National Minerals Information Center

Minor Metals and Renewable Energy—Diversifying America's Energy Sources

Solar photovoltaic (PV) and wind turbine technologies are projected to make up an increasing proportion of electricity generation capacity in the United States in the coming decades. By 2050, they will account for 36 percent (or 566 gigawatts) of capacity compared with about 11 percent (or 118 gigawatts) in 2016 (fig. 1; EIA, 2017).

There are several different types of commercial solar PV and wind turbine technologies, and each type makes use of different minor metals. "Minor metal" is the term used for metals for which world production is small compared with the more widely produced base metals, and they are often produced as byproducts of the mining or processing of base metals. Minor metals used in renewable energy technologies often have complex supply chains, are often produced primarily outside of the United States, and are also used in many other applications. A larger amount of minor metals will be needed in the future to support the projected increases in solar PV and wind energy production capacity (Nassar and others, 2016).

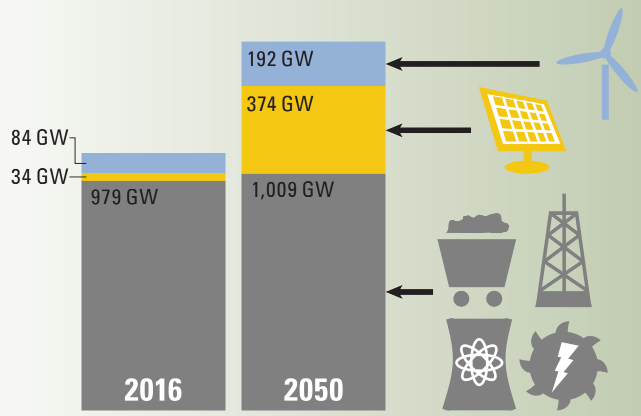

Figure 1. U.S. electricity generation capacity, in gigawatts (GW), for wind, solar photovoltaic (PV), and all other sources (fossil fuels, nuclear, hydroelectric, and so forth) for 2016, with projections for 2050 (EIA, 2017).

