

**Electric Vehicles' Engines and their Impact on the Global Warming**

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On my honor as a University Student, I have neither given nor received aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature           *Sragdhara Khakurel*           Date 4/20/2020

Sragdhara Khakurel

## Peer Reviews and Comments

I would first like to thank Professor Mike Gorman. Professor Gorman reviewed my paper and gave me many comments that I would like to address here. I was worried about reusing too much of my prospectus in my paper, especially the introductory paragraphs. Gorman said that doing this was fine since "I said it best in proposal anyways". Professor Gorman asked a clarifying question about temperature anomalies. I realized that I wasn't very clear about that and so I clarified that in my paper. Professor Gorman also asked a clarifying question about what a 'full recovery' of the environment means. I expanded upon this in my paper. Professor Gorman asked how deadly Global Warming is. I decided to not address this in my paper, since I think that I would have to give a very long explanation about that, and I deemed it unnecessary. Professor Gorman also asked a question about the tipping point about the environment. I also decided not to address this since many different scientists believe many different things about the tipping point. Addressing this would have also led to an unnecessary long explanation. Professor Gorman suggested that I put my results from my Vehicle Analysis section into a table so that it would be easier to understand. I followed his advice I created a table. In the Network Analysis section, Professor Gorman recommended me to create a visual representation of the current network and the network that I think it must change to. I have created these two tables and placed them properly so in my paper. I also listened to his suggestion to expand upon on how electricity companies have to change their business model as what will happen to oil and gas companies if a network change occurs. Gorman asked me why it's a problem that researchers get money from the government. I expanded my thought process on this issue, and I think this will also be much clearer with the network diagrams.

I would also like to thank Sajal Rohatgi. Sajal and I talked a lot about my paper. I originally wanted to include more aspects of the electric car in my paper. As I was writing I realized that my paper would have gotten too long and out of focus if I did this. I discussed this at length with Sajal to ensure that I was making the best decision for paper. I also bounced off my ideas with him, especially when I was first structuring and writing the paper. I didn't know whether I wanted to put my vehicle analysis or my network analysis first. Sajal helped me realize that the vehicle analysis should be first. Sajal also proofread the final version of my paper, changing some grammar, sentence structure, and analysis. There were also a couple of times that Sajal could not understand the paper, since he does not have a technical background. This was very helpful to me since I was able to ensure that my paper would be able to be understood by all those who were reading it.

## Electric Cars Overview

There are many advantages and disadvantages to the very popular Tesla's electric cars. These cars have technologically advanced features that will, according to the company, eventually accumulate in becoming a fully autonomous car. Furthermore, these electric cars are also known for being better for the environment than traditional gasoline-powered cars. Because of this, many environmentalists are very proud of the electric vehicle and encourage many who are worried about the environment to go purchase it. A downside to these vehicles is that they are expensive, especially when adding the technologically advanced features. Tesla is not the only company making self-driving cars and electric vehicles. There are many different companies making electric vehicles and many different types of electric vehicles as well.

There are four main types of electric vehicles. The first are hybrids. Hybrids “combine both traditional gasoline engines with an electric motor”<sup>1</sup>. In these cars, the batteries are charged when the car breaks by “converting the kinetic energy to electricity”<sup>1</sup>. Toyota Prius is a popular example of Hybrid. The second type of model is plug-in hybrids electric vehicles. These are very similar to the hybrid model, except that the battery can also be charged<sup>1</sup>. The third type is fuel cell electric vehicles. Fuel cell electric vehicles are a little different in that they store hydrogen instead of using batteries. “The hydrogen combines with oxygen to create electricity” which powers an electric motor<sup>1</sup>. Just like filling up on gas, this car will fill up on hydrogen. This paper will not be looking at either hybrids, plug-in hybrids electric vehicles, or fuel cell electric vehicles. Instead, the paper will focus on battery electric vehicles. Battery electric vehicles have an electric motor and a battery. These cars need to be charged and can go up to “200 miles on a

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<sup>1</sup> Goldman, J. (2014, Feb. 14). Comparing Electric Vehicles: Hybrid vs. BEV vs. PHEV vs. FCEV

single charge”<sup>1</sup>. One example of battery electric vehicles is Tesla’s cars. This paper will focus on battery electric vehicles since they are more popular in the market than fuel cell electric vehicles and are fully electric unlike hybrids and plug-in hybrids electric vehicles<sup>1</sup>.

