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Environmental footprint of electric cars

The Wuling Hongguang Mini is the top selling EV[1]

Electric cars (or electric vehicles, EVs) have a smaller environmental footprint than conventional internal combustion engine vehicles (ICEVs). While aspects of their production can induce similar, less or alternative environmental impacts, they produce little or no tailpipe emissions, and reduce dependence on petroleum and greenhouse gas emissions, and health effects from air pollution.[2][3][4][5] Electric motors are significantly more efficient than internal combustion engines and thus, even accounting for typical power plan efficiencies and distribution losses,[6] less energy is required to operate an EV. Manufacturing batteries for electric cars requires additional resources and energy, so they may have a larger environmental footprint from the production phase.[7][8] EVs also generate different impacts in their operation and maintenance. EVs are typically heavier and could produce more tire, brake, and road dust air pollution, but their regenerative braking could reduce such particulate pollution from brakes.[9] EVs are mechanically simpler, which reduces the use and disposal of engine oil.

Contents

Advantages and disadvantages compared to fossil-fueled cars

Battery electric cars have several environmental benefits over conventional internal combustion engine vehicles (ICEVs), such as:

- Elimination of harmful tailpipe pollutants such as various oxides of nitrogen, which kill thousands of people every year[10]
- EVs use 38 megajoules per 100 km in comparison to 142 megajoules per 100 km for ICE cars.[11]
- Less CO_2 emissions globally than fossil-fuelled cars, thus limiting climate change[12]

Plug-in hybrids capture most of these benefits when they are operating in all-electric mode.

Electric cars have some disadvantages, such as:

- Possible increased particulate matter emissions from tires. This is sometimes caused by the fact that most electric cars have a heavy battery, which means the car's tires are subjected to more wear. The brake pads, however, can be used less frequently than in non-electric cars, if regenerative braking is available and may thus sometimes produce less particulate pollution than brakes in non-electric cars.[13][14] Also, some electric cars may have a combination of drum brakes and disc brakes, and drum brakes are known to cause less particulate emissions than disc brakes.
- Pollution emitted in manufacturing, especially the increased amounts from producing batteries.
- Reliance on rare-earth elements such as neodymium, lanthanum, terbium, and dysprosium, and other critical metals such as lithium and cobalt,[15][16] though the quantity of rare metals used differs per car. Though rare earth metals are plentiful in the earth's crust, only a few miners hold exclusivity to access those elements.[17]

Materials Extraction Impact

Raw material availability and supply security

Common technology for plug-in hybrids and electric cars is based on the lithium-ion battery and an electric motor which uses rare-earth elements. The demand for lithium and other specific elements (such as neodymium, boron and cobalt) required for the batteries and powertrain is expected to grow significantly due to the future sales increase of plug-in electric vehicles in the mid and long term.[18][19] While only 7 g (0.25 oz) of lithium carbonate equivalent (LCE) are required in a smartphone and 30 g (1.1 oz) in a tablet computer, electric vehicles and stationary energy storage systems for homes, businesses or industry use much more lithium in their batteries. As of 2016 a hybrid electric passenger car might use 5 kg (11 lb) of LCE, while one of Tesla's high performance electric cars could use as much as 80 kg (180 lb).[20]

Lithium

The main deposits of lithium are found in China and throughout the Andes mountain chain in South America. In 2008 Chile was the leading lithium metal producer with almost 30%, followed by China, Argentina, and Australia.[19][23] Lithium recovered from brine, such as in Nevada[24][25] and Cornwall, is much more environmentally friendly.[26]

The Salar de Uyuni in Bolivia is one of the largest known lithium reserves in the world.[21][22]

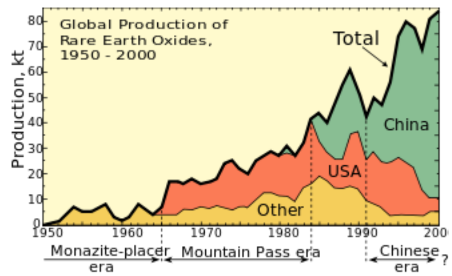
Nearly half the world's known reserves are located in Bolivia,[19][21] and according to the US Geological Survey, Bolivia's Salar de Uyuni desert has 5.4 million tons of lithium.[21][24] Other important reserves are located in Chile, China, and Brazil.[19][24]

According to a 2020 study balancing lithium supply and demand for the rest of the century needs good recycling systems, vehicle-to-grid integration, and lower lithium intensity of transportation.[27]

Cobalt

Rare-earth elements neodymium and praseodymium

Most EVs use permanent magnet motors as they have better performance than induction motors, which don't use rare-earth elements.[28] These neodymium magnets use neodymium and praseodymium. Although not actually rare these elements can be dirty and difficult to produce.[28][29]



