Spring 2023

Powering Electric Vehicles: Are We Ready?

Christian Yoder
cdy8@uakron.edu

Electric Vehicles: Are We Ready?

University of Akron

Williams Honors College

Christian Yoder

Civil Engineering

Contents

Background:

Climate change and global warming are very large concerns for the planet and all the population. Large contributors to this are difficulty releasing heat to space and greenhouse gasses caused by burning fossil fuels. Fuels like coal, oil, and gas are the largest contributors to greenhouse gases. It is estimated that over 75% of global greenhouse gas emissions are caused by burning these three fuels (1). Reasons for burning so much fuel are nonrenewable energy production, industrial operations, and transportation. With transportation, road vehicles contribute more than other modes of travel. Vehicles contribute more than 25% of harmful carbon dioxide emissions (1.) This is due to the burning of petroleum-based gasses in a combustion engine. The average passenger vehicle will emit over four and a half metric tons of carbon dioxide in a year (2.) Figuring out how to relieve some of these problems is very important and highly sought after today.

The most obvious and most effective way to cut these emissions would be to stop burning fossil fuels. This is, however, impossible with the current use and reliance on energy and electrical power for essentially every person and every business worldwide. The best that the world can do is to move toward much cleaner renewable energy and cut down on burning fossil fuels wherever possible. This is very difficult because renewable energy is expensive and not nearly as consistent as the demand. Sources of renewable energy like solar and wind are not necessarily applicable in every location without stopping. This is because the sun is not always shining, especially at night or in many areas. This is the same for wind as it is not always windy in all areas at all times of the day.

Another way that will seem to cut emissions is to remove combustion engines from the common passenger vehicle. This is where fully electric vehicles come in. Without burning gasoline or diesel fuel the electric vehicle uses a rechargeable battery to travel around with zero tailpipe emissions. Acknowledging this, people in the USA are being highly encouraged to switch to electric vehicles. Tax breaks and deductions are available for citizens, as well as grants and funding are available for businesses for driving electric.

With this push for the USA to drive electric, it is worth asking if the national infrastructure is ready for such a change from gasoline to electric battery-powered vehicles. This is important because these electric vehicles will need to charge. A new push for as many people as possible to start driving electric–powered cars will use an exceptionally large amount of electricity. This will not be important if only a few high-powered level 3 chargers are used. This is likely not the case and the push for as many people as possible to start driving electric will be incredibly significant to electric power companies. Now, they will need to produce much more electricity to keep up with the demand. This could and will be very difficult, especially with outdated technology. Today more than 70% of power lines and large transformers are over 25 years old in the USA (3.) This is alarming considering the growth in electrical demand just over that time. It is reasonable that whatever growth factors they were using then in design would have to be surpassed or nearly to its limit. Adding a new large influx of electric vehicles and charging stations would only make these more constrained.

The objective of this report will be to investigate electric vehicles and how much energy they will likely be consuming. This will be followed by a look at the power grid and how we get the power that we have at our fingers. Then, a discussion on the big takeaways from conversations with one of the nation's largest electric companies, FirstEnergy. Discussed were some of the steps that will be and are being taken to adapt to the possibility of a large electric vehicle takeover. This will help find out if the US and this area, in particular, are ready.

Electric Vehicles:

Electric vehicles seem to be the transportation method of the future in the eyes of many. This is especially true with the people trying to reduce the effects of global warming. Turning toward electric transportation will eliminate tailpipe emissions drastically. This would mean that cleaner energy production will bring a decrease in greenhouse gasses from two distinct large contributors. These contributors would be energy production and tailpipe exhaust.

Federal and State Support

Worldwide nations are adopting the zero-emission standard and are setting definitive goals for achieving this soon than many people would expect. Reports coming from the 2021 United

Nations Climate Change Conference aka COP26, hundreds of stakeholders including over 30 nations pledged to transition to 100% emission-free car and van production by 2040 (4.) This means that these nations will no longer be selling combustion engine vehicles new by this point and will be all in on electric.

