
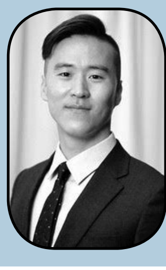

Is Electric Battery Storage Overrated as a Clean Technology?

Thomas N. Russo and Kwangjin "Marcus" Kim

The United States and the world are undergoing an accelerated energy transition with high stakes regarding energy security (i.e., the availability, affordability, accessibility, reliability, and acceptability of energy). Concerns about climate change and greenhouse gas (GHG) emissions are dominating the debate about which energy technologies are politically most acceptable to meet energy needs. Renewable energy, energy efficiency, and electric battery storage technologies appear to be the preferred technologies. However, we believe the notion that renewables and electric storage (batteries) are "clean" has been overstated. This column will shed some light on the following: what "clean energy" means; the environmental impacts of lithium-ion batteries; and what governments and electric vehicle and battery companies must do to reduce carbon dioxide emissions and reduce environmental impacts associated with the lithium-ion electric battery supply chain.

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CLEAN ENERGY—A RELATIVE TERM

Most politicians, academics, environmental groups, and the energy industry tout their favored fuel source or technologies as "clean energy" to some degree. *Webster's Dictionary* defines "clean energy" as energy that is produced through means that do not pollute the atmosphere. Solar, wind, and hydropower obviously qualify as "clean energy" sources. However, most energy technologies produce some degree of environmental impacts on land, water, fish and wildlife, and the atmosphere either during operation or extracting fuels, minerals, and products that are components of the technology. Even energy efficiency has some degree of environmental impact, as foam insulation is derived from petrochemicals that come from natural gas.

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Rather than succumbing to the sirens of "clean energy," we simply acknowledge that every energy technology has environmental impacts and challenges that must be effectively addressed, particularly if you consider such impacts over the technologies'

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life cycle. For example, bird and bat mortality increases with the growth of onshore wind farms. Likewise, the construction of submarine power lines to move power from offshore wind farms to land might cause an adverse impact on marine life during construction. Even closed-loop pumped storage projects, which are gaining public support as sustainable energy storage projects in the Pacific Northwest, may cause some degree of negative environmental impacts to terrestrial resources, although they don't affect free-flowing rivers and lakes.[1] Whether or not an energy technology is acceptable is a more important question for each country and region.

ENVIRONMENTAL IMPACTS OF STORAGE SYSTEMS

The capacity to store energy offers an exciting view of the future, in which efforts to reduce carbon dioxide emissions get a boost with easier integration of renewables into the grid. However, in order for this vision to materialize in a way that minimizes negative externalities, the potential consequences entailed with a growth in electric storage systems must be identified to inform policymakers.

Although 99 percent of the current worldwide electric storage capacity comes from pumped-storage hydropower facilities,[2] the technology best poised for growth is the lithium-ion battery. Prices have plunged 85 percent since 2010,[3] and its demand is forecasted to grow 32 percent annually, increasing from 80 gigawatt hours (GWh) in 2016 to 2,300 GWh in 2030, mainly fueled by the increasing demand for electric vehicles (EVs) (**Figure 1**).[4]

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Growth in battery use for utility-scale storage would mean more integration of renewable energy, and in turn less dependence on fossil-fuel power plants. Growth in electric vehicles (EVs) would mean that cars would no longer need gasoline and diesel fuel. As such, lithium-ion batteries will undoubtedly play a significant role in transitioning away from fossil fuels in transportation. However, they also bring with them a host of environmental challenges that will only

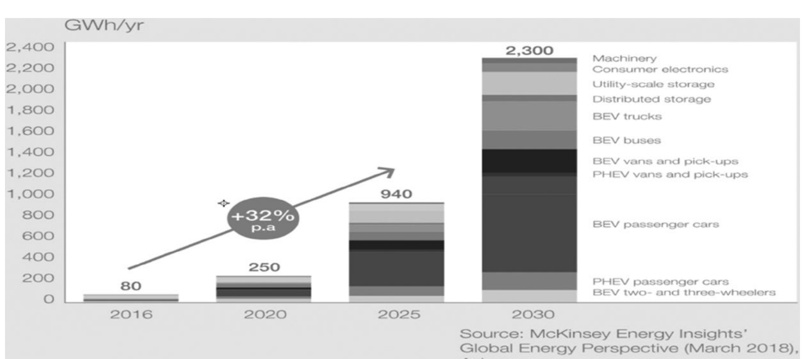
[1] Russo, T. N. (2019). Pumped storage hydro: Reliable choice for the new electric storage era. *Natural Gas & Electricity, 36*(2), 25–32.

