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Testimony before the United States Senate
Committee on Energy and Natural Resources
16 March 2021

Senator Joe Manchin III, Chairman of the Senate Energy and Natural Resources Committee
Senator John Barrasso, Ranking member of the Senate Energy and Natural Resources Committee
Senate members of the Energy and Natural Resources Committee
Ladies and gentlemen,

I am honored to be here to testify at this hearing examining ways to strengthen research and development in innovative transportation technologies with a focus on solutions that decrease emissions, reduce America's reliance on foreign supply chains, and increase manufacturing in the United States.

Allow me, from the outset, to make it clear that I am speaking in my personal capacity and that the opinions expressed in this testimony are my own, not those of my employer, the United Nations Conference on Trade and Development (UNCTAD). My testimony draws from my 30-year research experience as a development economist, including the last ten years researching the interaction between natural resource dependence and development. The material I present today is based on three main sources: *Commodities at a Glance: Special issue on strategic battery raw materials* (UNCTAD, 2020, New York and Geneva); *Commodities at a Glance: special issue on rare earths* (UNCTAD, 2014, New York and Geneva); La guerre des métaux rares: la face cachée de la transition énergétique et numérique—The war over rare metals: the hidden face of the energy and digital transition (my own translation)—(Guillaume Pitron, 2018, Les Liens qui Libèrent). I use this opportunity to thank my colleagues Alexandra Laurent and Rachid Amui, who worked on UNCTAD's two reports. My presence here is that our work is relevant and useful for policymaking, which is the overarching objective of UNCTAD's research.

My testimony is presented in three parts. First, I highlight the key natural resources associated with innovative transportation technologies as we know them today, focusing on rechargeable electric batteries as this is arguably the key ingredient for successful green mobility. I also show where these natural resources are found, and what is the United States position in this space. Secondly, I argue that the United States does not need to have deposits of such natural resources in its ground to be a key player in the energy transition. Most opportunities lie in downstream segments of the value chain. Stronger United States involvement in commodity value chains especially through joint ventures with producer countries could help diversify US supply sources and reduce the country's strong reliance on foreign supply chains. Indeed, the few countries holding most of the strategic natural resource reserves are developing countries in need of partners and a different business model that could allow them to capture more value from their natural resources. The third aspect of my testimony briefly touches on the importance of frictionless international trade as a way of ensuring steady and predictable supply.

1. Natural resources associated with innovative transportation technologies

The world is going through an energy transition. There is a strong movement towards decarbonization of energy consumption with the introduction of renewable energy systems such as photovoltaic solar panels, wind turbine systems, and more recently rechargeable energy storage batteries. Batteries are used to provide energy for household use, and power electric vehicles, appliances and gadgets used in day-to-day life, such as mobile telephones. Batteries are also used in military, industrial, and several commercial applications.

Natural resources that fuel transportation systems associated with low Greenhouse Gas (GHG) emissions are mainly those used in the production of rechargeable electric batteries, particularly lithium-ion batteries (LIBs). The LIB is particularly prized thanks to its high technical performance; it has the highest energy and power density of all rechargeable battery types. LIBs are also lighter and smaller than other rechargeable batteries, allowing them to be most suitable for use in the fast-growing market of electric vehicles (EVs). Furthermore, the LIB offers a higher number of charge and discharge cycles in the battery's life than nickel-based batteries, for example. In addition, LIBs have the potential for further improvement in costs and performance with respect to battery chemistry, energy storage capacity, manufacturing scale and charging speeds, suggesting that they are likely to remain dominant parts of EV manufacturing for the seeable future.

The current and evolving battery technology relies on a limited number of raw materials. The main are lithium, cobalt, manganese, and natural graphite. Most have few substitutes and are not widely globally distributed. Therefore, rapid growth in the demand for LIBs, largely driven by environmental concerns, coupled with LIBs cost and efficiency advantages over other rechargeable battery types, is expected to boost demand for the commodities used to manufacture them. This is an opportunity that countries producing these raw materials should take advantage of. However, exploitation of these commodities may also present a challenge. Experience shows that their exploitation has often been associated with an undesirable environmental footprint, poor human rights, and poor worker protection. The commodities' low substitutability and limited geographical distribution also raise the question of sustainability of supply, particularly in view of rising demand for them.

