POLICY BRIEF

RECOMMENDATIONS FOR THE NEW ADMINISTRATION

Minerals and Materials for Energy: We Need to Change Thinking

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This brief is part of a series of policy recommendations for the administration of President Joe Biden. Focusing on a range of important issues facing the country, the briefs are intended to provide decision-makers with relevant and effective ideas for addressing domestic and foreign policy priorities. View the entire series at www.bakerinstitute.org/recommendations-2021.

While considering the energy transition and the future energy mix, the dominant paradigm is to pick technology "winners" and to kick the can down the road when it comes to materials inputs and their footprints. As a nation, we need to shift this paradigm to encompass a real and immediate focus on the availability of advanced materials that can drive the performance of both legacy and alternative energy fuels and systems and ensure sustainable footprints.

All materials requirements are rooted in access to minerals. Access to minerals, in turn, puts pressure on extractives industries and processing worldwide. Even the most conservative energy transition scenarios represent a "call" on minerals and materials. Between 1984 and 2018, total worldwide tonnage output of nonfuel minerals increased more than 2.5 times.[1] One estimate is that the demand for battery metals alone to support various models of electric vehicle (EV) could increase nearly 20 times by 2040.[2] In the most assertive views, minerals and materials requirements could exceed anything in human experience. It is vital that we step back for a big picture view.

A key concern is to make materials supply chains more diverse and robust. At heart is a proper definition and focus on minerals critical to existing energy fuels and systems as well as to new technologies. Federal-level initiatives on critical minerals thus far provide a starting point.[3] We propose that the Biden administration preserve and expand these efforts and incorporate the recommendations in this brief.

FOCUS ON MATERIAL INTENSITY

Higher energy densities enable more energy available per unit of material input, e.g., raw materials, land, water, feedstocks for manufacturing components, energy to build facilities and the like. Advanced materials can help reduce raw materials inputs. The search is on for:

- better battery chemistries to improve specific energy and support mobility requirements
- new films to improve solar photovoltaic (PV) conductivity
- materials to support high-efficiency electric power transmission and distribution
- materials to refurbish existing natural gas pipelines for hydrogen carriage

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- new composites to support a vast range of applications, from lighter-weight to battery casings that protect against thermal runaway[4] to high-durability wind turbine blades and more.

In the electric power sector, roughly 6,000 natural gas turbines and 96 nuclear reactors provide about 60% of U.S. electricity generation. It takes nearly 66,000 grid-scale wind turbines and 4,000 grid-scale solar arrays to provide just 10%.[5] To reach an often-stated goal of 50% of electricity from wind and solar would mean almost 459,000 wind turbines and 77,000 solar arrays and/or other solutions for capturing more energy from existing facilities. Additionally, wind and solar will require more electric power transmission grids and some form of energy storage, such as batteries.

When it comes to transportation, even the best batteries today still cannot provide the performance of liquid fuels for vehicles. The energy density of gasoline remains 100 times higher than that of the best lithium battery designs.[6] In 2016, Argonne National Laboratory estimated that pure battery electric vehicles (BEVs) could be at par with equivalent internal combustion engine (ICE) vehicles by 2045.[7] To reach that goal, battery energy and motor power densities must each come close to doubling. A distinct consideration for vehicles is safety. It is laudable to try to increase the energy density of batteries, but doing so can present safety risks that we must also consider.[8]

Hydrocarbons are critical minerals as sources of both energy and materials. Every technology and technology component requires hydrocarbons. We derive most, if not all, of the advanced materials for wind, solar, electric vehicles, batteries, and countless other vital technologies from hydrocarbons. Plastics content in modern light-duty vehicles today comprises about 50% of materials volume. They reduce the weight of vehicles, improving fuel economy while preserving safety (today's advanced composites in vehicles are nothing like early versions). Electric vehicles will incorporate even more plastics content for vehicle performance.

