AUGUST 24, 2022

Are There Enough Metals in Mother Earth to Replace Oil?

A phase out of fossil fuels by mid century looks to be a nearly impossible “Sisyphean task”.

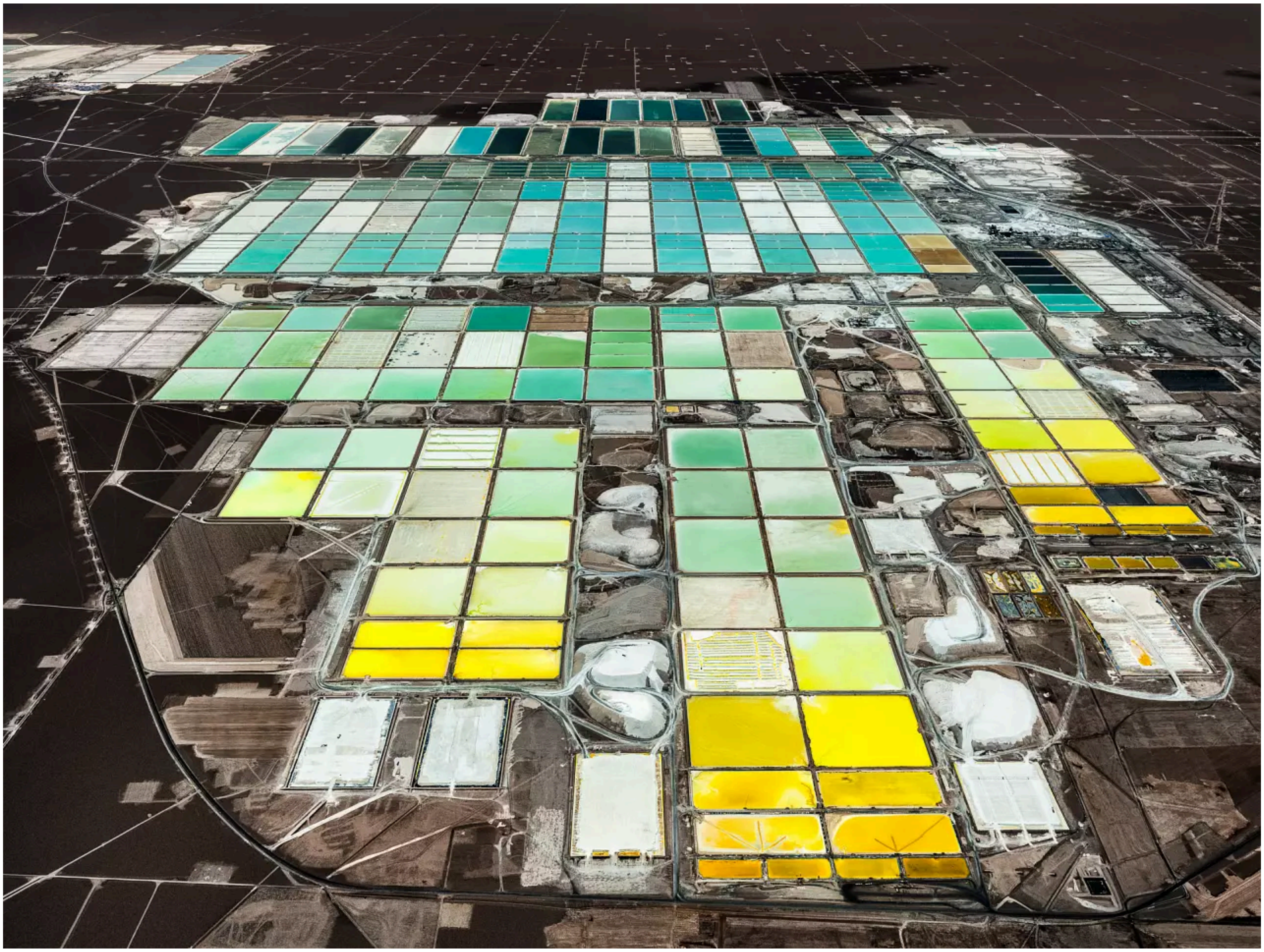


Photo of the “negative-environmental-externalities” of lithium mining in Chile

Are there enough metals in Mother Earth, (such as lithium, copper, zinc, cobalt, vanadium, etc.) for the raw materials needed to manufacture the renewable energy economy of solar, wind and electric batteries and vehicles, in order to replace oil? The short answer is no, not even close!

