

North American net import reliance of mineral materials in 2014 for advanced technologies

by J. Brainard, R.G. Sinclair, K. Stone, E. Sangine and S.M. Fortier

Abstract ■ The U.S. Geological Survey and Natural Resources Canada conducted a study on the net import reliance of each North American country, and the impact of North American trade on the net import reliance of 12 nonfuel mineral commodities that are associated with advanced technology products: cadmium, cobalt, gallium, germanium, graphite, indium, lithium, nickel, rare earth elements, selenium, silver and tellurium. The combined results for North America, using 2014 data, showed greatly reduced net import reliance for nearly all of the commodities evaluated, which is largely the result of pooling the resources of production and recovery in Canada and Mexico of materials that are consumed in the United States. This study highlights the mitigation of potential supply risk for critical materials that results from trade within the North American trade bloc.

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Introduction

Multiple metrics and definitions exist for what constitutes a critical material, but there is broad acknowledgment that a mineral commodity may be considered critical if, among other factors, its production is geographically concentrated, if it has few or no

substitutes, or if the country of origin is politically unstable. Numerous governmental and independent researchers have proposed methods of investigating criticality, with differing priorities such as economic resilience or strategic military supplies (European Commission, 2014; Graedel et al., 2015; U.S. National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains, 2016). While criticality really depends on who is asking the question, and despite the differing priorities, there are several commodities that are commonly found to be of concern. In particular, some critical or potentially critical materials are used increasingly in advanced technologies, or they have complicated supply chains because they are coproduced or are produced in controlled markets.

Commodities for which imports are required to satisfy domestic demand are those for which the importing country is net import reliant. Net import reliance (NIR) in this study is calculated as the amount of imported material, including changes in stockpiles, minus exports and is expressed as

a percentage of domestic consumption:

$$\text{NIR (\%)} = (\text{Imports} - \text{Exports} + \text{Changes in Stocks}) / \text{Consumption} \times 100$$

For example, a mineral commodity that is not produced in a country and for which the same country relies entirely on imports to satisfy domestic demand has an NIR of 100 percent.

NIR is a quantifiable means of evaluating the numerous strategic and economic concerns about a commodity by highlighting the dependence on foreign sources over domestic production, and it can show the relative importance of various foreign trading partners as well. For example, the annually published NIR chart for the United States from the National Minerals Information Center at the U.S. Geological Survey regularly reports Canada and Mexico as being top sources for many commodities with a high NIR (U.S. Geological Survey, 2018). However, it would be incorrect to equate a high NIR figure with supply risk, particularly where trade within North America is concerned, given the established, reliable and cost-effective supply chains

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between the three countries.

This study illustrates that NIR alone does not provide the context for the assessment of risks to critical mineral supply chains, and that relationships with suppliers are nearly as important for evaluating such risks. While the scope of this study is the North American linkage, the premise would be equally applicable to other highly integrated trading blocs.

Selected commodities

More than 90 different mineral and metal commodities are produced, traded and used globally. The 12 nonfuel commodities selected as examples for this study are considered essential for the fabrication of advanced technologies, including military devices, high-end consumer goods, renewable-energy products and computing equipment. The list is by no means exhaustive or intended to exclude any materials that one group or another might consider critical.

The commodities selected for this study fall into three broad end-use categories: (1) battery components, which include cobalt, graphite, lithium and nickel, (2) permanent magnets, which are the primary end use of rare earth elements, and (3) solid-state electronics, which use cadmium, gallium, germanium, indium, selenium, silver and tellurium.

Battery technologies have undergone substantial changes in the past two decades, as nickel-cadmium and metal hydride batteries have been increasingly replaced by lithium-ion (Li-ion) technology, resulting in reduced cadmium use. Lithium is used in Li-ion batteries both as a cathode component, where lithium is often combined with cobalt, nickel or another metal, and as an electrolyte (Jaskula, 2016). The anode material is typically carbon, either purified natural graphite or synthetic graphite. Numerous materials are used to make other battery types, including manganese, vanadium and aluminum, but they are not covered in this study primarily due to their comparatively minor share of the current energy storage market.