Evolution of global rare-earth oxides production by country (1950–2000)

China has 48% of the world's reserves of rare-earth elements, the United States has 13%, and Russia, Australia, and Canada have significant deposits. Until the 1980s, the U.S. led the world in rare-earth production, but since the mid-1990s China has controlled the world market for these elements. The mines in Bayan Obo near Baotou, Inner Mongolia, are currently the largest source of rare-earth metals and are 80% of China's production.[30]

Impacts due to Manufacturing

Electric cars also have impacts arising from the manufacturing of the vehicle.[31][32] Since battery packs are heavy, manufacturers work to lighten the rest of the vehicle. As a result, electric car components contain many lightweight materials that require a lot of energy to produce and process, such as aluminium and carbon-fiber-reinforced polymers. There are two kinds of motors used by electric cars: permanent magnet motors (like the one found in the Tesla Model 3), and induction motors (like the one found on the Tesla Model S). Induction motors do not use magnets, but permanent magnet motors do. The magnets found in permanent magnet motors used in electric vehicles contain rare-earth metals which are used to increase the power output of these motors. The mining and processing of metals such as lithium, copper, and nickel requires much energy and it can release toxic compounds. In developing countries with weak legislation and/or enforcement thereof, mineral exploitation can increase risks further. As such, the local population may be exposed to toxic substances through air and groundwater contamination. New battery technologies may be needed to resolve those problems.

Several reports have found that hybrid electric vehicles, plug-in hybrids and all-electric cars generate more carbon emissions during their production than current conventional vehicles but still have a lower overall carbon footprint over the full life cycle. The initial higher carbon footprint is due mainly to battery production,[33] but as of 2021 more research is needed to reduce this, as there is a lot of uncertainty in supply chains.[34]

Consumer Use Impacts

Air pollution and carbon emissions in various countries

Electric cars have several benefits over conventional internal combust engine automobiles, reduction of local air pollution, especially in cities, as they do not emit harmful tailpipe pollutants such as particulates (soot), volatile organic compounds, hydrocarbons, carbon monoxide, ozone, lead, and various oxides of nitrogen.[35][36][37] Depending on the source of the electricity used to recharge the batteries, there may be some pollution from the generation plants.[38] This is referred to as the long tailpipe of electric vehicles. However it is far less than fossil fuelled cars because power plant emissions are far less per unit of power than internal combustion engines.[39] The amount of carbon dioxide emitted depends on the emission intensity of the power sources used to charge the vehicle, the efficiency of the said vehicle and the energy wasted in the charging process. For mains electricity the emission intensity varies significantly per country and within a particular country, and on the demand, the availability of renewable sources and the efficiency of the fossil fuel-based generation used at a given time.[40][33][41]

Charging a vehicle using renewable energy (e.g., wind power or solar panels) yields a very low carbon footprint-only that to produce and install the generation system (see Energy Returned On Energy Invested.) Even on a fossil-fueled grid, it's quite feasible for a household with solar panels to produce enough energy to account for their electric car usage, thus (on average) canceling out the emissions of charging the vehicle, whether or not the panel directly charges it.[42] Even when using exclusively grid electricity, replacing ICE cars with EVs comes with major environmental benefits.[43]

United Kingdom

Sales of purely fossil-fuelled cars will end in 2030 and hybrids in 2035, although existing ones will be allowed to remain on some public roads depending on local rules.[44] One estimate in 2020 said that if all fossil-fuelled cars were replaced UK greenhouse gas emissions would fall by 12%.[45] But because UK consumers can select their energy suppliers, the amount of the drop depends on how 'green' their chosen supplier is in providing energy into the grid.

Two-thirds of road transport (not just automobiles) particulate matter contamination arise from tire, brake, and road dust, the UK government disclosed in July 2019 and particulate matter pollution was forecast to continue to increase even with electric cars.[9]

United States

In 2016, the transportation sector overtook the electric power sector as the number one source of annual greenhouse gas emissions in the United States.[46] Increasing the EV share of the vehicle fleet and cleaning up the power sector are key steps in reducing both the transportation and power sector emissions. According to a 2021 Union of Concerned Scientists study 97% of people live in places where driving on electricity is cleaner than a 50 MPG gasoline car.[47]

Germany

Some months in 2019 have seen more than 50% of all generation from renewable sources and is expected to rise further as coal generation is first used only for standby and slowly phased out.[48]

France

In France, which has many nuclear power plants, CO_2 emissions from electric car use would be about 24 g/km (38.6 g/mi).[49] Because of the stable nuclear production, the timing of charging electric cars has almost no impact on their environmental footprint.[33]