The United States was a notable omission from the United Nations declaration. However, according to released statements by the current presidential administration, the United States is moving toward 50% of new car sales to be electric vehicles by the year 2030 (5.) This as well as adding charging infrastructure will help the administration reach its goal of 100% net zero emissions for new cars by 2050 (5.) This shows that the United States is just as committed to achieving zero-emission car transportation. However, they feel they will take a little longer than these other countries are claiming. Some are suspicious of the US ambitions because it seems with the low amount of current electric vehicles being sold that the growth to 50% in around 7 years would be very difficult. Even with that being said the growth would have to ramp way up to get to that rate then it would slow down to not reach 100% until 2050. The growth would obviously not be linear. With the infrastructure growth, the rate would more likely be slow to climb and then gain more momentum as energy and charging infrastructure improves.

The United States is also making large commitments toward charging infrastructure as well. The President's 'Bipartisan Infrastructure Law' aims to invest $7.5 billion in electric vehicle charging (5.) This combined with many states also investing large sums into charging infrastructure will certainly help the growth of electric vehicles tremendously. For example, in Ohio Governor DeWine has announced funding of over $100 million is now available for charging in the state aside from the federal investments (6.) This money is significant but states like California have announced another $5.5 billion of state funding toward charging to add to the already massive 80,000 plus chargers that they already have (7.)

The $100 million in state funding for Ohio stipulates that the new charging stations being funded will have at least four direct current fast chargers at the location. Ohio currently only has 13 locations that would meet these requirements (6.) This shows how relatively new Ohio is to the electric vehicle charging and driving game.

Fully Electric vs Plug-in Hybrid vs Hybrid

The zero-emission, frequent charging of fully electric vehicles without combustion engines will be the focus of this research. However, this is not the only option for driving with a battery-powered vehicle.

Hybrids are primarily combustion gas vehicles that have a battery to help fuel economy. This technology is not new and has been around for over 20 years with models like the Toyota Prius. These hybrids do not charge and only refuel with gasoline. Hybrids improve gas mileage by using the battery while traveling at slow speeds and while coasting or braking. This allows the engine to shut off until it is needed for bursts of acceleration or traveling uphill. This ability to shut down the combustion engine periodically allows for fewer emissions than a comparable fully gasoline vehicle and gets more miles out of the gallon of gas. The battery is able to gain and retain charge using regenerative braking. This allows the otherwise lost energy while braking to charge the battery.

Plug-in hybrids on the other hand have a substantially stronger more useful battery as well as the traditional gasoline combustion engine. This better battery means that the vehicle does need to charge. As the name implies, it will need to be plugged in. These plug-in hybrids have the capability to serve as fully electric for short trips with a full battery which is something the regular hybrid is not capable of. With the dual engine, the plug-in can also drive without being charged and just with the combustion engine. Keeping a charged battery will keep emissions lower in comparison to combustion or regular hybrids. This is because the vehicle will use the battery more often than the hybrid and the regenerative braking will add range to the battery life. This option is perfect for those who travel a large range of distances and live with access to a plug. Plug-ins are usually fine for level 1 charging which is done at home using an outlet. This way the customer who normally has a short commute can use its fully electric capabilities yet during a long trip they will be able to use a normal gas station instead of tracking down an electric vehicle charging station.

The fully electric vehicle has no access to a combustion engine at all. This means all the travel is done with the charge on the battery. This is great for emissions as the tailpipe does not even exist with these models. With no liquid fuel being burned the car releases no harmful waste into the air. These fully electric vehicles are much quieter and cleaner than the combustion engine and even hybrid competitors. Fully electric vehicles experience no abrupt changing of engines like the others may and have much faster response time when pressing the accelerator pedal. Electric vehicles run solely off of battery so they will need to be charged no matter what to work. Charging can often be time-consuming and if the consumer travels considerable distances a level 1 charger will not always be sufficient.