[2] Deutsche Energie-Agentur. (n.d.). Pumped-storage integrates renewable energy into the grid. Retrieved from https://www.dena.de/en/topics-projects/energy-systems/flexibility-and-storage/pumped-storage/.

[3] Baker, D. (2019, April 3). Battery reality: There's nothing better than lithium-ion coming soon. Bloomberg. Retrieved from https://www.bloomberg.com/news/articles/2019-04-03/battery-reality-there-s-nothing-better-than-lithium-ion-coming-soon.

[4] Campagnol, N., Eddy, J., Hagenbruch, T., Klip, D., Mulligan, C., & van De Staaij, J. (n.d.). Metal mining constraints on the electric mobility horizon. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/oil-and-gas/our-insights/metal-mining-constraints-on-the-electric-mobility-horizon.

Figure 1. Annual Lithium Battery Growth by End Use



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be amplified with this growth in battery demand. We highlight the environmental challenges related to the three phases of a lithium-ion battery's life cycle: mining and production, deployment and usage, and recycling and disposal.

MINING AND PRODUCTION PHASE

There are multiple natural elements needed to manufacture a lithium-ion battery. Four of the most important elements are lithium, cobalt, nickel, and graphite.[5] These rare earth metals are found largely outside of the United States. If lithium-ion battery growth accelerates, the United States will have to import large quantities of the metals from China, and the Democratic Republic of the Congo. The elements, or metals, exist as raw materials that have to be mined from the ground. From a purely environmental perspective, the act of mining is a naturally dirty process, not to mention the sheer amount of land that needs to be cleared. It is an energy-intensive process carried out by gigantic machinery that generates GHG emissions and pollutes the surrounding air and water. This is further compounded by conflicts with local communities and inadequate working conditions. These challenges are explained in the context of each metal below.

5 Öko-Institut. (2018, March 8). Ensuring a sustainable supply of raw materials for electric vehicles. Agora Verkehrswende. Retrieved from https://www.agora-verkehrswende.de/fileadmin/Projekte/2017/Nachhaltige_Rohstoffversorgung_Elektromobilitaet/Agora_Verkehrswende_Rohstoffestrategien_EN_WEB.pdf.

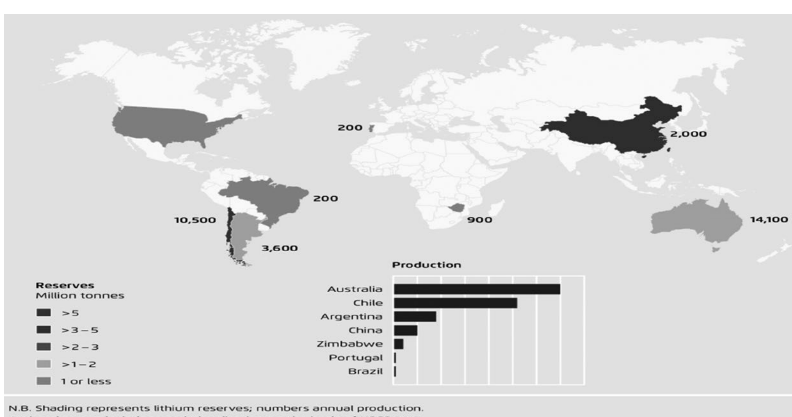
Lithium

Australia and Chile are the two largest producers of lithium, jointly comprising 75 percent of total supply (**Figure 2**). However, miners in these two countries use different methods to extract the lithium from the ground. For example, in Australia, mining for lithium resembles traditional hard rock ore mining, a process that requires significant energy consumption and generates CO_2 emissions and chemical waste such as sulfuric acid, which contaminates the surrounding environment. In Chile, brines containing lithium are pumped from underground reservoirs to evaporation ponds, where they are then left out in the sun to be dried and concentrated. This process requires large volumes of water, and disputes with local communities are common, given that these sites are located in arid deserts where water is scarce. Methods that use less water would lead to less conflict, and are being developed. An additional source of frustration for these affected communities is that stakeholder engagement by mining company representatives and government officials has been very poor. This has led to discontent and a sense that their ancestral lands are being exploited by outsiders, with not much for them to gain from the bargain.[6]

