Electric Vehicles

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Keywords

- Internal Combustion Engine (ICE)
- Hybrid Car
- McKinsey & Company Electric Vehicle Index
- Battery Charging Station
- Conflict Minerals
- Carbon Footprint

Chapter Menu

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Figure 1. Cobalt miners from the Democratic Republic of Congo. Source: Julien Harneis. Licensed under CC BY-SA 2.0.

The Blood Diamond of Batteries

While most of their friends are still asleep by 5:00 in the morning, children in the Democratic Republic of Congo (DRC) are crawling into mineshafts to begin their workday. These children, drastically impoverished, will walk hours just to get to these mines 6 or 7 days a week. Once they reach their destination, they begin to excavate away at hard rock in hopes to collect bits and pieces of the mineral so vital to their survival, cobalt. By the middle of the day, these children have already filled bag after bag of this heavy material, and they must haul it all the way to a camp to be traded or sold. These children will even take pride in the little money they get in return for their hard efforts but are without a clue that there is a multibillion-dollar market for the pieces of metal they are breaking away from the hard rock. Still, they endure the toxic air, the threat of collapsing mines, and thieves, only so they can sell this grayish-blue metal that will end up in luxury items all over the world.

It is easy to take the everyday items we use for granted and overlook how that product came to be, like the iPhone or electric car batteries. While children across America are using their iPhones for social media and sending texts, kids in the Democratic Republic of Congo as young as 7 years old head to the mines where they will spend up to 12 hours of their day to collect cobalt to be used for the batteries that power those same iPhones. In 2014, as many as 40,000 children worked day and night in mine shafts, work that is even dangerous for adults (AI, 2016). The big problem here is that families in the DRC have basically no other option. They choose to mine, or they starve. While technology continues

to change, scientists continue to move away from cobalt in their batteries, meaning these families only income may be dwindling away, while they dwindle away themselves. Even if some of these children do not mine, they are still victims of the circumstances. Many are orphaned or lose a brother or a sister because a mineshaft collapsed. There is an onslaught of toxicity that permeates the air they breathe and contaminates the water they drink. Still, they spend their whole day digging a deep tunnel with a small shovel just to collect enough of this metallic mineral to survive.

As one of the largest sources of cobalt, the Democratic Republic of Congo produces more of this mineral than any other region in the world at over 60 percent (Shedd et al, 2017). Cobalt has become a sure means of earning a living for locals. The stakes are high for the poverty-stricken citizens of Congo, and they are willing to go to extreme depths to dig this money-making mineral. It has become a free-for-all to capture what is being called "Blood Cobalt", and locals are using artisanal methods that dangerously violate human rights (Chen, 2018). The cobalt mining industry has remained largely unregulated, which has allowed these small-scale miners to dig through the floor of their home to try to break into a vein of cobalt. Problems have stemmed from this lack of regulation which encompasses a variety of health concerns such as deadly mining-related illnesses, safety issues, as well as the exploitation of children and the environment (AI, 2016).

As electric vehicles become more popular, the demand for the batteries to make them run increase as well. Cobalt is a key element in these batteries. Since the turn of the millennium, demand for cobalt as grown rapidly as a major component of lithium-ion rechargeable batteries that are used in portable electronics such as laptops and phones. Cobalt demand in electric vehicles is projected to increase from 6,650 tons in 2017 to upwards of 400,000 tons in 2030 (Alves Dias et al. 2018). Projecting to the near future, electric vehicles have set demand to increase exponentially with the expansion of the emerging market.

It is evident that because of the detrimental conditions in the Democratic Republic of Congo, that there is a dire necessity of regulation of higher quality. Opposing views to regulation will argue that a free-market approach would create a better socio-economic outcome because of the unlikely nature of developing countries to follow regulation if even implemented. Regardless, these artisanal miners are contributing to the global supply of cobalt that is a part of the supply chain between the Democratic Republic of Congo and major companies on the international scale. Some companies like Apple, Samsung, and Tesla have noted in press releases the ethical implications of producing electronics and electric vehicles using cobalt that might have been mined by a child in a foreign country, and there is a call-to-action against these companies and their peers to not include cobalt in their products. However, in the 2010 US Dodd-Frank Act section 1502, cobalt was not included as a conflict mineral despite the prevalent use of child labor since the DRC is listed as a conflict free designation (SEC, 2012).