## **Global Warming Overview**

“No challenge poses a greater threat... than climate change,” President Obama declared in his 2015 state of the union address. The US remains the second-largest emitter of carbon dioxide in the world, following China, which increases temperatures by trapping heat<sup>2</sup>. The past 18 years have been the hottest on record<sup>3</sup>. Due to the expected addition of 1.2 billion people in the world, energy consumption is expected to increase<sup>4</sup>. Currently, fossil fuels-oil, gas, and coal-power most of the world. However, the world will run out of oil by 2052, gas by 2060, and coal by 2088<sup>5</sup>. As the amount of these nonrenewable energies decreases, the value of them will increase. The barrel of oil, which currently costs \$55, is expected to cost over \$200 in 2040<sup>6</sup>.

The scientific consensus is that climate change is real and is extremely likely that it is caused by humans emitting greenhouse gases<sup>7</sup>. Global temperature anomalies, which are the difference between current temperature and a baseline temperature, have increased dramatically nearly 1 degree Celsius, since 1880<sup>7</sup>. Temperature anomalies are important to compare to

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<sup>1</sup> Goldman, J. (2014, Feb. 14). Comparing Electric Vehicles: Hybrid vs. BEV vs. PHEV vs. FCEV

<sup>2</sup> Park, M. (2015, Jan. 21). Obama: No Greater Threat to Future than Climate Change.

<sup>3</sup> NASA. (2019). Global Temperature.

<sup>4</sup> National Intelligence Council. (2012). Global Trends 2030: Alternative Worlds

<sup>5</sup> Ecotricity. (n.d.). The End of Fossil Fuels.

<sup>6</sup> U.S. Energy Information Administration. (2019). Annual Energy Outlook 2019

<sup>7</sup> Earth Science Communications Team at NASA’s Jet Propulsion Laboratory. (n.d.). Scientific Consensus: Earth’s Climate is Warming.

because take into consideration a slightly cooler summer one year, since they calculate the base temperature. Multiple countries, academies, and scientific associations agree that global warming is occurring <sup>7</sup>. Without clean energy technologies, fossil fuels will continue to be used, resulting in the environment to become even more damaged. The effects of global warming include but are not limited to ocean levels rising, more droughts, stronger hurricanes, ocean acidification, and a loss of biodiversity <sup>8</sup>. The environment might not recover if it ever gets to this stage. Full recovery would mean that there would be a normal amount of carbon dioxide in the air, normal ocean levels, little to none ocean acidification, and an environment that supports all forms of life on the planet. Humans inherently need a healthy environment to survive; continuing on this path is deadly for all living beings including us.

Climate change is already affecting the United States and the World, so there is no better time to take action. The United States must reduce its greenhouse gases emission levels. Since “cars and trucks account for nearly one-fifth of all US emissions”, one of the easiest ways to reduce carbon dioxide emissions is to have green cars <sup>9</sup>.

## **Paper Focus**

The question that this paper will explore is, can electric vehicles help solve global warming? Are they part of the solution that will help the United States and the World curb its carbon dioxide emissions? This issue will be explored by using an Actor Network Theory framework. Actor Network Theory is best defined as a theory that “examines the mechanics of

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<sup>8</sup> Earth Science Communications Team at NASA’s Jet Propulsion Laboratory. (n.d.). The Consequences of Climate Change.

<sup>9</sup> Union of Concerned Scientists (2014, July. 18). Car Emissions and Global Warming.

power through the construction and maintenance of networks (both human and non-human)”<sup>10</sup>.

The network is essentially a combined set of relationships between people, animals, objects, and the environment.

## Vehicle Analysis

One of the main differences between electric vehicles and gasoline-powered cars is their engines. Gasoline-powered cars get their energy from gas. The gas is combined with air to create a spark. This spark burns the fuel and moves parts in the engine. The result is an exhaust made up of carbon dioxide and other chemicals<sup>11</sup>. This is very different from an electric vehicle.