Many countries classify these commodities as strategic raw materials because they serve an essential function in the manufacturing of many products that are considered of high importance for a country's economic and/or national security. As these natural resources have few or no substitutes, some countries may put in place measures to control their conservation and/or distribution. The list of strategic raw materials may depend on each country's specific interest. Moreover, the list may vary over time depending on technology advances, new discoveries, changes occurring in their global supply and demand, concentration of production, and current policy priorities.

There are five different types of lithium-ion batteries (Table 1). Lithium Cobalt Oxide has the highest capacity as well as the highest cobalt content. The table shows what types of natural resources are needed to manufacture LIBs required for the transportation industry. Lithium and cobalt come out as two essential raw materials in the production of these batteries.

Table 1: Types of lithium-ion battery chemistries

Name	Abbreviation	Chemical Formula	Cobalt content	Properties and applications
Lithium Cobalt Oxide	LCO	LiCoO2	60%	High capacity. Mobile phones, tablets, laptops, cameras
Lithium Manganese Oxide	LMO	LiMn2O4	0	Safest; lower capacity than LCO but high specific power and long life. Power tools, e-bikes, EVs, medical devices
Lithium Iron Phosphate	LFP	LiFePO4	0	
Lithium Nickel Manganese Cobalt Oxide	NMC	LiNiMnCoO2	10 – 30%	
Lithium Nickel Cobalt Aluminium Oxide	NCA	LiNiCoAlO2	10 – 15%	High capacity; gaining importance in electric power train and grid storage; industrial applications, medical devices

Lithium and cobalt are central to the manufacturing of rechargeable batteries used in electric vehicles, trains, and bicycles, according to Table 1. Given the United States interest in this sector, the question is where is it going to find these raw materials? The following figures provide the answer.

Figure 1: Lithium reserves

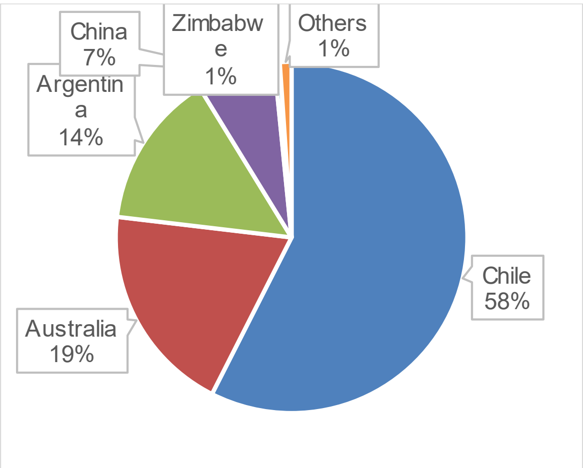
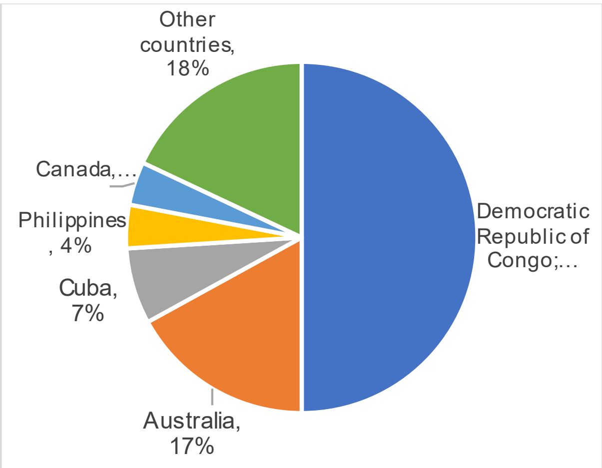


Figure 2: Cobalt reserves



Figures 1 and 2 show that only two countries account for more than half of world reserves of lithium (Chile with 58%) and cobalt (the Democratic Republic of Congo with 50%).[1] This level of concentration suggests that these two countries are key players in the ongoing energy transition. It is also relevant to note that, apart from Australia, the two natural resources are found in their natural form in developing countries. The third take away from the two figures is that the United States does not appear as a producer of lithium and cobalt.

