Battery Material Supply Chain Challenges Puts Energy Storage Ambitions at Risk

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A rush to immediately rewrite building codes to mandate electrification, including requirements for battery energy storage, place unrealistic demands on even the long-term supply chain. Without energy storage, homes and businesses lacking access to alternative heating sources such as fuel gas are at the mercy of unpredictable power outages and the natural inconsistencies of wind and solar power output. Such a policy literally puts lives at risk, a lesson relearned by Americans every winter. Sustainable energy options such as bioethanol, biodiesel, green hydrogen, hydrocarbons derived either from green hydrogen plus captured carbon dioxide or harvested from recycled plastics, and landfill gas are examples of domestically secure fuel diversification tools that can make progress toward decarbonization goals while also providing desperately needed flexibility in the face of critical mineral shortages and infrastructure financing gaps. We should be expanding our portfolio of available energy solutions rather than constricting them with arbitrary prohibitions which rely on unavailable resources.

The global energy transition currently underway involves a complex mix of goals and challenges. We are attempting to massively increase worldwide energy consumption[1] to enable an American-style quality of life for a growing human population that is expected to exceed 10 billion by 2100[2]. At the same time, we are searching for radically new ways to produce, transport and store all of this new energy so that its use will not continue to exacerbate atmospheric pollution and climate change. Meanwhile, technology in every other arena also continues to advance, creating competition for many of the raw materials that are needed to complete the energy transition. Perhaps nowhere is that more true than for the supply of critical minerals key to the production of batteries. The White House recently put this in perspective:

> "Critical minerals provide the building blocks for many modern technologies and are essential to our national security and economic prosperity. These minerals—such as rare earth elements, lithium, and cobalt—can be found in products from computers to household appliances. They are also key inputs in clean energy technologies like batteries, electric vehicles, wind turbines, and solar panels. As the world transitions to a clean energy economy, global demand for these critical minerals is set to skyrocket by 400-600 percent over the next several decades, and, for minerals such as lithium and graphite used in electric vehicle (EV) batteries, demand will increase by even more—as much as 4,000 percent. The U.S. is increasingly dependent on foreign sources for many

[1] International Energy Agency (2021), World Energy Balances: Overview, IEA, Paris https://www.iea.org/reports/world-energy-balances-overview , License: CC BY 4.0 .

[2] United Nations (2022), "Population", https://www.un.org/en/global-issues/population#:~:text=The%20world%20population%20is%20projected,surrounding%20these%20latest%20population%20projections .

> of the processed versions of these minerals. Globally, China controls most of the market for processing and refining for cobalt, lithium, rare earths and other critical minerals.[3]"

We must proceed carefully. Energy transitions have occurred before, and it is important to understand why this one is different. For almost all of human history, i.e. prior to the Industrial Revolution that began in the early 1700s, the only usable energy sources were those which could be easily harvested by hand without the use of machines. These energy sources were predominantly animal and human muscle energy for manual labor and transportation, and wood and animal manure for heating fuel[4].

This situation prevailed for millions of years[5], but it was easy to change almost overnight. Why? Because it involved little or no replacement of infrastructure. Infrastructure, defined by Encyclopedia Britannica[6] as "the basic equipment and structures (such as roads and bridges) that are needed for a country, region, or organization to function properly", becomes increasingly difficult to replace as it grows in sophistication and as the number of people and technologies it supports multiplies. This is true not only because the infrastructure itself is expensive to build, but also because the maintainers of technologies designed to exploit the infrastructure have an economic interest in perpetuating its use. Recall the old saying to the effect that the advent of the automobile was bad news for buggy whip manufacturers and you will begin to see the scope of today's infrastructure replacement problem.

