Environmental Impacts of Extraction, Processing, Use, and Disposal of Key Components in Gasoline, Electric, and Hybrid Vehicles

Elizabeth St. Hilaire

How do the environmental impacts of extraction, processing, use, and disposal of key components compare between gasoline, electric, and hybrid vehicles?

Abstract:

Recent emphasis on electric vehicles because of societal and governmental pressure to mitigate climate change has sparked debate when determining which type of vehicle is better for the environment. This review compares gasoline, electric, and hybrid vehicles to evaluate associated environmental and ethical concerns. While gasoline vehicles are still the most readily accessible, their emission of greenhouse gasses is detrimental to the environment. When used correctly, hybrid and electric vehicles are much less damaging in an environmental context; however, ethically sourcing materials like cobalt and lithium for the batteries in these vehicles has proven to be a challenge. To evaluate the environmental and ethical considerations, each car's life cycle is broken into the extraction of materials, production of critical parts, use, and recycling or disposal options available. Each phase of gasoline, electric, and hybrid vehicles' life cycle is examined for emission levels, efficiency, and ethics.

Keywords:

Electric vehicle, hybrid vehicle, gasoline vehicle, transportation emissions, lithium-ion batteries

1: Introduction

While gasoline-powered vehicles still make up roughly 82% of the vehicles on the road in the United States, sales have decreased by 20% since 2012. In 2023, electric and hybrid vehicles made up 16% of new car sales in the U.S. compared to just 3% in 2014 ("U.S. share of electric and hybrid vehicle sales decreased in the first quarter of 2024 - U.S. Energy Information Administration (EIA)," n.d.). This drastic uptick in hybrid and electric sales is in part due to a societal shift towards environmentally friendly practices, but governments are looking to increase motivation for clean energy in transit; as countries around the world work towards climate neutrality, new policies limiting gasoline-powered vehicles have become a priority for many nations. The European Union's "Green Deal" has banned all production of gasoline cars by 2030, with a total hybrid production ban set for 2035 ("What the European Green Deal Means for the UK | Chatham House – International Affairs Think Tank," 2020). As of 2024, eleven U.S. states have implemented a gas car ban for 2035, with dozens more likely to follow ("GASOLINE VEHICLE PHASEOUT ADVANCES AROUND THE WORLD - Coltura," 2023). With all of these regulations set, there must be a reason for such drastic measures: pollution.

In North America, the largest source of fine particulate matter—harmful particles that are easily inhaled because of their small size—is transportation, accounting for roughly 15% of air pollutants ("Air Pollution Note – Data you need to know," 2021). These compounds pose several health concerns and contribute to the depletion of the ozone layer, causing poor air quality in surrounding areas. These consequences have led to a global initiative to stop harmful practices from inhibiting quality of life.

With production bans set in more than twenty-five countries worldwide and electric vehicle sales increasing at an alarming rate, companies and consumers alike wonder: are electric vehicles actually better for the environment? This paper compares the environmental impacts of gasoline, hybrid, and electric vehicles in their current iterations. To evaluate these environmental impacts, the key components in each car type are examined at each step in a vehicle's life cycle: extraction of materials, processing of key components, everyday use, and disposal or recycling potential. Each stage is assessed for energy use, efficiency, harmful emissions, and ethical concerns.

2: Gasoline

The most significant contributor to global emissions in gasoline vehicles is the primary source that powers them: gasoline. These vehicles have both a battery and a combustion chamber; the battery provides the electricity needed to start the engine and run electronic features, while the combustion chamber ignites the fuel– a gasoline and oxygen mixture– to reconfigure the energy that sustains the engine ("Alternative Fuels Data Center," n.d.). Harmful emissions from this process begin before fuel hits the combustion chamber; the creation of gasoline is a multi-step process that generates many opportunities for harmful emissions to escape into the atmosphere.