Rare earth elements (REEs) have a variety of end uses, including catalysts and electronics. Their use in permanent magnets for electric motors and power generation turbines

has driven demand growth in recent years (Gambogi and Bleiwas, 2013). REEs are among the most commonly identified commodities for supply-chain risk due to highly concentrated production within China, and they have been subject to intentional supply disruptions in the past. As a result, REEs are typically classified as highly critical and have been extensively studied for possible supply risk mitigation (King and Eggert, 2017).

The remaining metals have a range of uses, with many only recently being used in new high-technology applications. Tellurium, for example, has been used primarily in alloys but is becoming increasingly important in cadmium-telluride photovoltaic cells (Bleiwas, 2010). Gallium, germanium, indium, selenium and silver have all found uses in integrated circuits as well as various sensors and luminescent cells (Anderson, 2016; George, 2016; Guberman, 2016; Tolcin, 2016). Gallium consumption, in particular, has been increasing due to its use as a component of light-emitting diodes (Wilburn, 2012).

While it is difficult to project future demand for these downstream high-tech products — particularly those that have yet to be designed — it is certain that minerals and metals like the ones covered in this study will continue to be of fundamental importance, both for their enabling characteristics and for the economic benefits to downstream consumers that will be generated by associated supply chains of materials embedded with these commodities.

North American trade

The North American nations of Canada, Mexico and the United States are each among the top 15 traders of merchandise globally, including fuel and metal products (World Bank, 2017a, 2017b, 2017c). These economies are not only significant entities in the global marketplace but also form a highly integrated and mutually beneficial trading bloc. Total trade between the three countries amounted to \$1.04 trillion in 2014, and it has been at a comparable level for a number of years. This high level of trade reflects the geographical proximity of the three countries as well as the strong invest-

Figure 1

Each nation's contribution to North American exports of ores and metals, by value.

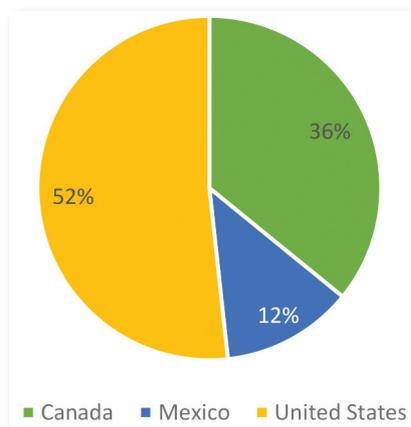
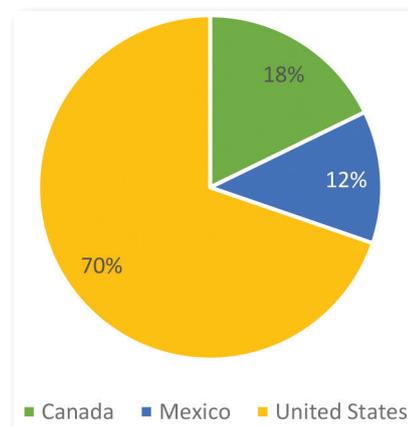


Figure 2

Each nation's share of North American imports of ores and metals, by value.



ment, trade and commercial relationships that link suppliers and customers within North America.

Of the three nations, the United States is the largest trader of mineral ore and metal commodities as defined by the Standard International Trade Classification (UN Comtrade, 2017). It is the largest source and destination of trade in and out of North America (Figs. 1 and 2) (World Bank, 2017a, 2017b, 2017c). In 2014, the United States was the source of approximately 56 percent of mineral ore and metal commodity imports into Canada and 65 percent into Mexico, while these two nations provided 43 percent of the imports into the United States (Figs. 3a-c)(World Bank, 2017a, 2017b, 2017c). Imports of ore and metal commodities represented between 2 and 3 percent of the total import values for each of the three nations. Exports of these materials accounted for 6.8 percent of total exports from Canada compared with 2.8 percent and 2.9 percent for Mexico and the United States, respectively.