Electric vehicles have an electric motor and get their energy from an electric battery. Because of this, an electric vehicle has no exhaust. On the outside, this seems that an electric vehicle is much better for the environment than a gasoline-powered car since it does not emit any carbon dioxide. However, the issue becomes how an electric vehicle gets its electricity. In the United States, 81 percent of electricity is created from fossil fuels, meaning that carbon dioxide is still entering the air<sup>12 13</sup>.

Does having an electric battery help the environment at all? This question can be answered through some mathematical calculations. An electric car battery can vary from 20 kWh

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<sup>10</sup> Rodger, K., S. A., & Newsome, D. (2009, October 16). WILDLIFE TOURISM, SCIENCE AND ACTOR NETWORK THEORY

<sup>9</sup> Union of Concerned Scientists (2014, July. 18). Car Emissions and Global Warming.

<sup>11</sup> Woodford. C. (2019, May 4). Car Engines.

<sup>12</sup> Clarke. S. (2017, Dec.). How Green are Electric Cars?

<sup>13</sup> Porter, E. (2019, September 23). What Types of Electricity Sources are Generated in the US?: Direct Energy Blog.

to 90 kWh<sup>14</sup>. The average of all of these is about 60 kWh, which is what this paper will be using for this analysis. Each kWh produced by fossil fuels emits about 0.9884 pounds of carbon dioxide when the electricity is from home or work<sup>15</sup>. The 60 kWh battery electric vehicle can go about 200 miles without recharging<sup>12</sup>. The 60 kWh battery electric vehicle then emits 59.304 pounds of carbon dioxide for every 200 miles when the car is charged at home or work. In other words, an average electric vehicle emits about 0.29652 pounds of carbon dioxide per mile. According to the Union of Concerned Scientists, the average gasoline-powered car emits “around 24 pounds of carbon dioxide and other global-warming gases for every gallon of gas”<sup>9</sup>.

A car can give from 10 to 30 miles per gallon. Assuming that the average car gives 20 miles per gallon, the average gasoline-powered car emits 1.2 pounds of carbon dioxide per mile. This means that a gasoline-powered vehicle emits about 0.9 pounds of carbon dioxide per mile more than the electric battery-powered vehicle. This analysis means that electric cars only output about 20 percent of carbon dioxide the average gasoline-powered car does. This result coincides with this study done by the Union of Concerned Scientists<sup>9</sup>.

<b>Results</b>	Average Car	Electric Car
Type of Engine	Gasoline	Electric Battery (60 kWh)
Number of Miles	20 miles per gallon	200 miles on full charge
Amount of CO2 Released	1.2 pounds per mile	0.29652 pounds per mile

## Network Analysis

<sup>9</sup> Union of Concerned Scientists (2014, July. 18). Car Emissions and Global Warming.

<sup>12</sup> Clarke. S. (2017, Dec.). How Green are Electric Cars?

<sup>14</sup> Battery Universtiy. (n.d.). BU-1003: Electric Vehicle EV.

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The analysis in the previous section assumes that the source of electricity is just fossil fuels. With the increase of renewable energy technology in our society, the amount of carbon dioxide an electric vehicle emits into the atmosphere would decrease. In fact, a study has been conducted showing that as a county increases its amount of renewable energy, the amount of carbon dioxide emissions of the electric vehicle decreases<sup>16</sup>. Renewable energy does not produce any carbon dioxide and is a very ecofriendly alternative for the Earth. For electrical vehicles to be truly successful in helping to cut carbon dioxide emissions, the United States should have more renewable energy sources.