A recent scientific study from Finland puts a damper on the prospects of phasing out fossil fuels in favor of renewables. **More to the point, a phase out of fossil fuels by mid century looks to be a nearly impossible Sisyphean task. It’s all about quantities of minerals/metals contained in Mother Earth. There aren’t enough.**

It’s Time to Wake Up! The Currently Known Global Mineral Reserves Will Not Be Sufficient to Supply Enough Metals to Manufacture the Planned Non-fossil Fuel, Renewable Energy, Industrial Systems.

Contrarian research from Geological Survey of Finland GTK (published August 20, 2021) shows that if we want to transition away from fossil fuels; the mining of minerals and using recycled minerals and metals from industrial waste streams in new ways, **will have to increase greatly**. Thus the need to develop a global circular economy, with the true social costs of transitioning away from fossil fuels, to be paid for by the energy consumers of the renewable energy economy; and not the public treasury.

Exploration for more at required volumes will be difficult." **(Simon Michaux, PhD, of the Geological Survey Finland has done a detailed study of what's required to phase out fossil fuels in favor of renewables,** to wit: "The quantity of metal required to make just one generation of renewable tech units to replace fossil fuels is much larger than first thought. Current mining production of these metals is not even close to meeting demand. Current reported mineral reserves are also not enough in size. Most concerning is copper as one of the flagged shortfalls. **P. Michaux, Associate Research Professor of Geometallurgy Unit Minerals Processing and Materials Research, Geological Survey of Finland, August 18, 2022 – Seminar: What Would It Take To Replace The Existing Fossil Fuel System?)**
https://mcusercontent.com/72459de8ffe7657f347608c49/files/be87ecb0-46b0-9c31-886a-6202ba5a9b63/Assessment_to_phase_out_fossil_fuels_Summary.pdf

The metals/minerals required to source gigafactories producing renewables to power the world's economies when fossil fuels phase out, looks to be one of the biggest quandaries of all time. **There's not enough metal on the planet.** Dr. Michaux researched and analyzed the current status of the internal combustion engine fleet of cars, trucks, rail, maritime shipping, and aviation for the US, Europe, and China; accessing databases to gather information as a starting point for the study. Michaux's calculations for what's required to phase out fossil fuels uses a starting point of 2018 with 84.5% of primary energy still fossil fuel-based and with less than 1% of the vehicle fleet as electric. Therefore, the first generation of renewable energy is only now coming on stream, meaning there will be no recycling availability of production materials for some time. **Production will have to be sourced from mining.**

A key issue for the accomplishment of renewables is power storage because of the impact of wind and solar intermittency, both of which are highly intermittent. Most studies assume gas will be the buffer for intermittency. Other than using fossil fuel such as gas as a buffer, an adequate power storage system to handle intermittency will require 30 times more material than what electric vehicles require with current plans, meaning the scope is much larger than the current paradigm allows.

One factor that will influence what materials and systems are used to build out renewables is the fact that EVs require a battery that is 3.2 times the mass of the equivalent of a hydrogen fuel tank. Therefore, an analysis of EVs versus hydrogen fuel cells indicates it'll be necessary to build out the global fleet with EVs for city traffic and hydrogen fuel cells for all long-range vehicles like semi-trailers, rails, and maritime shipping.
The entire renewable build-out requires 36,000 terawatt hours to operate, meaning 586,000 new non-fossil fuel power stations of average size. The current fleet of power stations is only 46,000, meaning it'll take 10 times the current number of power stations, yet to be built.

The new annual energy capacity of 36,007.9 terawatt hours will supply (1) 29 million EV Buses (2) 601.3 million Commercial EV Vans (3) 695.2 million EV Passenger Cars (4) 28.9 million H2-Cell Trucks (5) 62 million EV Motorcycles (6). Hydro will also need to be expanded by 115% by 2050 and nuclear will need to double. Biomass will stay the same. It's already at limitations. Geothermal triples.

Additionally, buffer systems are crucial to handle intermittency. For example, Hornsdale Power Reserve in Australia, which is an Elon Musk project with a 100-megawatt capacity. The EU is using Hornsdale as the standard buffer system. Globally, 15,635,478 Hornsdale-type stations will need to be built across the planet and connected to the power grid system just to meet a 4-week buffer system. **This is 30 times the capacity compared to the entire global vehicle fleet. Therefore the market for batteries is substantially larger than currently understood and unaccounted for in planning for a renewable economy.**

The International Energy Agency (IEA) released a report on how much metal is required per unit to build out a renewable economy. As well as a study of what 2040 market share would look like for batteries for light duty vehicles and heavy duty vehicles and power storage at the level of the global fleet for solar panels in 2040 and hydrogen fuel cells, trucks, freight locomotives, maritime shipping, wind turbines and power storage buffer.