Norway & Sweden

Since Norway and Sweden produce almost its entire electricity with carbon-free sources, CO_2 emissions from driving an electric car are even lower, at about 2 g/km (3.2 g/mi) in Norway and 10 g/km (16.1 g/mi) in Sweden.[49]

Particulates

Like all cars, electric cars give off particulate matter (PM) from road tyre and brake wear, and this contributes to respiratory disease.[50] In the UK alone non-tailpipe PM (from all types of vehicle not just electric) may be responsible for between 7,000 and 8,000 premature deaths a year.[50]

However, lower fueling, operation, and maintenance costs of EVs could induce the rebound effect, thereby releasing more particulates than would be otherwise avoided. In other words, cheaper driving costs serve to encourage more driving, thereby engendering more tire wear. (Other costs, such as congestion and the resulting incentive to pave more land in order to expand the road network, also arise.)

Electricity generation for electric cars

A solar energy charging station in North America

One considerable advantage that EVs present compared to conventional vehicles is that they can potentially reach zero lifecycle emissions. However, since the electricity currently used to charge electric vehicles across the world does not come from 100% carbon-free sources, today's EVs still contribute to global greenhouse gas (GHG) emissions. Electric cars emit less greenhouse gas over their lifetime than fossil fuel cars.[51][52] The difference in emissions between EVs and ICEVs depends on the distance driven as well as the source of the electricity, because ICEVS typically have a cleaner production stage and electric vehicles typically have a cleaner operational (driving) stage.[53]

Cleaning up the electric grid by shifting generation from fossil fuel plants to renewable and low-carbon power sources will also make EVs cleaner. This is important since most countries' electricity is generated, at least in part, by burning fossil fuels.[54] The emissions of electrical grids are improving over time as more low-carbon generation and grid-scale energy storage are deployed.[55] Thus EVs become cleaner over time.[56][57] Smart meters and time of use electricity pricing encourage motorists to charge at times when electricity generation is cleaner.[58][59]

Many, but not most or all countries are introducing CO_2 average emissions targets across all cars sold by a manufacturer, with financial penalties on manufacturers that fail to meet these targets. Additionally, some governments are introducing Zero Emissions Vehicle (ZEV) mandates, requiring that a certain percentage of new vehicle sales each year be electric or hydrogen fuel cell vehicles. These policies have created an incentive for manufacturers, especially those selling many heavy or high-performance cars, to introduce electric cars as a means of reducing average fleet CO_2 emissions.[60]

Lower operational impacts and maintenance needs

Battery electric vehicles have lower maintenance costs compared to internal combustion vehicles since electronic systems break down much less often than the mechanical systems in conventional vehicles, and the fewer mechanical systems onboard last longer due to the better use of the electric engine. Electric cars do not require oil changes and other routine maintenance checks.[61][38]

Internal combustion engines are relatively inefficient at converting on-board fuel energy to propulsion as most of the energy is wasted as heat, and the rest while the engine is idling. Electric motors, on the other hand, are more efficient at converting stored energy into driving a vehicle. Electric drive vehicles do not consume energy while at rest or coasting, and modern plug-in cars can capture and reuse as much as one fifth of the energy normally lost during braking through regenerative braking.[61][38] Typically, conventional gasoline engines effectively use only 15% of the fuel energy content to move the vehicle or to power accessories, and diesel engines can reach on-board efficiencies of 20%, while electric drive vehicles typically have on-board efficiencies of around 80%.[61]

Battery reuse and recycling

Like ICE cars, as of 2021, many electric cars also contain lead–acid batteries. In some countries lead acid batteries are not recycled safely.[62][63] Lithium-ion batteries from cars can sometimes be re-used in factories[64] or as stationary batteries.[65] When lithium-ion batteries are recycled, if they are not handled properly, the harmful substances inside will cause secondary pollution to the environment.[66]

See also

- Battery fade
- Full cost accounting
- NEV's and electric velomobiles: low-weight battery electric vehicles[67]
- Converting existing vehicle to electric (see environmental impact of manufacturing)
- Solar car: car powered by an electric motor, fed by a PV-panel; this does not have some of the disadvantages noted in this article
- Fuel cell car: car powered by an electric motor, fed by a fuel cell; this may not have some of the disadvantages noted in this article (if not foreseen with an additional battery)
- Induction motor: does not have permanent (rare-earth) magnets[68]
- Modal shift
- Phase-out of fossil fuel vehicles
- Plug-in hybrid electric car: is a hybrid electric vehicle whose battery can be recharged by plugging it into an external source of electric power, as well by its on-board engine and generator. While running in all-electric mode (EV mode), the plug-in hybrid operation is similar to an all-electric vehicle.
- Vehicles powered by advanced biofuels: carbon-neutral vehicles[69]
- Robotic disassembly of electric car batteries
- Downcycling of end-of-life e-automotive batteries

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