Chargers

Plug-in hybrids and fully electric vehicles need to be charged to either run or run the most fuel efficiently. Charging a vehicle is an electrically demanding process depending on how it is being done. There are three distinct charging levels that a consumer can use to charge up their electric vehicle.

The first type of charging is level 1 charging. Level 1 charging is also usually known as at-home charging. This charging is using a standard 110/120-volt outlet being carried by a 15 to 20-amp circuit (8.) This version of charging will pull around 4 kWh (kilowatt hours) of electricity. This charging method is ideal for a consumer who travels very short distances on a daily basis and can plug in overnight in a garage-type setting. The problem with this charger is that it is very slow. A level 1 charger will gain the electric vehicle approximately 5 miles of charge in 1 hour of charging (8.) This means that a nearly drained electric vehicle with a max range of 250 miles would take about 2 full days of charging to reach max charge. This clearly means it cannot be driven or used at this time to reach max charge.

The next charging method is level 2 charging. Level 2 charging can also be done at home with the installation of a 240-volt plug. This is similar to the home clothes drier. These level 2 chargers use a 240 V outlet carried by a 30-80 amp circuit (8.) Level 2 chargers can pull anywhere from just under 7 kWh to nearly 20 kWh of electricity. Home models will likely fall on the low side while industrial level 2s would be more likely to range closer to the high end of the spectrum. These level 2 chargers are able to add between 10-20 miles per hour of charging to the electric vehicle (8.) This would mean that the 250-mile ranged car would likely spend over 16 hours charging to reach full from empty. The Us department of Energy claims that the majority of plug-in electric vehicle drivers (plug-in hybrid and full electric) will do 80% of charging at home (8.) This implies that a vast majority of charging is done using level 1 and level 2 charging methods.

The final method is level 3 or direct current fast charging. These chargers use the power of direct instead of alternating current to charge the electric vehicles much faster. Depending on the system a DC fast charger will use anywhere from 25 kWh to up to 500 kWh of electricity. Tesla supercharger stations for example use between 90-250 kWh to charge (8.) These level 3 chargers are almost exclusively for definitive charging stations such as superchargers or public mobility hubs. These chargers are very expensive to install and pull a massive amount of electricity from the grid. However, these chargers are very fast. A consumer can often expect 60-100 miles of battery life with just 20 minutes of charging (8.) This would make it so that the 250-mile ranged electric vehicle would be able to go from out to full usually in under an hour.

Power Grid:

The electrical power grid is how Americans and frankly the world has access to electricity. Electricity is arguably one of the most important resources and utilities available today. Without electricity things like transportation, communication, and access to necessities would be nearly impossible. No power would make would impact the lives of everyone very severely. Unlike many other resources and utilities, electricity is not easily capable of being held or stored at all. With water and other more physical utilities production can run all day and night without worrying about slow or peak usage times throughout the day, week, or year. Water and other products or goods can be held until it is needed without much issue. This is not the case with electricity. Electricity is not something physical that could be dumped into a box and held until it is needed.

For these reasons, the production of electricity needs to be fast, efficient, and adaptive. Believe it or not, the energy used to power the light switch in a room or power to the device used to read this report was just produced somewhere likely far away just an instant ago (9.) This means that the power companies can not get away with just producing the daily usage of energy spread out throughout the whole day. They have to be able to supply the needs of every user at any moment's notice. The supply and grid are amazing because this electricity is at the consumer's fingertips at all times.

A customer does not need to call or notify the power company before doing something like flipping a light switch or turning on the air conditioner. Yet, conveniently the power is right there in an instant. This is because of the ever-adapting supply of electricity through all the steps of production and making its way to a home or business. The power supplied through outlets in a person's home makes it through many steps from production to accessible power.

PJM

PJM is the regional transmission organization (RTO) in charge of overseeing Ohio as well as about a dozen other states in the surrounding area. An RTO works independently of the power plants and power companies to make sure that electricity is being handled properly and regulates all the steps behind the scenes. This means that they will direct the operations of power lines and generators for the owners (10.) PJM acts as the independent authority to ensure fair trade and access to all consumers and companies alike. They make it so that companies and producers will all work together to bring electricity to every consumer. They analyze and track all the movement of energy through all the steps. They specialize in making sure that power is provided for all and projecting the future to see what areas of transport need upgrading or adjusting.

