focus is on the technology and the future of manufacturing. And, for the record, I'm a strategic partner in a venture fund dedicated to startup companies in digital oilfield technologies.

Permit me to start by noting an obvious fact, but one that deserves restating in the context of this hearing. Every product and service that exists requires extracting minerals from the earth. And all those minerals must be refined, transported and converted into materials, then fabricated into products and ultimately disposed of or recycled. All of that activity entails the use of land and energy somewhere. Thus all environmental, economic, social and geopolitical consequences derive from the quantities of materials needed and where it all comes from.

As this committee well knows, the issue of America's strategic dependencies on a small set of "critical minerals" is not a new subject. However, the issue on the table now is the potential for "clean energy" policies to inadvertently create entirely new mineral dependencies.

And, as the Committee also knows, there are advocates who claim that the wind and sun could provide 100% of America's energy needs, compared to today's 3% share. While the credibility of this claim is not our focus today, it bears noting that achieving that goal is simply not possible, any more than it's possible to use airplanes to fly to the moon. And the often-used analogy, that an ostensible energy tech revolution will echo the characteristics and velocity of the information revolution is, to put it diplomatically, fallacious.

Set aside for now whether such a huge jump in the share of wind and solar is desirable or even feasible. The fact is, a more vigorous pursuit of clean energy by the U.S., especially in concert with other nations, would lead to an unprecedented expansion in global mining and chemical processing, and collaterally a radical increase in the quantities and sources of import dependencies and geopolitical risks for the United States -- and it would produce astonishing quantities of waste. And this says nothing about the demonstrably destructive economic impacts.

To understand why, we must first dissect two deeply misleading tropes used in our national debate about America's energy future: the idea that wind and solar are "free" and that the machines access those energy sources are "renewable."

There is no such thing as free energy, at least not delivered in a way that matters to survival. The seductive idea that the air and sun are free is no more true than is the case for oil and gas. Mankind had nothing to do with creating either. In order to deliver useful energy to society, all sources require access to and use of land, and all require construction of physical hardware, all of which has costs.

Thus, there's no such thing as a renewable energy machine. All energy machines must be built from non-renewable minerals and all machines wear out and must be disposed of and replaced. This is, not to wax philosophical, society's central Sisyphean struggle.

More practically, these two points are the nub of the challenge for policies that propose to radically increase America's use of energy from wind and solar machines. The clean energy path leads to astounding increases in materials use and dependencies.

These consequences do not derive from design flaws in the green machines, in effect from a failure in human engineering or imagination. The consequences, regardless of policies or aspirations, arise from the inherent nature of the physics of energy in our universe. Per unit of useful energy delivered to society, whether measured in miles of travel, tons of products, or gigabytes of data, the wind and solar path increases both land and material uses by something like 500 to 1,000 percent.

Of course we find elements like iron, chromium, silver and neodymium used to build frack pumps in the shale fields as well as in wind turbines. But the physics difference between the quantities needed is literally visible: A wind or solar farm stretching to the horizon can be replaced by a handful of gas-fired turbines, each no bigger than a tractor-trailer.

For example, to replace the lifetime energy output from a single shale rig producing gas requires building a 6-fold greater quantity of similar-sized wind turbines. Of course, the shale rig 'disappears' from that shale field, and is re-used to produce more energy, while the field of wind turbines stays in sight for decades, until they wear out. And consider, because wind and solar are nearly useless without storage, it takes 60 pounds of battery to store the energy equivalent of just one pound of oil. Such realities are what leads to the 'invisible' amplification in the quantities of materials mined upstream, somewhere.

That amplification is made particularly clear if we examine a few specific examples in terms of total fuel-cycle mineral requirements. The battery for a single electric-car weighs about 1,000 pounds. About 50 pounds of oil can provide the same vehicle range. Fabricating that single battery involves digging up, moving and processing more than 500,000 pounds of raw materials somewhere on the planet. Meanwhile, measured over the lifespan of the battery (seven years), using oil involves one-tenth as much in cumulative material weight extracted from the earth to deliver the same vehicle-miles.

Or consider one more example. Building one wind turbine requires 1,500 tons of iron ore, 2,500 tons of concrete and 45 tons of non-recyclable plastic. For an equal amount of energy production, solar power requires even more cement, steel and glass—not to mention other metals. Increasing the wind and solar share to, say, just a one-third share of America's energy arithmetically requires a 1,000% increase in the materials already consumed to produce such machines.

The resource realities of clean energy have not escaped the attention of international organizations including the World Bank and the International Energy Agency (IEA). But it is remarkable how little attention has been afforded to the implications for U.S. energy policymaking.

It's worth highlighting just some of the conclusions. According to IEA analyses, in order to meet current solar forecasts, for example, global silver and indium mining will jump 250% and 1,200% respectively over the next couple of decades. Similarly, world demand for rare-earth elements—which, I note, aren't rare but are rarely mined in America—would rise 300% to 1,000% by 2050 just to achieve the Paris Accord goals.

Or, as numerous similar analyses have shown, replacing conventional cars with EVs would drive up global demand for cobalt and lithium by more than 2,000%. We'd also see a 200% jump in copper mining, along with at least a 500% rise in graphite demand. EVs, typically, use more aluminum too in order to offset the enormous weight penalty from the battery. And none of this counts the materials demand if batteries are scaled to back up wind and solar grids.

Last year a Dutch government-sponsored study concluded that the green ambitions of the Netherlands alone would consume a major share of global minerals. Considering that the U.S., never mind the world, consumes 30-fold more energy than the Netherlands, it's unsurprising that the study also concluded: "Exponential growth in [global] renewable energy production capacity is not possible with present-day technologies and annual metal production."