The total metals required for one generation of technology to phase out fossil fuels is listed by Required Production followed by Known Reserves for all metals based upon tonnes, as follows:

Copper 4,575,523,674 vs. 880,000,000 – a serious shortfall -reserves only cover 20% of requirements
Zinc 35,704,918 vs. 250,000,000 – adequate reserves
Manganese 227,889,504 vs 1,500,000,000 – adequate reserves
Nickel 940,578,114 vs. 95,000,000 – huge shortfall – reserves 10% of requirements.
Lithium 944,150,293 vs. 95,000,000 = huge shortfall – reserves 10% of requirements.
Cobalt 218,396,990 vs. 7,600,000 – huge shortfall – reserves 3.48% of requirements.
Graphite 8,973,640,257 vs. 320,000,000 = huge shortfall – 3.57% reserves of requirements.
Silicon (metallurgical) 49,571,460 – adequate reserves
Silver 145,579 vs. 530,000 – adequate reserves
Vanadium 681,865,986 vs. 24,000,000= huge shortfall -3.52% reserves of requirement
Zirconium 2,614,126 vs.70, 000,000 – adequate reserves.

Prior to 2020- the global system mined 700 million tons of copper throughout all history. Looking forward, the same 700 million tons will need to be mined over the next 22 years, which is based upon current economic growth rates without giving consideration to what's needed for one generation of renewables.

Current global reserves of copper are 880 million tons. But 4.5 billion tons of copper are required just to manufacture one generation of renewable technology.

Moreover, each renewable technology has a life cycle of 8 to 25 years. Thereafter, they need to be decommissioned and replaced. Also, whether renewables are strong enough, and sustainably enough to power the next industrial era is a question that hangs in the air.

THE PAST – "An industrial ecosystem of unprecedented size and complexity, that took more than a century to build with the support of the highest calorifically dense source of cheap energy the world has ever known (oil) in abundant quantities, with easily available credit, and unlimited mineral resources." (Michaux)

THE PRESENT – "We now seek to build an even more complex system with very expensive energy, a fragile finance system saturated in debt, not enough minerals, with an unprecedented number of the human population, embedded in a deteriorating environment." (Michaux)

Current global mineral reserves are <u>not adequate</u> to resource metal production, to manufacture the generation of renewable energy technology; as current mining is not even close to meeting the expected demand for just one generation of renewable technology.

When Dr. Michaux presented this basic information to EU analysts, it was a shock to them. To his dismay, they had not put together the various mineral/metal "supply-demand" data requirements to phase out fossil fuels and replace them with renewables. The EU central planners assumed, using "guesstimates", the metals would be available.

The author is Robert Hunziker who lives in Los Angeles. Carl L. McWilliams posted this article on Google Docs and suggests a pathway to a "circular economy" and "monetizing negative-environmental-externalities" as a function of "opportunity costs".

Why is Lithium Extraction Bad for the Environment?

Any type of resource extraction is harmful to the planet. This is because removing these raw materials can result in soil degradation, water shortages, biodiversity loss, damage to ecosystem functions and an increase in global warming.

But when we think of extraction, we think of fossil fuels like coal and gas. Unfortunately, lithium also falls under the same umbrella, despite paving the way for an electric future.. Lithium can be described as the non-renewable mineral that makes renewable energy possible - often touted as the next oil.

https://www.euronews.com/green/2022/02/01/south-america-s-lithium-fields-reveal-the-dark-side-of-our-electric-future

The salt flats (satellite photos above) in South America where lithium is found are located in arid territories. In these places, access to water is key for the local communities and their livelihoods, as well as the local flora and fauna. In Chile's Atacama salt flats, mining consumes, contaminates and diverts scarce water resources away from local communities.

Approximately 2.2 million litres of water is needed to produce one ton of lithium.

The other problem with lithium is the “scalability to manufacture” the new energy technologies. Furthermore, lithium is difficult in a “linear manufacturing model" as opposed to recycled minerals and metals.

The container ship Felicity Ace (pictured above) sank off the coast of the Azores on March 1, 2022, after fire broke out on board. The ship was carrying 3,965 Volkswagen Group cars, including electric vehicles. A Harbourmaster in the Azores told the media that lithium-ion batteries were the cause of the fire, though this has not been proven. All 22 crew members were safely evacuated, while insurers estimate the loss of goods on board at $438 million.