Currently, Argentina and China produce approximately 20 percent of the global supply of

6 Frankel, T., & Whoriskey, P. (2016, December 19). Tossed aside in the 'white gold' rush. *The Washington Post*. Retrieved from https://www.washingtonpost.com/graphics/business/batteries/tossed-aside-in-the-lithium-rush/.

Figure 2. Global Lithium Production by Country



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lithium, and their shares are expected to rise alongside the increasing demand for batteries. As these countries start mining more and more lithium, the environmental and social risks entailed with each method of extraction will continue to follow them. If trade wars between the United States and China continue, the price of lithium prices could increase and/or supplies curtailed.

Cobalt

Approximately two-thirds of the global supply of cobalt comes from the Democratic Republic of the Congo (**Figure 3**),[7] a country characterized by political instability.[8] It is estimated that about a fifth of the cobalt mined in the DRC comes from small-scale (informal) miners, who have no equipment other than very basic tools such as headlights, hammers, and chisels. These risky and unprotected working environments expose these miners to fatal accidents and a range of health hazards linked to metal poisoning, birth defects, and sulfuric acid contamination. Child labor is also associated with the informal mining practices in the DRC.

As political and consumer expectations are increasingly pressuring multinational corporations to uphold certain ethical standards, this is a cause of concern for many businesses with batteries in their supply chains. With the demand of cobalt expected to double by 2025, these issues will likely only continue, raising international concerns about this precious metal.

With the absence of an effective regulatory framework, the responsibility falls on private companies such as LG Chem and Apple to implement internal ethical standards in their supply chain of cobalt. LG Chem announced it stopped sourcing minerals from the DRC in late 2015, and Apple, with interest in cobalt to make batteries for its devices, pledged it will map all of its suppliers to ensure they meet standards set by the Organisation for Economic Co-operation and Development.[9] Electric vehicle manufacturers such as

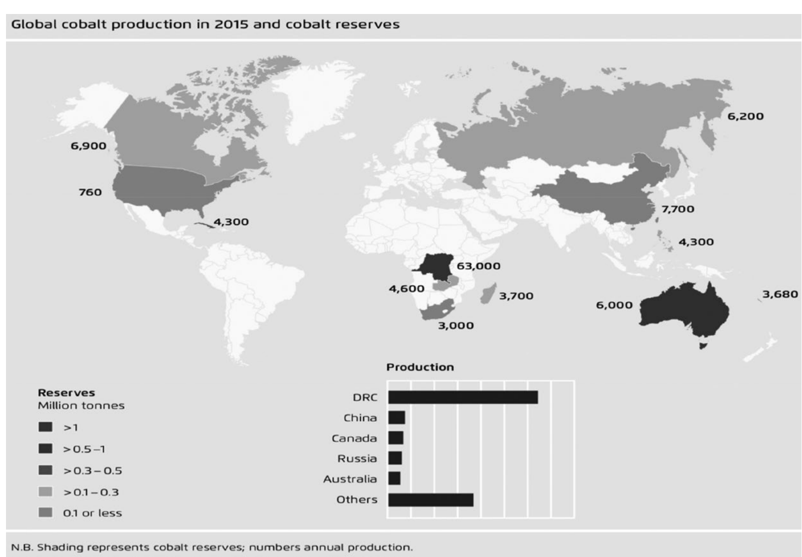
[7] See Note 5.

[8] Frankel, T. (2016, September 30). The cobalt pipeline. *The Washington Post*. Retrieved from https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/.

Frankel, T., & Whoriskey, P. (2016, December 19). Tossed aside in the 'white gold' rush. *The Washington Post*. Retrieved from https://www.washingtonpost.com/graphics/business/batteries/tossed-aside-in-the-lithium-rush/.