Production

The first step in the power grid is the production of electrical energy. PJM oversees the operations including production. According to PJM, the fuel sources for electrical production under them most prominently include coal, natural gas, and nuclear (11.)

Natural gas is the largest fuel for electrical power in Ohio according to PJM. It makes up about 36% of Ohio's electricity (11.) Natural gas is burned to produce either steam or combustible gasses that move turbines to create electricity. Coal works similarly, it is burned to produce heat to turn water into steam. This steam again pushes the turbines in the generators to produce power. It is worth noting that Ohio was once very dependent on coal for electricity but not that has come down substantially. Now coal comes in under natural gas at about 24% of the electricity (11.) The other main source of electricity is nuclear power. This is done by the fission of uranium atoms. Fission splits the atoms releasing large amounts of heat. This heat again is used on the water to produce steam to move turbines. Nuclear power comes in just under natural gas with about 34% of Ohio's electrical fuel source (11.) Ohio also uses some renewable resources to create electrical power. The most common renewable source in Ohio is wind power followed by hydro and solar power. These are very small contributions with all the renewables combined accounting for about 5% of electrical production (11.) This number would need to be much greater to really see a significant impact on greenhouse gas emissions with electric cars.

Transformers

One of the most important aspects of transporting electricity is that it is done efficiently. Moving high-current energy through conductors produces a large amount of heat energy. Electrical energy is converted to heat energy in this case. This conversion of energy is lost electrical energy. The lost energy is a huge problem because now companies are not able to sell all of the electricity they have produced. Using Ohm's law, it can be found that moving the electricity at a higher voltage will decrease the current in the lines. High currents are the cause of these losses of energy, this is shown by Watt's law. Companies use this to their advantage.

Electric production is usually done at a relatively low voltage. This low voltage will make for a high current in the transportation of this energy. A way to increase this voltage was found using Faraday's Law of Induction. This law basically states that a change in a magnetic field will induce a current on a coil of wire. Using alternating current and ideally spaced coils of wire a new current can be sent from one coil to the other. This is the basis of what a transformer does. This current in the second coil is also proportional to the number of loops in the coils. This means that if the voltage was to be stepped up 4 times then the second "induced" coil would need 4 times the amount of coils as the line coming into the transformer.

This is very important because high voltage and low current conditions are ideal for minimizing losses while the electricity travels. However, the voltage is not only stepped way up moving out of production it is also stepped down in the same way. This is because high voltage can be very dangerous and hard on equipment. These voltages are much too large to have access to in a home. For this reason, transformers are not only near production to ramp up the voltages but they are also at substations and on power lines right at the point where it is ready to go to the consumer. At the substations, the voltage is stepped down to be safe for normal power lines. The line transformers step the voltage down one last time to be safe for consumers' homes and businesses. These line transformers are the small, often cylindrical container at the tops of normal power lines.

Power Lines

Power lines are responsible for moving the majority of produced electricity from production all the way to consumers. High-voltage lines are usually supported by really tall steel towers that are much more sturdy than regular telephone pole-style line holders. These line towers are so tall and built more securely because the lines are very high voltage and would be dangerous if interfered with. Power lines are not insulated as this would be inefficient for costs (12.) Instead, they are placed far overhead so that a person or vehicle will not be able to interact with them. High voltage makes the electricity very easy to move. This high voltage means electricity will be more likely to move through other objects even if they are not great conductors. With this ease of movement, it is important to make sure that the lines do not arc or get too close to any sources of ground to cause a short. To prevent this these towers need lots of space between wires and non-energized components. The higher the voltage the more space is needed around energized components.