Figures 3 and 4 extend the discussion to manganese and natural graphite, the latter being the commonly used battery anode material. While these two commodities are more widely geographically distributed relative to lithium and cobalt, developing countries dominate the distribution.[2] Moreover, the United States does not appear in the distribution, again.

Figure 3: Manganese reserves

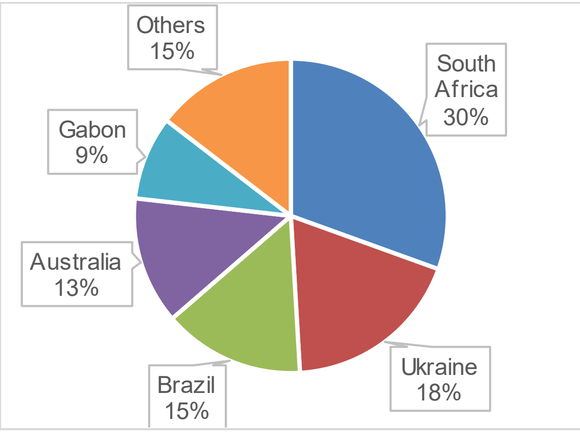
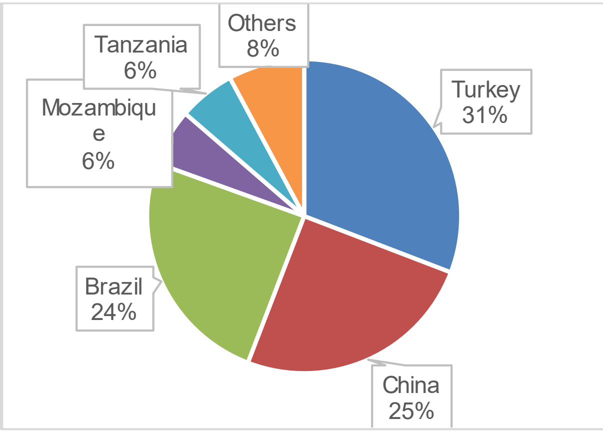


Figure 4: Graphite reserves



Other natural resources of interest to the so-called "green mobility" are rare metals or rare earths.[3] A typical electric and hybrid car may contain 9 to 11 kilograms of these natural resources. They include lanthanum and cerium in a hybrid battery; cerium/zirconium and lanthanum in the catalytic converter; several neodymium-based magnets in the electrical engine; neodymium in lamps; cerium in windshield, windows and mirrors; europium, yttrium, and cerium in ACL screens; yttrium for captors; and neodymium, praseodymium, dysprosium and terbium in the engine and electric generator of a hybrid car. In addition to hybrid and electric cars, these natural resources are used in all sectors of modern technologies including mobile telephones, television screens, satellites, oil refining, military and defense sector, green energy technologies, etc.

[1] Bolivia is part of the "Lithium Triangle" (Argentina, Bolivia, Chile). However, it is not ranked in Figure 1 as its reserves remain undeveloped due to technical, geographic, and political challenges. But the country is considered as having the largest reserves of lithium and it may soon become a key player in the lithium market if the current challenges are overcome.

[2] Graphite is either synthetically produced (artificial graphite) or mined from the ground (natural graphite). Extracted graphite is heavily processed to serve as anode. Both types of graphite are used for Li-ion anode material with about 55% being synthetic and 45% natural graphite. Synthetic graphite has been preferred to natural graphite because of its superior consistency. However, the trend is changing. Modern chemical purification processes and thermal treatment have made it possible to achieve a purity of 99.9% from natural graphite compared to 99.0% for synthetic graphite. Purified natural graphite has a higher crystalline structure and offers better electrical and thermal conductivity than the synthetic material. Unprocessed natural graphite is not only cheaper, lowering production cost with the same or better Li-ion performance, but also more environmentally friendly than the synthetic type.

[3] Rare earths and rare metals are used interchangeably in this document.

The distribution of these rare metals and rare earths is also concentrated but not in the same countries as the four natural resources discussed above. Even though exact information on these highly strategic materials is difficult to gather, it is widely accepted that one country, China, accounts for the largest share of rare earth resources, ranging from 23% to 55% of world reserves, depending on the source used. The United States is also in a good position as a producer of rare metals; it may account for 11% to 13% of world reserves, depending on the source used. The United States may hold 90% of beryllium and 73% of helium reserves.