2.1: Extraction

The main component of gasoline, crude oil, is drilled predominantly in the United States, Saudi Arabia, Russia, Canada, and Iraq, as well as other areas in the Middle East ("Where our oil comes from - U.S. Energy Information Administration (EIA)," n.d.). The process of drilling for crude oil releases volatile organic compounds (VOCs)– damaging particles that can be vaporized at standard temperature and pressure, allowing for easy distribution– into the atmosphere. After a pipe has been inserted into a drilling site, high-pressure water or acid is pumped into the ground, pushing the oil to a tank above. This step allows hydrocarbons, a type of VOC, to escape from underground ("Offshore oil and natural gas in depth - U.S. Energy Information Administration (EIA)," n.d.). VOCs are small and easily inhaled by humans and animals alike, causing a host of health issues, including damage to the central nervous system, liver, and kidneys; some VOCs are also proven carcinogens ("Volatile organic compounds (VOCs) | Minnesota Pollution Control Agency," n.d.). Because of this, the extraction of materials needed for gasoline disproportionately affects developing areas where oil drilling is concentrated. The dangerous practice is kept to remote regions generally inhabited by at-risk families in underdeveloped areas. Hydrocarbons spread in the atmosphere, causing individuals closest to the site to suffer the most health consequences from air pollution. There is also a risk of water contamination; drills can puncture water sources underground, or holes could be left improperly sealed, resulting in even more air and water pollution concentrated in these areas ("7 ways oil and gas drilling is bad for the environment | The Wilderness Society," n.d.).

2.2: Production

(DeLuchi) After crude oil is extracted, it needs to be processed into workable compounds for gasoline production. Raw oil is treated to remove any dissolved gasses and water incorporated into the drilled mixture. Isolated oil is then stored in small containers that are emptied and filled frequently at high temperatures. This combination of circumstances results in a high volume of VOCs released into the atmosphere due to high amounts of evaporation. Oil is then transferred to large transport containers for processing at a different site. Depending on the amount of space left between the oil and the lid of the container, evaporation and spills continue to add to the total VOCs emitted from the extraction process of gasoline (DeLuchi).

(DeLuchi) Once oil has been transported to a processing site, it is poured into refinery boilers, where it is turned into gasoline. These large boilers burn substantial amounts of natural and refinery gas to create enough heat for combustion. They produce large quantities of nitrogen oxides– fine gaseous particles that cause respiratory issues, warmer climate, and acid rain– sulfur oxides– inhibit plant growth, damage ecosystems, and pollute water sources– and particulate matter–impede plant growth and production of nutrients. (DeLuchi).

(DeLuchi) As soon as new gasoline is ready for distribution, it is put into a series of containers and transport vehicles until it is eventually stored underground, ready to refuel vehicles. This series of gasoline storage and transport until ultimate combustion inside a vehicle invites many opportunities for gasoline evaporation, leaks, and fires. Gasoline is also highly flammable, making transit vehicles and extensive storage facilities vulnerable to fires contributing to human health side effects as well as large-scale air pollution magnified by smoke’s ability to carry VOCs longer distances. Gasoline spills and leaks, while less common, can also induce unwanted evaporation and spread of VOCs into the atmosphere, sometimes leaking into underground storage systems and contaminating soil or nearby water sources (DeLuchi).

2.3: Use

The combustion chamber is the primary power source in a gasoline vehicle where most harmful particles are emitted while in use. The combustion process effectively takes thermal energy generated from the fuel mixture and converts it to mechanical energy. Inside these internal combustion chambers, gasoline and oxygen are combined and then compressed. A spark then ignites the mixture, causing combustion to occur (“Internal Combustion Engine Basics,” n.d.). Exhaust– a mixture of carbon dioxide, water vapor, and other byproducts of the combustion process– is then released through exhaust pipes, and the cycle repeats itself with new fuel and oxygen (Humans, 1989). Carbon dioxide does not threaten human health but contributes to climate change by staying in the atmosphere and heating the Earth’s surface. However, incomplete combustion occurs regularly when oxygen levels do not meet the required thresholds, especially under low temperatures or high altitudes (“Incomplete Combustion - an overview | ScienceDirect Topics,” n.d.; “MIT School of Engineering | » Which engine is better at high altitude,” n.d.). This process releases carbon monoxide, unburned hydrocarbons, soot, nitrogen oxides, and polycyclic aromatic hydrocarbons (Überall et al.; x-engineer.org, n.d.). These particles can be extremely harmful and even toxic to humans and the environment (Udoka et al.).