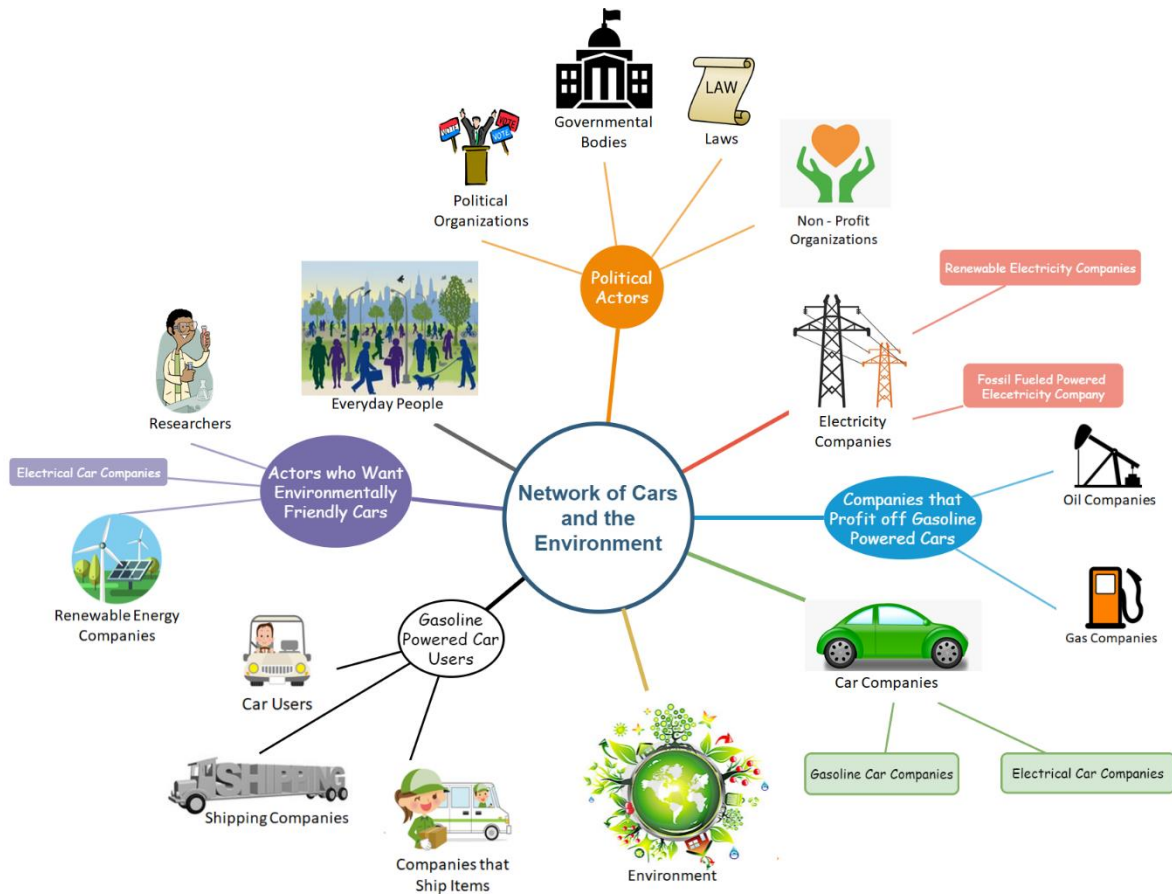


Figure 1. The Current Network of Cars and the Environment<sup>17</sup>

<sup>9</sup> Union of Concerned Scientists (2014, July. 18). Car Emissions and Global Warming.

<sup>16</sup> Zdeněk, Č. & Pavel, M. (2011). Electric, Hybrid Electric and Combustion Engine Driven Cars and Their Impact on Environment.

<sup>17</sup> These pictures are cited at the end of the Bibliography

To do this however, requires a complete shift in the current network of cars and the environment. The network of cars and the environment today includes many different actors. The actors are: the environment, car companies, oil companies, gas companies, shipping companies, any company that has to ship items, electric companies, renewable energy companies, different governmental bodies (local, federal, and international), laws, political organizations, non-profit organizations, car users, researchers, and every day average people. You can see this network in Figure 1<sup>17</sup>. Just changing one or two relationships is not enough. The network needs cooperation from most if not all of the network for these cars to be completely ecofriendly.