In view of the information discussed above, the second section of the testimony focuses on how the United States could position itself in the growing lucrative market for innovative transportation systems. What are the challenges and opportunities?

2. Opportunities in the green transportation value chain

The discussion in Section shows that the United States does not appear to have any of the four commodities central to the manufacturing of electrical batteries, namely lithium, cobalt, manganese, and natural graphite. Therefore, the United States needs to rely on supplies from the countries shown in Figures 1-4.

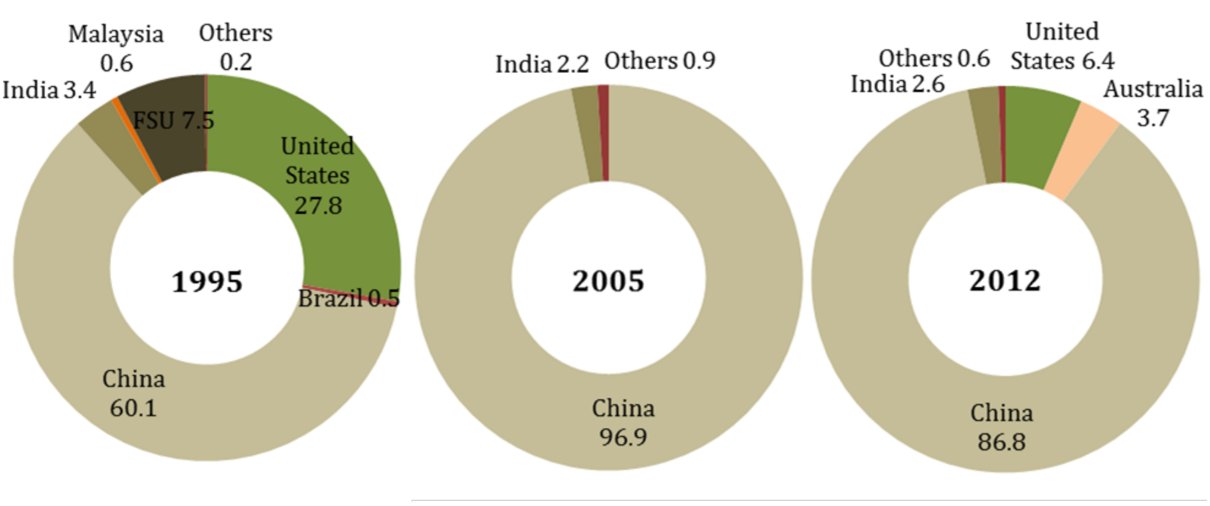
Regarding rare earths deposits, the United states is relatively well endowed. In fact, the United States dominated the rare earth sector between 1965-1985. It was the largest producer of these materials, mainly from one production site, the Mountain Pass Mine in California, exploited by Molycorp, an American mining company. The country lost its leadership position in the 1990s and early 2000s due to two factors. First, China got seriously involved in the production of rare metals at about this time. With production costs that were a fraction of the United States' production from the US became uncompetitive. Second, the high cost to the environment and a series of environmental accidents at the gigantic Mountain Pass Mine invited scrutiny from the government. Molycorp judged that the mine would not be profitable if it were to modernize its equipment to comply with environmental regulations, amid stiff competition from China. The mine was eventually closed in early 2000s.

The case of Mountain Pass Mine is instructive in several ways. A country may have deposits of a natural resource, but this does not mean that it can be extracted profitably. Lithium in Bolivia is another illustrative case. The extraction of rare metals is particularly tricky. Even though some countries extract rare earths directly, most of the quantities commercialized come from mines where rare earths are in small concentration, in combination with another less rare metal such as nickel or copper. Therefore, it might not make economic sense to exploit a nickel or copper mine for the sake of extracting rare earths if market conditions are not jointly conducive for the two or three commodities.

Environmental concerns that led to closure of the Mountain Pass Mine had the same effect in Europe. Mining of rare metals in countries such as France was discontinued for the same reasons environmental. By discontinuing mining in Europe and the United States, the negative environmental effects associated with rare metal mining in Europe and the United States were externalized to countries that did not have the same level of environmental standards at the time. The consequence was that Europe, and the United States, became strongly dependent on external suppliers.