Cobalt is a commodity that has a demanding market with the potential to grow exponential over the next few decades. The Democratic Republic of Congo suffers despite the budding opportunity for expansive wealth in the realm of commodities. It is estimated that about a fifth of the world's cobalt supply comes from informal mining practices. A major player in buying this commodity is China. China runs several industrial mines

regionally, but they spend a lot of time buying artisanal cobalt from these people. There, it is mixed with the industrial cobalt and marketed to major global institutions to use for their products.

While market prices for cobalt have amplified over the past two years, the ethical dilemma surrounding the harsh environment these people endure is significant, and none of that increase in the price for cobalt is seen by these miners. Electric vehicles are a step to take care of the world we live in, so these companies that are creating batteries with the help of cobalt are beginning to feel the pressure. A free-market approach could be a solution to the artisanal cobalt dilemma, but that would mean foreign companies creating new industrial mines that can help standardize competition and eliminate the issues from a few large suppliers.

Are there any substitutes to cobalt that can mimic the minerals unique properties? With demand increasing at such a rapid rate, can market power cause a social reaction to invoke enough corporate responsibility to ethically buy this mineral? Why is it that companies continue to use cobalt and instigate production without quality regulation monitoring the methods used to extract it? By observing the mining and marketability of cobalt, we can shed significant light on the global impact there can be for somebody who is simply driving their electric vehicle.

Brief History

Mad Scientists

Figure 2. Electric vehicle from the 20th century.

The history of both batteries and electric cars are related to each other, in that as the technology of batteries evolve, so do the electric automobiles. In 1800, Alesandro Volta established that specific chemicals have the capacity to store electric energy, producing the foundation for modern day batteries. In 1831, Michael Farraday displayed the properties of electromagnetism through the relationship between magnetism and electric currents, creating the framework for generators and motors powered by electricity (Hoyer, 2008). Also, in the early 1800s, Scottish inventor Robert Anderson designed the blueprint for one of the first electric vehicles with the "horseless carriage," that utilized the power of non-rechargeable batteries (Dean, 2011). But it wasn't until 1893 when William Morrison successfully debuted America's first electric automobile, that was powered by a massive 786-pound rechargeable battery and reached speeds up to 14 miles per hour. In 1901, inventor Thomas Edison helped develop the nickel-iron battery, which is 40% more efficient than the past lead batteries, and helped pushed the innovation of electric vehicles forward as well. (Hoyer, 2008).

Market Competition

During the 1900s, electric cars were competing with the gasoline **internal combustion engine (ICE)** and steam powered vehicles for market control (Hoyer, 2008). The ICE is a type of motor that ignites and combusts fuel to convert some of the energy produced to do work and move the vehicle (DOE). In 1903, around 4000 motor vehicles were registered in New York, with only 20% of them being powered by electricity, compared to the 53% of them being steam powered, and the remaining 27% of the vehicles being gasoline powered. The peak of electric powered vehicles in the United States was in 1912, with about 30,000 electric cars being sold (Hoyer, 2008). Technology of electric drive motors was evolving, with the principle of regenerative braking, or the ability to have the motor act as a generator and charge the battery of the vehicle while the car is moving downhill. Developments in fast charging batteries was happening around this time as well, with charging station infrastructures being implemented across the nation. However, this grid of power stations could not keep up with the more extensive network of gasoline stations. After Henry Ford's "Model T" and assembly line boom, electric cars and the associated technology lost popularity through the 1960s (Hoyer, 2008).