Abstract:

Simon Michaux

- Geological Survey of Finland

Current industrialization has a foundation in the continuous supply of natural resources. The methods and processes associated with this foundation have significant momentum. This paradigm will not be undone easily. Human nature and human history make it so. Currently, our industrial systems are absolutely dependent on non-renewable natural resources for energy sources. For the last 15 years, it has been apparent that the industrial business environment has been more challenging and volatile. This report will present the thesis that this persistent volatility is the forerunner of temporal markers that show the industrial ecosystem is in the process of radically changing. Current thinking is that European industrial businesses will replace a complex industrial ecosystem that took more than a century to build. This system was built with the support of the highest calorifically dense source of energy the world has ever known (oil), in cheap abundant quantities, with easily available credit, and unlimited mineral resources. This task is hoped to be done at a time when there is comparatively very expensive energy, a fragile finance system saturated in debt, not enough minerals, and an unprecedented number of human populations, embedded in a deteriorating environment. It is apparent that the goal of industrial scale transition away from fossil fuels into non-fossil fuel systems is a much larger task than current thinking allows for. To achieve this objective, among other things, an unprecedented demand for minerals will be required. Most minerals required for the renewable energy transition have not been mined in bulk quantities before. Many of the technology metals already have primary resource mining supply risks At its foundation, the current industrial ecosystem was and still is based around the consumption of natural resources, which were considered to be infinite. The very idea that there might be system based limits to the global extraction of resources is considered foolish by the current economic market. The volume of manufacture was influenced by the consumption demand of products. Growth and expansion with no considered limits of any kind was the underlying paradigm. The majority of infrastructure and technology units needed to phase out fossil fuels has yet to be manufactured. Recycling cannot be done on products that have yet to be manufactured. In the current system, demand for metals of all kinds have been increasing, just as the grade of ores processed has been decreasing. Global reserves are not large enough to supply enough metals to build the renewable non-fossil fuels industrial system or satisfy long term demand in the current system. Mineral deposit discovery has been declining for many metals. The grade of processed ore for many of the industrial metals has been decreasing over time, resulting in declining mineral processing yield. This has the implication of the increase in mining energy consumption per unit of metal. Mining of minerals is intimately dependent on fossil fuel based energy supply. Like all other industrial activities, without energy, mining does not happen. A case can be made that the window of viability for the fossil fuel energy supply ecosystem has been closing for 5 to 10 years. Geological Survey of Finland The Mining of Minerals and the Limits to Growth 1.3.2021 Geologian tutkimuskeskus | Geologiska forskningscentralen | Geological Survey of Finland It becomes highly relevant then to examine how mining the ecosystem interacts with the energy ecosystem. The IMF Metals Index and the Crude Oil Price Index correlates strongly. This suggests that the mining industrial operations to meet metal demand for the future are unlikely to go as planned. The implications are that the basic prediction of the original Limits to Growth systems study (Meadows et al 1972) was conceptually correct. Just so, it should be considered that the industrial ecosystem and the society it supports may soon contract in size. This implies that the current Linear Economy system is seriously unbalanced and is not remotely sustainable. The Limits to Growth conclusions suggest at some point, the global society and the global industrial ecosystem that support it will radically change form. It is clear that society consumes more mineral resources each year. It is also clear that society does not really understand its dependency on minerals to function. Availability of minerals could be an issue in the future, where it becomes too expensive to extract metals due to decreasing grade. This report proposes that the fundamental transformation of the global ecosystem predicted by the original Limits to Growth study, has been in progress since 2005, for the last 16 years. The industrial ecosystem is in the process of transitioning from growth based economics to contraction based economics. This will affect all sectors of the global ecosystem, all at the same time (in a 20 year window). We are there now and should respond accordingly. If the Limits to Growth study is truly a good model for predicting the industrial ecosystem, then the current industrial practice is inappropriate. The continued development of the economic growth paradigm would become increasingly ineffective, and a waste of valuable resources. All such efforts would be pushing in the wrong direction with poor results. The rules of industrialization and the sourcing of raw materials are changing into a new era of business model. Change is happening, whether we are ready for it or not. A possible response to these structural changes is presented after conclusions on page 52, where it was recommended that a new resource management system should be developed after genuinely understanding the net position of long term minerals supply. Also, it was recommended that new mining frontiers be opened, but the minerals extracted should be used differently.

