Analysis of the Recent Growth of the Electric Vehicle Market, and the Environmental Costs of EV Battery Production vs. Carbon Emission Reduction

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

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Introduction

In the global automobile industry today, electric vehicles (EVs) and hybrid-electric vehicles (HEVs) made up 20% of vehicle sales in the United States in 2024 (Wayland, 2025). Although traditional internal combustion engine (ICE) vehicles still hold a majority of the market, this landmark makes it clear we are entering a new age in the automobile world, not only in the United States, but around the world. According to J.P. Morgan estimates, ICE vehicles accounted for 98% of the global vehicle market in 2015, but this number is forecasted to drop to just 41% by 2030, effectively being dominated by electric and hybrid automobile options (J.P. Morgan, 2018). Considering the tenure of the ICE in the world of automobiles, this shift in the market, being so drastic and over such a short period of time, is remarkable. The interesting element of this situation is the fact that the invention of the first practical electric vehicles was as early as the 1840's (Deal III, 2010). Yet the meteoric rise of the EV and its related alternatives has been exclusively in the last few decades. This timing and swiftness could be attributable to technological developments, the increase in environmental concerns and sustainability, improvements in EV performance, or a number of other factors. This paper analyzes the aforementioned EV market growth using a Hughsian systems analysis, as well as an Actor-Network Theory (ANT) framework approach.

Undoubtedly, one of the major factors that contributed to the growth of the EV market is the increased awareness in sustainability in the 21st century, and the reduction of carbon emissions through the use of EVs. Using an EV effectively eliminates the carbon dioxide contribution, as there are no tailpipe emissions as in typical ICE vehicles. This reduction in emissions leads most of the general public to believe that for those concerned about sustainability and taking care of the environment, going electric is clearly the more desirable option for automobiles. However, there are aspects of EVs, specifically regarding the production and disposal of the lithium-ion batteries they utilize, whose environmental repercussions are little-known and less comprehensively understood. This paper analyzes the environmental consequences of ICEs and EVs, specifically the carbon emissions of the ICE and the ecological effects of the EV lithium-ion batteries, and provides a recommendation on how the environmentally conscious should go about choosing their vehicle.

Hughes's Systems Analysis

Thomas Hughes is one of the United States's most accomplished historians, writers, and engineers. In one of his well-known literary works, Networks of Power: Electrification in Western Society, 1880-1930, Hughes analyzes the growth and expansion of the electrical power networks of the United States from the late 19th to early 20th century. Hughes focuses on the different social, technological, and economic factors attributing to the rise of the electrical power system in America, with emphasis on the complex integration of the different components and their contribution to the technological system. The work looks at individuals who played a role, such as Thomas Edison and George Westinghouse, political influences, like government regulations and business interests, and technological choices, such as alternating current (AC) vs. direct current (DC), among other factors. This book is a perfect example of the application of Hughes's systems analysis framework, which he describes in detail in another book of his, The Evolution of Large Technological Systems.

Hughes's systems analysis revolves around the concept of the "Large Technological System," which is a complex infrastructure of components surrounding a technology, that includes not only the technology itself, but also other factors. These factors can be, among other things, social structures like politics or labor forces, external technical factors and supporting technology, or the organizational structures involved in the establishment, maintenance, and growth of the system. Therefore it is important for the system in question to not only be large in scale, serving large demographics and geographic areas, but also consist of many components, all of which interact with one another interdependently. The different components must be diverse in that they exist in different dimensions of society. So said components should not only be of the technological kind, but also be composed of social, political, and economic forces, for example. Hughes's systems analysis takes all these different constituents and analyzes how their functions and interconnections work together to contribute to the system as a whole.

An important aspect of Hughes's systems analysis is the examination of how the system under consideration evolves over the time period in question. As time goes on, new technology is developed, and social and political landscapes change, so technological systems must also grow and adapt. This often requires significant problem solving to overcome challenges, adaptation to changing environments and business landscapes, and significant expansion, all of which is analyzed through Hughes's system analysis. Some other key aspects of Hughes's systems analysis are the concepts of technological momentum and path dependency. Technological momentum refers to the tendency of a technological system which is already in place to gain "momentum," continuing to expand, while simultaneously making it more difficult for any other option to challenge its position. Path dependency refers to the significance of early design choices of large technological systems, and how an early set course is difficult to change down the line. These concepts are important aspects of Hughes's systems analysis framework, and are tools that provide valuable insight into large technological systems throughout history.