To be sure, there are good reasons for stabilizing infrastructure within a society. Economic resources are always limited, and the wholesale transformation of businesses and municipal service providers diverts those resources from the tasks of serving new customers and residents, or from providing enhanced levels of service to existing customers. But there are times when the change is compelling. Moving from reliance on literal horse power to steam-driven mechanical power for transportation in Britain had the following impact as described by researchers at the London School of Economics:

> "[Rail] transport was initially wholly dependent on steam engines and can be seen as a manifestation of a developing [General Purpose Technology] at work. The first major scheme was the Liverpool and Manchester railway opened in 1830. **By the early 1850s the core trunk routes of the network were in place and about 7000 miles of track were open**. Eventually the network grew to about 20000 miles. Railways were a massive investment by the British economy which was undertaken rapidly such that **by 1855 their capital stock was equal to 30 per cent of GDP**.[7]" [emphasis added]

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[3] The White House (2022), "FACT SHEET: Securing a Made in America Supply Chain for Critical Minerals", February 22, https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/ .

[4] World Economic Forum (2022), "The 200-year history of mankind's energy transitions", April 13, https://www.weforum.org/agenda/2022/04/visualizing-the-history-of-energy-transitions/#:~:text=The%20History%20of%20Energy%20Transitions&text=These%20changes%20were%20driven%20by,provide%20more%20efficient%20energy%20inputs .

[5] University of Southampton (2022), "TIMELINE OF THE HUMAN CONDITION — Milestones in Evolution and History", https://www.southampton.ac.uk/~cpd/history.html .

[6] Encyclopedia Britannica (2022), "The Britannica Dictionary", https://www.britannica.com/dictionary/infrastructure .

[7] Crafts, N. (2003), "Steam as a General Purpose Technology: A Growth Accounting Perspective", Working Paper No. 75/03, Department of Economic History, London School of Economics, https://www.lse.ac.uk/Economic-History/Assets/Documents/Research/LSTC/wp7503.pdf .

Retirement of the horses was a relatively straightforward process, the number of affected workers was manageable, and their migration to factory labor was achievable with a moderate level of retraining. On the other hand, even a modest technological change to the established rail infrastructure had to take place slowly: reducing standard track width took six decades as chronicled by the UK National Archives[8]:

> "**In 1830s Britain there were two widths, or gauges, of railway track**. The engineer Isambard Kingdom Brunel favoured rails 7 feet apart (Broad Gauge) on the Great Western Railway, while George and Robert Stephenson used a gauge measuring 4 ft 8 ½ inches (Standard Gauge).While Broad Gauge had advantages, more lines used the narrower, and cheaper, Standard Gauge system. Over time the advantages of a national standard gauge railway outweighed the benefits of wider tracks. **Gradually all broad gauge lines were converted to standard gauge, ending with the Exeter to Truro route in May 1892**." [emphasis added]

Returning to the present day, we see extensive efforts to electrify every industry. A core stated benefit by electrification proponents is that, by doing so, we can drastically reduce or eliminate carbon pollution due to the burning of fossil fuels. But their argument is predicated on the ability of society to build new infrastructure, a task that is expected to cost the United States alone between $1 trillion[9] and $7 trillion[10]. Noting that the US government recently spent roughly $8 trillion on the wars in Iraq and Afghanistan between 2001 – 2021[11], a legitimate question arises as to whether policymakers (or electrical ratepayers!) are prepared to shoulder that level of expense. We consider below just one aspect of this expense: the procurement of batteries for energy storage: electricity itself cannot be stored, and the other main proven power storage method, pumped hydro, is geographically limited[12].

The Biden Administration recently announced a $39 billion plan to increase the availability and security of critical minerals in support of the energy transition[13]. While admirable, it relies in no small part on our ability to locate, permit, and exploit new mines: a slow process that, like any resource exploration and extraction endeavor, is fraught with uncertainty and will generate environmental and social conflict. The US Government Accountability Office echoes this concern in a report outlining the many challenges and risks facing our domestic critical minerals industry, including a finding that "[r]esearch and

[8] The National Archives (2022), "'All Change!' on Britain's Railways", https://www.nationalarchives.gov.uk/railways/ .

[9] McLaughlin, T. (2022), "Creaky U.S. power grid threatens progress on renewables, EVs", Reuters, https://www.reuters.com/investigates/special-report/usa-renewables-electric-grid/

[10] Hyman, L. and Tilles, W. (2021), "The $7 Trillion Cost Of Upgrading The U.S. Power Grid", Oilprice.com, https://oilprice.com/Energy/Energy-General/The-7-Trillion-Cost-Of-Upgrading-The-US-Power-Grid.html

[11] Brown University (2021), "Costs of the 20-year war on terror: $8 trillion and 900,000 deaths", News from Brown, September 1, https://www.brown.edu/news/2021-09-01/costsofwar .

