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Review

Understanding the Future Impacts of Electric Vehicles—An Analysis of Multiple Factors That Influence the Market

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Abstract: The electric vehicle market is an increasingly important aspect of the automotive industry. However, as a relatively new technology, several issues remain present within the industry. An analysis is utilised to examine these issues, along with how they affect the industry and how they can be tackled. Several key issues that affect the electric vehicle market, as well as how efforts to address these issues influence the market, are identified. The analysis also includes the examination of ethical issues, with the issues that arise from the production of raw materials for electric vehicles. The analysis and examination of ethical issues display a wide range of problems in the industry. However, it did highlight the efforts being made to lessen the effect of these problems by various groups, such as regulation by EU and US governing bodies on the materials mined. From this analysis, this paper identifies that many of the other factors examined are directly or indirectly influenced by political and economic factors, also examined in this review. This highlights the impact that governing bodies and businesses have on a vast number of issues that are present within the market and how they can resolve the harmful factors examined.

Keywords: automotive; electric vehicles; ethical; batteries; political; technological; social; economic; environmental; legal

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1. Introduction

The electric vehicle market covers a wide range of vehicles and processes, including battery electric vehicles (BEVs), fuel cell-powered vehicles and hybrid vehicles, which typically combine one of the previous technologies with an internal combustion engine. There has been an increase in electric vehicles on the road, with numbers increasing to 7.2 million BEVs and plug-in hybrid passenger cars on the road in 2019 from around 2 million in 2016, with yearly sales also experiencing a 30% increase over that time [1]. This represents a step forward in decarbonising transportation systems.

Alongside the vehicle market is the infrastructure needed to allow the purchased vehicles to be charged, with 7.3 million charging points available globally [1]. However, 6.5 million of these are private chargers rather than publicly available ones (with charging points in workplaces and multiple occupancy buildings being considered private [1]. This may be harmful to the practicality of electric vehicles as limited public charging points can reduce the distance a vehicle can cover based on the driver's access to these private chargers and how those chargers are spread out along a long journey. This is more likely an issue for more rural areas and journeys between isolated urban centres, as can be the case with some US states. The proliferation of petrol stations across the world shows the importance of refuelling infrastructure to the transport industry. The lack of readily accessible charge points has likely helped to fuel concerns from consumers about buying or using an electric vehicle, with other concerns relating to the compatibility of a vehicle with a charge point [2,3]. These concerns range from different charger connectors needed for different electric vehicles to the absence of a standardised payment system for using the charge points [2,3].

These changes in the market have been influenced by a variety of elements [1]:

- Economic, e.g., changes to the overall size of the passenger vehicle market;
- Political, e.g., reduced subsidies for electric vehicles in key markets;
- Technological, e.g., customer expectations as to improvements to the technology.

Additionally, technological improvements have already contributed to the dropping cost of battery production for electric vehicles, with costs per kWh dropping from USD 1100 kWh^{-1} in 2010 to around USD 137 kWh^{-1} most recently [4,5]. Some batteries are now being sold for less than USD 100 kWh^{-1} in 2020, with new pack designs being one of the contributing factors [4,5]. However, other factors also attributed to this fall, including the increase in electric vehicle sales and increased order sizes from battery manufacturers [4,5].

It is becoming increasingly important to understand how the changing market situation affects society in more detail than just economic impact or carbon emissions. There are many other factors to consider when thinking about the overall impact of electric vehicles or other technologies. By having a clear understanding of these factors, mitigation strategies can be developed to ensure that the decarbonisation of transport can continue without unnecessary barriers, reducing the overall impact of climate change in the long term.

To truly understand how electric vehicles are influencing society now and in the future, an examination of several different factors is required. The major factors examined in the analysis include political, economic, social, technological, environmental and legal factors [6]. It is also important to include ethics due to several relevant ethical issues that influence electric vehicle batteries, relating to the production of raw materials for battery production [6]. There is a lack of papers that discuss the different factors that influence the electric vehicle market, along with how they relate to each other, which is a niche this review should help fill.

2. Materials and Methods

To properly examine these areas, the research needs a question to formulate the search around. For this, the query of "What factors affect the electric vehicle industry, how do they affect them and what actions are or can be taken to provide the best outcome?" was used as the base research question.

A search was conducted to find appropriate sources to analyse the above factors in the EV industry, drawing from a wide range of sources and information. Additionally, legal sources were able to provide information on how laws and regulations have changed [7], with both the UK and EU governments providing online records of their laws and regulations [8,9]. As some factors, such as political factors, can often be heavily dependent on personal opinion, sources from some groups, such as political think tanks, were examined, with bias noted where appropriate.

Non-peer reviewed sources were also included, although an examination of the reliability of the publication was also conducted, with groups such as the International Energy Agency (IEA) being one considered reliable. Papers, reports and sources that were published during or after 2010 were examined as the past decade has been significant in the electric vehicle market, although preference was given to more recent publications. A few exceptions were made to this criterion, although this was only to examine past initiatives in the electric vehicle market or to support a point that is still applicable in the industry today. Many sources focused on the United Kingdom as well as the electric vehicle market worldwide. Sources focusing on other nations were also used, mostly to look at different actions taken there and their effect on the electric vehicle market or due to important parts of electric vehicles being produced there, such as the battery materials used.