Hughes's systems analysis is a suitable framework for the analysis of the EV market surge in the past few decades. The technological system of the EV certainly qualifies as a complex, large technological system. Besides the technology itself, there are several diverse components involved in the system like government policies, various social factors, and economic forces. The EV technological system has also certainly dramatically evolved over the time period, technologically, infrastructurally, and otherwise. The aforementioned concepts of momentum and path dependency also make the EV an apt topic for a system analysis. EV technology has certainly gained significant momentum in a short amount of time, and has many defining design choices that have significant impact on the trajectory of the technology. Therefore Hughes's systems analysis framework provides an interesting perspective on the EV technological system.

Actor Network Theory

Actor-Network Theory (ANT) is another framework of analysis, used in multiple works of literature by many accomplished historians and sociologists, such as Bruno Latour and John Law. In Law's piece Technology and Heterogeneous Engineering: The Case of Portuguese Expansion, he utilizes this approach to analyze Portugal's colonial expansion in the 15th and 16th centuries. Latour, in a similar way, explores the technological process of pasteurization in his book The Pasteurization of France. ANT operates on the belief that science, technology, and society are intertwined through networks consisting of various actors and their interactions. The main tenet of ANT is that all factors, both human and non-human, contributing to the network in question are treated as "actors." The behavior of these actors and how their interactions shape and alter the network are then studied. For example, in The Pasteurization of France, Latour studies not only Louis Pasteur as an actor, but also considers non-human actors, such as fermentation experiments and laboratory infrastructure, and their influence, considered equally in the network of the spread of pasteurization.

ANT scrutinizes the interactions between the various actors in a network, leading to a few concepts being emphasized in the analysis. One of these concepts is the power of actors relative to one another. Oftentimes in these networks, some actors hold greater influence over the trajectory of the network than others, and this power dynamic is an integral part of ANT. ANT analysis also considers actors aligning their interests and forming alliances around certain technologies, constructs, or projects, which is often referred to as translation. Translation is key when looking at the interactions between actors because it often involves compromise and negotiation, a point of emphasis in ANT. The consideration of both human and non-human actors and their interactions makes ANT a powerful tool for analyzing social, technological, and economic networks.

ANT is an appropriate analysis approach for the EV market due to the wide variety of components that contributed to the propulsion of the EV in the last couple decades. As far as human actors are concerned, environmental organizations and automobile manufacturing companies are considerable, whereas for non-human actors things like the EV charging infrastructure, lithium-ion batteries, and global warming are significant factors. ANT is a perfect approach to examine the behaviors of and interactions between all of these actors and more. The concepts of translation and power are also certainly relevant to the EV market. Using ANT to understand the EV market through the network of actors and their interplay helps one understand how and why the EV made such a meteoric rise in recent years.

Key Similarities and Differences Between the Two Frameworks

Utilizing both Hughes's systems analysis and ANT to analyze the EV in the last three decades may seem redundant to some, as the two frameworks have lots of important similarities. Both frameworks focus on analyzing the relationship between technology and socio-economic factors. They also recognize that technology does not operate alone, but is involved in large systems or networks with both human and non-human components. The complex interactions between these components and the technology and the impact they have are a key focus of both analysis methods. These similarities are part of the reason why these frameworks are so applicable to the topic at hand.

However, there are some key differences which provide an interesting perspective on said topic when the techniques are used alongside one another. The primary difference between the two approaches is the importance given to the different components of the system or network under analysis. Hughes's system analysis tends to give more agency to the human components of the system, such as engineers, designers, and executives, with non-human components being seen more as supporting tools or facilitators. Whereas on the other hand, ANT views all actors in the network equal agency, viewing the non-human actors as active contributors to the network. In a system analysis, the technology is also often viewed as just a component of a larger system, whereas in ANT the technology is an actor with its own influence in the network. These fundamental differences between the two methods of analysis provides some interesting conclusions when considered in parallel.