In Canada, internal combustion chambers account for 42% of atmospheric nitrogen oxides (Canada's Air Pollutant Emissions; US EPA, 2015). In an average year, a typical passenger is responsible for releasing 4.6 metric tons (4,600 kg) of carbon dioxide into the atmosphere, and transportation causes 28% of greenhouse gas emissions in the U.S. annually (Carbon Pollution from Transportation). While extraction and processing release small amounts of VOCs into the atmosphere, the continuous nature of internal combustion chambers during use releases excessive amounts of harmful particles.

2.4: Disposal

The disposal of gasoline-powered vehicles is mainly carried out via recycling and energy recovery. Each recycling method has its own side effects on the environment, and the disposal process is frequently subject to governmental intervention due to several logistical and ethical issues to consider.

The first and most easily recycled component is the vehicle's structure. This structure includes the steel framing, metal pieces, and tires. Each metal piece is cleaned, and fluids are drained. They are then melted or shredded into separate groups and distributed to steel mills for reuse (Gerrard, J. and M. Kandlikar). Non-ferrous materials like concrete and rubber are separated from the rest of the materials for processing. Plastics, glass, and magnesium are then removed before the material can be sent to other processing plants for reuse.

Tires require special attention when recycling because they are vulcanized– a process that alters the structure of rubber molecules to create a more durable product, making it nearly impossible for tires to simply be melted down for reuse. Because of this, tires can be shredded into ground tire rubber (GTR). GTR can be used to fill asphalt, concrete, and polymers. Alternatively, tires can be retreaded for repeated road use, incinerated for energy recovery, or deconstructed through pyrolysis to collect carbon black– one of the additives in vulcanization (Ali Fazli and Denis Rodrigue, 2020). Each of these methods is valuable as without them, tires would sit in landfills for roughly 80-100 years before decomposing ("A recycling guide to tire shredding - Contec," n.d.).

Batteries in gasoline-powered vehicles use lead as the acid base. Each component can be easily separated for repurposing, resulting in a 99% recycling rate for these types of batteries. To prepare for recycling, spent lead-acid batteries are ground into a mixture and then separated through a series of filters. Any plastics are melted together and formed into standardized pellets that are redistributed to manufacturers for reuse as battery casings. Similarly, lead is melted into ingots before being sent off to be reproduced in another battery. Battery acid can either be neutralized and released into sewer systems or repurposed into sodium sulfate, which can be used in laundry detergent or glass manufacturing ("How a Lead Battery Is Recycled," n.d.).

High recycling rates on lead-acid batteries are valuable for the environment, but the handling of lead often results in humanitarian concerns. Contamination of water and soil systems in areas surrounding recycling plants is common, and as regulations increase in the U.S., more and more product is exported to other countries with fewer guidelines, putting their citizens at risk at rates disproportionate to those living in more developed nations ("Getting the Lead Out," n.d.).

The rest of the vehicle is considered to be "unrecyclable" and is collected to be ground into very fine particles called automobile shredder fluff (ASR). This toxic dust consists of metals, plastics, fibers, rubber, foam leftover from recycling, and any additional parts deemed too harmful for reuse. The resulting powder is incredibly detrimental to humans and is often used as a substitute for dirt coverings in landfills. ASR can also be used as fuel if burned because of its high petroleum content (Gerrard, J. and M. Kandlikar).