For searching the literature, scientific databases of papers and journals, such as Science Direct, were utilised to examine a range of published pieces relating to the various factors examined in this analysis. Search engines, such as Google and Bing, were also used, although this was to access organisation websites for the information present there, including the government websites of the United Kingdom or company websites such as those owned by Umicore. To find appropriate papers, a range of search terms was used to narrow down the search to the desired scope, with Table 1 displaying those used.

Table 1. Search terms, synonyms, acronyms, and alternate and related phrases.

Search Term	Synonyms, Acronyms, Alternate and Related Phrases
Electric vehicles	Electric cars, electric buses, EV's, cars, vehicles, automotive
Factors	Impacts, causes
Batteries	Cells, lithium-ion, sodium-ion, Li-ion, Na-ion
Organisations	Manufacturers, companies, institutions, governments, groups, businesses
Materials	Minerals, cobalt, lithium, sodium
Drivetrain	–[a]
Range	Capacity, distance covered
Political	Think tanks, politics, policy, laws, acts, regulations, standards
Economic	Monetary, business models, investments
Social	Societal, community
Technological	Innovations, improvements
Environmental	Life cycle assessment, environmental impacts, LCA, global warming potential, GWP
Legal	Law, agreement, treaty
Safety	Safe, safety standards
Patent	–[a]
Ethics	Ethical, moral, morally

[a] No additional keywords used.

These keywords were used in conjunction with the limitations of the search to find appropriate data for the review, with the different search functions when considering whether the search term was present in the title or bulk text. They were often used in combination with each other to pinpoint texts with the desired information. Once found, the documents, reports and texts containing this information were examined, with areas of interest noted within them and examined further to find relevant information. This process was enhanced in the digital sources with the use of the find function to search the texts more thoroughly for appropriate keywords.

3. Analysis of Relevant Factors

3.1. Political Factors

Many governments have made investments in the research and development of electric vehicles. In the UK, the Air Quality Plan states a commitment to end the sale of conventional petrol and diesel vehicles by 2040 [10]. The UK government has helped to establish the UK Battery Industrialisation Centre (UKBIC) with assistance from local governments and the WMG (University of Warwick) [11]. The UK government has given a target of 2.4% of GDP for research and development by 2027 and a clear commitment of GBP 246 million to research the next generation of batteries [10]. This has assisted in the examination and production of both new batteries and battery chemistries, which can be useful in solving issues with the current electric vehicles, such as increasing energy storage, which, in turn, increases the vehicles' range. The continued commitment of resources to research, given by the government's targets, can lead to further innovations within the battery sector of the electric vehicle industry, although this is dependent on the government adhering to these targets. With the uncertainty relating to recent political and socio-economic events, including Brexit and COVID-19, there could be a fall in industrial support for these schemes. There could also be concerns that the innovations produced from these schemes may be implemented in EV production outside the UK due to current and possible future political events.

Several other national governments have also invested in the electric vehicle industry, with countries such as Japan supporting research and development in the market as well as passing legislation to assist in producing the needed technologies [12]. While the original intention of the scheme was to boost the development of battery-powered electric vehicles, it may also have contributed to the success of hybrid electric vehicles in the market, with resources from the government supporting the development of electric drivetrains [12]. While this did boost a more environmentally friendly branch of vehicles and provided demand to expand the battery industry because of hybrid vehicles needing expanded battery capacity compared with conventional vehicles, it also showed the unpredictability of results such funding has. The paper notes that the idea of "picking winners" is not straightforward with government policy, which can exemplify one of the issues with government intervention in industry. This does not suggest that government intervention cannot work, but that just allocating monetary resources is not a panacea, as some may portray it.

The UK government is also providing funding to produce the infrastructure to support electric vehicle use, such as charging stations [13]. As described by the Department for Transport in the UK, approximately GBP 400 million is being invested in public charging points, with a further GBP 40 million in new charging technology, including wireless charging [14]. Availability of charging points is a key factor to consider for the future of the electric vehicle market [15]. Currently, most vehicles in commercial production have a modest range, and this is a potential factor against the purchase of an electric vehicle. Therefore, improving access to charging stations has the potential to increase electric vehicle purchases by enabling drivers to achieve greater distances. Currently, the UK government has invested in producing charging stations to keep pace with the increased number of electric vehicles in the UK [15]. This has resulted in a steady increase in charging points, with 19,487 public charging points being available in October 2020, with 3530 of these being rapid charging points [16]. This reached an 18% increase across the UK since January 2020. The paper also noted that the charge point distribution was uneven, with the majority of English regions being below the average for England of charge points per 100,000 of the population, with, notably, London having double that average [16]. They attributed this to UK local authorities not bidding for funding for the charging infrastructure and most of the distribution being based on demand from businesses, with hotels listed as an example [16]. This is in contrast to the direction of several other nations, with the German government providing online tools for investors and local governments to better position their charging infrastructure [17]. Initiatives such as these suggest that there is a drive from government bodies to promote the electric vehicle market, although failure from certain parts of the governing bodies to secure funding has hampered their efforts. A focus on placing the infrastructure in businesses that would see the most use publicly is a sound strategy, although this may miss opportunities to instil growth in the EV market as it is dependent on individual businesses being proactive with requests for charge points for their customers.