Methods

Domestic production, imports and exports for each selected commodity were compiled for and by each respective party, and all cross-border trade was removed to treat North America as a single trade bloc with trade only external to Canada, Mexico and the United States. The calculation of NIR for the bloc as a percentage of consumption required the collection of trade data compiled from a commercial source (IHS Markit, 2016), rather than each nation's respective governmental trade agencies, to maintain data consistency and corroboration between each party. The target year for this study was 2014, as data for the selected commodities were available but sufficient publication time had passed to ensure that future data revisions would be unlikely.

International trade in goods is classified into a system of codes that describe a given product, allowing for more streamlined trade information sharing, processing and handling between the different nations' customs officials. These

Figure 3

Sources of ore and metal imports into (a) Canada, (b) Mexico and (c) the United States by value.

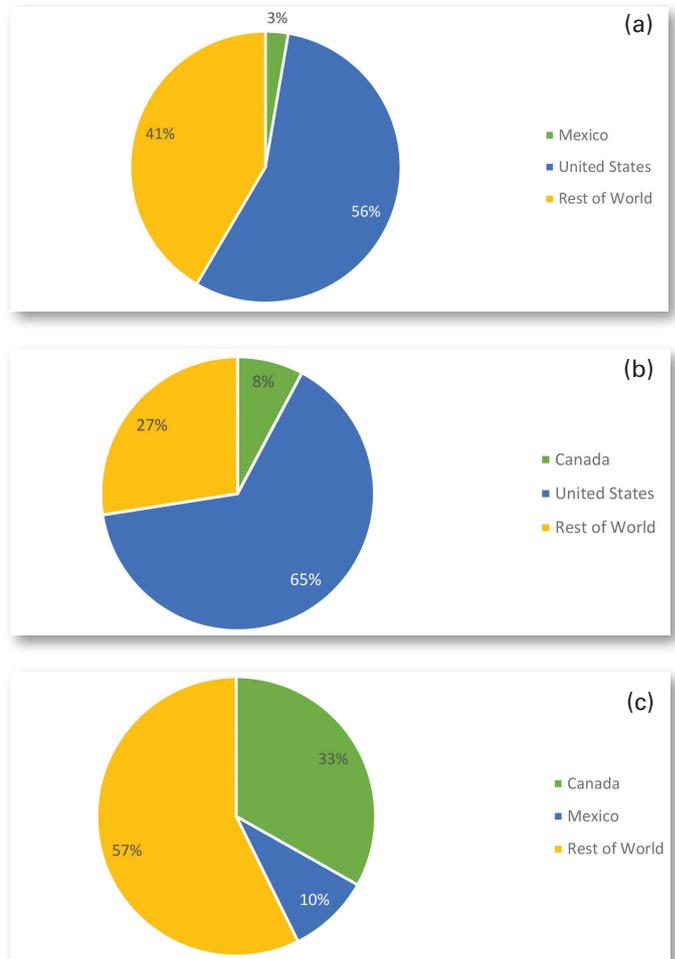
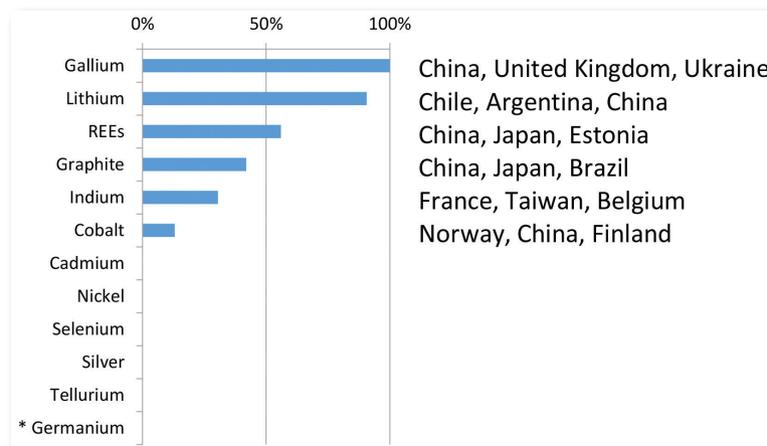


Figure 4

2014 combined net import reliance for North America by commodity. The three dominant import sources are included for reference.



*Germanium export data were aggregated and cannot be accurately calculated for North America.