Internal Combustion Engine (ICE)

A type of motor that ignites and combusts fuel to convert some of the energy produced to do work and move the

Public Outcry

In 1962, Rachel Carson's book *Silent Spring* was published (Hoyer, 2008). This brought up environmental issues such as chemical pesticide and herbicide use in agriculture and shifted the public's attention to similar ecological problems such as lead pollution, carbon monoxide emissions, and the creation of smog. During this time lead was being used as an additive in gasoline, and the ICE engine and gas-powered automobile was being singled out as a culprit of environmental health degradation (Hoyer, 2008). The social response was for the solution to be found in electric cars. In 1966, the British Ford Motor Company instructed a research team to create a compact urban electric vehicle following the criteria of; Small initial and running expenses, simplicity of operation, high maneuverability, low pollution, and a size compact enough to take up minimum parking and road area. The prototype was created in 1967 and was given the name *Comuta.* The vehicle had a lead battery and could reach max speeds up to 40 mph and had a range of around 40 miles at 20mph (Hoyer, 2008). Ultimately, the prototype was not efficient enough for commercialization. Another company, United States General Motors, created two prototypes for electric cars in the mid-1960s. Named *Electrovan* and *Electrovair,* the technology was advanced. These electric motor vehicles had either a fuel cell or silver-zinc battery and could also travel up to 230 miles on single charge (Hoyer, 2008). Unfortunately, these prototypes did not make it to assembly lines either. Again, similar results occurred in the 1970's in France with the electric car VEL (Hoyer, 2008). The designs and ideas of these companies were ambitious, yet the technology

was not advanced enough to make electric cars a sustainable option compared to the capabilities of gasoline powered cars.

Hybrid Havoc

In 1990, California passed regulations on automobile pollution and created an initiative for zero-emission vehicles (Hoyer, 2008). This once again kickstarted the public and commercial interest into electric cars. In the transition to electric cars, **Hybrid Electric Vehicles (HEVs)** became popular. HEVs use a traditional fuel source as well as electrical power to reduce emissions and enhance efficiency of the vehicle (Dictionary, 2012). This technology tried to bridge the gap between ICE cars and completely electric cars, in that it had decreased emissions and carbon footprints, yet could compete with purely gasoline powered vehicles in speed, range, and ability. In 1993, the Clinton administration announced an initiative aiming at the development of a "clean car" with fuel consumption standards. This initiative was known as the "Partnership for a New Generation of Vehicles" or PNGV. A few years and one billion dollars later, three hybrid prototypes were manufactured, but none of them were used on a commercial production level (Hoyer, 2008). This step-back did not stop the demand for hybrids. In 1997, Toyota put the *Prius*, a four-door hybrid sedan, into commercial production on the Japanese marketplace. Also, in 1997, the car manufacturer Audi launched their *Duo* hybrid for commercial use, in response to their failed attempt to create a purely electric vehicle. Ultimately, this model was discontinued after little success in sales. In 1999, Honda's two-door *Insight* model was the first hybrid to be launched in the American market. In 2000, the Toyota *Prius* was finally marketed in the United States. A couple years after this, Honda launched another hybrid petrol-electric car the Honda *Civic Hybrid* in 2003. In the following year, the Toyota *Prius II* was released, winning multiple awards, including Car of the Year. The most popular hybrid vehicle to date is Toyota's *Prius* (Hoyer, 2008). Once the technology of batteries continued to advance, the push for battery only electric vehicles (BEVs) intensified.

Hybrid Electric Vehicle (HEVs)
Vehicles that use a traditional fuel source as well as electrical power to reduce emissions and enhance efficiency of the vehicle.

Figure 3. Electric car charging in Europe. Source: Ludovic Hirlimann. Licensed under CC BY-SA 2.0.