Figure 5 illustrates how the standing of the United States in the production of rare metals waned from the 1990s to the 2000s, with some recovery starting in early 2010s. From 28% of total world production in 1995, the share of the United States dropped to nil in 2005. By 2012, the United States re-appeared in the list of producing countries, with a share of 6.4% in 2012. In contrast, China's shares in total production increased from 60% in 1995 to 97% in 2005. By 2012, China was still comfortably in the leading position, accounting for 87% of total world production.

Figure 5: Rare metals producing countries



More recently, in 2019, the United States produced 26,000 MT of rare earths, up 44% from 2018. The United States rare earths come exclusively from the Mountain Pass mine discussed above. After it went bankrupt, the mine was purchased by MP Mine from Molycorp. Data from the US Geological Survey shows that The United States has become again one of the world's largest producers of rare earths, second only to China. This suggests that the United States was able to find solutions to the problems that had plagued the sector in the 1990s. Technological developments can indeed make an otherwise unprofitable operation to be economically feasible. The United States has an opportunity to become, again, a key player in the strategic sector of rare metals.

As stated earlier, opportunities in the context of innovative transportation systems that reduce America's reliance on foreign supply chains and increase manufacturing in the United States do not materialize only in areas where the country has its own natural resources. In fact, most opportunities lie with operations that take place after the extraction of the natural resource. Indeed, the United States might not have its own deposits of lithium, cobalt, manganese, and natural graphite, but it can benefit from opportunities that these raw materials offer along their relatively long value chains. The lifecycle of the metals of interest may be summarized as follows: exploration, extraction, basic treatment (e.g., grinding), production of intermediary or basic material after primary transformation (e.g., anodes and cathodes), further transformation (e.g., pipes, cables, tubes), use in final product (e.g., cars, wind turbines), and disposal or recycling (e.g., waste and its eventual treatment).

Two main factors put the United States in a privileged position in terms of the benefits it could derive from the natural resources discussed above: technology and financial capital. Each segment of the lifecycle requires specific technologies and investments. The United States is a leader in research and development and the country sits on the technology frontier. The United States can leverage its unique technological position to enter any of the segments of the value chains of the commodities we are discussing, from exploration to recycling. Similarly, the country has a financial industry and financial resources that could help it position itself as the investor of choice in the sector. The current reality shows that he who controls the technology and capital controls the value chain, irrespective of where the resources are extracted.

It is useful to recall that most resources associated with electric battery technologies are in developing countries: Chile and Argentina for lithium; Democratic Republic of the Congo, Cuba, and Philippines for cobalt; South Africa, Brazil, and Gabon for manganese; and Brazil, Turkey, Mozambique, and Tanzania for natural graphite. Many of these countries may well hold important reserves of these strategic commodities, but they generally lack the technologies and investments required to extract them efficiently and economically, let alone transforming them domestically. To illustrate, Figure 6 shows that the companies that refine cobalt are not from the DRC even though 66% of world production takes place there.

Figure 6: Refined cobalt—chemicals (tons), 2017

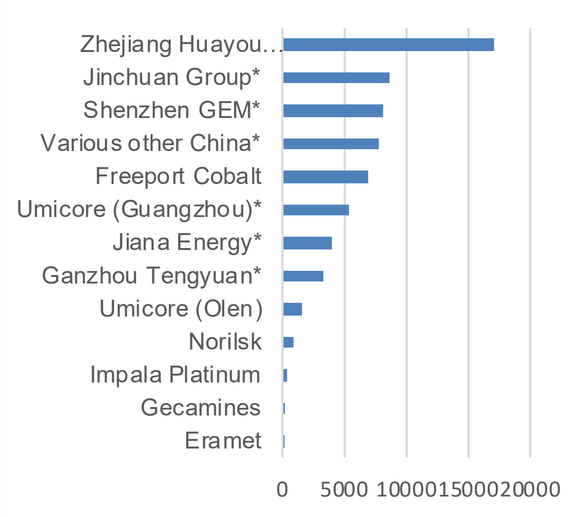
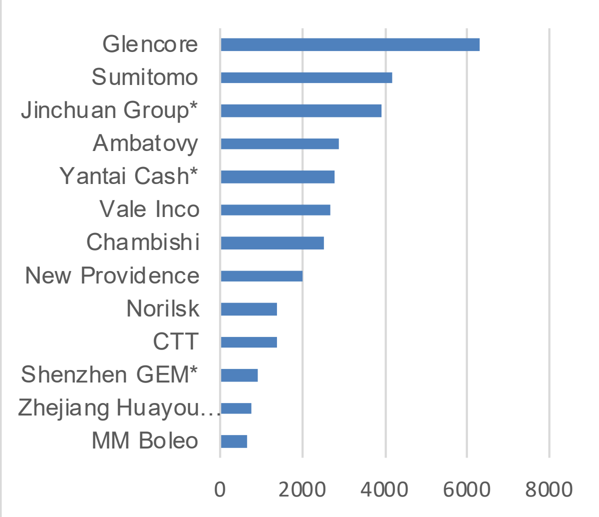