This can be a factor of concern, particularly in rural regions, with maps showing limited public charging point availability outside cities in the UK, with many rural charge points only having a single charger [18]. The data from Zap-Map is the source of the UK government's findings in its October 2020 report, which raises the question of how the data is portrayed. A high number of charge points may indicate availability, but if the majority are spread out between multiple locations in a location, this would likely limit customer confidence in charging availability in an area, especially compared with the multiple refuelling points at UK petrol stations. This is supported by Zap-Map's data, indicating 13,438 locations with 21,198 devices as of January 2021, which is an average of 1.58 devices per location [18]. Coupled with limited battery capacity and many charging points not offering rapid charging, this would likely leave these charging point locations with a low throughput of charged vehicles. Similar issues on availability can also be seen in other countries, with France having a greater number of public charge points compared to the UK but a lower density of them per 100 km^2 due to the nation's size [19].

Climate change is currently a high-profile topic, and there is a public perception that electric vehicles are a green transport alternative to allow people to continue with their lifestyles without a negative impact on the environment. Therefore, the underlying motivation for such government investment may be driven by both voter and lobbyist perspectives on a need to tackle climate change, as noted by Think Tank Bright Blue [20]. It has published several different articles on environmental issues, such as papers by Hall [20] or, another example, from Sarygulov [21], on public attitude to net-zero emissions. While this highlights that some political lobby groups are showing interest in tackling climate change and are undertaking relevant research that may influence the electric vehicle market, their results may need careful consideration to identify possible political bias. As an example, Bright Blue describes itself as a group of liberal conservatives and receives contributions from a range of members of the UK Conservative party, including members of the current government cabinet [22], which may influence its perspective on this matter.

Another example would be the work conducted by the Heritage Foundation in the United States, a conservative think tank that has published reports on climate matters [23,24]. The think tank does have a history of climate change denial, in both its reports and prominent members, and significant links to governing bodies, with several members being part of the former Trump administration [25–27]. Differences in political viewpoints are always going to be present between groups, although the closeness of certain think tanks to government bodies does raise questions on the impartiality of the research they produce, particularly when they are close to the current governing party.

Assumptions can also influence government policy, with the UK government funding only a limited number of public charging points because of the assumption that most of the charging of electric vehicles will take place at the owner's home [15]. This may be a fair assumption for now, as many electric vehicles are utilised over shorter distances due to their limited range. However, as technology improves and the range of electric vehicles increases, there is likely to be an increase in demand for public charging points. To improve access to charging, there are currently grants available in the UK for companies to install workplace charge points. This will contribute up to 75% of each installation, up to a maximum of GBP 350 per charging point, with a maximum of 40 charging points being covered [28]. While this is financially supportive, it will be up to companies to fund the rest of any installation, with no gain to the company. While some may be able to provide the extra funding, viewing it as a move to support employees and part of their CSR, others may be unwilling to adopt the technology or will need to pass on charges to the employees. The biggest employer in the UK is the NHS, which as a public organisation, would mean the government would be shouldering the full cost [29,30]. Other assumptions have also influenced government views on electric vehicles, with the US government often basing their estimates on electric vehicle emissions on assumed driving behaviours, which is not guaranteed to be how drivers act [31].

As well as investment in research, industry and infrastructure, government policies have also included incentives to purchase and use electric vehicles. However, these have often been indirect financial incentives, such as congestion charge exemptions, vehicle tax, and free parking with charging [32–34]. Superficially, these incentives appear supportive of electric vehicle ownership, and they may have a positive impact on electric vehicle ownership. However, it should be noted that they would not provide a significant financial incentive for many vehicle owners. For example, congestion charge exemptions provided in the UK are only of benefit to those who live or work in cities where these charges are in place. Additionally, while some vehicles are subject to high vehicle tax, there are already a number of low emission petrol cars subject to low or no vehicle tax [14].

Some national governments, such as that of the People's Republic of China, have looked at other incentives such as preferential access to roads for electric vehicles [32,33]. It could be argued that such policies would simply have a negative impact on those using internal combustion vehicles rather than incentivising a change to electric vehicles as this may result in certain roads being restricted rather than new roads being built with preferable access for EVs. However, discouraging the use of traditional means of powering vehicles can benefit the electric vehicle market even though it does not directly push for electric vehicle adoption, with such a policy currently offering an advantage for the use of electric vehicles. The significant flaw in this policy is that it would not be sustainable upon significant expansion of the market for electric vehicles, especially if electric vehicles were to outnumber internal combustion vehicles [32].