[9] Campbell, R., Massie, K., Tivey, J., & Khodabakhsh, S. (2018, June 27). Building a sustainable battery supply chain: Is blockchain the solution? White & Case LLP International Law Firm, Global Law Practice. Retrieved from https://www.whitecase.com/publications/insight/building-sustainable-battery-supply-chain-blockchain-solution.

Figure 3. Global Cobalt Production by Country



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Tesla, Volkswagen, BMW, Mercedes-Benz, and China's BYD and NIO will also be under pressure to follow LG Chem's and Apple's example. Ford and IBM are also experimenting with blockchain technology in order to make the supply chain of cobalt more transparent.[10]

Nickel

In contrast to lithium and cobalt, nickel production is not concentrated in any specific country or region. It is evenly spread across multiple countries, with the Philippines, Russia, Canada, and Australia comprising slightly over half the global share.[11] Nickel mining is associated with acid mine drainage, which will have negative long-term environmental impacts on the surrounding soil and water. Along with CO_2, the mining process also generates sulfur dioxide, which causes acid rain. In Canada and Russia, mining for nickel led to biodiversity losses, heavy metal contamination, and acid rain, followed by health concerns and loss of agricultural land.

Graphite

Although the largest graphite reserves are known to be in Turkey and Brazil, almost two-thirds of global graphite supply comes from China, mainly due to the lower cost of mining in the country. However, this low cost comes at the price of low environmental standards and enforcement. Graphite mines in China have been reported to emit immense amounts of dust that blanket entire towns and villages, leaving citizens with no alternative but to breathe in the pollution. This dust kills trees, affects the water supplies, and can lead to heart and respiratory diseases.[12] Unless the Chinese government decides to improve the enforcement of its environmental regulations, once again, it falls upon private companies to clean up their supply chain.

DEPLOYMENT PHASE

Once the various metals are sourced and manufactured into batteries, they present another set of potential issues that must be examined and addressed. The environmental footprint of a battery depends on the carbon intensity of the electricity being used to manufacture and charge the battery. This means the energy mix of the country or region in consideration plays a significant role in determining how clean the deployed batteries really are. If most of the electricity from a battery comes from coal-fired power generation, the batteries have simply shifted the time of carbon emissions from the time the batteries are actually used. Hence, using the battery has not necessarily reduced the amount of carbon emissions. However, if the grid operates mainly on renewable energy, not only will the batteries be contributing to the integration of renewable power generation plants, they will also be storing electricity generated from carbon-free sources. This connection between battery deployment and energy mix on the grid will be further clarified in the context of EVs.

EV LITHIUM-ION BATTERIES: PRODUCTION MAY CONTRIBUTE MORE CARBON EMISSIONS

Concerning EVs, unless renewable energy generation was being used, during production of the batteries alone would have contributed approximately 75 percent more carbon emissions than building traditional gasoline-fueled cars.[13] Using Germany as an example, where 40 percent of the energy generation mix consists of coal, it would take 10 years for the EV to break even with a gasoline-fueled vehicle's emissions (**Figure 4**). Naturally, in countries with a cleaner energy generation mix, such as Norway, which has hydropower, or France, which relies heavily on nuclear power, this break-even time will become shorter,

[10] Lewis, B. (2019, January 16). Ford and IBM among quartet in Congo cobalt blockchain project. Reuters. Retrieved from https://www.reuters.com/article/us-blockchain-congo-cobalt-electric/ford-and-ibm-among-quartet-in-congo-cobalt-blockchain-project-idUSKCN1PA0C8.

[11] Öko-Institut. (2018, March 8). Ensuring a sustainable supply of raw materials for electric vehicles. Agora Verkehrswende. Retrieved from https://www.agora-verkehrswende.de/fileadmin/Projekte/2017/Nachhaltige_Rohstoffversorgung_Elektromobilitaet/Agora_Verkehrswende_Rohstoffestrategien_EN_WEB.pdf; pp. 44, 45.

[12] Whoriskey, P. (2016, October 2). In your phone, in their air. *The Washington Post*. Retrieved from https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/.

[13] Rolander, N., Starn, J., & Behrmann, E. (2018, October 15). The dirt on clean electric cars. Bloomberg. Retrieved from https://www.bloomberg.com/news/articles/2018-10-16/the-dirt-on-clean-electric-cars.