We always should want to reap as much useful energy as we can from less material input, given the profound implications for natural resources and the environment. ***We recommend that the Biden administration engage relevant multilateral agencies to foster technical collaborations that accelerate the role of advanced materials in new energy technologies.***

CRITICAL MINERALS: U.S. IMPORT DEPENDENCE AND CHINA'S DOMINANCE

For the U.S., "criticality" is often a measure of import dependence. The U.S. Geological Survey (USGS) provides at least one version of criticality for 52 minerals of interest.[9] Of these, 39 rank high for supply risk and import dependence. Moreover, 36 of the 39 are essential for alternative energy technologies and systems, including existing and new battery chemistries, advanced solar power, hydrogen fuel cells, and wind power. Of these 36 critical minerals, the U.S. is among the top 10 producers for only a few—notably rare earths elements (U.S. is a distant third), lead (fourth), zinc (fourth), palladium (fourth), platinum and rhodium (fifth), copper (fifth), selenium (sixth), lithium (seventh), and silver (tenth). U.S. demand for all of these critical minerals far exceeds what domestic supply chains can serve.[10]

In 2018, the U.S. constituted 12% of total global nonfuel minerals production. China constituted 23%.[11] China is the largest single producer of 19 of the 36 critical minerals. Even when China is not the dominant producer, it often is among the top five (for instance, China is the third largest producer of copper and the fifth largest producer of lithium). China's dominance of mineral production and processing effectively allows control of supply chains and pricing for a number of minerals that are key for energy, electronics, telecommunications, pharmaceutical and other needs, including defense applications.[12] The key to the long-term dissolution of the risks of market dominance—by China or any other dominant player—is the development of a transparent market with multiple actors. Therefore, ***we recommend that the Biden administration encourage market transparency so that more robust and fungible supply chains can develop.***

ADDRESSING LONG-TERM CONCERNS OVER ESG IN MINING AND PROCESSING

Mining and minerals processing are energy- and resource-intense and are often in locations that pose substantial environmental, social, and governance (ESG) risks. Many countries, such as Chile and the Democratic Republic of Congo, have "informal mining" sectors and sensitive "above-ground" risk factors where best practices and safety are limited at best. Local communities, especially indigenous groups, are a focus for risk and uncertainty assessment, especially as new and frontier minerals projects are and will be located in or proximal to indigenous lands and communities.

Emissions associated with life-cycle processes for batteries and alternative energy applications are particularly difficult to measure. Emissions profiles are highly dependent upon the energy source for battery production. For example, global lithium battery manufacturing, including for electric vehicles (EVs), stands at roughly 740 gigawatt hours (GWh) with nearly 80% located in China, supported by nearly 3,000 coal-fired power plants, the backbone of China's electric power grid. This means a potential output of carbon dioxide emissions that nearly equals all of those associated with U.S. domestic oil and gas systems.[13]

In addition to the "well-to-wheel" supply chain footprint, end-of-life decommissioning, recycling, and disposal must be considered concomitantly with development. Currently less than 5% of lithium battery product is recycled worldwide. Electronic waste, or "e-waste," is expanding rapidly, and wind and solar components along with batteries will contribute heavily to e-waste streams. Hence, full life-cycle assessment should be part of licensing and permitting decisions.

We can conduct mining and minerals processing safely, soundly, and sustainably, but doing so requires best practices and enforcement. After the Vale tailings dam failure in Brazil, a mining industry representative commented that there are too few engineering groups worldwide certified for tailings dam audits.[14] The example illustrates the need for integrity and operating assurance capabilities around the world to expand. ***We recommend that the Biden administration encourage governments to commit to regulatory design and promote international industry standards that ensure commitment to best practices for extraction, processing, and end-of-life of critical minerals.***

ENDNOTES

1. Based on open source data from the World Mining Congress, https://www.world-mining-data.info/?World_Mining_Data.

2. Bernstein Research, based on several battery chemistries and with no meaningful improvement (i.e., "business as usual"). *Climate Change Scenarios: What does battery metal demand look like in 1.8 degree world?*, September 22, 2020, proprietary report.

3. See the U.S. Department of Energy's guidance on critical minerals for loan applicants and related background actions at https://www.energy.gov/articles/doe-issues-notice-guidance-potential-loan-applicants-involving-critical-minerals.

4. Thermal runaway is a situation where the current flowing through the cell or battery on charge or overcharge causes the cell temperature to rise, which increases the current with a further rise in temperature. See *Encyclopedia of Electrochemical Power Sources*, Elsevier, 2009

5. Averages for 2019 based on U.S. Energy Information Administration, https://www.eia.gov/electricity/annual/html/epa_04_03.html for facilities and capacities and https://www.eia.gov/electricity/data/browser/ for net generation, and the U.S. Geological Survey/EIA wind turbine database,

https://eerscmap.usgs.gov/uswtdb/. USGS provides tools and information on the variety of risks from wind turbines to many species of interest, https://www.usgs.gov/centers/fresc/science/statistical-tools-wind-and-solar-energy-development-and-operations?qt-science_center_objects=0#qt-science_center_objects.