Contemporary Times

Today we have many more options with electric cars including the Nissan Leaf, Chevrolet Spark and Volt, Audi E-Tron, Lexus Nx 300, BMW i3S, Jaguar I-PACE, and Tesla Model 3, Model S, and Model X (Dean, 2011). Moving forward, as technology advances, so will electric cars and their availability. An analysis of the current

markets and commodities of electric cars, as well as the ethics, justice, and equity involved with vehicles will give us a better understanding of the present situation and a prediction of the future.

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Markets and Commodities

Electric Vehicles are becoming more and more popular by the year. Because of carbon emissions from traditional vehicles, environmental problems are causing the demand of EVs to rise, and the market is responding accordingly with increased sales every year. Unfortunately, these promising results are also aligned with problems of future production and supply. While society has made some good strides regarding EVs and their components, not near enough as occurred yet for the future of EVs to be sustainable.

Box 1.1 Environmental Solution? Elon Musk and Tesla Motors

Tesla Motors Incorporated and its founder Elon Musk have led the pack on the electric vehicle frontier. With 3 successful electric cars on their roster (the model 3, model X, and model S) and future models coming out (the roadster), Tesla has shown how to create a flourishing business while at the same time reducing greenhouse gas emissions and decreasing humanities dependence on non-renewable resources (Tesla, 2018). Elon musk and his team have even created an electric semi-truck, capable of moving massive amounts of products and material across country without any carbon pollution (Tesla, 2018). These electric automobiles will have artificial intelligence operating systems that are automated, being able to drive themselves from point A to point B with little to no human input. So far, Tesla products have saved almost 4 million tons of carbon dioxide emissions (Tesla, 2018). A network of charging stations has been implemented, with more being built each day. Musk hasn't stopped their either, he has created other companies that look to create better transportation systems that use underground tunnels and a hyperloop with his "Boring Company," more energy efficient houses and buildings that use solar panels as roof shingles with his "SolarCity" company, and created reusable rockets with his company "SpaceX" that looks to eventually colonize and terraform planet Mars (Philip, 2015). Tesla Motors and its front-man Elon Musk has forever changed history, not only on the economic market, but the ecological health of the entire world. This modern-day mad scientist is working to combat global warming, produce clean energy for everyone, and make humanity a multi-planet species.

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Global Electric Vehicle Index

A problem with our global markets is that they react slowly to environmental problems. However, their responses also come from supply and demand, and currently the demand for greener vehicles is steadily increasing. This can be seen with the growth of electric vehicle sales in the US, but this trend is similar in many countries across the globe. A good way to analyze the trend of EVs in markets comes from **McKinsey & Company's Electric Vehicle Index**, which is an assessment of the E-Mobility performance of EVs in fifteen countries based on two dimensions: markets and demand, and industry and supply. This tells us that the current status of EVs globally is at a slow growth overall, and improvement has occurred in five out of the seven largest markets. Out of these seven countries, three of them have the biggest global impact: China, Norway, and the US.

McKinsey & Company's Electric Vehicle Index

An assessment of the E-Mobility performance of Electric Vehicles in fifteen countries based on two dimensions: markets and demand, and industry and supply

Three Biggest Influencers

First, we have China, who is the global leader in sales to date and as obtained the most significant improvement in EV influence since 2014. On top of their roughly 580,000 in sales last year (Assis, 2018), they also increased their market share by 1.9% in the last four years since 2014, their number of available models is up to 100, and the supply of EVs and their components has improved as well (McKinsey & Company, 2018). Next, we have Norway, whose EVs have the largest share of the market across the globe. Their market penetration has increased from 11% to 32% since 2014, have several monetary and nonmonetary incentives, and have increased their number of available models (McKinsey & Company, 2018). Finally, we have the US, who will play a major influence because of their dominance in the western half of the United States. Even though the market share has increased by 0.5% up to 1.2% since 2014, this is still relatively low and the production share of EVs and their components has decreased during that same time span (McKinsey & Company, 2018). So even though our demand for EVs is on the rise, we must ask ourselves what the biggest influences of EVs are in the markets and why does the US remain at a lower influence, and