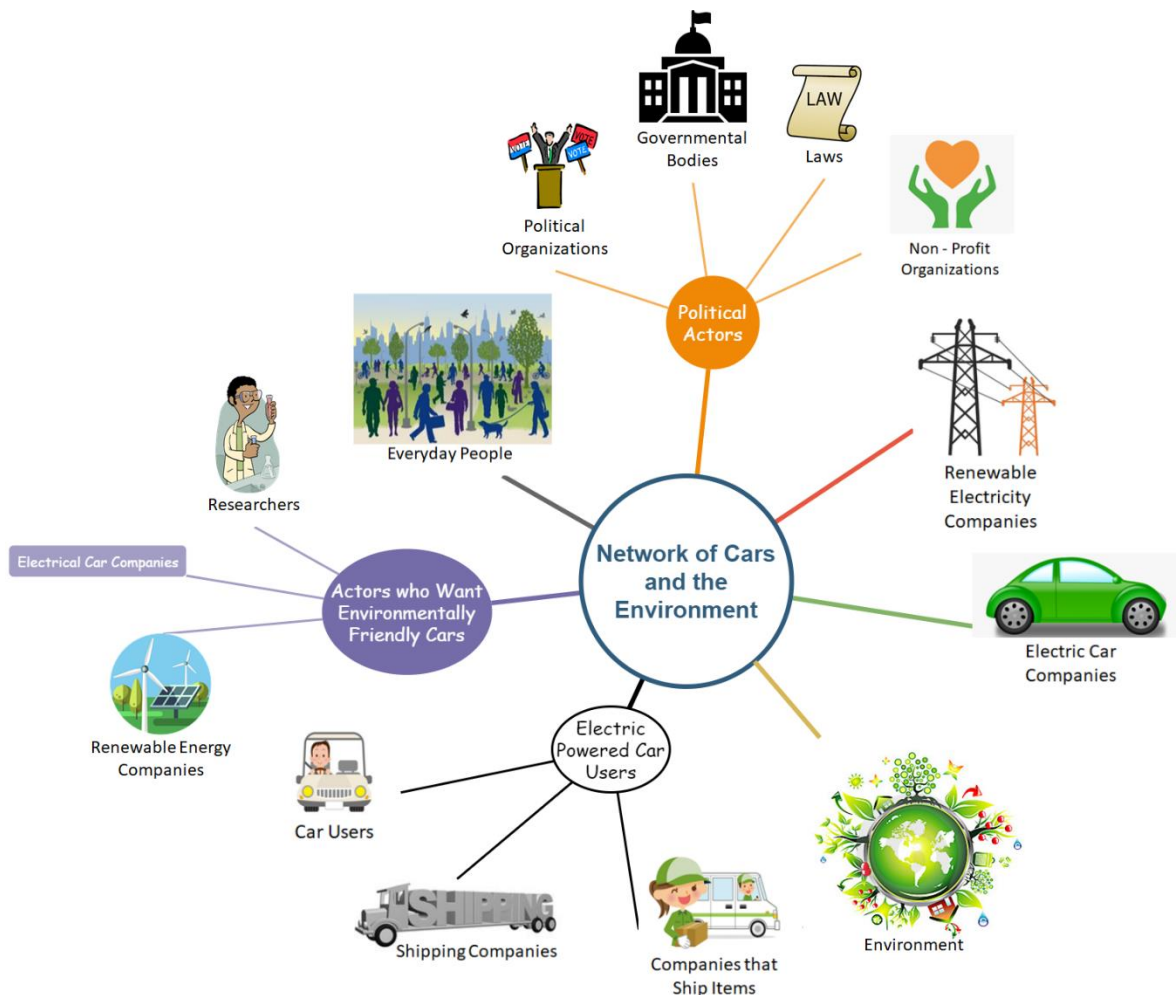


Figure 2. The Ideal Network of Cars and the Environment<sup>17</sup>

<sup>17</sup> These pictures are cited at the end of the Bibliography.

Having clean energy is very complicated and involves a multitude of actors. A change in the network is required, forming a network that is shown in Figure 2. Renewable energy companies have to provide products for electricity companies and the average person to buy. Electricity companies have to be willing to change their entire business model; instead of burning fossil fuels they have to buy new machinery from renewable energy companies that create renewable energy. The average person has to be willing to buy renewable energy technology that is expensive. New car companies, such as Tesla, have to meet the customer demand for electric vehicles. Customers have to be willing to buy these expensive cars. Typical car companies without electric vehicles are likely to resist the change. The same is said for oil companies and gas companies. This change in the network hurts the company. Instead of everyone buying gas for their car, now everyone is charging their car with ecofriendly electricity. These companies have invested millions of dollars into drilling for oil and other nonrenewable energy sources and don't want to see their investment go to waste. These companies will either have to change their business model or will go out of business. The government also has a large part to play. The government has to encourage the switch to renewable energy and electric vehicles by providing renewable energy tax credits. The government should also fund research that would help the electricity companies. However, having the government to cooperate is unreliable. The government is split in many ways about this issue. Some political parties don't believe that global warming is occurring and think that switching to renewable energy sources will hurt companies. Because of this, the amount of money provided for these efforts change often. Furthermore, changing this network globally is very difficult because all of the different governments have to come together and work together – a feat that is tiresome, demanding, and almost unfathomable.