Another important contrast between Hughes's system analysis and ANT is the scope of each method. System analysis views the system from a high level perspective, looking at the entire system as a whole. This macro-level point of view allows the analyst to better understand how specific components fit into the complex system, as well as observe the evolution of the system over time. ANT focuses much more on micro-level interactions between specific actors within the system, and how said actors' behavior propagates development and change throughout the network. Therefore ANT is less concerned with the network as a whole, but rather local relationships and exchange between actors. The different perspectives provided by the different frameworks is useful to get a full understanding of the technological system and the network surrounding it.

Background Information

The Shift from ICE Vehicles to EV

The four-stroke ICE was first developed in 1876 by Nicholas Otto (Ferguson 2015), and has been the primary source of power for transportation vehicles since the early 20th century. The ICE vehicle has effectively dominated the automobile industry without any significant competition for a great while. However, since the beginning of the 21st century, there has been a significant shift in the transportation industry toward EVs and HEV options. The popularity of EVs and related alternatives has spiked in the last few decades, and the market is reflecting as such. Sales of EVs and HEVs alike have experienced a significant increase in recent years (see Fig. 1), with fully electric options seeing borderline exponential growth. In 2022 alone, EV sales in the United States increased by 55% (Pickett, 2024). This trend of growth is expected to continue for the foreseeable future, according to various forecasts (see Fig. 2). Some organizations such as JPMorgan even expect EVs and similar options to overtake ICE as the prominent force in the automobile market as early as 2030, which is astonishing considering the dominance the ICE vehicle has held over the industry throughout history.

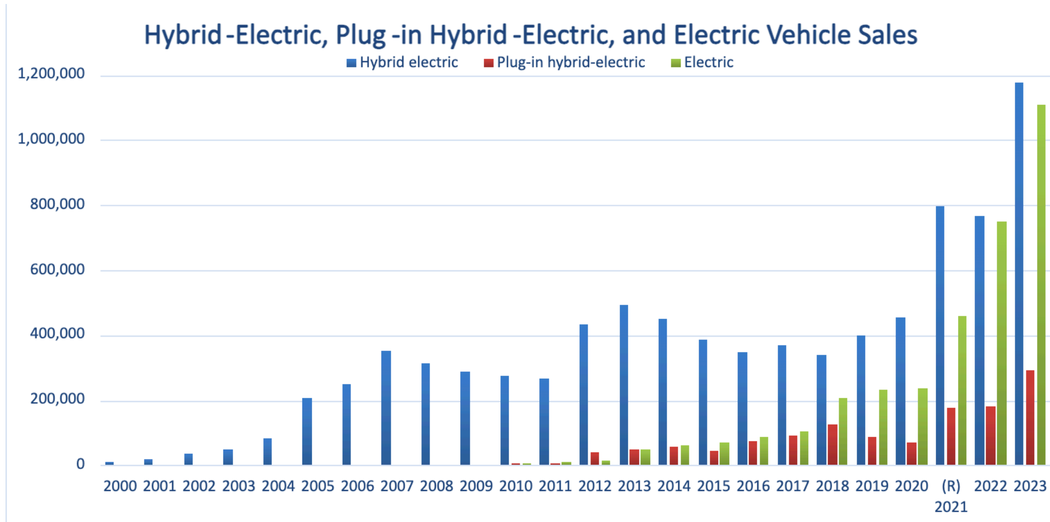

Fig. 1: Electric & Hybrid Vehicle Sales Since 2000 in the United States (BTS, 2024)