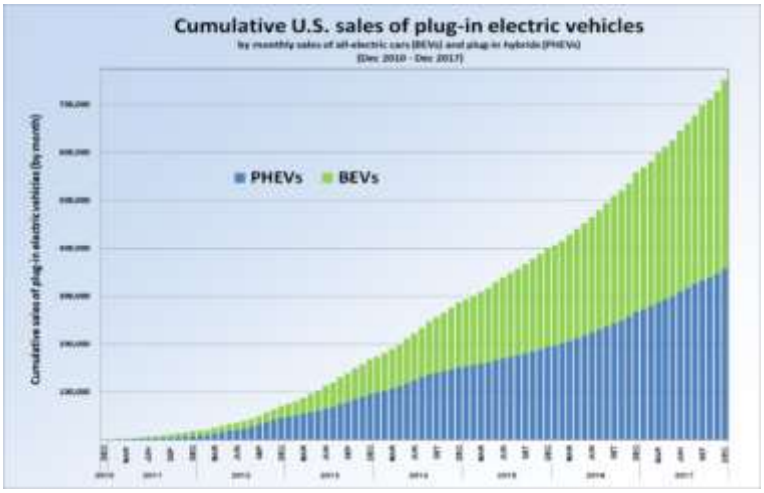

Figure 4. US Sales of plug-in Electric Vehicles since 2010. By Mario Roberto Durán Ortiz. Licensed under CC BY-SA 3.0.

for that we look to the charge being led by Norway and China.

Government Impact

Because of increased incentives and investment, China and Norway are the leaders of EV influence around the globe today, and these examples at least deserve some consideration from the US government. Norway's monetary and nonmonetary examples include escaping import and purchase taxes, avoiding road taxes and road tolls, half the price of ferries, free municipal parking in cities, and the ability to use the bus lane (Jones, 2018). China, on the other hand, drives its growth through subsidies and government regulation (McKinsey & Company, 2018). Their regulation includes exemption in some cities from license plate lotteries and auctions, and the introduction of Green License Plates in late 2017. These plates allow its owners to access eligibility for preferential treatment, which includes increased amounts of loans and special windows to speed up the license plate system. Substantial subsidies are provided from the Chinese government as well, which are helpful because they government reduce the concern of EV costs upfront and can lead to bigger markets. Something to consider with these countries' subsidies, however, is they can have a long-term negative impact on companies producing these vehicles because they disincentive them from acting as competitive or market friendly because of their help from government. While most of things aren't in practice in the US, they are things to consider that could potentially drive faster growth of EV influence in our market. But looking to the future of EVs, which has serious potential, has some serious doubts due to problems with our markets and commodities.

Growing Demand

Battery Charging Stations

An element in infrastructure that provides electric energy for the charging of electric vehicles

While we know that the demand for EVs are increasing, the future of this object is overshadowed by problems with production and supply. The biggest problem is that the metals going into these batteries are not going to keep up with future demand growth. A cause for concern comes from lack of cobalt supplies, as the demand for cobalt is expected to be 10 to 25 times higher by 2030 than what it is now (Assis, 2017). Supplies of Lithium and Nickel are expected to be limited by 2050, as both metals' demand will be six to seven times higher by 2026 alone (Nelson, 2017). And Copper, which is an industry that has produced 35.8 million tonnes in 120 years, will now only have 20 years to produce the same amount (Defotis, 2017).

Problems with Production

Because of this rising demand with lack of supply, the costs of these metals also make the future of EVs a lot less promising. In 2017 alone, the price of Cobalt doubled to $72,000 per ton, Lithium's price went up by 29%, and Nickel's went up by 12% (Nelson, 2017). On top of all that, it is expected that the US will need a $350-750 billion dollar increase in the global mining industry (Defotis, 2017). This means that we need to find a greater of supply of these metals and we need to import them from other countries. The problem is that right now, there aren't very many sources, and more countries are going to have to get involved with the global movement. Currently, 90% of cobalt is refined in China, and 60% is produced within the Democratic Republic of Congo (Assis, 2017). An even bigger problem lies within the DRC, due to many countries leaving the country because of political instability and child labor issues. If more leave, then our supply diminishes even more, and we are at greater risk of increased costs. Finally, a new production concern comes from **battery charging stations**. The stations currently have problems with length of charge, lack of availability, and other efficiency issues. Therefore, new production methods need to be established for them along with EV batteries, these could also get more countries involved with trade, which would help the costs and flow of these commodities across the globe.