2.5 Gasoline Vehicle Summary

Gasoline vehicles and internal combustion chambers have been releasing harmful exhaust since the invention of the automobile in the late 19th century. While their longevity has ensured broad access to personal transportation, environmentalists are concerned about their constant output of harmful particles: VOCs are released during both the production and use of gasoline. Environmental negatives seem to outweigh the accessibility positives. Governments are slowly phasing gasoline vehicles out in favor of slowing climate consequences, forcing producers to spend more energy developing a new model: the electric car.

3: Electric

Unlike gasoline and hybrid vehicles, electric vehicles (EVs) do not have an internal combustion chamber. Instead, an electric motor connected to a large battery– usually a lithium-ion battery (LIB) – is responsible for making a car run; this means that EVs do not have an exhaust pipe or any other fuel-related features like pumps and tanks, significantly reducing harmful environmental effects ("Alternative Fuels Data Center," n.d.). Accessibility is frequently an issue tied to these vehicles as batteries in particular tend to be significantly more expensive or less readily available than gasoline-powered options. However, the cost of EV batteries has decreased by 86% over the past ten years as more research has been carried out to improve both the production and disposal of these vehicles. Sourcing and recycling of materials, particularly in LIBs, have historically raised ethical concerns, but an increase in research towards better practices has left consumers optimistic about the future of EVs.

3.1: Extraction

During the past decade, demand for LIBs has increased by roughly 40% each year, primarily due to the amount of EVs in production (Solomon). This has put worldwide stress on resources as businesses clamor to extract as much material as possible, leading to global humanitarian issues (Sharmili et al.). Each LIB requires raw materials. Most likely, these are cobalt, nickel, lithium, manganese, and graphite. Current mining practices for these ores cause a host of ethical issues linked to child or forced labor. Modern-day slavery in the form of forced labor is concentrated in regions with the most natural resources; the Democratic Republic of Congo is the lithium and cobalt capital of the world, leaving its citizens vulnerable to harmful labor tactics disguised as a way out of poverty (“The human cost of cobalt,” 2024). Roughly 70% of the world’s mined cobalt comes from Congo, and an estimated 15-30% of that cobalt is obtained through forced or child labor; the likelihood of owning a product containing the ores from these horrific mines is high in today’s digital world (“From Artisanal Mines to Electric Cars,” n.d.).

Several indications of devastating environmental repercussions include damaged ecosystems, contaminated water supplies, and air pollution (Slanger, 2023; Zheng, 2023). Extraction of these materials is the most significant contributor to global emissions in the EV life cycle because of the amount of carbon dioxide released into the atmosphere during mining (“How much CO2 is emitted by manufacturing batteries?,” n.d.). Airborne cobalt and other metals are released during the mining process, subjecting miners and surrounding individuals to a multitude of long-term health conditions, including lung disease and cancer. Even without forced labor, environmental and health issues do not affect all people equally; in the U.S., most ore reserves are within thirty miles of Indian Reservations and Territories (Slanger, 2023). Increased interest in these ores from the expanded development of EVs only snowballs these issues, reinforcing the importance of ethically sourcing materials.

3.2: Process

After metals have been extracted, there are four main steps to creating the battery: electrode coating, slitting process, cell assembly, and battery electrochemistry activation (Sharmili et al.). Electrode coatings take up the most energy in the LIB production process because of the gas used in the heating and cooling process of current collectors (Liu et al.). Each battery is charged and discharged several times, making the production of electric vehicles more energy consuming than that of gasoline cars. (Liu et al.; Sharmili et al., 2023).

3.3: Use

Electric vehicles are fully rechargeable, and even though the recharging process uses grid energy from the burning of coal or fossil fuels, driving EVs does not create any exhaust because energy is taken directly from the battery in the form of electricity. This means that air pollution is significantly lower on a daily basis, conserving the environment and limiting adverse health effects (“Have questions about electric cars?,” n.d.). Energy from the grid is considered cleaner than fossil fuel energy, and grids are constantly improving; in the U.S., roughly 20% of usable electricity in the grid is generated through renewable energy, and in Canada, about 62% is renewable. Governments worldwide are working to increase clean energy margins through wind, hydropower, solar, biomass, and geothermal methods, making EVs a worthy environmental investment (About Renewable Energy in Canada; “Renewable Energy,” n.d.).