The standard power lines that are seen on the sides of residential streets are supported by poles that are smaller and shorter than the high-voltage counterparts. This is because the electricity in these lines has less voltage across them (12.) This means a higher current but it also means the electricity is not as 'excited' to move. This makes it safer to be closer to citizens and brings the lines closer to the consumer which is the final destination.

Substations

Substations are often the links between the different stages of electrical life. These stages are production, transmission, and distribution (13.) Substations are often different depending on what stage in the journey the power is on and what it is needed for on the other side. A substation is often the termination point of many individual power lines. This creates redundancy, which is helpful in the case of issues or a down transmission line(13.) This redundancy will help make sure that power is still supplied where it needs to be even if this happens. A substation will have switches to isolate equipment for maintenance or control the flow of electricity where it needs to be. Breakers are also a part of substations. These breakers and switches help protect equipment and infrastructure in cases of faults or shorts (13.) Substations also include transformers to act as a transition point between high-voltage power and lower-voltage power lines. Regulators are also at substations to make small adjustments to voltage and current before it makes its way toward the consumer. This is because customers are expected to use the voltage within a very specific range.

Another very important job of a substation is to have safety and monitoring equipment all around. A substation needs to be accessible for linemen and grid workers to be able to test and maintain the equipment. A substation is really the only place where the extra high voltage lines are close to the ground so instruments and equipment are in place to make sure this is safe to inspect and test on. Most all equipment is protected by large insulators so that they can avoid arcs to ground. Much of the equipment is actually walled off from one another to avoid interference. The substations are also all built above a network of ground rods under the surface this way in the rest of a problem very large amounts of electricity can be grounded with as little resistance as possible (13.) This will trip the breakers as soon as possible. These underground networks are also useful because electricity during a fault will want to return to its source. Often that is the substation transformer, grounding paths help keep the transformer safe. Another key feature is that all the equipment is kept at the exact same equipotential (voltage) level (13.) This voltage consistency will ensure that current is not created by being touched by a person. The last way substations are made with safety in mind is they are surrounded by large fences or barriers and warnings so that citizens do not find themselves unknowingly messing with substation equipment.

Are We Ready?:

With all the encouragement and goals for pushing electric vehicles, it is worth asking if the current infrastructure is even capable of supporting such a large jump in the use of electric vehicles. As mentioned earlier the most effective charging method is the direct current, level 3 fast charger. However, these chargers pull a massive amount of power from the grid.

To find out more about this a conversation was arranged with a FirstEnergy Manager of Distribution Planning and Protection, Justin M. Price PE. Mr. Price has been working with FirstEnergy for over 15 years as an electrical engineer and has had several positions many of which involve grid analysis, design, troubleshooting, optimization, and modernization. His experience and expertise make him a trusted source for obtaining information on what exactly is expected from electric vehicles. He also gives insight into how a large company like FirstEnergy is preparing to handle this new imminent increase in demand. FirstEnergy was targeted as a source because of the large scale of the company as well as its prominence in the area of the University of Akron.

Constraint

One of the first topics of discussion was constraint. Constraint exists in all phases of the process of the production and delivery of electricity. This starts with the generation of electricity. According to Mr. Price PJM governs all of the ins and outs of constraint with generation (14.) With this, he was saying that it seems like generation is not an issue. It is hard to know exactly because of PJM's role in dictating production.

Substations offer the most prevalent amounts of constraints. This means that much of the equipment and technology involved could be constrained in some way. FirstEnergy and other companies study these substations using projected loads and load data from previous comparable times. Some kinds of constraints that they could face are in the constraint values for the equipment as well as transformer ratings. The equipment at the entrance and exits of the substation could also be constrained. All of the conductors as well as above and below-ground tech can all be constrained. Another large source of constraint is the service transformers for direct access for the customers.