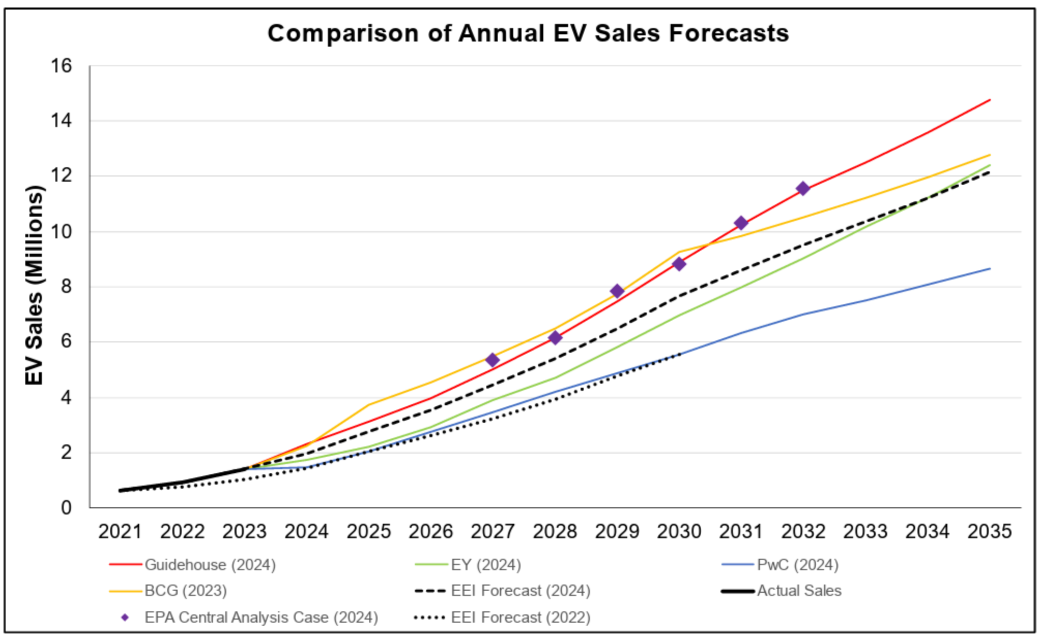

Fig. 2: Annual EV Sales Forecast Comparison (EEI, 2024)

The Growth of EV Technology

While the practical EV has existed for quite some time, the EV itself has seen some significant improvements in recent years. One significant component of the EV that has seen light years of improvement recently is the battery technology, with the lithium-ion battery's introduction. Prior to the lithium-ion battery, EVs primarily used lead-acid batteries, which led to limited range capacity, such as the General Motors EV1, which only had 74 miles of range (USCCG, 2024). Then Tesla revolutionized the EV in 2008 with its Roadster model, which had over 200 miles of range with its lithium-ion battery (USCCG, 2024). This led the way for other models, like the Nissan Leaf in 2010. EV battery technology has only continued to improve, with range and performance improvements across the board. HEV and other related options only bolstered the popularity of electric power, as in most cases they match up to, if not surpass, gas-powered vehicles performance wise (see Fig. 3). And as EV technology continues to improve, their economic feasibility also has been increasing. As batteries get cheaper and more efficient, the cost of EVs is following suit. Recent studies also show that in terms of fuel costs for the average consumer, EVs cost 75% less than ICE vehicles (Venugopal, 2022), with additional maintenance related savings over the vehicle's lifetime. More automobile manufacturing companies have also embraced the technology, developing more EV and HEV model options for consumers. The electric car charging infrastructure has also improved in recent years, with more and more charging stations available, partially thanks to government legislation such as the Infrastructure Investment and Jobs Act of 2021 which allocated $7.5 billion to the construction of a nationwide charging network (Colato, 2023). Lots of other policies and legislation has been put into place at various levels of government incentivizing the use of EVs, to work towards reduced emissions and combating climate change.

	ICE			HEV		
Parameter	**Toyota Camry**	**Audi A3**	**Honda Accord Sport**	**Toyota Camry Hybrid**	**Audi A3 E-Tron**	**Honda Accord Hybrid Sport**
Fuel capacity (liters)	50	50	56	50	54.8	48.4
Fuel efficiency (Kmpl)	17.4	19.2	13.6	22.5	30	18.2

Fig. 3. Comparison of HEVs and IC Vehicles (Venugopal, 2022)

Climate Change and the Sustainability Movement

Climate change, especially since the start of the 21st century, has established itself as the most pressing issue facing life on the planet Earth. In fact, according to NASA, global warming is proceeding at a rate not seen in millennia (NASA, 2024). A central contributor to this is human activities burning fossil fuels and producing atmospheric gases, such as carbon dioxide, that create a greenhouse effect in Earth's atmosphere, trapping the Sun's energy. Today the atmospheric concentration of CO2 is significantly greater than it has ever been (see Fig. 4), and is increasing more than 250 times faster than it did due to natural sources after the last ice age (NASA, 2024). While the sustainability movement has existed for quite a while throughout history, the devastating effects of climate change, such as severe weather and rising sea levels, have led to the amplified emergence of sustainability efforts in recent years. Today there are more policies and legislation in place, greater networks of outreach and support, and research and development than ever before, all geared towards the purpose of protecting the planet.