The most significant concern attached to these vehicles is battery life, but the average capacity ranges from 250 to 500 miles per charge (400 to 800 km), making everyday commutes and longer road trips feasible for EV drivers (“Electric Car Range: How Far Can An EV Go In One Charge? | CU SoCal,” n.d.). Additional costs during use are also far less than gasoline vehicles; fees at charging stations are typically minimal, and many users can recharge at home.

3.4: Disposal

Similar processes are used in gasoline and electric vehicles for most ferrous and nonferrous materials. The critical difference between the two is how LIBs are handled at the end of their valuable life. Currently, LIBs in EVs can last for 10-20 years, a statistic that has been steadily increasing throughout the past few decades (“How Long Can Electric Car Batteries Last?,” 2023). However, when they do reach the end of their optimal lifetime, proper disposal is imperative to preserve the environment and the health of those around disposal sites. LIBs can be recycled in several ways: supporting the grid, pyrometallurgy, hydrometallurgy, and direct recycling (Mrozik et al.).

Once LIBs are deemed too inefficient for operation, they can be recycled into additional energy storage to support the grid: LIBs can be restored to up to 80% of their original capacity (Mrozik et al.). It is ideal if batteries recycled into the vehicle to grid system (V2G) are surrendered at roughly 70% efficiency, requiring consumer knowledge and action towards clean recycling (Zhao and Baker, 2022). Put simply, part of the grid’s job is to generate electricity, store it in a different form until use, and then convert it back to its usable form for distribution. The storage of energy in the grid already largely relies on LIBs because of their high energy density and long life cycles. Energy storage systems, like the ones reliant on LIBs, can help stabilize the entire power system because of their instantaneous ability to charge and discharge. This, in turn, increases the entire system’s efficiency (Chen et al., 2020). V2G is a positive addition to the grid as well as a low-maintenance way to recycle; reusing LIBs in their original form takes off a lot of the burden of extracting specific materials like cobalt and nickel from recycling plants, saving time, money, and a significant amount of emissions from entering the atmosphere (Mrozik et al.).

(Mrozik et al.) Other recycling options are more traditional because they separate materials for reuse in new LIBs or other applications. There are several ways of doing this. The first is called pyrometallurgy. This method requires smelting nickel, cobalt, copper, and iron into an alloy that can be reused to make new batteries. While efficient, pyrometallurgy uses a significant amount of energy and releases a number of greenhouse gasses during the smelting process. In addition, one of the products is black mass, a hazardous mixture of cobalt, manganese, and lithium that is dangerous for humans. Lithium recovery is also incredibly limited in this process. The next recycling method is called hydrometallurgy, a process by which acids are used to separate metals. While releasing much less greenhouse gas than pyrometallurgy, wastewater needs to be treated after this method, causing disruptions in water ecosystems. Recovery rates of lithium are also higher in hydrometallurgy (Mrozik et al.).

(Mrozik et al.) However, both of these methods are exponentially better than the alternatives; landfilling is far more detrimental. While landfilling is quite common with smaller LIBs, it is estimated that only 5% of EV LIBs are properly recycled, though it is difficult to obtain an accurate estimate of this globally. LIBs in landfills account for 25% of landfill fires which can be incredibly harmful to the environment due to the harmful release of particulate matter, heavy metals, and VOCs from other discarded items. Proper landfilling disposal of LIBs involves neutralizing and immobilizing batteries before they enter a landfill. Landfilling LIBs is a large issue that disproportionately affects developing countries. Large amounts of products are often shipped to countries with fewer regulations relating to LIB disposal. When these often active batteries are dumped, they can spontaneously catch fire and release harmful emissions (Mrozik et al.).

