



Environmental protection 80 kWh

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Lithium-ion batteries are a popular power source for clean technologies like electric vehicles, due to the amount of energy they can store in a small space, charging capabilities, and ability to remain effective after hundreds, or even thousands, of charge cycles. These batteries are a crucial part of current efforts to replace gas-powered cars that emit CO₂ and other greenhouse gases. These same capabilities also make these batteries good candidates for energy storage for the electric grid. However, that does come with a cost, as the manufacturing process of the batteries and their components emits CO₂, among other environmental and social concerns.

Producing lithium-ion batteries for electric vehicles is more material-intensive than producing traditional combustion engines, and the demand for battery materials is rising, explains Yang Shao-Horn, JR East Professor of Engineering in the MIT Departments of Mechanical Engineering and Materials Science and Engineering. Currently, most lithium is extracted from hard rock mines or underground brine reservoirs, and much of the energy used to extract and process it comes from CO₂-emitting fossil fuels. Particularly in hard rock mining, for every tonne of mined lithium, 15 tonnes of CO₂ are emitted into the air.

Battery materials come with other costs, too. Mining raw materials like lithium, cobalt, and nickel is labor-intensive, requires chemicals and enormous amounts of water--frequently from areas where water is scarce--and can leave contaminants and toxic waste behind. 60% of the world's cobalt comes from the Democratic Republic of the Congo, where questions about human rights violations such as child labor continue to arise.

Manufacturing also adds to these batteries' eco-footprint, Shao-Horn says. To synthesize the materials needed for production, heat between 800 to 1,000 degrees Celsius is needed--a temperature that can only cost-effectively be reached by burning fossil fuels, which again adds to CO₂ emissions.

Exactly how much CO₂ is emitted in the long process of making a battery can vary a lot depending on which materials are used, how they're sourced, and what energy sources are used in manufacturing. The vast majority of lithium-ion batteries--about 77% of the world's supply--are manufactured in China, where coal is the primary energy source. (Coal emits roughly twice the amount of greenhouse gases as natural gas, another fossil fuel that can be used in high-heat manufacturing.)

For illustration, the Tesla Model 3 holds an 80 kWh lithium-ion battery. CO₂ emissions for manufacturing that battery would range between 2400 kg (almost two and a half metric tons) and 16,000 kg (16 metric tons).¹ Just how much is one ton of CO₂? As much as a typical gas-powered car emits in about 2,500 miles of driving--just about the same weight as a great white shark!

Researchers across the globe are trying to design new manufacturing processes or new battery chemistries that



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can work with more readily available, environmentally-friendly materials, but these technologies aren't yet available on a wide scale. "If we don't change how we make materials, how we make chemicals, how we manufacture, everything will essentially stay the same," Shao-Horn says.

Despite the environmental footprint of manufacturing lithium-ion batteries, this technology is much more climate-friendly than the alternatives, Shao-Horn says.

In the United States, the electric grid (which is a mix of fossil fuels and low-carbon energy such as wind, solar, hydropower and nuclear power) is cleaner than burning gasoline, and so driving an electric car releases less CO₂ than driving a gas-powered car. "An electric vehicle running on [electricity generated with] coal has the fuel economy equivalent in the order of about 50 to 60 miles per gallon equivalent," says David Keith, a professor at the MIT Sloan School of Management who studies the emergence of new technologies in the automotive industry. "So the dirtiest electric vehicle looks something like our best gasoline vehicles that are available today."

And an electric vehicle running on electricity generated by hydropower, solar, wind or other low-carbon energy sources can be significantly cleaner. "In New England or the Pacific Northwest, the fuel economy equivalent of an EV is into the hundreds: 110-120 miles per gallon equivalent," says Keith.

When you add this up over hundreds of miles, even though the U.S. electric grid isn't currently carbon-free and even when accounting for the initial emissions associated with manufacturing the battery, electric cars still emit less CO₂ than gas-powered cars.² This is a key feature, given that, within the United States, the transportation sector produces the largest share of greenhouse gas emissions--nearly one-third of the country's total emissions.³

A second major environmental benefit these batteries could offer is energy grid stabilization, Shao-Horn adds. As the world moves towards renewable energy resources, like solar and wind power, demand grows for ways of storing and saving this energy. Using batteries to store solar and wind power when it's plentiful can help solve one big problem of renewable energy--balancing oversupply and shortage when the weather isn't ideal--making it much easier to switch from CO₂-emitting fossil fuels.

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