The UK government has published quite extensively, with documents such as Road to Zero and Clean Air Strategy, which appear supportive of the move to electric vehicles [14]. This is in line with other nations' efforts to increase electric vehicle uptake, such as the zero-emissions vehicle mandate in China, which requires vehicle manufacturers and importers to have electric vehicles that are at least 10–12% of their stock [35,36]. However, the legislation appears to be more directed to improving the emissions of current diesel and petrol vehicles than more direct intervention to actively facilitate the uptake of electric vehicles. The UK government has stated the aim of having 25% of the central government car fleet comprise of ultra-low emission type vehicles, which includes electric vehicles, by 2022 [14]. This appears supportive of the environment and appeals to voters. However, this will include some less polluting petrol cars and hybrids and has no impact on prospective buyers of electric vehicles. This would support the electric vehicle industry in scrutinising government schemes and targets and should also encourage them to confront the government over policies that are presented as helping the industry but which assist only in a minor way or not at all.

Direct political will can make a massive impact, and this is shown in Norway, where around 45–60% of new car sales in the first half of 2019 were electric [37,38]. Here, there is a long history of support for electric vehicles [39]. There was a reduction in annual registration tax for electric vehicles as early as 1996, followed by access to bus lanes and, later, free road ferries. Norway has also adopted a "polluter pays" tax system for new cars. As a result, a new VW Golf has an import price of EUR 22,046 and an eGolf of EUR 33,037. However, because of taxes, the eGolf retails at approximately EUR 1000 lower to the consumer, making the electric option the cheaper alternative. This suggests that government intervention, in both providing benefits to electric vehicles and disincentives to new conventional vehicles, can be beneficial in improving the standing of electric vehicles to consumers.

In the UK, the government has provided some financial support for the development of electric vehicles and the associated infrastructure. There was some early subsidies for the purchase of electric and other low-emission vehicles. Previously, there was a modest "plug-in car grant" worth up to GBP 3500 for some vehicles, including hybrids. However, it has now been discontinued for hybrids; the government indicated that rather than expanding this scheme to encourage a further increase in electric car usage, it intended to discontinue it, although this was changed to a cut in the grant to EUR 2500 [40,41]. Climate change is currently prominent in both public perception and on the international stage, so the UK government will be keen to take a positive stance on the adoption of electric vehicles. However, analysis of the current evidence would suggest that while there appears to be a positive attitude from the UK government, there is limited action to improve electric vehicle adoption. While other nations have also taken positive stances on the widespread adoption of electric vehicles, many of them will likely need more ambitious policies to achieve the goals they have set themselves [1].

3.2. Economic Factors

Efforts to ensure that the increase in electric vehicle production can be sustained while ensuring that such operations are profitable are driven by economic factors [42]. A sustained, profitable increase in production can be achieved by developing technology that achieves targets for emissions while being available at a price that encourages consumers to buy the vehicle and the means to recharge it when necessary [43]. Examining the current market, battery electric vehicles showed an increase of 7% between 2015 and 2016, although battery electric vehicles still only comprised 0.4% of the total automotive market in 2016 [43]. In 2019, almost 4.8 million battery electric vehicles were on the roads globally, with 2.58 million in China [44]. This represents an almost 240,000% increase since 2010, when less than 20,000 battery electric vehicles were on the market globally [44], a substantial increase in a decade.

A report by Ricardo also notes that the shrinking diesel market in Europe, in part due to the "Dieselgate" scandal, may decrease the ability of the market to achieve its emissions targets, as many consumers are currently turning to petrol vehicles as an alternative [43]. Increased numbers of electric vehicles within the automotive market will be required to meet the emissions targets [43], but this raises the question of how this can be achieved. Ensuring that electric vehicles are affordable to a wider market would contribute towards meeting these targets. However, this must be balanced with ensuring that these sales are profitable to companies if they are to ultimately replace conventional vehicles in the automotive market. Current BEVs are challenging to make profitable, with current data indicating that a majority of manufacturers expect a profit margin of less than USD 1000 per vehicle, with only 18% expecting more than USD 3000 per vehicle [45].

Increasing the size of the market would require the costs of electric vehicles to fall, with prices needing to be similar or lower than those of equivalent petrol or diesel vehicles [46]. One cost that substantially increases the price of the vehicle is that of the battery. A battery capable of giving a vehicle a range of 100 miles can cost as much as a small petrol vehicle, although this cost is currently falling [47]. Battery costs are projected to continue to decrease with an increase in production, although the lifetime cost of batteries may still be very high as the batteries may need to be replaced every 10–20 years, with some companies offering warranties up to 8 years [47]. This would increase the costs of maintaining the vehicle during the use phase of its life cycle and may deter people from buying them. An expansion of the warranty system offered by some companies could resolve this concern with consumers, but this would inherently increase the financial burden on companies over the lifetime of the vehicle, which, in turn, may incentivise suppliers to raise prices. It may also have minimal effect, as some reports suggest that affinity for extended warranties may be driven by consumers having poor information on the probability of failure in a product, with acceptance rates falling when consumers are given accurate information [48].