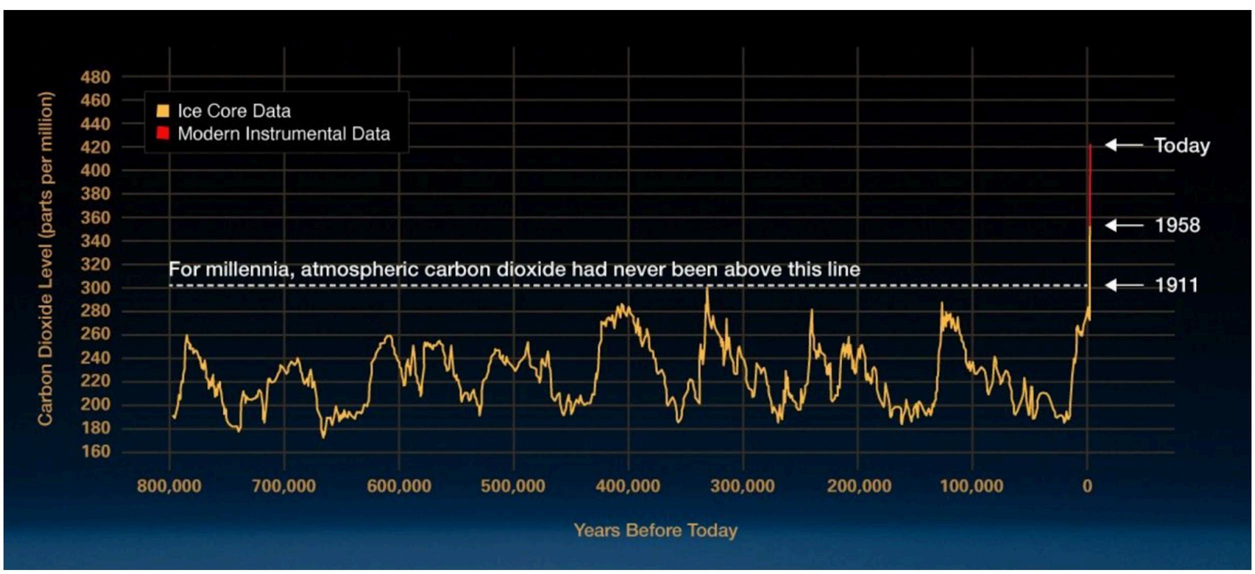

Fig. 4: Carbon Dioxide Level in the Earth's Atmosphere Over Time (NASA, 2024)

STS Analysis

Hughes's Systems Analysis

To use Hughes's systems analysis approach to analyze the EV's large technological system since the start of the 21st century, first the components of the system under consideration must be defined. The technological components of the system are the EVs and their supporting technology (batteries, software, and vehicle design), and the charging infrastructure (charging station, home charging options, fast-charging technology). The social components are a bit more nuanced, but in this analysis those under consideration include consumer behavior, sustainability movement and awareness, and political stakeholders and legislation. Finally the economic stakeholders include those on the selling end (automakers, energy companies, raw material suppliers, and battery manufacturers), those on the buying end (consumers), and others involved (service providers, auto dealers, and financial institutions).

The evolution of EV technology has been stark over the past 25 years. The early challenges that EVs faced for so long with range capacity and high vehicle costs were solved with the development of the lithium-ion battery. This along with improvements in energy efficiency technology paved the way for milestone EV models which demonstrated EVs as high performance and a viable alternatives for ICE vehicles.

When considering the technology, it is important to look at design decisions which spurred the immense growth in popularity. For the EV, the most influential design decision has been the aforementioned development of the lithium-ion battery. Although many consumers may have considered EV options in the past as an effort to be more sustainable, before the lithium-ion battery technology was adopted to EVs, the risks associated with battery life and cost were too great to ignore. However, with the lithium-ion battery's introduction, these concerns were alleviated, and the EV became a more feasible option, changing the trajectory of the system immensely.