Figure 7: Refined cobalt—metal (tons), 2017



Foreign countries have been able to capture the opportunities offered by the refining segment of the value chain for cobalt—the picture is similar for most commodities produced in developing countries. For example, out of 13 companies involved in cobalt refinery to derive cobalt chemicals, seven are Chinese; and all seven Chinese companies are among the top eight in terms of production. Finland's Freeport Cobalt comes five, with companies from Belgium, Russian Federation, South Africa, DRC, and France accounting for smaller amounts. The United States does not feature in the list. A comparable picture emerges with respect to cobalt refineries extracting metal. Four out of 13 are from China and the United States does not have any of the 13 companies.

Cobalt refineries are rarely located near cobalt mines. Refiners purchase cobalt concentrate from various mines and ship to their own locations for transformation. Generally, refiners buy cobalt ore, ship it to their countries where they undertake the refining and other upstream transformation processes. This starves producing countries of opportunities to add value and internalize at least some of the benefits accruing to these activities. Upstream transformation generates positive spillover effects in the economies where it takes place: job creation, tax payment, technological development, etc. These forgone benefits may explain why some countries well-endowed continue to have some of the highest levels of poverty in the world. The Democratic Republic of the Congo is one of them.

The absence of the United States from the value chains of strategic commodities imply that the country is forgoing benefits that should accrue to its technological and financial leadership. At the very least, buying ore and transforming it in the United States, as other countries are doing, would also remedy the lack of natural resource within its boundaries, reducing its dependence on external suppliers. Most of the countries in Figures 6 and 7 do not have a single domestic cobalt mine but they become important players in the sector by procuring the commodity where it is.

It is important to note that the extractive model pursued by most foreign companies has created frictions and even serious problems in their host countries. There are recent well-known cases of large-scale environmental damage, human rights violations with impunity, and child labor in mining operations. These practices have created tensions in host communities, particularly in countries with weak institutions where these multinational companies are not held to account. No host country appreciates these practices but most of the times, affected communities are powerless when they face unscrupulous large and powerful companies. This business approach may generate maximum short term financial returns for company shareholders, but it based on a model that is more and more decried across the world. It is also important to note that developing countries caught in this extractive model do not appreciate the fact that the benefits from their natural resources are limited to selling the raw commodity. These countries would also like to internalize at least some segments of the value chain as a way of capturing more revenue from their natural resources. With the current model, natural resources benefit more foreign companies and the countries where value is added. This system perpetuates underdevelopment of natural resource-rich countries.

Should United States firms engage more in natural resource value chains, they could adopt a model that does not consider their engagement as a zero-sum game. The world is moving towards more responsible investment models, where sharing benefits more fairly with host countries does not prevent profit making. Key investors, particularly institutional investors, have been pushing for more sustainable investing. To be clear, the relatively new concept of "impact investing" is gaining traction in investment circles. Impact investing implies that an investment in not assessed just by its rate of return. Other considerations including the investment's impact on the community where it takes place, its environmental footprint, and its social impact, are equally important. Impact investment does not mean that profit is not important. It simply means that profit should be made but respecting environmental and social sustainability principles.