3.5: EV Summary

Electric vehicles are becoming more accessible; a recent study suggests that some EVs are more cost-effective in the long term due to the nullification of staggering gasoline prices (“Electric vs. gasoline vehicles,” 2024). However, due to mammoth prices, only 15% of Americans can actually afford an EV currently (*Electric Vehicles Are Out of Reach for Most U.S. Consumers - AMPO*, 2022). Energy from the grid is becoming increasingly cleaner with the addition of hydro, wind, and solar power, so EVs of the future could run solely on renewable energy making them virtually emission-free.. While EVs do not have the same inner workings as gasoline vehicles, they still pose environmental threats through the mining of materials for LIBs and their disposal, especially if not handled properly. On top of this, the demand for EVs has exponentially increased the demand for LIBs, exaggerating humanitarian crises that have concentrated in cobalt- and lithium- dense areas like the Congo. EVs can be an infeasible option for buyers who don’t have access to charging stations in their home. Hybrid vehicles, which utilize both electric and traditional power sources, can be a more cost-effective and comfortable option instead.

4: Hybrid

There are two types of hybrid vehicles on the market today: hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs). HEVs are powered by both an internal combustion chamber and electric motors which get power from batteries. Although the batteries are not explicitly rechargeable, they are recharged by regenerative braking and the internal combustion engine (“Alternative Fuels Data Center,” n.d.). Both of these mechanisms directly make a car run, and because of the additional power coming from the electric motors, hybrid electric vehicles are more fuel efficient and release smaller amounts of exhaust. PHEVs function similarly, but the key difference between the two hybrids is that PHEVs have the option to run solely on their electric motors. These cars contain multiple batteries and electric motors that can sufficiently power a vehicle independent of an internal combustion chamber. When those batteries run out, the internal combustion chamber automatically kicks in to keep the car in motion. As the name suggests, the batteries in PHEVs can be recharged through a wall outlet, but regenerative braking systems are also included in these cars ("Alternative Fuels Data Center," n.d.).

Several advantages of these types of vehicles make them more attractive than fully electric cars. The first and most obvious reason is that they are cheaper than fully electric cars; both types of hybrids are a cost-effective option to limit the amount of emissions due to transportation. Because of the electric motor and internal combustion chamber, hybrid drivers don't need to worry about traveling long distances. Once the battery runs out, they don't need to find a compatible charger because the internal combustion engine system will automatically take over. Hybrids seem like an automatic superior choice in the car industry, but their dual-engine nature can potentially cause more harm than good.

4.1: Extraction

Similar to electric vehicles, both HEVs and PHEVs most commonly use lithium-ion batteries, just on a much smaller scale ("Alternative Fuels Data Center," n.d.). The same components needed in an electric vehicle are also required for hybrids, bringing up the same forced-labor concerns surrounding the extraction of cobalt and lithium. Because HEVs rely on another fuel source for the internal combustion chamber, oil drilling is also a relevant issue in these vehicles. PHEVs also depend on gasoline to a certain extent, but they have the potential to run solely on electricity, so the environmental effects of PHEVs are less than those of HEVs. However, they have larger batteries than HEVs, meaning more cobalt and lithium need to be mined, exaggerating the demand for inhumane mining practices.

4.2: Process

Like the extraction process, HEVs and PHEVs follow a similar structure to their gasoline and electric models. Battery production still requires a significant amount of energy even though the batteries are smaller, and gasoline evaporates and releases large amounts of VOCs into the atmosphere: however, both of these dangers are taking place in a much smaller context as gasoline is used more efficiently and batteries are smaller.