An Ideal Future

All in all, the markets have reacted as expected and we are seeing more of a prominent presence of EVs in our society today. But if we don't deal with these concerns of rising demand and diminishing supply, then this presence will die down quickly either from too high of a cost of a drained supply of commodities. Governments everywhere are reacting to the demand of EVs but are doing so in a way that's too short and too short-term. If more long-term reactions are established in the mindsets of government officials, then EVs have an outlook that's very promising for the future.

Ethics

Over the past decade there has been a dramatic increase in the manufacturing and purchasing of electric vehicles. There are several reasons why one might make the switch to electric vehicles such as the efficiency compared to combustion engines, low maintenance, and they do not produce nearly as many carbon dioxide emissions. In a sense, electric vehicles are thought to be the means to meet some of the environmental and resource issues we face in modern society, like global warming. Global warming endangers people's health, jeopardizes our national security, and ultimately threatens basic human needs. Some impacts include record high temperatures, rising seas, and severe floods and droughts. Our

Figure 5. A typical battery found in an electric vehicle. *By DKMcLaren Licensed By CC BY-SA 4.0*

vehicles are a major piece, they account for one fifth of all United States emissions, emitting around 24 pounds of carbon dioxide and other greenhouse gasses for every gallon of gas (IPCC 2007). So, by switching to electric vehicles to combat this process seems like a good approach to producing a smaller **carbon footprint**. Carbon footprint is defined as the total amount of greenhouse gases produced by a given individual, group, economic sector, or commodity production process (Robbins et al. 2014).

Carbon Footprint

The total amount of greenhouse gases produced by an individual.

Precious metals

However, there are some questions one might ask themselves like what kind of carbon footprint is left behind from the manufacturing and production of these electric cars? How is the electricity generated to run these electric cars? Where do the minerals needed for the battery come from? The fact is electric cars have a heavy reliance on rare earth elements and rare metals like cobalt, reliance on rare earth elements is as problematic as these resources are finite. The cobalt used can be considered like a **conflict mineral**, which is defined as a mineral or its derivatives determined by the Secretary of State to be financing conflict in the Democratic Republic of the Congo or an adjoining country.

Conflict Mineral

A mineral or its derivatives determined by the secretary of state to be financing conflict in the Democratic Republic of the Congo or an adjoining country

The batteries used in these electric vehicles contain metals that are scarce, most of the cobalt for the batteries are mined in the Congo with child labor. In this area, the working conditions are very poor, and the miners face the risk of long-term health issues with a high risk of fatal accidents. Most of the miners work long hours every day, handling cobalt without even the most basic protective equipment (Wilson 2017). Demand keeps increasing for cobalt as more electric vehicles are produced. Few commodity markets are so dominated by a single supplier, which presents an ethical problem for the world's automakers. Do the environmental benefits outweigh human suffering? Mining for cobalt in the Democratic Republic of Congo often cause human rights violations and vast ecological devastation such as deforestation, polluted rivers, and contaminated soil. Ask yourself is this ethical? What kind of alternatives do these big-time car producers have in obtaining this precious metal? How can they better track where the cobalt they acquire comes from?