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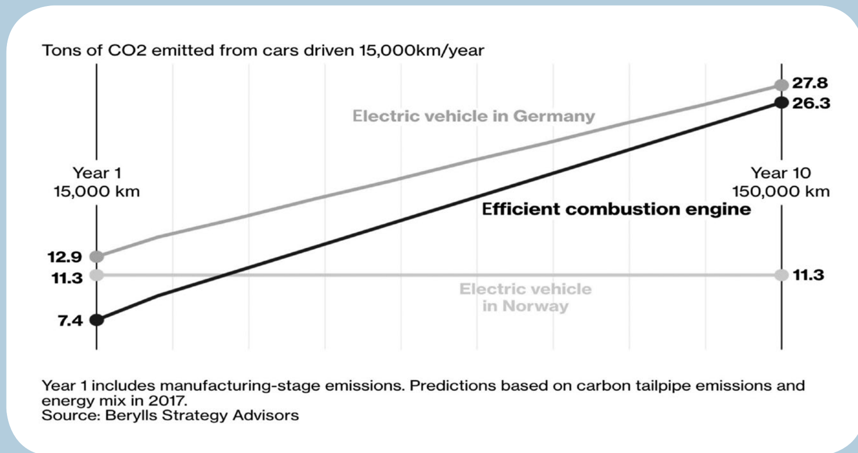
Figure 4. Tons of CO2 Emitted With Electric Vehicles Using Batteries Manufactured With Fossil Fuel Versus Renewable Energy



and the lifetime carbon emissions would be much lower than traditional gasoline-fueled vehicles.

Thus, in order to deploy batteries as tools to reduce carbon emissions, policies must be put in place to incentivize the use of renewable energy generation over fossil fuels for charging, and to allow easier entry for batteries in wholesale energy markets.[14] A growing theme in this area is to pair solar and wind farms with storage, allowing the batteries to be charged when there is excess generation.[15]

As costs for renewable technologies drop and coal generation is phased out, natural gas plants are being forced to become more flexible to accommodate grid variability. Storage can play an important role here as well, optimizing the efficiency of the power plant by allowing it to operate for longer hours at a steady pace. This will allow the power plant to quickly ramp up and down without compromising reliability, in turn reducing carbon emissions. There are already two natural gas power plants in Southern California operating under this hybrid model paired with storage.[16] These hybrid plants operate very effectively and provide the added benefit of being able to operate as a stand-alone storage system without burning any natural gas if desired.

In the deployment phase of the battery, another way to reduce the potential negative impacts is to extend its life. When the capacity of electric vehicle batteries drops to about 70–80 percent, they are no longer strong enough to power cars and are replaced,[17] though they are still able to perform functions carried out by stationary batteries. So companies like Nissan and Bosch are implementing programs to collect and repurpose these EV batteries for residential use.[18] The market for second-use batteries is expected to grow.

DISPOSAL PHASE

When lithium-ion batteries are completely used up, they pose yet another difficulty. The metals contained in the batteries can leach out into the environment and into the surrounding soil and water supply. Nickel and cadmium are known carcinogens,[19] and lithium-ion batteries

[14] See Note 1.

[15] Mai, H. J. (2019, April 1). Solar storage projects to drive utility-scale deployment of batteries: Navigant. *Utility Dive*. Retrieved from https://www.utilitydive.com/news/solar-storage-projects-to-drive-utility-scale-deployment-of-batteries-na/551724/.