Nonetheless, many nations including the U.S. government, and numerous states, are incentivizing, if not requiring, greater use of these co-called clean energy technologies. The implications of all this are obvious in terms of environmental, social justice and geopolitical fallout.

It's not just the need to responsibly address the environmental challenges of mining in and of itself, as you Chairman Murkowski are painfully aware vis-à-vis Alaska's Pebble Mine fiasco. One must also consider the astounding quantity of green machines that will wear out and all that old equipment that must be decommissioned, all generating millions of tons of waste. The IEA has calculated that solar goals for 2050 consistent with the Paris Accords – which it bears remembering are a mere shadow of green ambitions now being proposed -- will require disposing of solar panels that will constitute more than double the tonnage of all today's global plastic waste.

There are collateral issues. The Sydney-based Institute for a Sustainable Future, for one, cautions that in a global "gold" rush for clean-energy minerals, mining will be pushed into "some remote wilderness areas [that] have maintained high biodiversity because they haven't yet been disturbed."

Then there's the staggering increase in materials production that will lead, necessarily, to a comparably radical rise in the physical transport of energy materials on global sea-lanes, both increasing and changing the locus of geopolitical supply-chain risks. We note that those who propose to allocate a share of the U.S. Navy's budget to the cost of protecting oil supply-chains should consider a similar calculation for green supply chains.

With respect to America's security and import dependence, it bears noting the U.S. is a minor or non-existent player in most of the materials necessary for clean energy. As this Committee knows, today the U.S. imports over half of more than four-dozen minerals that are commonly used, and 20 of the minerals must be entirely imported.

It is extremely unlikely that any increased mineral production will come from mines in Europe or the U.S. Instead, much of the necessary additional mining will take place in nations with significant geopolitical consequence, and where in many cases labor practices are oppressive and generally not transparent. The Democratic Republic of the Congo produces 70% of the world's raw cobalt, and China controls 90% of cobalt refining.

The desire expressed by many citizens and corporations to ensure ethical supply chains is a particularly thorny one in general, and especially so when it comes to green energy tech. For example, the World Economic Forum's Global Battery Alliance (and numerous pieces of investigative journalism) has observed that the "raw materials needed for batteries are extracted at a high human and environmental toll." The London Metal Exchange proposed last year to ban the sale of "tainted" cobalt. But a broad consortium of NGOs opposed that move, worried that it would simply lead to less transparency and would just increase the amount of trade conducted in "underground" transactions.

The mineral supply chain can sometimes be rendered invisible by other means. Instead of importing minerals, America imports the finished products such as solar panels and batteries. China already has nearly 60 lithium battery manufacturers accounting for over half of the world's production, and is on track to two-thirds dominance by 2030. As a relevant aside, all that production occurs on an electric grid that's nearly two-thirds coal-powered. And, relevant to that fact: it takes the energy-equivalent of 100 barrels of oil to fabricate a battery that can store the energy-equivalent of one barrel.

Setting aside the ethical quagmire of sourcing more of America's, and the world's energy materials from places like China, Bolivia, Russia, and the Congo, one might reasonably observe, as the world bank has, that greater mineral demand would be a huge "opportunity" for citizens in such nations as Chile, Canada, Australia, Brazil, Argentina, and Peru.

But that also presents for the United States at least, another ethical question: Replacing oil, gas and coal with wind, solar and batteries takes jobs and economic output away from our citizens and adds jobs and economic benefits to other nations. Some may see this as a good outcome, but we should be honest about the realities.

More than $300 billion per year of economic output comes from America's oil and gas production. And now our nation is not merely essentially self-sufficient in energy production, but on track to becoming a net overall energy exporter. By contrast, the clean energy materials path both increases the cost of energy and radically increase the share of those costs that comes from imports. And it would of course, reverse the recent historic gains of energy independence.

Some have proposed that the massive gap in materials disparities between hydrocarbons and green energy could be closed by spending more money on improving clean technologies. Of course useful improvements are possible for creating more efficient green machines that thus use fewer materials per unit of energy produced. But we know that those gains are limited by the fact that wind, solar and battery technologies are approaching the physics limits of performance. This means that throwing more money and subsidies at these technologies won’t lead to radical improvements in material-use efficiency. Ironically, for hydrocarbon technologies, the distance to physics limits is further away, which means greater efficiency gains are still possible for oil and gas than for green tech.

However, to the extent that ‘the train has left the station’ and our nation is embarked on a path to expand clean energy, permit me to suggest four actions Congress should consider.

First, Congress should direct an examination and accounting of the full fuel-cycle upstream materials impacts of greater use of clean energy. This will improve the transparency associated with environmental, social, economic and geopolitical impacts.

Second, Congress should direct an examination of the state of recycling clean energy minerals. Notably, only three minerals in general have achieved a 50% level of recycling, according the International Union of Geological Sciences. And rather than institute economically or operationally punitive requirements for greater recycling, efforts should be directed towards research that could yield more economically efficient recycling technologies.

Third, Congress should examine the state of basic research funding associated with the development of both more efficient and new ways to use existing minerals and even the creation of new classes of products that can replace critical minerals. This research should center on the materials genome program that targets the use of supercomputers to invent new classes of alloys that can enhance mineral flexibility and minimize the use of rare elements.

Fourth, and finally, Congress should enact policies that will encourage, not impede, the investment in and development of U.S. mines.

Geological data show that the United States has a vast untapped abundance of mineral wealth. Until engineers invent an element that one might call “unobtanium” -- a magical energy-producing element that appears out of nowhere, requires no land, weighs nothing, and emits nothing – we will need more mining. We should do it here if we want to enjoy the benefits and if we want to ensure the most environmentally sound approaches.
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