Electricity

Another question asked was, how is the electricity generated to run these electric cars? It turns out that electric cars that get their electricity from coal-fired power plants are bad for both the climate and human health. In fact, the environmental and human health costs of operating an electric vehicle using electricity generated from coal may be up to 80 percent greater than driving a gasoline powered vehicle (Magill 2014). Hundreds of thousands of people die from air pollution in the United States annually, some of which come from the burning of transportation fuels. Vehicles running on electricity that is produced from coal fired power plants ranked highest for both annual deaths and health costs compared to gasoline. So again, it is important to ask yourself where is the electricity generated from? If that electricity came from solar or wind generators, then an electric vehicle is among the cleanest forms of transportation. In fact, the environmental health cost of driving electric vehicles using electricity generated from solar or wind generators can be as much as fifty percent less than the environmental and health toll of using gasoline powered vehicles (Magill 2014). So electric cars can have a better environmental impact than gasoline powered vehicles, but it is important to know what source you are generating the electricity from.

Manufacturing

It is important to keep in mind the environmental impacts associated with the manufacturing and production of electric vehicles. When compared to the environmental impact of producing gasoline powered vehicles, electric vehicles have a higher environmental impact. The production of gasoline powered vehicles on average will involve emissions amounting to the equivalent of five and a half tons of carbon dioxide. While the average amount of carbon dioxide produced by manufacturing electric vehicles is over eight- and three-quarter tons (Nealer et al. 2015). So currently the production of electric vehicles poses the biggest environmental problem.

Bringing it all together

Ethics can be defined as moral principles that govern a person's behavior or the conducting of an activity, knowing right from wrong. When it comes to analyzing the ethics of electric vehicles it is important to view things from several angles. There are several reasons why switching to electric vehicles is a good thing, the move to electric cars will improve air quality and cut down on carbon emissions that

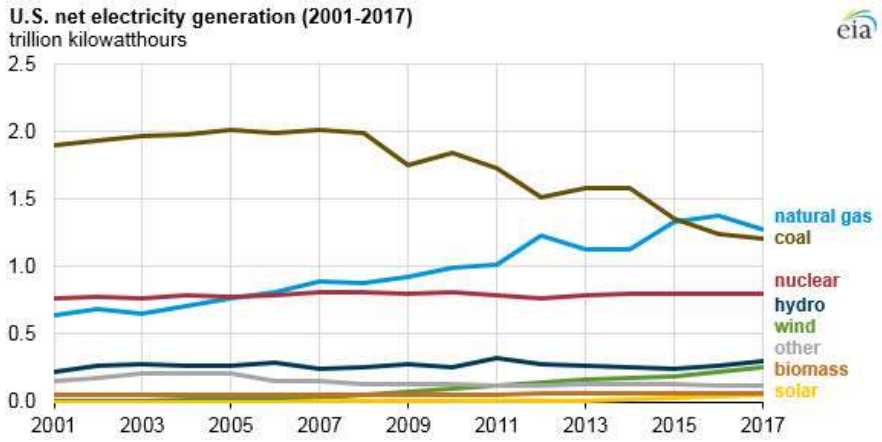

Figure 6. Net electricity generation in the U.S since 2001. Source: U.S. Energy Information Administration, Electric Power.

have pushed our planet to its breaking point. But as discussed, some electric vehicles are not currently, as ethically clean as manufacturers would have us believe. The cobalt mined by children and adults in extremely hazardous conditions enter the supply chains of some of the largest carmakers. The electric car industry must understand that transparency of human rights risks abuses arising in their supply chains is the way forward. It is also important to understand how the electricity is generated to run these electric vehicles, where does it come from? Make sure it is not coming from a coal powered power plant, because electricity from this source has worse environmental and human health risk than gasoline powered vehicles. Instead find a source of electricity that comes from a cleaner source such as solar or wind powered electricity. And know when producing electric vehicles more emissions of carbon dioxide are produced than gasoline powered vehicles. Although when comparing life time carbon dioxide emissions, electric vehicles are the better choice compared to gasoline powered vehicles. Overall there are pro's and con's to switching to electric vehicles it is up to the buyer to balance these and make an ethical decision based on their own beliefs and upbringing.