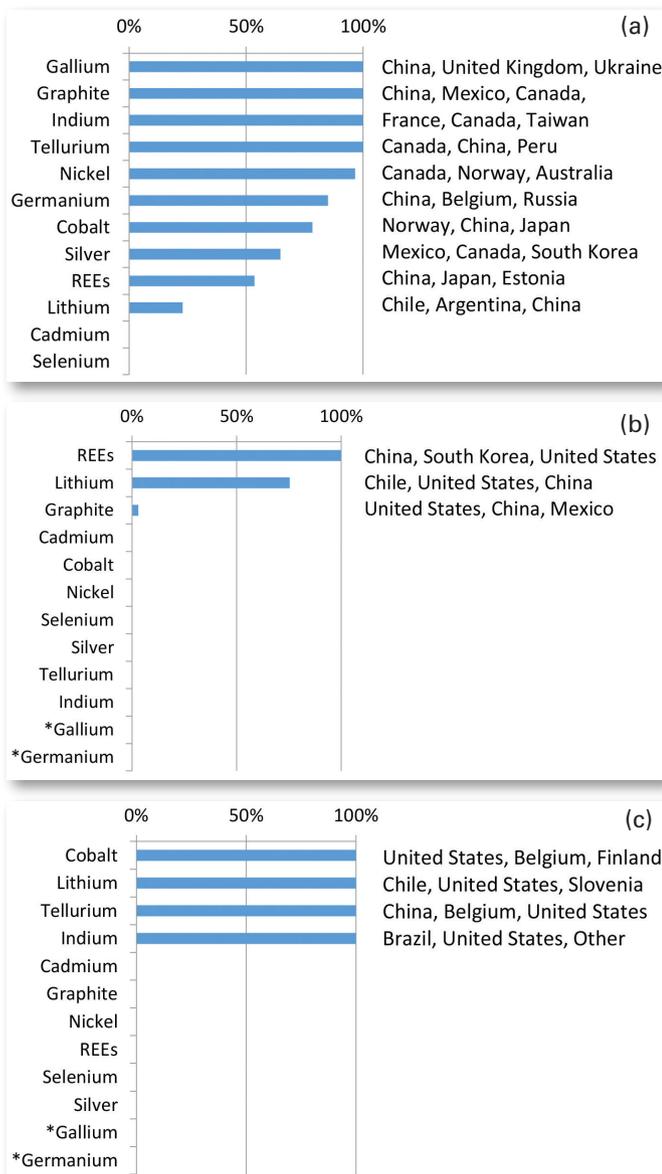
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Harmonized System (HS) codes for each commodity were selected to reflect the imports of primary commodities in unmanufactured forms. These forms include: powders, flakes, acetates, mattes, ores and concentrates, wrought and unwrought metals, oxides, hydroxides, chlorides, sulfates, carbonates, bullion and doré, and waste and scrap. Some of these material forms, which have different chemical and

physical properties, are not used in the manufacture of the high-technology products mentioned previously, and as a deeper analysis of these material flows is beyond the scope of this study, the results of this work should be used to understand the total trade of the selected materials but not conflated with their end use. These various commodity forms were converted to the contained weight of the commodity of interest for meaningful compilation, which was primarily achieved through stoichiometric ratios of the commodity in a compound.

Figure 5

2014 individual net import reliance for (a) the United States, (b) Canada and (c) Mexico by commodity. The three dominant import sources are included for reference.



*Reported Canadian and Mexican gallium and germanium export data were aggregated, making quantification impossible. There was no known gallium production in Canada, making the net import reliance likely 100 percent. Canada was an exporter of germanium, though the amount is unclear. There was also no known gallium or germanium production in Mexico, making the net import reliance likely 100 percent.

The production data for determining apparent consumption were supplied by the participating countries' domestic data sources: Natural Resources Canada, and the National Minerals Information Center (Natural Resources Canada, 2016; U.S. Geological Survey, 2016). The production data for Mexico, when available, as well as the withheld, for confidentiality, Canadian graphite production were supplemented by data from the National Minerals Information Center (George, 2014; Wacaster, 2014).