The importance of balancing short-term gains against the medium- and long-term effects should be noted, although developing effective business strategies and models to combat these effects can be taken. This has been examined with academic spaces [49]. There are also projections of technological improvements to the lifetime of these batteries to consider, which would hopefully eventually lead to batteries lasting the whole life cycle of the vehicle and would likely render the warranty unnecessary for most vehicles. Accidents and random failures would also have to be considered, although this is also true for conventional vehicles as well, so it shouldn't require a significantly different strategy for batteries.

However, the assumption of the need for battery replacement is dependent on the electric vehicle not having reached the end of its life by the time the battery fails. At this time, the average scraping age of a vehicle is approximately 14.2 years of use, as of 2019 [50], which is within the current expected life span of an electric vehicle battery. However, it is also within the range that may require some batteries to be replaced during the vehicle's life, should they fail before this time. Electric vehicles can be scrapped for a variety of reasons, including the availability of government schemes that encourage scrapping and changes in the world economic climate [50]. Therefore, it is possible that if the battery reaches the end of its life, a consumer will choose to scrap the vehicle rather than replace the battery. Bodywork problems such as rust, particularly in northern European countries, may contribute towards scrappage or the failure of other car parts before the expected end of the vehicle's life span. However, improvements in design and the use of newer oils and coolants for key components has already led to an increase in vehicle longevity, and it is predicted that electric cars may have an even greater lifespan compared with conventional vehicles as they have fewer moving parts [51]. An increased lifespan for the battery should improve the economic viability of using and maintaining an electric vehicle and deter unnecessary scrappage of the vehicles. This should only improve with time if the current trend of decreasing battery prices continues at a rate of around 13% annually [52]. There is likely to be an upper limit on the usable life span of a vehicle that is economically viable for both companies and consumers, and finding this ideal limit would be beneficial for suppliers and companies involved in the upkeep of the vehicle during its usable lifespan [53]. Future electric vehicles are expected to have a lifetime driving distance of 150,000–350,000 km, an improvement on estimates of 100,000–300,000 km for current electric vehicles [53].

It should be noted that electric vehicle ownership has other economic advantages, looking at electrical costs vs fuel costs for petrol and diesel vehicles. Currently, a 100-mile journey utilises around GBP 4 of electricity against GBP 9 of petrol for an equivalent journey, as of 2020 [54]. This is clearly a positive element over the lifespan of the car, although it is dependent on the electricity generation industry and how prices change based on this industry and the economy of the nations the industry is based in. Technological improvements can also affect this factor, as more efficient electric motors would assist in increasing the range of a vehicle, which, in turn, would reduce the cost per unit of distance to travel. One new design, focusing on a dual-motor arrangement, suggests that around a 9% increase in average efficiency could be achieved when compared with single-motor designs [55], which would increase the range of the vehicle for the same battery size.

Other long-term advantages to electric vehicle ownership also include reduced road tax and potentially increased vehicle longevity, all of which may make the ownership of an electric vehicle an economically attractive, long-term option. This includes a benefit-in-kind (BIK) tax reduction, with electric vehicles often only paying no initial tax in the first year, compared with a 16–32% tax for petrol and diesel vehicles [56,57]. However, a prospective buyer still needs the funds to cover the currently higher initial cost of the vehicle and possibly a home charging point, which may place ownership out of reach of many potential customers. The refinement of the manufacturing process for the vehicles and expanded production can help reduce the price of both items, although this is a medium to long term strategy given the economic effort and time required to expand production sites and implement improved processes.

3.3. Social Factors

Social factors need to be considered with the potential expansion of the electric vehicle market. One of the barriers to the adoption of electric vehicles is that they are a new technology, so consumers lack knowledge about the potential advantages. They will also be deterred by the cost and any perception of risk, which itself will be influenced by personal experience, emotions, the media and social connections [58].

Perception of vehicle safety is an important factor to potential buyers [59], with accident rates needing to be considered when looking at safety. Electric vehicles are required to fulfil the same safety standards as all vehicles [60,61], which, with some members of the public having reservations on electric vehicle safety, is an important point to make clear. In the US, as noted by the US Department of Energy, electric vehicles have additional safety standards that are due to the nature of the vehicles, such as regulations to limit any chemical spillages and electrical hazards from the vehicle [60]. Electric vehicles also have safety standards for their charging points, which are recommended, in the UK, to be from a dedicated socket [62]. Providing new regulations as more and more new technology is used by consumers is expected and can be beneficial for consumer trust in electric vehicles by providing a standard to show their safety. This has been used in the past to support public confidence in electric vehicle safety, including guidelines in Europe to improve safety with electromagnetic fields from EVs to alleviate public concerns [63].

While regulations are useful in alleviating social concerns on electric vehicle safety, the media coverage of incidents involving electric vehicles can often fuel these fears even more. Electric vehicles are a relatively new technology, so the public will have concerns about safety. However, these need to be compared with the potential safety risks of diesel and petrol cars. In London in 2019, the London fire brigade responded to 1898 vehicle fires from petrol and diesel cars, while only 54 fires were due to electric vehicles [64,65]. However, this gives incident rates for vehicle fires of 0.1% for electric vehicles in London, with petrol and diesel vehicles only having a rate of 0.04% in comparison [64]. This could be due to the lower number of electric vehicles on the road compared with petrol and diesel vehicles, although this could also be used to explain the overall numbers of petrol and diesel vehicle fires, being nearly twenty times as large. There are valid concerns about batteries re-igniting after being extinguished, requiring more fire suppressant materials to be used to control the vehicle fire [66]. The continued development of new fire-suppressing methods is necessary for a safer view of electric vehicles.