The Carbon Footprint of Mining
Energy Transition Metals

By Tonnes of CO_2 per Tonne of Metal Produced

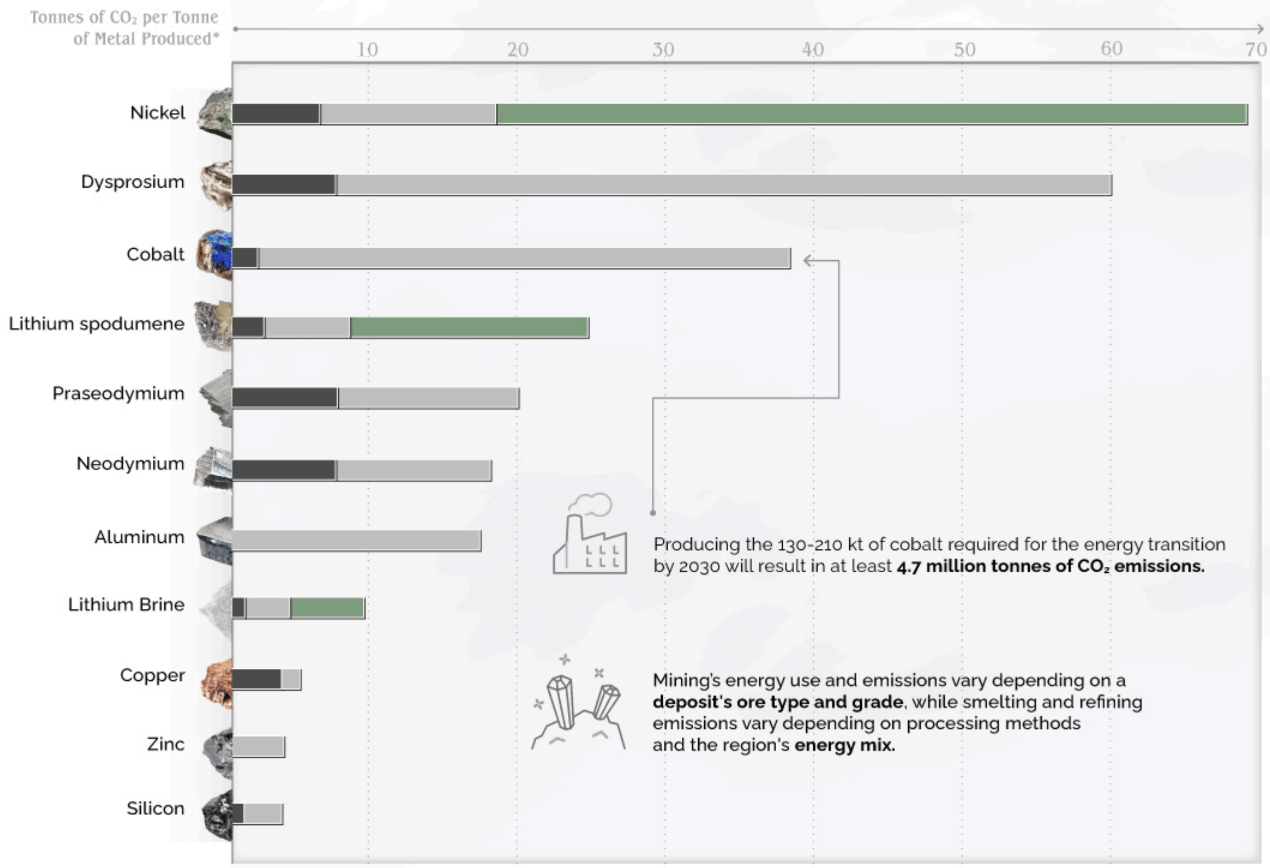
Metals are essential for the production of renewable energy infrastructure and EV batteries powering the global energy transition.

But how much carbon does mining and refining these metals end up producing?

Mining | Smelting & Refining | Range Variability

The metals and mining sector accounts for around 10% of global greenhouse gas emissions (7% from steel, 2% from aluminum, and 1% from other metals production).

The range of carbon emissions from lithium and nickel production varies depending on the kind of deposit, processing method, and end-product.



Producing the 130-210 kt of cobalt required for the energy transition by 2030 will result in at least **4.7 million tonnes of CO_2 emissions.**