The Electric Car Puzzle

The history of electric cars relates to the technology of batteries in that as batteries advance, so did electric vehicles and their capabilities. Electric automobiles go back as far as the early 1800s with the design of a horseless carriage, but it wasn't until 1893 when the first electric vehicle was actually created. This was the beginning of a long future of electric cars, but the first prototypes were not successful due to their short range, inefficient batteries, slow speed, and inability to be mass produced. Technological advancements in the batteries, regenerative braking, charging, and the assembly line made the electric cars more feasible, but the technology wasn't quite there to compete with the ICE gasoline powered vehicles. With the introduction of hybrids, this bridged the gap between pure gas-powered vehicles and battery only electric vehicles. These HEVs had the best of both, more fuel efficiency and a reduced carbon footprint, with the speed and range to compare to ICE cars. This transition from ICE vehicles to HEVs gave time for the pure battery only electric vehicles to perfect their technology, design, and mode of production. Nowadays, electric vehicles are more popular than ever, with companies like Tesla, Honda, Toyota, Audi, Chevrolet, BMW, Nissan, and Jaguar all having battery only electric vehicles in their lineup. More availability also means more demand, and countries across the globe are responding with increased investment and incentives. But not all is well regarding the future of this society changing experiment. Even though the demand has been growing, and sales have increased as a result, concerns lie regarding the supply of commodities that go into these EV batteries. Prices of Lithium, Nickel, Cobalt, and Copper are all becoming drastically too expensive, and supply of some of these is expected to diminish by 2050. In order to solve this problem, methods of production need to improve, and more countries need to get involved in producing these metals. By doing so, the movement of switching to electric vehicles can be one of promising sustainability. There are several reasons why switching to electric vehicles is a good thing, the move to electric cars will improve air quality and cut down on carbon emissions. But as discussed earlier in the chapter some electric vehicles are not currently as ethically clean as

manufacturers would have us believe. The cobalt mined by children and adults in extremely hazardous conditions enter the supply chains of some of the largest carmakers. It is also important to understand how the electricity is generated to run these electric vehicles. Make sure the electricity source is not coming from a power plant fueled by coal, because electricity from this source has worse environmental and human health risk than gasoline powered vehicles. Ultimately, electric vehicles are an environmentally conscious action that is certainly a step in the right direction. If we can correct the issues associated with electric vehicles, then we have conquered a serious environmental problem that can lead to much improved environmental sustainability.

Exercise 1: Should your city begin promoting electric cars?

Do research on your cities top industries, its rate of carbon emissions, and availability of resources needed to make electric cars. Also do some research on the presence of electric cars in your area. Questions you should be able to answer that pertain to your city include: How many people use electric cars? Does it provide the minerals needed such as lithium or cobalt? How well are we doing with limiting carbon emissions? Are sales of electric cars growing in our area? From these, you can determine if your city is an area of high or low potential of permanent electric car use.

Exercise 2: How can you encourage the use of electric cars and charging stations in your city?

The key ingredient to environmental change starts with our lawmakers. Do some research and determine who your local representatives are for federal and state congress and what they stand for. Do they support environmental efforts, more specifically the use of electric cars? Do you believe they can begin taking steps to switching to electric cars? If they don't seem that way, then their other ways to make a difference. How can you as an individual promote electric cars? Can you find a support group or even create one yourself? What barriers are in our local community towards this permanent switch?

Exercise 3: What impact does environmental policy have on automobile emissions?

In this chapter, we have assessed how the implementation of electric vehicles can impact the environment. When it comes to implementing environmental policy, California is consistently a leader. Visit and read California's Climate Plan (https://www.arb.ca.gov/cc/cleanenergy/clean_fs2.htm). What action is California taking to address the environmental impact that that automobile emissions have on the environment? Think back to Exercise 2 when you answered how lawmakers can create change. Is the

California Climate Plan taking enough of a step in the direction of affecting change? Is it enough to inspire change on a global scale? Explain why or why not, and if it is not enough, what should they be doing differently to invoke this sort of global change.

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