The social, economic and technical elements of the system, their mutual influence of one another, and their interactions are very important to the swift evolution of the system. The growing concern with climate change in the 21st century has been accompanied by the rise of sustainability movements. These movements have promoted governments, companies, and individuals alike to make efforts to reduce their carbon footprint, and move away from fossil fuel use. This social pressure has led to across the board investments into EV technology, as a means to reduce emissions. As consumer demand for sustainable options increases, automakers become more motivated to develop the technology to meet this demand. Governments, as representatives of the common people, also have taken action, establishing more policies and legislation encouraging EV use and technological development in the industry. This also motivates automakers to invest in research and development in the technology, spurring more improvements in both the technology and the infrastructure. Improvements in technology and infrastructure lead to further implementation and adoption among consumers due to both convenience and quality of the product, which expands the network and further increases the demand. This positive feedback loop between the different socio-economic components of the system brings about rapid growth of the system.

Subsystems within the EV network are also worth considering. The EV industry, that is to say manufacturers, suppliers, research and development teams invested in EV technology, have over a short period of time grown significantly. Prior to the 21st century, the EV was an expensive and inefficient niche in the automobile industry as a whole, but now it has grown into a significant player in the industry. The energy and charging infrastructure has similarly expanded. Again, parallel to the increase in sustainability efforts, more renewable energy sources have been developed, these power sources along with the EV have increased the sustainability appeal of the technology, promoting the growth of the system. Finally the growth of the charging infrastructure has been essential to the growth of the EV. With more charging networks, both public, private, and even at home-charging options being established, the mass adoption of EVs becomes even more popular. This is another example of a positive feedback loop, as the adoption of EVs drives the need for more charging stations, and the increased convenience of charging makes EVs more practical and attractive to the average consumer.

Now that the interactions between the different components in the EV system are better understood, the power dynamics throughout the system are considered. The evolution of the EV has been spurred by environmental advocacy groups, industry players, and governments alike. However, there are certain entities that may hold more power than others in the system. The sustainability movement and environmental advocacy groups have spurred the public desire for emission reduction, leading to the propulsion of EV technology research, development, and implementation. But as the market grows, more conventional corporate entities are investing more and taking more control. Currently in the industry, certain automakers like Tesla have a dominance over the market currently, giving them greater influence over technological development and infrastructure deployment. As the EV continues to be more widely adopted, and other automakers increase their stake in the industry, this dominance could be challenged, and the effects of which will be quite vital to the trajectory of the system. Government legislation and regulations related to reducing emissions and the use of EVs have also been instrumental to the growth of the system. As the industry grows, the interaction between the policies and the industry players will also be an important factor in the system.

The EV system's growth is undeniably tied to values of sustainability and environmental responsibility. As climate change continues to take place, and awareness of the issue grows, the drive to be more sustainable does the same. The societal norm has shifted to one of being environmentally conscious. This social pressure for environmentally friendly options has driven the dramatic increase in EV technological improvements and consumer adoption. Now EVs are a viable alternative to ICE vehicles, have a comprehensive charging and service infrastructure that continues to expand, and more models and hybrid options available than ever before. As far as the EV system is concerned, since the issue of climate change continues to persist and influence public opinion, the government, and industry, the technological momentum the EV has gained will not be stopping anytime soon.

Actor-Network Theory

Using ANT to analyze the EV network begins with the identification of the human and non-human actors in play. The human actors under consideration include: sustainability activists and organizations, consumers, automobile and battery manufacturers, governments and policymakers, and investors. On the other hand, the non-human actors in the network are: EVs, the charging infrastructure, energy grid, lithium-ion batteries, climate change, renewable energy sources, and EV and climate related legislation.

The threat of climate change has powered the rise of sustainability movements across the globe, giving way to numerous activist organizations. These activist organizations are a key actor in the EV network. By influencing public opinion, their social pressure has pushed governments, industries, and the general public to take action to reduce emissions. The relationship between the EV and sustainability activists is also key. By framing the EV as a method of reducing carbon emissions due to the lack of tailpipe emissions, the EV has become tightly associated with the transition away from fossil fuels, especially in tandem with renewable energy sources like solar and wind. The sustainability organizations as an actor play a major role in the network as their promotion of the EV combined with the social pressure to move towards sustainability has encouraged the consumers, manufacturers, and governments to invest in EV technology as a means to reduce emissions and combat climate change. This is an example of translation within the network, as the different aforementioned actors have transformed their behavior to align with the other actors in the network, working towards a common goal.