Additionally, fuel needs to be transported by road in tankers, and any accidents can lead to spillage of a highly flammable liquid, causing significant risk to life. It is possible that due to the established nature of conventional vehicles, public opinion is more accepting of these risks compared with similar risks in electric vehicles. Ensuring the public is educated on the risks of electric vehicles, coupled with the ever-expanding number of electric vehicles on the road, is likely to diminish the overall fear of their safety. Public perception of electric vehicles can change, with studies showing that individuals have a changed perspective of electric vehicles after an experience of driving one [67]. This would only bring it down to the same level held with conventional vehicles, given they share several safety concerns that are present in all vehicles, such as crashes, but this should not be an issue as it is already tolerated for conventional vehicles as an inherent possibility in their use.

Electric vehicles are quiet compared with petrol- or diesel-powered vehicles, with very little noise at low speeds of less than 30 mph (50 km h^{-1}), although they do get louder at higher speeds due to the tyres producing noise [62]. This difference in noise includes times when the EV is stationary, with a 20 dB difference in noise between electric vehicles and conventional vehicles [68]. While this may be a positive factor when looking at noise pollution, it does have the potential to increase accidents. A quieter vehicle is far harder to hear for pedestrians when at low speeds, which impacts the safety of the vehicle as pedestrians may not hear the oncoming vehicle [62]. This has led to trials of utilising new sounds for cars to improve safety [60]. This has the potential to ensure that pedestrians will hear the vehicle, although there may be some initial confusion if a pedestrian is unfamiliar with the noise as they may not associate it with a vehicle. Some tones have been identified as annoying to respondents when employed as back-up alarms for electric vehicles, although this was not universal among those who took part in tests [68]. Attempting to produce a new sound similar to the noises made by a conventional vehicle could help alleviate this, along with education on other sounds made by electric vehicles, with participants' reactions to different electric vehicle sounds examined both in real-world and virtual environments [69]. Ensuring electric vehicles and their infrastructure remain as safe as conventional vehicles across all potential causes of harm is key to keeping the public perception of the vehicles positive, which would improve the probability of a consumer choosing an electric vehicle over a conventional one.

It has been described that the car that a person chooses to buy is usually not based simply on practical considerations but also on emotional ones, such as how the individuals view themselves and how they want to be perceived by others [70]. As electric vehicles are considered eco-friendly, then driving an electric vehicle might appeal to those who feel that they identify with those who are concerned about the environment. The price differential remains a barrier in many countries; individuals may want to adopt the new technology but simply cannot afford an electric vehicle. Improvements to the manufacturing processes, improved designs, and the emergence of a second-hand EV market will assist in reducing prices, which can be coupled with advertising campaigns across different types of media to encourage the purchase of electric vehicles. Tesla has high profile launches, not always seen with electric vehicles produced by manufacturers who also produce conventional vehicles, which has helped boost Tesla's EV range's image in the public eye. However, any promotion would need to be carefully managed to create a positive image. Problems at the launch event of the Tesla Cybertruck, where a shatterproof window failed during a demonstration, resulted in a significant fall of 6% in share price for the company [71,72]. This can also be how live events can go wrong, not only affecting the public perception of a company or group but also the perception of the group by stakeholders, regardless of the various merits they can offer.

3.4. Technological Factors

There are several technical challenges that the electric vehicle industry faces that could have a negative impact on prospective buyers. However, new technologies are being developed to overcome some of these issues. The limited range of electric vehicles has been widely reported as a barrier to electric vehicle usage [62]. There is a desire from consumers to be able to travel long distances by road, as it is an option currently offered to them by conventional vehicles. Batteries with greater storage are more expensive and have a larger mass, which would reduce the overall increase in vehicle range. Coupled with limited capacity, long charging times for electric vehicles are also perceived to be a major obstacle to a customer's desire to purchase an electric vehicle [33]. Improved charging access is an alternative to increasing range without a directly negative impact on vehicle pricing, although there are other factors that influence the construction of such infrastructure, as mentioned in Sections 3.1 and 3.2.

Innovation in charging infrastructure is another factor that needs addressing, not just access to charging infrastructure. Rapid charging stations, which can be capable of charging an electric car to 80% of its battery capacity in around an hour [47], have now been developed to improve the distance electric vehicles can cover overall. However, while this is an improvement, it is still less convenient and more time consuming compared to conventional vehicles. Although a fast-charging station can charge an electric vehicle in 30 min, this is significantly slower compared to only 4 min to re-fuel a conventional petrol or diesel vehicle [33]. This is almost certainly going to be an ongoing issue with the current design of batteries used in electric vehicles, given the inherent differences between chemical fuel and electric power. The rapid charging points can only rapidly charge up to 80%, as the remaining 20% capacity is charged at a slower rate to prevent damage to the batteries [47]. An acceptance of reasonable charging times may need a change in public attitude towards refuelling a vehicle as, even with further technological advances, charging times are unlikely to match conventional refuelling and give vehicles the same range between charges.