Incumbent investors will probably find it difficult to change their old business model. This is an opportunity for entrants interested in following the new trend. Moreover, there are many untapped opportunities in natural resources that American companies might consider taking advantage of. Exploration is key among them. The fact that regions such as Africa are highly under-explored offers immense opportunity to companies that have the modern technologies used in natural resource exploration elsewhere. Even sectors already in development might need more efficient and less polluting technologies that American firms may possess or develop. For example, the extraction of Chilean lithium is so inefficient and polluting that new extraction technologies are needed. They are apparently under development and could be deployed soon, drastically reducing extraction time and cutting the ecological footprint of current operations. There are also opportunities in recycling. To date, the rate of recycling of rechargeable batteries and electronic products that use the raw materials discussed here is very low. Developing the relevant recycling technologies would provide an advantage to firms interested in this segment of the commodity lifecycle.

3. Importance of frictionless international trade

No country in the world can depend on its own natural resources for all its needs, no matter how well it is endowed with natural resources. Even for the most endowed countries such as China and Australia, self-reliance has its limits. Countries, including the United States should, therefore, foster a frictionless international trading system. Countries should be able to access strategic commodities through international markets. Ironically, some countries that procure through trade ores from developing countries for refining and further processing into intermediary and final products have sometimes imposed export restrictions on processed goods derived from the imported raw materials hurting importing country industries. Developing countries supplying these raw materials do not benefit either. Therefore, should not trading in strategic natural resources be governed by the same rules governing international trade?

Thanks to international trade, developing countries transform their natural capital (natural resources) into other forms of capital (physical, financial, human) needed for their development. Countries importing natural resources also owe the revenues they derive from transforming them to international trade. Figure 7 and 8 show, for example, the top five exporters of oxide and hydroxide from cobalt and from lithium. They are mainly developed countries that import the raw materials.

Figure 7: Cobalt (% share)

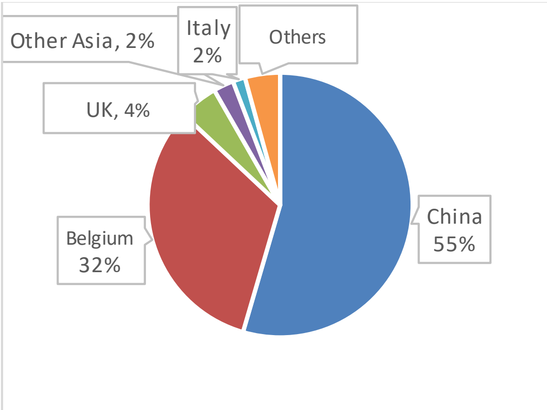
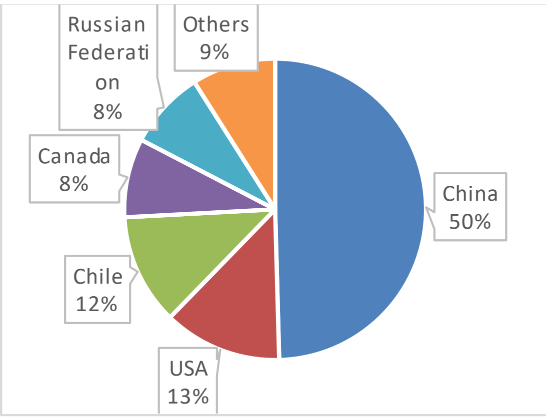


Figure 8: Lithium (% share)



Except for Chile (for lithium), no other exporter is a major producer of cobalt or lithium. Belgium and China dominate cobalt exports, despite the fact they are not cobalt producers. China, again, dominates lithium oxide and hydroxide exports despite not being a major producer of lithium. This confirms a point made earlier: a country does not need to have important deposits of a natural resource to dominate its value chain and trade.

In conclusion, as the United States does not possess some of the natural resources needed to fuel its green mobility, it would benefit by fostering an international system that guarantees access to such resources. Frictionless trade is one avenue. Another opportunity is to leverage America's technological and financial leadership to actively get involved in commodity value chains, from exploration to recycling. The United States could lead by adopting and spreading a new business model that is more sustainable, seeking profit while at the same time making a positive impact in host countries. Sustainability should be pursued at every segment of the commodity cycle the country is involved in.

[THE END]