As the governments embrace and promote EV technology, they write and employ policies and legislation that contribute to the network. Legislation promoting greener manufacturing practices has been around for a while, but along with the push for sustainability in recent years, governments have established more strict regulatory policies for manufacturers and clean vehicle production. This increases the demand in the market for EVs and promotes research and development into the technology across the industry. Policies also exist that provide tax credits and other incentives make the EV a more attractive option to manufacturers and consumers alike. Other legislation contributes to the expansion of the charging infrastructure for EVs. This expanded charging network is another factor contributing to the widespread adoption of EVs, with more convenient charging abilities and less concern of being stranded without power. The governments and policymakers use legislation to mediate between the sustainability activist organizations, whose primary concern is combating climate change, and the automobile manufacturers and industry investors, who are focused on meeting consumer demand and making money. These policies and legislation serve to direct the trajectory of the different actors in the network towards compromise with the common goal of EV implementation and in turn, emission reduction.

The EV network's expansion is also largely due to technological improvements to the technology itself over the past 25 years. The early issues that faced EVs, like low range and high cost, have been solved by other actors in the network. Thanks to the collaboration between researchers, battery manufacturers, and automobile manufacturers, a new technology was produced, the lithium-ion battery, with higher energy density, better rechargeable capacity, and lower production costs. The introduction of the lithium-ion battery to the EV network completely changed its trajectory, with the new EV models becoming much more attractive to manufacturers and consumers. Other developments in EV technology include automobile manufacturers developing different models of EVs, giving the consumers more options. More options expands the potential consumer base of the EV, giving the technology more popularity and expanding the network further. Other technological actors that played a role include the charging network and the energy grid. The improvement of these components made EVs a more feasible option for the typical consumer. All of these technological improvements were brought about by the cooperation of the different actors, as they aligned their interests towards improving EV technology. This cooperation involved compromise and innovation, to work towards sustainability while maintaining high performance standards, cost effectiveness and convenience for the consumers.

After seeing how the different actors in the network are interconnected and influence one another, it is easier to analyze the power dynamics of the network and how they have evolved over time. For one, the powerful companies in the market have been largely shaped by investors, providing the financial backing for research and development into EV technology early on in its growth in popularity. Government policies have also shaped the system, often favoring companies with already established stakes in the EV network. Clearly the growth of the EV network and the widespread adoption of the technology is a result of synergistic contributions from a variety of human and non-human actors. Collaboration and compromise between manufacturers, consumers, and sustainability activist groups, driven by developments like the lithium-ion battery, charging networks, and emission reduction legislation, have all contributed to the evolution of the EV network. However, the lynchpin of the entire network is the danger of global warming and the social desire to be more environmentally conscious. Government legislation supporting EVs is rooted in reducing emissions. For consumers, the desire to use EVs as opposed to traditional ICE vehicles is grounded in the desire to reduce carbon footprint. And the automobile manufacturers who develop the cars are doing so to meet consumer demand and abide by government regulations, which, as previously mentioned, are driven by sustainability efforts. Sustainability drives the EV market's growth and popularity, and as long as global warming persists and climate change threatens the planet, the technology will continue to improve and the network expand.

Insights From the Different Frameworks

Using both Hughes's system analysis and ANT to analyze the EV since the beginning of the 21st century gives different perspectives and a better understanding of the socio-technical system. System analysis gives us a more historical view of the EV, with a broader scope of analysis, looking at the system as a whole. It tells us how the different components of the system have all contributed to the momentum the EV has garnered over the past 25 years. ANT on the other hand takes a closer look at the more specific interactions within the system, looking at both the human and non-human aspects of the EV network as equals. Both approaches provide insight on the evolution of the technology, power dynamics between the various stakeholders, and the trajectory of the EV moving forward. Both approaches agree that the most pivotal constituent of the growth of the EV is the sustainability movement of the 21st century. The reduction of emissions from the use of EVs has propelled the technology into a position synonymous with sustainability. This framing, however, does prompt some important questions regarding the comprehensive environmental effects of EVs, and more specifically, the lithium-ion batteries they operate with. Although the general opinion seems to be that EVs are the better option environmentally since they don't produce greenhouse gases, due to the consequences of lithium-ion battery production and disposal, it remains to be seen whether or not the overall effects are comprehensively better for the environment.