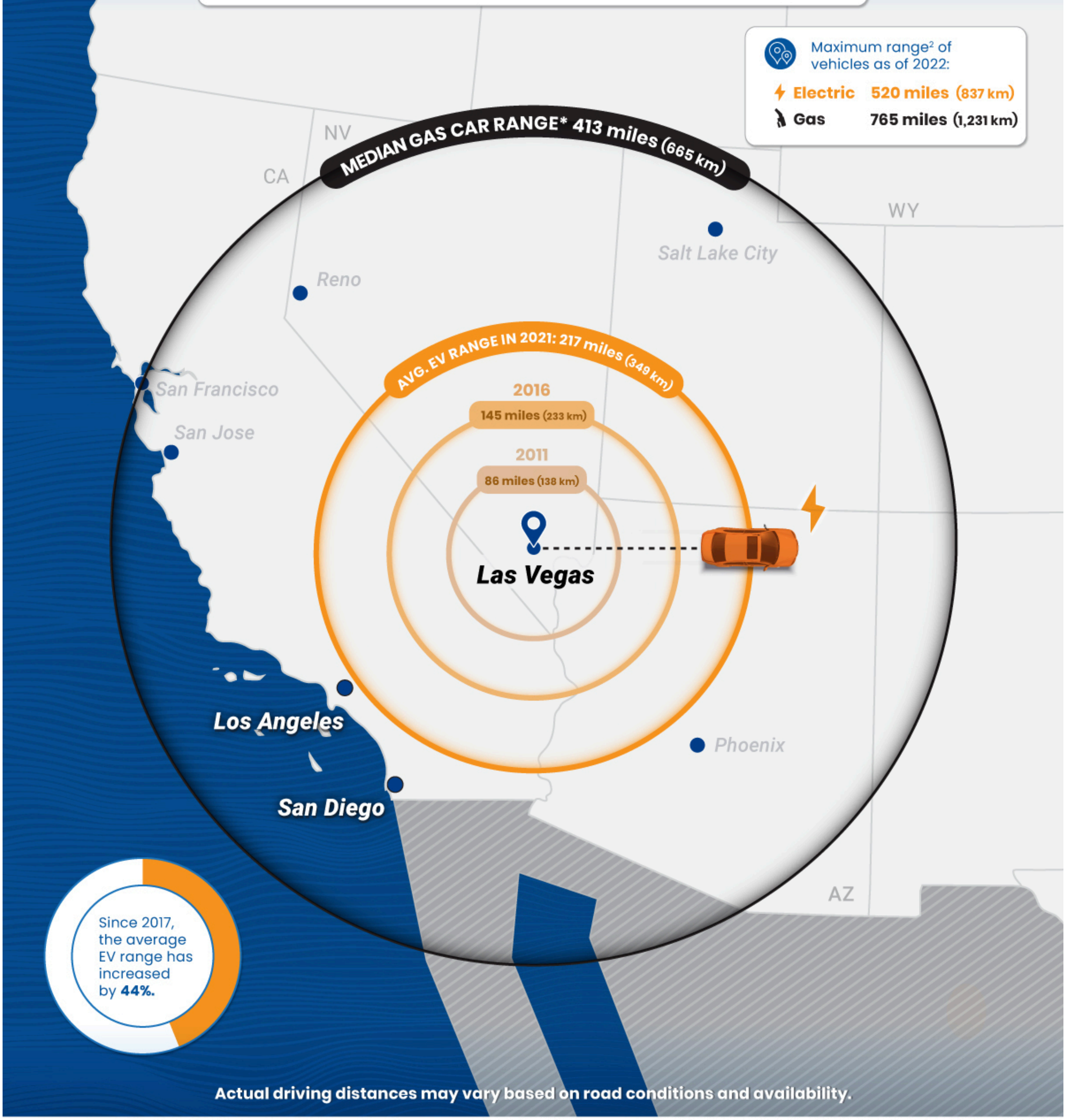
Mining's energy use and emissions vary depending on a **deposit's ore type and grade**, while smelting and refining emissions vary depending on processing methods and the region's **energy mix.**

*For lithium spodumene and brine, tonnes of CO_2 per tonne of LCE (lithium carbonate equivalent).