4.3: Use

The efficiency of all hybrids depends on several factors. Because HEVs use both traditional and electric means to simultaneously power a vehicle, a large amount of exhaust is still released. Including regenerative braking means that these cars are more fuel-efficient in stop-and-go traffic rather than on open roads with high speeds. The constant use of the internal combustion engine makes HEVs significantly less fuel-efficient and, therefore, less environmentally friendly than PHEVs ("Alternative Fuels Data Center," n.d.). PHEVs can be just as efficient as EVs when used to their fullest potential– charged enough to reach a destination using only the electric engines. However, traveling longer distances and relying on the internal combustion chamber changes this. Similarly, if PHEVs are not charged for everyday use and strictly rely on gasoline, their negatives can outweigh the positives; the battery production causes severe environmental and humanitarian issues, while the perpetual use of gasoline adds unnecessary greenhouse gasses to the atmosphere (CER - Market Snapshot).

4.4: Disposal

Just like every other category of hybrid vehicles, disposal requires the fusion of gasoline and EV-specific practices. Both types of hybrids have a substantial battery and an internal combustion chamber, provoking the creation of ground tire rubber, shredder fluff, and black mass as well as repercussions related to improperly recycled batteries like landfill fires and human health issues.

4.5: Hybrid Summary

Hybrid vehicles have become exceedingly popular in the past few decades, providing the environmental benefits of fully electric vehicles for a fraction of the cost. PHEVs allow drivers to make short commutes completely exhaust-free because of their array of batteries and electric motors. Depending on the model and habits of drivers, these vehicles can be just as eco-friendly as electric vehicles. HEVs are far more fuel-efficient than regular gasoline vehicles, limiting total emissions. For consumers looking to limit their carbon footprint conveniently, hybrids are a great starter vehicle. There are many reasons these types of cars are being phased out worldwide: if not utilized conscientiously, hybrids can result in a combination of electric and gasoline vehicle concerns, both environmentally and ethically.

5: Analysis/Conclusion

In their current iterations, all types of vehicles on the market have either significant environmental side effects or humanitarian issues linked to their production, use, or disposal. The task for consumers is to determine which type of model will fit with their lifestyle while limiting emissions and humanitarian issues when possible.

Gasoline vehicles have been the dominant car type since they were invented, and for good reason; they are reliable for long distances, easily accessible, and easily maintained, but they also account for 22% of transportation-related carbon dioxide emissions in the U.S. each year (Frequently Asked Questions). Fuel is expensive, and with rising prices, the cost benefits don’t seem to outweigh the environmental repercussions.

Unlike gasoline vehicles, EVs do not have an internal combustion chamber, eliminating most carbon dioxide emissions that would usually come from an exhaust pipe. Researchers strive for a future where EVs have a net-zero impact as grid energy becomes increasingly renewable. In the grid’s current state, EVs on average release roughly 1.93 metric tons (1,930 kg) of carbon dioxide into the atmosphere each year from recharging: less than half of gasoline's 4.6 metric tons (4,600 kg) (Frequently Asked Questions). The central point of contention in the purchase of EVs is sourcing LIB materials, such as cobalt; cobalt mines have become a hot spot for forced or child labor. Increased enthusiasm for EVs results in an uptick in humanitarian crises. Researchers are working towards improvement and widespread implementation of alternative battery solutions to alleviate humanitarian and environmental concerns (Wu et al., 2024).

The combination of these two models– hybrids– has its own upsides and downsides. Like EVs, PHEVs have the potential to run solely off the grid, making them an excellent option for buyers not looking to pay EV prices. However, when traveling longer distances or not routinely charging them, PHEVs still contribute to greenhouse gas emissions as they still contain internal combustion chambers. In contrast, HEVs do not need to be plugged in, but they cannot solely run on electric motors, meaning there is a constant output of harmful emissions tied to these vehicles, even though they are considered hybrids. LIBs are a vital component of all hybrid vehicles, continuing the demand for forced labor mines.

One fifth of greenhouse gasses in the transportation sector could be eliminated in the next few decades because of new research and policies encouraging the use of hybrid or electric vehicles, a massive step towards global climate neutrality. While each type of vehicle can be the right fit, the reality is that gasoline and hybrid production is being banned throughout the world: EVs are the future of transportation. The next task is to determine a sustainable and ethical way to go about climate neutrality in transit.

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