The battery limitations that contribute to the long charging time also tie into other issues that influence the electric vehicle market, such as the life of the battery and the maximum speed of the vehicle [33]. In particular, battery life is currently seen to be a potentially significant issue, with projections suggesting some batteries would require replacement at certain points in the vehicle's usable life, as mentioned in Section 3.2. A particular issue is that the battery loses capacity over time, with some 24 kWh battery packs losing approximately 30% of their capacity over 5–13 years of use [73,74]. This issue is being addressed by some companies, with Nissan already offering programs to replace batteries that lose capacity during the vehicle's life [74]. However, it is unclear how many other manufacturers are willing to follow suit. The longer lifetimes of electric vehicle batteries, as mentioned by EDF, would also contribute to helping alleviate this issue [47]. Improved stability of the battery's capacity would also improve the lifespan of the batteries, although this is more likely to appear in the medium term of battery development, given that current research seems more focused on battery capacity and charging time [75]. Papers have begun to come out to address this gap, examining the stability of lithium-ion batteries over their lifespan [75,76].

Some technical factors are difficult to gauge, especially when attempting to discern how they do or would affect the electric vehicle market. Disagreement within the scientific community and industry can also cause issues when examining technical factors, especially when the disagreement stems from competing technologies. There has been a long discussion on how different battery chemistries affect the vehicles they are used in and whether the said chemistry is suitable for use in that vehicle, with one paper noting that lead-acid batteries are still used in low-speed electric vehicles [77]. This can be considered surprising, as lead-acid batteries have typically been supplanted by lithium-ion and other battery chemistries in many electric vehicles [77]. Lithium-ion offers higher specific energy density values [77], which has helped increase the range of electric vehicles, so it can be easily seen why they were utilised to replace lead-acid batteries. However, with their low cost, high reliability and plentiful supply, lead-acid batteries have persisted and appear to have found continued use in some electric vehicles [77]. Perhaps this is what awaits many of the current widely utilised battery technologies—to find an appropriate niche within the industry until an improved battery chemistry replaces them in most electric vehicles.

3.5. Environmental Factors

The development of new electric vehicles and the technologies surrounding them have predominantly been in response to environmental pressure [78]. Most authorities and governments worldwide accept climate change and are signatories of the Paris agreement [79], which has driven changes aimed at addressing climate change. The departure and subsequent re-entry of the United Sates into the agreement can show how dependent such agreements are on the internal politics of member nations, although the United States is the only nation so far to leave the agreement.

While electric vehicles have many positive factors with regards to the environment, there are several downsides that also need to be factored in to consider the impact the use of electric vehicles has on the environment. A paper by Hawkins et al. notes that, although a drop in global warming potential is seen with the use of electric vehicles, they also display an increase in toxicity to the environment compared with conferential vehicles, including an increase in toxicity against humans [80]. The factors discussed also included freshwater eco-toxicity and freshwater eutrophication as the other toxicity factors observed during a life cycle assessment of electric vehicles [80]. The paper also lists metal depletion impacts as a negative factor in electric vehicles, with most of this depletion originating from the supply chain of the vehicle. As of the time of writing, the major focus of environmental impacts is on the effects a product has on global warming, often measured in kg CO_2 equivalent. Clearly, there is a risk of negative environmental effects if a solution is chosen just by this value. Is a product more environmentally friendly by reducing its greenhouse gas emissions if it ends up increasing pollution in water supplies or destroying more natural habitats in its production? There have been efforts made to remove several of the more harmful elements of batteries, such as a transition to water-based electrode inks and battery electrolytes, although these have run into issues, particularly with the solubility of water-based electrodes in water-based electrolytes. This can reduce the toxicity impacts battery production can have on the environment, although it can increase other environmental impacts. One example would be the increased energy needed to dry a water-based electrode vs. an N-methyl-2-pyrrolidone (NMP)-based one, which would increase the impact on global warming that the stage of battery production has [81]. These newer production materials will also need examination to see what other impacts they may increase or decrease over the entire life cycle of the battery, although this should be true for all new materials when examining their environmental factors. This can also be seen with the comparison of NMP- and water-based electrodes, as while the water-based electrode has a higher energy demand for drying, it does not require the solvent recovery that the NMP-based electrode does [81]. This reduces its energy demand by excluding that stage [81].

Overall resource depletion is another important factor that needs to be examined for electric vehicles [82]. Many components of electric vehicles, such as the powertrain of the vehicle, utilise certain resources, including lithium for lithium-ion batteries and a number of rare earth metals and precious metals [82]. As these resources are considered finite, an increase in demand for electric vehicles would put a strain on the supply of these resources, creating a supply–demand imbalance [82]. New sources of these materials would alleviate this, with companies such as Cornish Lithium investigating new deposits of lithium in Cornwall, UK [83]. However, this would only temporarily alleviate the supply–demand imbalance and does not address the core issues of the requirement of these finite resources for electric vehicles. Replacing these resources with more plentiful resources, such as replacing lithium with sodium or potassium for the cathode's active materials, would help alleviate these issues [84].