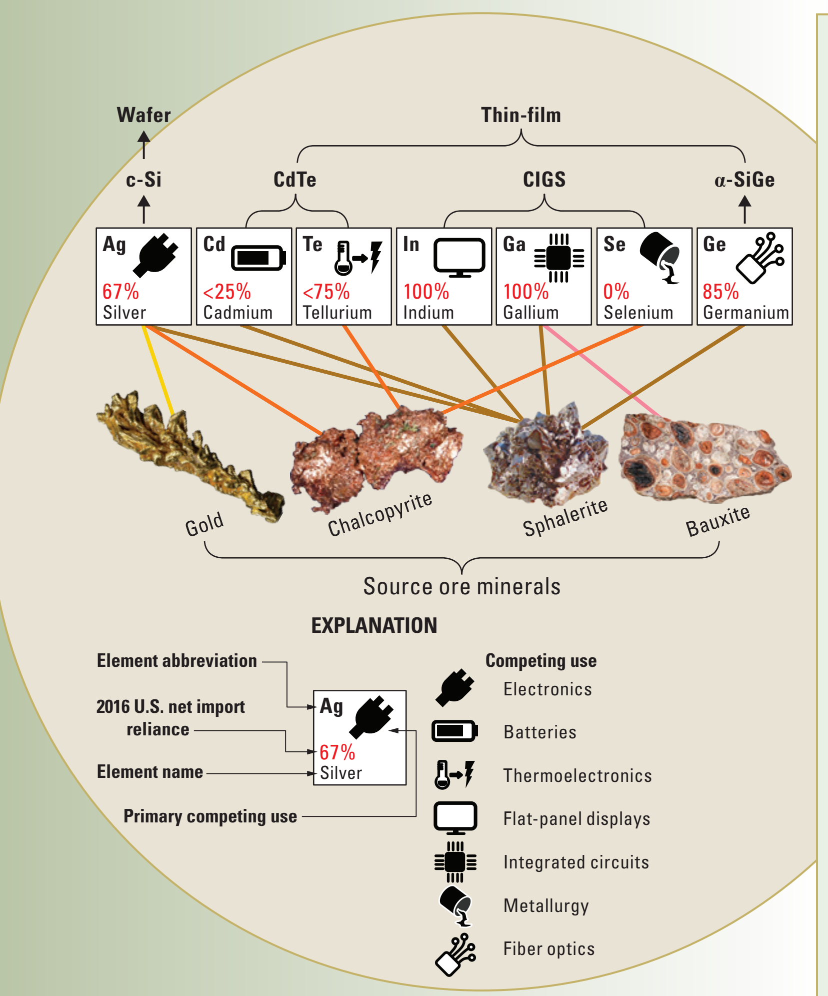

Figure 2. Minor metals used in wafer and three types of thin-film solar photovoltaic technologies, along with their source ore minerals, percentage of U.S. net import reliance in 2016, and major competing uses. α-SiGe, amorphous silicon germanium; CdTe, cadmium telluride; CIGS, copper-indium-gallium-(di)selenide; c-Si, crystalline silicon.

Solar Photovoltaic

Solar PV technologies (fig. 2) can be generally classified as either wafer or thin-film. Wafer-based solar cells, currently the dominant technology, are made mostly of crystalline silicon and use a conductive paste made of silver. Thin-film-based solar cells are named for the material in their light-absorbing layer that consists of cadmium telluride, copper-indium-gallium-(di)selenide, or amorphous silicon germanium. Thin-film-based solar cells may become more economically competitive in the future as their cost decreases and their electrical conversion efficiency increases. It is not yet clear, which, if any, of the three types of thin-film-based solar cells will eventually dominate the market.

A supply chain consists of the manufacturers, suppliers, technologies, information, and activities involved in creating and distributing products. For the minor metals used in solar PV technologies, the supply chain is complicated for several reasons. For instance, the minor metals are present in only trace amounts in the deposits from which they are recovered, so, for economic reasons, they are usually obtained as byproducts from the processing of ore minerals such as bauxite, chalcopyrite, gold, and sphalerite (fig. 2). The availability of these minor metals is therefore dependent on the supply of and demand for the main ore mineral(s) in the deposit. Additionally, these minor metals are also used in many other technology applications (such as batteries, electronics, fiber optics, flat-panel displays, integrated circuits, metallurgy, and thermoelectronics), so producers of solar PV cells may need to compete with others for the supply of these metals. Lastly, the United States is highly net import reliant—defined as imports minus exports plus adjustments for stock changes (Fortier and others, 2015)—on many of these minor metals, meaning that it relies on other countries for its overall supply of these commodities. The United States obtains more than one-half of its raw material consumption of gallium, germanium, indium, silver, and tellurium as imports from other countries, such as Canada, China, and Mexico, so the supply could be restricted if trade is disrupted for any reason.

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Wind Turbine

Modern wind turbine technologies can generally be classified into three categories: (1) induction, (2) hybrid drive, and (3) direct drive (fig. 3). These designs vary by the absence or presence of a gearbox, which, among other things, determines the frequency with which the turbines require maintenance, as well as the quantity of minor metals required for them to function. Direct drive turbines, which have no gearboxes, and hybrid versions, which contain only a simple gearbox, use generators with neodymium-iron-boron (Nd-Fe-B) permanent magnets (PMs) to function. These two designs require different sized PMs: about 200 kilograms per megawatt (kg/MW) for hybrid drive turbines and 500 to 600 kg/MW for direct drive turbines (Constantinides, 2016). Several rare-earth elements (REEs)—including dysprosium, neodymium, praseodymium, and terbium—are used in the PMs because of the various properties they impart.

The REEs used in these technologies are often present in only trace amounts in the deposits from which they are recovered, making mining of them dependent on the economics of the primary products in the deposits. In addition to wind turbines, many other products, such as hard disc drives and motors for electric vehicles, use magnets containing these REEs, and the REEs are also used in other technological applications, such as phosphors for various display and lighting applications. Demand for these REEs in other applications can affect their availability for wind power. Since 2016, the United States has had no domestic REE mines in operation and remains entirely reliant on imports from foreign sources, mainly China, for its supply of dysprosium, neodymium, praseodymium, and terbium, and for goods, such as magnets, that contain them.