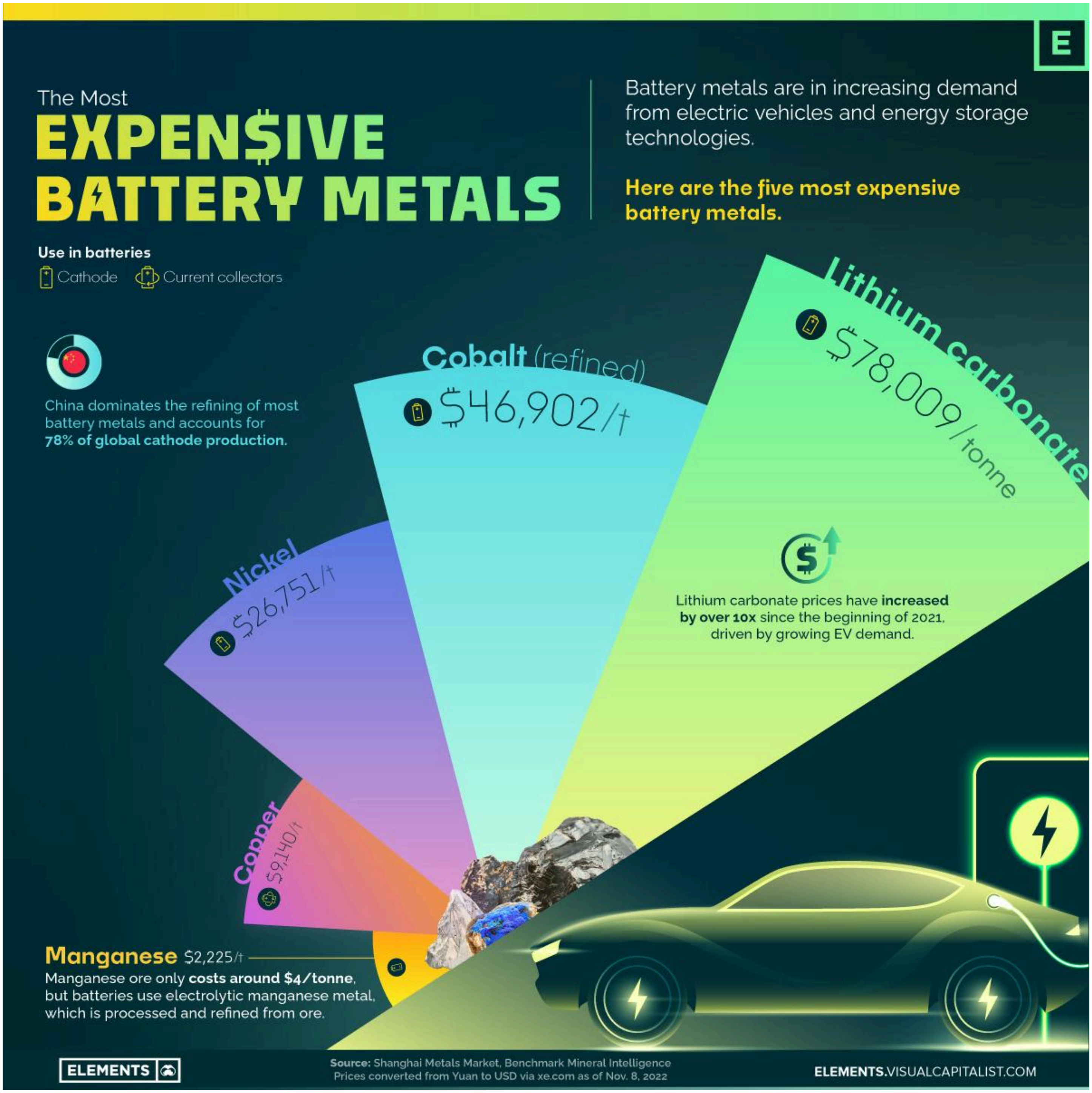
Source: MineSpans, Eckelmann, Li and Co LCA analysis

HOW FAR CAN AN EV GO ON ONE CHARGE?

With range anxiety often cited as a concern for potential EV buyers, how does the range of EVs[1] compare with that of gas cars?



[1] Graphic represents ranges for battery-powered fully electric vehicles.
[2] EV range is based on EPA's estimated range of the Lucid Air Dream edition (520 miles). The maximum range for gas-powered vehicles is from 2021 (latest available).
*Median gas car range on one full tank in 2021.



The Five Most Expensive Battery Metals

Battery metal markets are booming on the back of rising electric vehicle sales.
Supply chain issues and a global rush to secure supplies have skyrocketed battery metal prices over the last year. The above infographic highlights the five most expensive battery metals as of November 2022 using prices from [Shanghai Metals Market](#).

How Much Do Battery Metals Cost?

Cobalt was by far the most expensive battery metal until late 2021, which was when lithium prices hit an inflection point, heading towards all-time highs. A single tonne of lithium carbonate, one of the refined forms of lithium that's used in batteries, now costs over $75,000, up from around $6,500 at the beginning of 2021.

Metal	Price per tonne	Use in batteries
Lithium carbonate	$78,009	Cathode
Cobalt (refined)	$46,902	Cathode
Nickel	$26,751	Cathode
Copper	$9,140	Current collectors
Manganese (electrolytic metal)	$2,225	Cathode

Prices have been converted from yuan to USD via xe.com as of Nov. 8, 2022.