[12] Hunt, J.D., Byers, E., Wada, Y. et al. (2020), "Global resource potential of seasonal pumped hydropower storage for energy and water storage" Nat Commun 11, 947, https://doi.org/10.1038/s41467-020-14555-y

[13] US Department of Energy (2022), "DOE Announces $39 Million for Technology to Grow the Domestic Critical Minerals Supply Chain and Strengthen National Security", https://www.energy.gov/articles/doe-announces-39-million-technology-grow-domestic-critical-minerals-supply-chain-and

development that could lead to the technologies needed to safely and economically expand and recover domestically sourced supplies is limited"[14]. This means, at best, that improvement will be gradual.

Steps taken in response to these challenges have been to pursue vertical integration—control over one's entire supply chain in an effort to capture scarce raw materials. Argonne National Laboratory reported on the state of the US battery supply chain for electric vehicle manufacturers (just one of many industrial consumers of lithium ion batteries, as acknowledged by the White House). Most electric vehicle batteries produced between 2010 – 2020 were domestically sourced, and the vast majority of them were sold by Tesla[15]. General Motors seeks the same level of control over their battery supply[16]. Competition will inevitably limit the ability of other firms to replicate this strategy.

Opportunities do exist for increasing the US share of some critical battery mineral processing operations. For example, the National Renewable Energy Laboratory notes that Australia holds 47% of known global reserves of lithium, much of which is then processed by China[17]. This is unsurprising due to their geographic proximity to each other and the natural economic ties that accrue therefrom. With time, the US could develop closer supply relationships with Australian, Chilean, Argentine, and other key critical material source regions. However, the costs of doing so will have to increase along with global competition, and domestic manufacturing costs will likely also exceed what is currently paid by existing battery importers. Rising inflation of electrification technologies will impact the demand for electric vehicles, home battery storage systems, and consumer electronics; it will also negatively impact overall economic growth—an impact that will have increasing effect the more that electrification is expanded.

The upshot is threefold: 1) demand for critical minerals needed to manufacture energy storage batteries is projected to increase by several orders of magnitude; 2) supplies of these minerals are concentrated in relatively few regions globally, with limited opportunities expected to explore for domestic sources; and 3) the costs of competition, not only among nations, but among mineral-hungry industries, will inevitably cause inflation in a core technology needed to realize the ambitions of building code electrification advocates. Plus, updating current mining and mineral refining processes to eliminate the known environmental harms of expanding both exploration and processing of critical minerals domestically creates yet more technical and economic challenges for universal electrification[18]. These challenges are not being fully debated and addressed during many of the ongoing updates to building codes nationwide. Ensuring fuel diversity, and investing in all feasible low carbon energy sources, is a rational step toward ameliorating problems that can be expected from a proposed infrastructure replacement program that outstrips anything the world has ever seen—in scope, cost, and impact.

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[14] US Government Accountability Office (2022), "Critical Mineral Shortages Could Disrupt Global Supply Chains", June 21, https://www.gao.gov/blog/critical-mineral-shortages-could-disrupt-global-supply-chains .

[15] Koka, J. (2021), "A 10-year look at the battery supply chain in America", Argonne National Laboratory, https://www.anl.gov/article/a-10year-look-at-the-battery-supply-chain-in-america

[16] Reuters (2022), "GM's North American battery supply chain is key to EV profits", https://www.reuters.com/business/autos-transportation/gms-north-american-battery-supply-chain-is-key-ev-profits-2022-11-15/

[17] Igogo, Tsisilile A, Sandor, Debra L, Mayyas, Ahmad T, & Engel-Cox, Jill. "Supply Chain of Raw Materials Used in the Manufacturing of Light-Duty Vehicle Lithium-Ion Batteries", United States. https://doi.org/10.2172/1560124

[18] Brinn, J. (2022), "Electric Vehicle Battery Supply Chains: The Basics", National Resources Defense Council, July 7, https://www.nrdc.org/experts/jordan-brinn/electric-vehicle-battery-supply-chains-101