Minerals and Metals to Meet the Needs of a Low-Carbon Economy

Why is this issue important?

The technologies essential to the effort to limit climate change will affect demand for minerals used in their manufacturing

As nations strive to meet the goals of the 2015 Paris Agreement on climate change, which calls for “holding the increase in the global average temperature to … below 2ºC above pre-industrial levels,” solar power, wind power, energy-storage systems (batteries), and other technologies will become a much larger part of the globe’s energy systems. Countries that have the capacity and infrastructure to supply the minerals and metals required for these technologies have an opportunity to benefit from this growing market, but only if they do so in a sustainable manner—one that takes into account the impact of operations on local communities, water and ecosystems, energy use, and greenhouse gas emissions. The World Bank can support client countries in this endeavor and, in so doing, help them meet the twin goals of ending extreme poverty and promoting shared prosperity.

The World Bank commissioned an analysis to investigate the key role minerals and metals will play in supplying a low-carbon economy. This Live Wire is a summary of that analysis (World Bank 2017). As a starting point, we used climate and technology scenarios developed in the International Energy Agency’s Energy Technology Perspectives 2016 to estimate the technologies that would have to be deployed to meet warming-limit scenarios of 2º (2DS), 4º (4DS), and 6º (6DS). From that data, we then extrapolated what minerals would be required to manufacture each of the three technology groups (wind, solar, and batteries) to meet the three scenarios.

The technologies and transmission systems implicated in each of the scenarios will cover a much wider range than that reviewed here. For example, in the 2º scenario the overall share of renewable energy generation in the energy mix would likely rise from the present level of 14 percent to 44 percent and would include carbon capture and storage, hydropower, biomass, and nuclear technologies. But this brief and the larger work behind it are intended to engender a wider discussion among experts and policy makers around the material implications of a carbon-constrained future.

What effects will green energy have on the use of specific metals and minerals?

Wind, solar, and storage technologies all have a range of demand implications

The accompanying figures present estimated mineral demand for each of the three technologies covered in this study. Figure 1 shows the wind energy technology production curves for the 2º, 4º, and 6º warming-limit scenarios. In all three scenarios, electricity production from wind power (particularly onshore wind) will rise rapidly through 2050. Figure 2 presents an estimate of the increase in demand for key metals that would be created by deployment of wind-power technologies sufficient to meet the 2º and 4º scenarios. The impact is expressed as increases through 2050 over deployment under the 6º scenario. Figure 3 illustrates increases in the generation...
Precise estimates of demand for metals hinge on (1) the degree to which the global community actually succeeds in meeting its long-term climate goals, as laid out in the Paris Agreement, and (2) intra-technology choices. The question is not only how many wind turbines, solar panels, and low-emission vehicles will be deployed, but which technologies will come out on top in each category.

Figure 1. Electricity generation from wind power under the 2º, 4º, and 6º warming-limit scenarios, 2013–50

![Graph showing electricity generation from wind power under various scenarios](image)


of electricity from solar photovoltaic energy under the 2º, 4º, and 6º warming scenarios through 2050. Figure 4 is analogous to figure 2, but for solar PV.

Finally, with respect to batteries, figure 5 projects the energy storage required (in gigawatt-hours) for each of the three climate scenarios to 2050. Storage demand spikes sharply under the 2º scenario owing to substantial increases in the use of electric vehicles, as shown in the top panel of the figure. In this scenario, documented in IEA (2016), 140 million electric vehicles would be in operation by 2030, versus approximately 25 million in the more pessimistic 4º and 6º scenarios. The projections for automotive battery energy storage after 2030 are based on assumed annual growth rates of approximately 20 percent per year. The bottom panel of figure 5 shows the evolution of demand for other forms of energy storage capacity under the three scenarios.

The implications of increased use of storage batteries on demand for certain metals are remarkable. Figure 6 charts the increment in demand under the 2º and 4º scenarios over the 6º scenario, showing increases in the range of 1,200 percent.

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With respect to wind, geared turbines, mostly land based, currently predominate; they contain coil-driven generators that require significant amounts of copper. By contrast, direct-drive wind turbines—mostly used for offshore operations—are less maintenance intensive but require certain costly rare earth metals. The same can be said of solar, where there are four competing technologies, each of which carries different implications for minerals and metals demand.

Intra-technology choices will probably be most important in transportation. For example, electric, hybrid, and hydrogen have very different implications for metal demand: electric vehicles require lithium; hybrid, lead; and hydrogen, platinum.
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**Figure 2.** Increased demand for key metals occasioned by deployment of wind-power technologies sufficient to meet the 2º and 4º scenarios, expressed as increases over deployment under the 6º scenario

![Figure 2](source: World Bank (2017).)

**Figure 3.** Electricity generation from solar photovoltaic energy under the 2º, 4º, and 6º warming-limit scenarios, 2013–50

![Figure 3](source: World Bank (2017).)
The most notable finding is the global dominance of China in the base and rare earth metals that will be required to manufacture low-carbon technologies. China’s production and reserve levels often dwarf those of others, even resource-rich developed countries such as Canada and the United States.

What should mineral-rich developing countries be doing to prepare for changes in demand?

Resource surveys, market intelligence, long-term plans, and capital outlays will be necessary

A long-term trend toward greener energy and a low-carbon future will create global opportunities with respect to a number of metals and minerals.