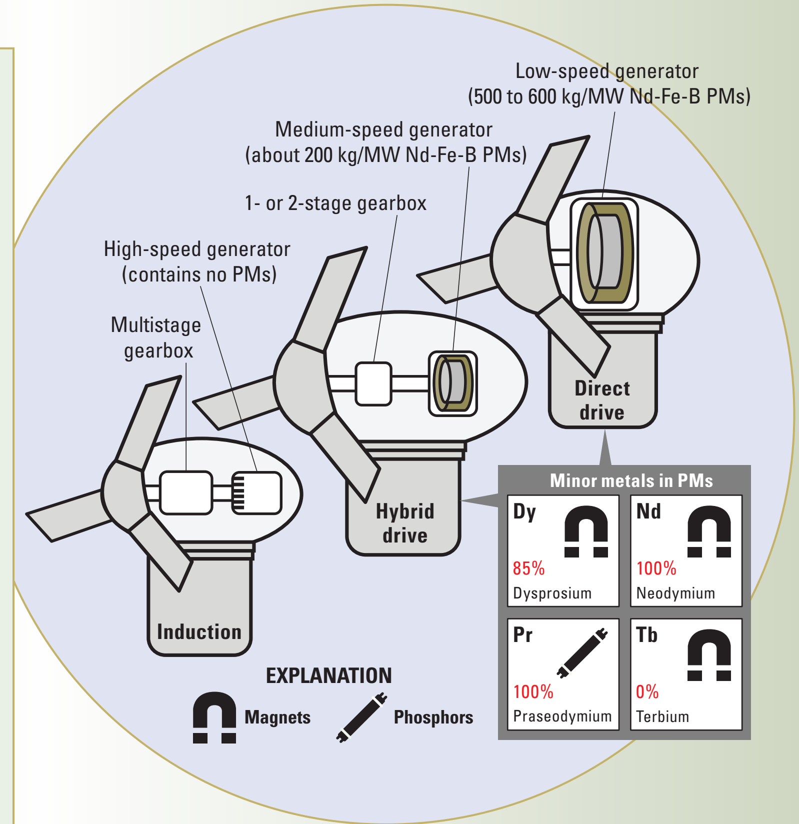

Figure 3. Wind turbine technologies and the minor metals required for hybrid and direct drive turbines, along with percentage of U.S. net import reliance in 2016 and major competing uses for these minor metals. The direct drive design, which contains no gearbox, has fewer maintenance requirements than the other designs but uses the largest neodymium-iron-boron (Nd-Fe-B) permanent magnets (PMs) and thus requires the largest amount of rare-earth elements to produce. kg/MW, kilogram per megawatt.

Key Points

Electricity generation capacity in the future is projected to increase to meet increased demand by homes, businesses, and industries. An increasingly larger proportion of the electricity supply is projected to come from solar PV and wind power—technologies that use a number of minor metals. In the future, more of these minor metals will be required, with the exact amount depending largely on which technology becomes dominant (Nassar and others, 2016). The future supply of and demand for these minor metals is uncertain because they are often produced as byproducts of other nonfuel mineral commodities, they are used in numerous competing applications, and the United States is heavily reliant on imports of these metals from other countries, especially Canada, China, and Mexico.

The U.S. Geological Survey (USGS) National Minerals Information Center tracks domestic and world production, domestic consumption, and trade data for minor metals as well as many other nonfuel mineral commodities. By analyzing these data, forecasting future trends in industry, and publishing regular updates, the USGS provides information to policymakers and members of industry to help them anticipate and react to changes in mineral commodity supply chains, thus helping to ensure a steady supply of these necessary mineral commodities.

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For more information, contact:

Director, National Minerals Information Center
U.S. Geological Survey
12201 Sunrise Valley Drive
988 National Center
Reston, VA 20192

Email: nmicrecordsmgt@usgs.gov

Or visit the USGS National Minerals Information Center website at
https://minerals.usgs.gov/minerals/

By Sheryl A. Singerling and Nedal T. Nassar

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