The North America NIR assessments for some commodities were complicated. Germanium and indium are identified in HS codes that include other materials, which obscures the trade of individual commodities. The North American NIR for germanium could not be numerically evaluated. However, industry relationships within North America were analyzed. It is known that ore mined in Alaska is refined in Canada and exported back to the United States for further manufacturing. Silver ore and concentrate exports from Mexico also introduce a significant amount of uncertainty as Mexican exports are reported in gross weight rather than contained weight, as is done for the United States and Canada. The silver content of these ores is largely unknown and could not be reliably estimated and therefore had to be discounted, though Mexico remains a net exporter of silver metal.

Results

When consolidated as a single entity, the total North American NIR exhibited greater than 50 percent NIR for only three commodities: gallium, lithium and rare earths (Fig. 4). Gallium was the only commodity studied for which North America was 100 percent net import reliant, as none of the three North American countries produced gallium in 2014.

The United States exhibited the greatest difference between its individual NIR and the aggregated North American NIR, with the largest reduction of import-reliant commodities due to cross-border trade (Figs. 4, 5a). The United States had the greatest exposure to import risk, with nine of the 12 commodities studied exhibiting greater than 50 percent NIR (Fig. 5a). This is largely because the United States is the primary raw material importer of nearly all technology-dependent commodities and has limited domestic production of these materials. By contrast, because Canada is a producer of many of the studied commodities, Canada was only import reliant for REEs, lithium and graphite (Fig. 5b), which reflects the fact that its economy is oriented more toward the resource sector than manufacturing (Statistics Canada, 2017). In fact, Canada runs a large positive trade balance where mineral extraction, smelting and refining are concerned. Its trade balance for semifabrication is usually

Figure 6

North American trade balance (exports minus imports) by commodity for 2014. Germanium and indium have aggregated export data and are not included.

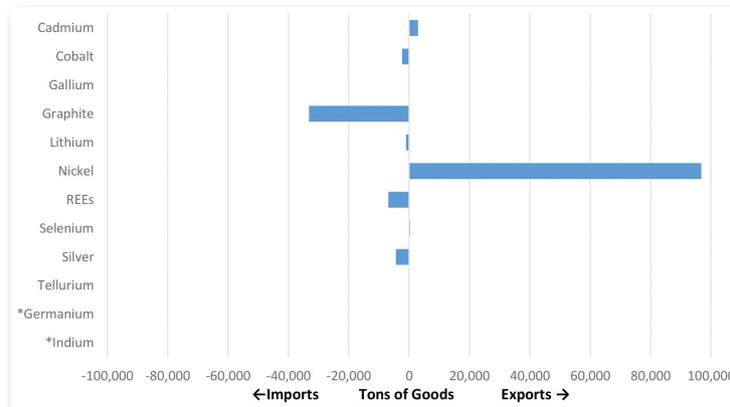
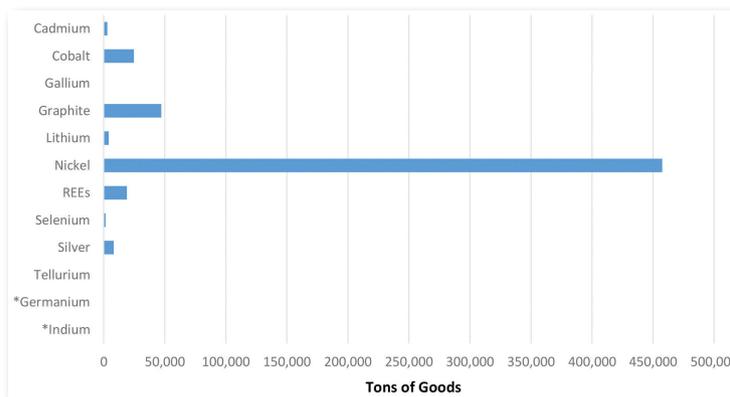


Figure 7

North American total trade (imports plus exports) by commodity for 2014. Germanium and indium have aggregated export data and are not included.



neutral, but for final fabrication its trade balance is large and negative. As a result, Canada’s domestic production of the other commodities included in this study satisfied domestic consumption. Mexico occupies a more hybrid position in the North American supply chain as both a consumer of products and a major source of some materials such as graphite and silver. The high Mexico NIR for some materials highlights import risk (Fig. 5c) but obscures the fact that Mexico imported a minor share of less than 2 percent of the total imports of studied materials for North America. However, Mexico exported a larger tonnage of the studied materials than the United States, dominated by graphite. This demand for materials in North America is in part satisfied due to Canada’s position as the dominant North American raw material supplier.