Lithium carbonate prices rose by around 496% in 2021, and have surged by over 100% year-to-date as of November 2022. Increasing EV demand and sales are driving prices from the demand side, with the lack of supply tightening the squeeze.

https://mcusercontent.com/72459de8ffe7657f347608c49/files/be87ecb0-46b0-9c31-886a-6202ba5a9b63/Assessment_to_phase_out_fossil_fuels_Summary.pdf

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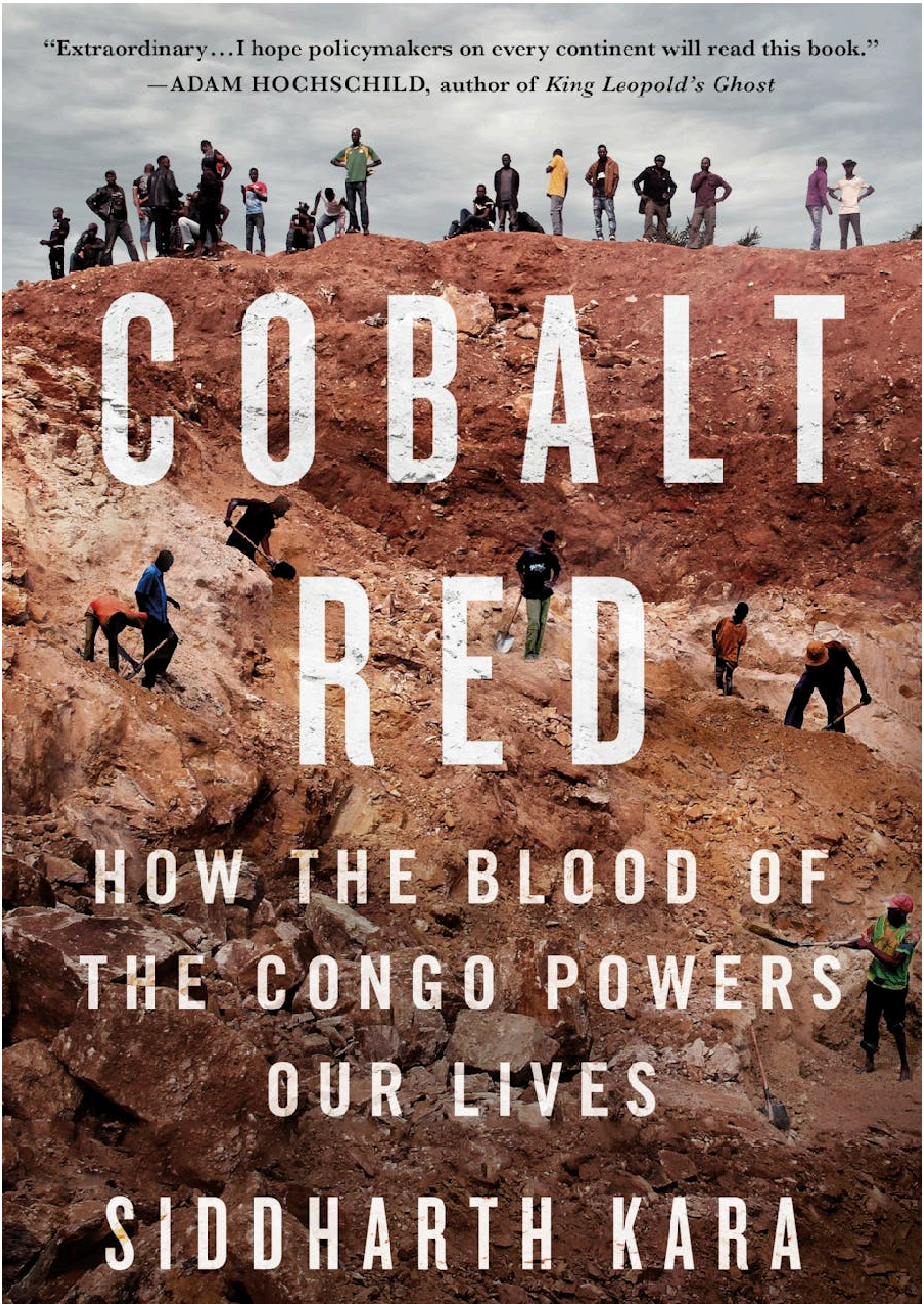
"Extraordinary...I hope policymakers on every continent will read this book."
—ADAM HOCHSCHILD, author of *King Leopold's Ghost*
COBALT RED
HOW THE BLOOD OF THE CONGO POWERS OUR LIVES
SIDDHARTH KARA