Concerns

One of the most obvious concerns related to electric vehicles is the massive amount of energy consumed by chargers during times when consumption is already high. Peak hours of consumption are the summertime from about 2-6 PM (14.) This is when businesses are running at their peak, as well as many people arriving home from work and using their technology and other electrical needs. These combined with this range being when it is the hottest in the day and air conditioning is blasting make this a significant peak in usage. Consumers heading home from work or daily activities and stopping to charge or plug in their vehicle at home during this time could certainly be a problem. This could be a problem because this time of the day during summer is when most of the areas of constraint are potentially being tested. As mentioned earlier, much of the United States' infrastructure is rather old, and electric demand has only gone up. Winter peak consumption is usually around 6 AM (14.) This is when businesses are starting up and people are waking up and needing a warm home or business space. According to Mr. Price, the majority of the year is usually below 80% of what the summer and winter peak is in most all cases (14.) The system is really only constrained during the absolute hottest or coldest hours throughout the year. This is really only a few hours a day for a couple of weeks a year (14.)

Implementing at-home level 2 chargers is also concerning for electric providers. Line transformers usually provide electricity to a small network of homes in residential areas. These smaller transformers are made to handle the daily use of all of these homes and not much more. Just one home or small cul-de-sac of homes getting electric vehicles can be too much for the small line transformer. FirstEnergy has done research that was shared showing the possible effects of this. Using randomized probability and statistics they show that in a typical case sometimes it only takes a few chargers from one transformer to exceed the limits of its capabilities with proper factors of safety. When this happens they need to react and make adjustments to this network. This could involve shifting some of the power demand off of the current transformer to another nearby transformer that has not been maxed out. Other alternatives would be to add another transformer or replace the current transformer with one of larger capacity (14.)

Price shared his concern about the supply chain and the importance of being ahead of adjustments that need to be made. When discussing substations he mentioned that the transformers are very costly with about a $600,000 minimum for new. On top of the price tag, there is also currently about a 3-year wait on getting the substation equipment built and installed (14.) This is in part because there is a very small number of places that actually are capable of producing all the necessary components. The massive size and weight also make the equipment very costly and difficult to ship. This has causes FirstEnergy to make new connections to global suppliers to keep up with their demand (14.) This is why he stresses the importance of being in constant contact with the substation transformer and component producers to make sure they do not end up being too late.

It is also worth noting that Mr. Price made sure to include that the boost in electric vehicles is not the only concern for providers like FirstEnergy. The encouragement and popularity of electric heat pumps are on the rise for many of the same reasons as electric vehicles. These heat pumps are used as an alternative to burning natural gas to heat homes. Heat pumps are all electric heating and cooling for homes that are beginning to overtake furnace sales in the United States. These heat pumps also use a very considerable amount of electricity that was otherwise not needed in homes. Price made a comment that these heat pumps may even be worse for them than electric vehicles for the threat of needing to upgrade equipment (14.) This cause for concern is because they are only constrained around the hottest and coldest moments in the year. Electric vehicles will have usage diversity in regard to the time of charging whereas heat pumps will be using the most electricity during these peak periods to heat or cool homes or businesses.

Plan/ Possible Solutions

One possible solution that was discussed by Price was some are considering having time constraints or incentives for when electric vehicle owners are allowed to charge their cars. This would make it so that businesses would not be able to plug in until after a defined time like 6 PM. This would help make sure that the grid is not tapped out during peak summer times. However, this method has some faults and Price is certainly not sold on it. From a logistical standpoint, it does not make much sense to make consumers wait to plug their vehicles in. Constraint does not exist for residential consumers. Customers are not told not to run the air conditioning between the hours of 2-6 PM to save electricity. Price's main point was that holding off on the charging will realistically just cause new almost peaking hours that otherwise did not exist. For example, in the summertime nights get cooler and people are less active. This means that much less power is required during these times. These transformers that were just running at max all day get a chance to cool down in the nighttime before they ran hard the next day (14.) Limiting all charging to after a certain point means the transformers will have to work hard during this cool-down period. Price says that these transformers will be much more likely to fail if they do not get an adequate cooldown (14.) He also acknowledged that electric fleets such as Amazon vans already follow a pattern of being plugged in after the work day (14.) So if everyone is constrained to charging at say 6 o'clock it will be a lot of demand all at once. With fleets they know exactly when and about how much energy is required at plug-in times and are able to adjust and meet the demand for them. This would be significantly more unpredictable with regular customers.