6. Fred Schlachter "Has the Battery Bubble Burst?" *APS News* 21, no. 8 (August/September 2012), https://www.aps.org/publications/apsnews/201208/backpage.cfm/.

7. Ram Vijayagopal, "Comparing the Powertrain Energy and Power Densities of Electric and Gasoline Vehicles,"presentation at Powertrain Strategies for the 21st Century, University of Michigan Transportation Research Institute, July 20, 2016, http://www.umtri.umich.edu/powertrain-strategies-21st-century-1; Ram Vijayagopal, Kevin Gallagher, Daeheung Lee, and Aymeric Rousseau, "Comparing the Powertrain Energy Densities of Electric and Gasoline Vehicles," SAE Technical Paper, April 5, 2016, https://saemobilus.sae.org/content/2016-01-0903/; ANL measures battery energy density in watt-hours per kilogram or W-h/kg and motor power density in kilowatts per kilogram or kW/kg. They estimate that each metric must improve from 135 to 320 W-h/kg and 8.6 to 16 kW/kg, respectively.

8. A primary risk for batteries used for stationary or mobile energy storage is thermal runaway. A widely reported and monitored explosion, fire, and release of hydrogen fluoride gas occurred at the Arizona Public Service McMicken Battery Energy Storage facility on April 19, 2019. See the DNV report and conclusion that the incident was a thermal runaway at https://www.aps.com/-/media/APS/APSCOM-PDFs/About/Our-Company/Newsroom/McMickenFinalTechnicalReport.ashx?la=en&hash=50335FB5098D9858BFD276C40FA54FCE. Following the event, Commissioner Sandra Kennedy, Arizona Corporation Commission, issued a letter with the opinion that typical lithium based batteries in typical use for utility grid energy storage "are not prudent and create unacceptable risks."See https://assets.documentcloud.org/documents/6240841/ACC-August-2-Kennedy-Letter-E000002248.pdf.

9. Nedal T. Nassar, Jamie Brainard, Andrew Gulley, Ross Manley, Grecia Matos, Graham Lederer, Laurence R. Bird, et al., "Evaluating the Mineral Commodity Supply Risk of the U.S. Manufacturing Sector," *Science Advances* 6, no. 8 (February 2020), https://advances.sciencemag.org/content/6/8/eaay8647.

10. For our complete "watch list" see Michot Foss, testimony before the Subcommittee on Environment and Climate Change, House Energy & Commerce Committee, September 16, 2020," Building a 100 Percent Clean Economy: Opportunities for an Equitable, Low-Carbon Recovery," https://energycommerce.house.gov/committee-activity/hearings/hearing-on-building-a-100-percent-clean-economy-opportunities-for-an-0.

11. Based on data from WMC, see endnote 7.

12. The most comprehensive effort to map China's influence in mining and minerals processing remains the Foreign Policy Analytics May 2019 special report, "Mining the Future–How China is Set to Dominate the Next Industrial Revolution."An FP subscription is required for access.

13. Battery manufacturing capacity from Wood Mackenzie. China's share from Daniel Yergin, "The New Geopolitics of Energy," *The Wall Street Journal*, September 11, 2020, https://www.wsj.com/articles/the-new-geopolitics-of-energy-11599836521?mod=searchresults&page=1&pos=1; U.S. Environmental Protection Agency greenhouse gas emissions estimates are at https://www.epa.gov/ghgemissions/overview-greenhouse-gases#methane; the Center for Energy Studies maps China's energy infrastructure, now including electric vehicle battery manufacturing. Our data and mapping are at https://www.bakerinstitute.org/chinas-energy-infrastructure/.

14. Following the Vale incident, the mining industry moved swiftly to develop more robust standards. See the International Council for Mining and Metals, ICMM for background, https://www.icmm.com/en-gb/news/2020/gistm-new-global-benchmark

15. See our policy brief with Missouri S&T for the G20, "Framing Energy and Minerals for Future Pathways," at https://t20saudiarabia.org.sa/en/briefs/Pages/Policy-Brief.aspx?pb=TF10_PB12.

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