This has implications for resource-rich developing countries. Latin America is in a relatively strong position to become a supplier for the climate-friendly energy transition, with Argentina, Brazil, Chile, and Peru being the best-positioned countries. Bolivia is also potentially set to benefit should it be able to translate its resources, such as lithium, into recognized reserves. Particular metals for which Latin America holds a key strategic advantage include copper, iron ore, silver and lithium; the region is also active in the aluminum, nickel, manganese, and zinc sectors.

Africa is also potentially significant given its reserves of platinum, manganese, bauxite, and chromium ores. Most of these reserves and production activities are in southern African, with the exception of Guinea. The lack of data and information on metals outside the south may reflect survey gaps more than the actual absence of those metals. For example, it is a relative certainty that Africa does, in fact, contain rare earth metals. What has not occurred is any comprehensive survey of its potential resources and how difficult it might be to translate those resources into reserves.

With respect to Asia, the most notable finding is the global dominance of China in the base and rare earth metals that will be required to manufacture low-carbon technologies. China’s production and reserve levels often dwarf those of others, even resource-rich developed countries such as Canada, the United States, and, to a lesser extent, Australia. India is dominant in iron, steel, and titanium, and Indonesia has opportunities with bauxite and nickel, as does Malaysia, though to a lesser extent. In Oceania,
Under the 2º scenario, 140 million electric vehicles would be in operation by 2030, versus approximately 25 million in the more pessimistic 4º and 6º scenarios. The implications of increased use of storage batteries on demand for certain metals are remarkable.

**Figure 5.** Global energy storage capacity scenarios

Top panel shows electric vehicle scenario only; the impact of the 2º scenario on demand for electric-car batteries is evident. Bottom panel shows all degree/storage combinations.

**Note:** 2DS = 2º scenario; 4DS = 4º scenario; 6DS = 6º scenario. Scenario data obtained from IEA (2015), International Electrotechnical Commission (2009), and IEA Energy Technology Perspectives (2016).
To make the most of the opportunities, developing countries will have to forge long-term strategies and make appropriate investments. Those investments, however, imply significant upfront capital spending based on assumptions about the value of relevant commodities a half-century ahead, given the typical life span of mines. Countries will also have to be flexible enough to meet evolving demand for individual metals and minerals as the component mix of low-carbon technologies changes with economic and technical developments.

Figure 6. Percentage change in demand for metals for energy storage technologies under 2º and 4º scenarios through 2050, expressed as percentage increase over demand in 6º scenario.

![Figure 6](image)


Note: 2DS = 2º scenario; 4DS = 4º scenario.

massive reserves of nickel to be found in New Caledonia should not be overlooked.

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Countries will also have to be flexible enough to meet evolving demand for individual metals and minerals as the component mix of low-carbon technologies changes with economic and technical developments. To position themselves well, they will need reliable sources of economic data and market intelligence, as well as the capacity to turn that information into plans, investments, and sustainable operations.

In its concluding section, the report provides a set of recommendations for future work related to policy and technology.

**Policy-related areas of inquiry** include the following:

*Achieving balance between opportunity and sustainability.*

Studies on the commodity implications of a carbon-constrained future typically focus on current reserves and the relative level of availability and access to materials needed to produce clean technologies under various scenarios. However, there is a growing awareness that clean technologies may pose new challenges for the sustainable development of minerals and resources. What is needed in resource-rich developing countries is dialogue between the mining and clean-energy constituencies to balance the opportunities offered by a growing market for key commodities with concern for equity and environmental sustainability.
Mapping minerals in developing countries. There is a significant gap in mineral mapping and data reporting in many developing country regions, particularly Africa. Capacity in this area is critical if resource-rich developing countries are to make the most of global changes in demand for their resources.

Predicting technology choice based on supply constraints and demand patterns. Much of the uncertainty about potential demand for many metals arises as much from choices within given technologies as it does from choices between them. Knowing where supply constraints may lie and where prices are most likely to rise will certainly affect some of these intra-technology choices, which, in turn, will help clarify demand.

Developing networks and raising awareness. One of the outcomes of this analysis is the realization that the implications of this work go far beyond the minerals and metals community as narrowly construed. Linkages should be pursued and facilitated with research organizations, business associations, and civil society (including public-interest groups).

Technology-related areas of inquiry pertain mostly to expanding the scope of future clean technologies. Areas to be covered may include electrical cabling and high-efficiency electric motors; ways to reduce vehicle weight; increasing the energy efficiency of buildings and technologies; new options for transmission and distribution; and the metal intensity of traditional and next-generation fossil fuel plants and nuclear facilities; differences between key rare earth metals; and recycling.

Key rare earth metals differ widely in how they are isolated (rare earth metals are typically not economically or physically retrievable as discrete ores but are often enmeshed with other base metals) and in where they are found.

The recycling of metals from end-of-life products can improve the future availability of those metals, but data on both current and future metal recycling rates are often poor and should be improved.

This report on which this Live Wire is based is a first step in examining the implications of changing material requirements for the mining and metals industry as the world contemplates a low-carbon energy future. It is intended to engender a broader dialogue between the clean energy, climate, and extractives communities on their roles in shaping that future.

Going forward, the World Bank will work with these constituencies to further define the minerals and metals implications of the shift to green energy and to develop policies and other measures that will ensure that the transition is managed in a way that complements the full array of sustainable development priorities, from environmental and resource concerns to equitable economic growth in developing countries.

References


The report summarized in this Live Wire was developed as a collaboration between the World Bank’s Oil, Gas, and Mining team of the Energy and Extractives Global Practice (GEEDR) and the Climate Change Group (CCSA). The team was led by Daniele La Porta and Kirsten Hund, with Michael McCormick and Jagabanta Ningthoujam. John Drexhage is the primary author.
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