The North American NIR is largely a reflection of the consumption and production patterns for each nation. The United States is the net mineral and metal consumer for North America, importing more commodities than it exports. Canada represents the opposite trend, being the domi-

nant mineral exporter for North America. While Mexico consumes many commodities, it produces several studied commodities and is a small net exporter. For the materials examined, the North American bloc imported 402,496 t (444,000 st) in total while exporting 522,392 t (576,000 st) in 2014. In terms of total tonnage traded — both imports and exports — of the 12 studied commodities, nickel, graphite and cobalt accounted for almost 94 percent of North American trade, followed closely by REEs (Figs. 6-7). Of the studied commodities, nickel was the largest North American export by tonnage, owing almost exclusively to Canadian production. By tonnage, graphite was the largest North American import studied, which speaks to the high demand for graphite as there is significant Canadian and Mexican production supplementing this trade. The monetary values of these flows would likely highlight the varying economic importance of commodities traded in North America. However, many of the commodities studied do not have directly relatable values or spot prices. Therefore, value-based comparison of the import reliant commodities was not possible.

Discussion

This study provides an overview of the reduction in import reliance of raw materials needed for high-tech applications from North American trade. However, there are limits to this study that should be noted. To analyze NIR for the studied commodities, imports and exports were generated by aggregating multiple HS codes to determine total material requirements, such as ores, oxides and metals. However, these different material forms have different characteristics and widely varying applications. This study did not analyze each individual form of the material and its NIR. The commodity as a whole may not be import reliant for North America, but a particular form of the material could be. This study focuses on raw and unmanufactured materials, the NIRs of which are only relevant if a nation possesses a robust industry that can utilize them. One example is the North American NIR calculated for rare earths does not include rare earths embedded in imported permanent magnets that are a major end use, although manufacturing of rare earth magnets is limited in North America.

There is also potential for uncertainty about the NIR for a nation — or, in this case, a bloc of nations — if materials are exported in certain stages of the supply chain and later imported as more processed goods, which would artificially inflate the processing nation as an exporter. An example of this would be nickel and cobalt, which are mined in and exported by Canada to Norway for refining (Kuck, 2013). These refined metals are then exported, making Norway the second largest source of nickel to the United States, yet this nickel largely originates from and is consumed within the North American bloc. Trade in semifinished goods therefore can result in anomalous NIRs if there is insufficient domestic ability to process and transform raw materials or if materials are exported for processing and then reimported. This highlights the importance of evaluating the whole supply chain rather than single nodes, which requires additional future studies of the largely opaque life cycles of many of the byproduct minor metals.

It is also important to note that this study looks at the production and trade statistics of the selected materials as it currently stands and does not address the mineral supply potentials that exist within the North American nations. Many of these minor metals have high import reliance due to insufficient domestic production, which is not always a reflection of geologic scarcity. Economics, including costs associated with cultural and political factors, is as important as favorable geology in the ability to mine and capture materials. Many of the materials studied here have only recently become economically important commodities, and future studies will hopefully help increase the knowledge of the North American potential to increase domestic supplies.

Conclusions

As a single entity, North America is much less dependent on other nations for the supply of materials for high-technology applications than as individual parties. The United States is the largest consumer of the materials studied and imports significant amounts of material from North American countries, which not only reduces supply chain risk but also provides a reliable economic partnership. Value chains

between the United States, Canada and Mexico are tightly integrated with the result that various materials and product components commonly cross continental borders multiple times, as value is added at each stop.

As the United States also consumes large amounts of other minerals for which Canada and Mexico may be significant sources of supply, it would be interesting to expand the analysis further to better understand the full extent of the economic synergies that exist within the North American trading bloc. Furthermore, NIR studies such as this can highlight the potential raw material supply risk for domestic manufacturing, but there remains a substantial amount of materials that are imported as embedded components in finished goods, which warrant future studies to fully assess both their mineral/metal content as well as their recyclability. ■

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