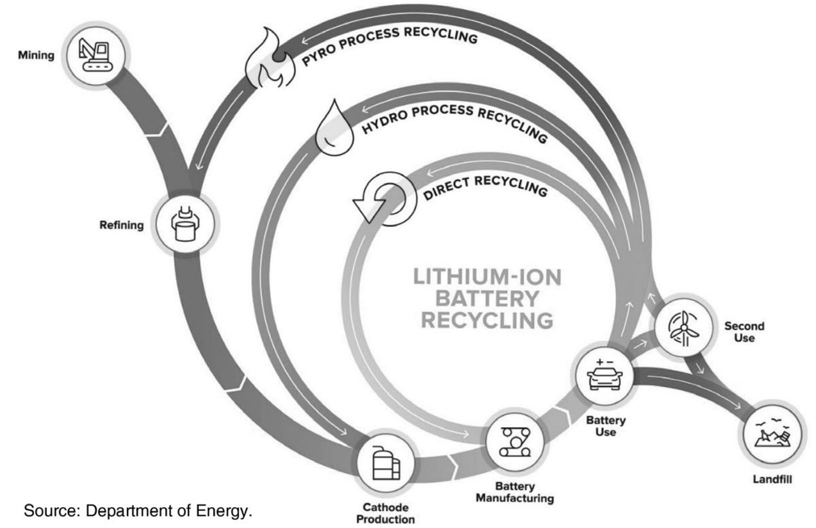
[16] Lin, J. (2018, October 25). Optimizing natural gas generation with energy storage. *Utility Dive*. Retrieved from https://www.utilitydive.com/spons/optimizing-natural-gas-generation-with-energy-storage/540401/.

[17] Eckart, J. (2017, November 28). Batteries can be part of the fight against climate change—if we do these five things. World Economic Forum. Retrieved from https://www.weforum.org/agenda/2017/11/battery-batteries-electric-cars-carbon-sustainable-power-energy/.

[18] Gordon, J. (2018, June 18). The potential of EV batteries in a closed supply chain. FleetCarma. Retrieved from https://www.fleetcarma.com/potential-ev-batteries-closed-supply-chain/.

[19] Kattenburg, K. (2019, May 7). What do batteries do to the environment if not properly recycled? Sciencing. Retrieved from https://sciencing.com/what-do-batteries-do-to-the-environment-if-not-properly-recycled-12730824.html.

Figure 5. Lithium-Ion Battery Recycling



Source: Department of Energy.

run the risk of exploding or starting fires in landfills.[20] Despite these risks, only 5 percent of lithium-ion batteries are recycled in the European Union,[21] mostly due to high investment costs. In fact, Morgan Stanley forecasts there will be no recycling of lithium in the coming decade due to lack of investments and infrastructure.[22]

With an expected boom in battery demand and production, attention must be drawn to this final stage of a battery's life cycle to minimize the potential environmental harm. In line with this concern, in February 2019, the Department of Energy launched its first lithium-ion battery recycling R&D center, called ReCell (**Figure 5**).[23]

[20] Weise, E. (2018, May 20). Cell phones thrown in the trash are exploding, causing 5-alarm fires in garbage trucks. *USA Today*. Retrieved from https://www.usatoday.com/story/tech/talking-tech/2018/05/18/cell-phones-lithium-ion-batteries-exploding-causing-trash-fires/619897002/.

[21] Gardiner, J. (2017, August 10). The rise of electric cars could leave us with a big battery waste problem. *The Guardian*. Retrieved from https://www.theguardian.com/sustainable-business/2017/aug/10/electric-cars-big-battery-waste-problem-lithium-recycling.

[22] Ibid.

[23] Kunz, T. (2019, February 15). DOE launches its first lithium-ion battery recycling R&D center: ReCell. Argonne National Laboratory. Retrieved from https://www.anl.gov/article/doe-launches-its-first-lithiumion-battery-recycling-rd-center-recell.

If lithium-ion batteries are to play a role in integrating renewables into the electric grid and driving the growth of EVs, more initiatives like this must be taken by government agencies and manufacturers of lithium-ion batteries and auto makers around the world to ensure a sustainable and circular supply chain.

CONCLUSION

Lithium-ion batteries have a promising future in the electric power and transportation sector. However, governments, mining companies, and battery and EV manufacturers face challenges in reducing the environmental effects of mining lithium, cobalt, nickel, and graphite. To really lower CO_2 emissions and live up to environmental claims that EVs are truly a "green" technology, leading battery and EV manufacturers like Tesla and Volkswagen must show to the public that their lithium-ion batteries are manufactured and electrically charged with renewable or nuclear energy. To do otherwise would mean that EVs would emit CO_2 emissions comparable to internal combustion engine vehicles. Finally, governments and the private sector must invest in lithium-ion battery repurposing and disposal programs to avoid lithium, cobalt, nickel, and graphite contamination of land and water.

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