FirstEnergy is doing all it can to stay ahead with projecting and planning what adjustments will need to be made. This is encouraging because they are well aware of these pushes for electric vehicles and know what their equipment is capable of. Although specifics of capabilities were not exclusively shown or stated it is obvious that the time to start upgrading is coming up very soon as the world is moving away from burning fossil fuels and toward electricity. Price did share a partial figure showing the different areas in need of above baseline spending in the near future. According to their projections, considerable and immediate spending will need to go toward the line transformers. This makes total sense with the residents putting in new chargers and heat pumps in their homes. Then in a couple of years, they will need to start spending more than baseline money on substation transformers (14.) Soon after that more money will need to be invested in upgrading the circuit (14.) Seeing the plan mapped out gives confidence that these companies are in fact very aware of what is happening with increasing demand and have set methods for handling it.

There was plenty of encouraging information shared in this conversation. One thing Price said was that he is confident that they will be fine in the short term. This means he does not foresee a problem in the immediate future that would cause something like blackouts or lack of energy being a problem soon. He also seemed pretty confident that the infrastructure is not capacity constrained. This meant he is not nervous that we will be using more energy than they can produce. However, he feels they may need to solve some problems with load diversity and finding a better time of use balance. Another good point that Price made is that this is not the first time that a large amount of load growth will be experienced and likely will not be the last. He mentioned that the 1960s era brought a large boom in load due to the implementation of central air conditioning going into most new homes. He pointed out that companies made it through that boom, and they should be significantly more prepared for one to arise now given all the technology and capabilities that they have now.

To conclude, unsurprisingly if the whole region bought electric vehicles and installed level 2 chargers in homes there would certainly be some huge problems. However, it seems that if the world takes time to transition like what is happening now, then these large companies like FirstEnergy will have time to make things work. After all the world using more electricity is good for the producer at the end of the day as long as they can handle it.

Sources:

1

https://www.un.org/en/climatechange/science/causes-effects-climate-change#:~:text=Fossil%20fuels%20%E2%80%93%20coal%2C%20oil%20and,of%20all%20carbon%20dioxide%20emissions.

2

https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#:~:text=CO2%2F%20gallon-,How%20much%20tailpipe%20carbon%20dioxide%20(CO2)%20is,emitted%20from%20driving%20one%20mile%3F&text=2%20per%20mile-,What%20are%20the%20average%20annual%20carbon%20dioxide%20(CO2)%20emissions%20of,of%20carbon%20dioxide%20per%20year.

3

https://cleanenergygrid.org/our-outdated-grid/

4

https://www.iea.org/reports/electric-vehicles

5

https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/

6

https://drive.ohio.gov/about-driveohio/news/ev-funding

7

https://www.govtech.com/fs/california-is-primed-for-a-massive-build-out-of-ev-charging

8

https://drive.ohio.gov/wps/wcm/connect/gov/4a58a392-917f-4735-8438-bfdbb3f0b7bd/2020-06-26_EV_Charging_Study.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=ROOTWORKSPACE.Z18_M1HGGIK0N0JO00QO9DDDDM3000-4a58a392-917f-4735-8438-bfdbb3f0b7bd-obUPMs1#page48

9

https://www.youtube.com/watch?v=v1BMWczn7JM

10

https://learn.pjm.com/

11

https://puco.ohio.gov/utilities/electricity/resources/how-does-ohio-use-electricity

12

https://www.youtube.com/watch?v=qjY31x0m3d8&list=RDLV7Q-aVBv7PWM&index=2

13

https://www.youtube.com/watch?v=7Q-aVBv7PWM&list=RDLV7Q-aVBv7PWM&index=1

14

Primary source. Justin M. Price PE Manager of Distribution Planning and Protection.