The network is already changing. Some actors and relationships are changing and adapting much quicker than others. An example of a company trying to change the current network is Tesla. Tesla is already making strides to make the energy in the United States cleaner. In 2016, the company changed its mission statement by one word. Before it was “to accelerate the world’s transition to sustainable transport”<sup>18</sup>. Now it has become “to accelerate the world’s transition to sustainable energy”<sup>18</sup>. Tesla recognizes that using electric vehicles helps solve a part of Global Warming, but it doesn’t lead to completely clean automobiles. Another actor that is trying to reduce the impact of electric vehicles on global warming is researchers. Researchers are trying to improve the technology for the battery used in electric vehicles. If the battery becomes more efficient, the electric vehicle will be able to drive more miles on a single charge. As the number of miles that the car can travel on a single charge increases, the amount of carbon dioxide emitted per mile decreases. As these batteries improve, electric vehicles will emit less carbon dioxide. However, researchers do obtain a lot of their money and grants from companies and the government. This can be a problem because as mentioned earlier, the government can be dynamic in its thinking about this issue. The whole network is connected. Every single actor has to work together to change the network so that it is one that doesn’t contribute to global warming.

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<sup>18</sup> Jesus, C. D. (2016, July 15). Tesla Changes One Word in its Mission Statement and it Already Says a Lot.

## Conclusion

Electric vehicles have the opportunity to greatly help the environment. They have the ability to greatly curb the amount of carbon dioxide the United States outputs. As found through the vehicle analysis section, electric vehicles would cut emissions by 80 percent. This result is very profound and has endless implications. For example, as mentioned in the global warming section, gasoline-powered automobiles are 20 percent of the United States' emissions. If everyone decided to buy and use electric vehicles, cars would only contribute to about 5 percent of all of the United States' emissions, assuming the vehicles were powered through electricity made by burning fossil fuels. Though it is very unlikely that everyone will buy an electric vehicle, especially due to the price, this scenario is possible in the future as gasoline cars get phased out. It is also a very important conclusion that for electric vehicles to become fully ecofriendly, the entire network of cars and the environment needs to change. The network needs to become one that emphasizes renewable energy instead of fossil fuel powered electricity. This change is possible, though albeit difficult because most of the actors in the current system have to work together. Many companies who are benefitting from the current system will not want the network to change. But it is important that this change does occur. If the network changes, electric cars will produce less carbon dioxide emissions as the United States increases its renewable energy sources. If the network changes, the United States could cut the full 20 percent of the emissions. These results are possible, in the United States, but only if all of the actors in the United States come together and work together. These results are possible globally, but only if the entire world links arms together to combat global warming and to make the Earth healthy again.

## Next Steps

This article focused on the impact of electric vehicles' fuel source on global warming. However, there are many other aspects of the electric vehicles that still need further exploration that I was unable to research in this article. A full life-cycle analysis of the electric vehicle needs to be conducted. Research can be done on how electric vehicle production affects global warming. Are these cars being made sustainably? Analysis can also be conducted on how these vehicles are being transported. Is the transportation of the vehicles sustainable? Further examination can be done on the effect of renewable energy. How much do these green sources of energy reduce the carbon dioxide emissions of the electric vehicle?

There are also many other parts of the environment that my research paper will not be able to explore. My research focuses on just global warming, but there are many ways that electric vehicles' construction can harm the environment. Electric vehicles need many raw materials to make their batteries. Mining for these raw materials often hurt the surrounding environment. How are Tesla and other electric vehicle companies getting these resources? Furthermore, these resources are often being mined in foreign countries. How can the United States ensure that these countries are mining their resources properly and safely? Electric battery disposal is another concerning issue. After some time, the electric battery becomes toxic. How can the United States ensure that these batteries are being removed properly? Is there a way that we can recycle the battery materials? Are there parts of the electric vehicle that can be reused-making the car more sustainable?

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