Environmental Impact Assessment

Traditional ICE Vehicle Emissions

The emissions from a traditional ICE vehicle produce carbon dioxide, which is an example of a greenhouse gas. Greenhouses gases, the buildup of which causes more of the sun's energy to be trapped within the atmosphere, causing global warming. Carbon dioxide is the most abundant greenhouse gas in the Earth's atmosphere, making up 82%, according to the most recent U.S. Greenhouse Gas Emission and Sink Inventory (EPA, 2023). In 2022, the transportation sector was the top contributing sector of greenhouse gases with 28%, and of that 28%, 57% was from light-duty vehicles, or passenger cars and trucks (EPA, 2024). That means that from a total of 6,343.2 million metric tons of carbon dioxide in 2022 (EPA, 2025), 1776.1 million metric tons was produced by the transportation sector, and 1,012.4 million metric tons of that by light-duty vehicles. A typical ICE passenger vehicle emits 4.6 metric tons of carbon dioxide every year (US EPA, 2024). While each individual car may seem insignificant in the grand scheme of things, with the wide adoption of EVs, the reduction of carbon emissions would certainly be a considerable step in the right direction towards combating climate change.

EV Lithium-Ion Battery Production and Disposal

However, the aspect of EVs that contradicts the general consensus of their sustainability resides in the production and disposal of their lithium-ion batteries. For one thing, the material mining and refining process, and the manufacturing of the batteries themselves requires significant energy, the generation of which produces greenhouse gases. Although some may argue that the production of standard ICE vehicle batteries also requires energy, the production of a lithium-ion battery for an electric car requires three times the cumulative energy demand than a regular car battery (Kim, 2022). For example, according to MIT Climate, the production of a single 80 kWh lithium-ion battery, the typical battery used in the Tesla Model 3, would produce up to 16 metric tons of carbon dioxide in emissions (Crawford 2022). Mining lithium also has ecological implications that need to be considered. The process requires large quantities of water and energy, and produces large amounts of mineral waste (Tedesco, 2023). It can also have adverse effects on the hydrological cycle and in turn, the surrounding ecosystems. Other issues arise further when the batteries reach the end of their lifespans. When obsolete lithium-ion batteries reach are put in landfills, they release toxins, and are high risks for long-lasting landfill fires (IER, 2023). The batteries can be recycled, but as of right now the recycling process requires harsh chemicals and high heat, demanding processes. According to Princeton University, only about 5% of used lithium-ion vehicle batteries are recycled in the U.S. today (Seltzer, 2022). Significant amounts of research and funding is being poured into more sustainable mining, production, and disposal and recycling practices for these batteries, as well as other battery possibilities. But until progress is made to those ends, it is important to consider the adverse effects of lithium-ion batteries in EVs when making vehicle decisions based on sustainability.

Conclusion & Recommendation

This paper has explored the EV and the different socio-economic components of its technological network, utilizing Thomas Hughes's system analysis and Actor-Network Theory as frames for analysis. Hughes's system analysis looked at the EV from an overarching, high-level perspective, focusing on how the different components have affected the technological evolution and growth as a whole. ANT on the other hand took a closer look at the actors, both human and non-human, within the EV network, their individual interactions with one another, and how said interactions have shaped and expanded the network. The two different frameworks drew similar conclusions regarding the growth of the EV in the last 25 years. The central motivating factor behind the widespread adoption and technological development of the EV was determined to be sustainability activism and the social pressure to be more environmentally concisous. It was also surmised that as long as global warming continues to threaten humanity, and the EV remains synonymous with sustainability in the public eye, the technology will continue to evolve and become more widely utilized.

As a continuation of this conclusion, this paper also investigated the true magnitude of both emissions due to ICE vehicles and the production and disposal of EV lithium-ion batteries. Through this exploration, the effect of ICE vehicle emissions on climate change was better quantified, and the less well known environmental consequences of EV battery technology were better understood. Due to the dissimilarity of many of the respective consequences, it is unfortunately very difficult to quantitatively weigh the two against one another. However, it is indisputable that both ICE vehicles and EVs have a negative impact on the environment in their own respective ways. With the immense funding currently being allocated to EV research and development, perhaps there will come a day when the EV is unequivocally better for the environment than the traditional ICE. Until then, when consumers are considering between the two options, it is important they make informed decisions and not buy an EV for the sole reason that society says it is good for the environment.

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