However, if scarce resources continue to be used in battery production, there will need for a drive towards further development in recycling technology. In the short term, resource scarcity could also be alleviated with expanded recycling, although this also raises a few issues, such as the ability of current recycling methods to recover the materials used in the vehicle, along with other issues. Firstly, many different lithium-ion batteries require different recycling methods to extract the wide range of materials present in the battery [78]. This is further exacerbated by the rapid development of battery technologies, which can lead to some recycling methods becoming obsolete or specialised in certain batteries very quickly if the batteries they were designed for cease production [78]. It is likely that these methods may still be needed for a substantial time after production ceases, although some proposed methods may be obsolete given the probable decades of life these electric vehicle batteries may have [85]. This is assuming that future recycling techniques are still incapable of recycling a broad range of batteries in a single process.

Additional problems with the recycling processes result from the designs for the batteries, particularly with the use of multiple cells and the coating of the active materials onto a metal current collector, further complicating the methodology required to recycle them [78]. New advances in recycling technology could increase the material that can be reclaimed from the batteries, although this is likely to require more energy for the recycling process. This raises the question as to whether the recycling process is environmentally sound if its energy demand increases. Is the environmental impact from the increased energy production required for these new recycling processes offset by the reduction of the impact of the production phase from fewer virgin materials being used as the recycling process recovers much of the battery's materials? The scarcity of certain materials may mean that the reclaimed materials from recycling would be the best source in the future, although, at that point, the question would be how economically and environmentally viable is the use of such a material?

3.6. Legal Factors

International agreements, such as the Paris agreement [79], designed to limit carbon dioxide emissions, can result in new governmental strategies and laws that influence the electric vehicle industry. Many of these laws are relatively new and can have substantial impacts on the market, with one law from the UK government detailing that all public charge points must be compatible with electric vehicles regardless of their make or type [86]. This is likely to increase the costs of manufacturing the charge points as they may need different charging cables to cater to every electric vehicle. This law also sets standards for safety and reliability, with the law aiming to improve consumer confidence in the charging infrastructure, which should improve the sales of electric vehicles [86]. This could increase the financial burden on the government and companies providing the infrastructure as cheaper but less reliable models could be pushed off the market. However, given the public expectation of safety and reliability with all modern infrastructure projects, this could be a relatively minor issue [87].

Currently, there are no laws specifically regulating the recycling of batteries from electric vehicles [78]. This does offer the process designers some latitude as to how they conduct their procedures, although there will likely be new regulations on this subject introduced in the future as such operations expand. Another legal issue that arises from the electric vehicle market is the consideration of patent protection, especially for companies such as Tesla Incorporated [88]. This can raise some issues with businesses, as some studies suggest that strong patent controls can negatively affect subsequent innovations of a technology by companies other than the patent holder, although other studies have not supported this conclusion [89].

For the electric vehicle market, patents are considered an important part of the innovation strategy for a number of companies, which allow for the company holding the patent to prevent others from utilising their innovation without an agreement for 20 years [90]. While this period could be viewed as having a negative effect on development, companies do need an incentive to continue to make large investments into research, which have been necessary to develop the technology so far. Many companies make some patents details available to the public, which can involve the publishing of applications and describing the invention and scope of the protection given [90]. There has been a recent push by some automotive companies to provide patents as open source, but this could lead to legal uncertainty, such as whether the original patent holder can use an improved patent from another company [91,92].

Another legal factor that needs to be considered is that vehicles will be subject to laws from countries other than where the parent company is based or the country of manufacture [7]. If a dealership for electric vehicles is to launch in a new country, then both the dealership and vehicles sold will have to comply with the laws in that country. A careful examination of regulations and laws within the market a company is planning to expand into can assist in ensuring that the electric vehicle is compliant. However, if a specific country has especially restrictive laws that affect electric vehicles, a company may decide that this market is simply not viable, given how regulations can affect assessments of market viability [93]. This does raise the question of whether political lobbying to change these laws or the examination of legal loopholes would be sufficient to allow a company to enter this market. This does raise ethical issues and may create public animosity towards companies seen acting in such a manner.

3.7. Ethical Concerns from the Raw Materials of Batteries

One major ethical concern regarding the electric vehicle market relates to the sources for several major raw materials. Organisations such as Amnesty International have raised a few issues relating to raw material extraction, including the use of child labour in the Democratic Republic of the Congo (DRC) to mine cobalt, which is a common element in lithium-ion batteries [94,95]. Amnesty International also claimed, in 2016, that several major battery producers purchased cobalt from Congo Dongfang Mining (CDM), with Amnesty International also indicating that CDM sourced cobalt from areas that often use child labour.

Alongside these claims, there is clear evidence that child labour has been utilised in other cobalt mines in the DRC, with a report from UNICEF in 2012 indicating that an estimated 40,000 children worked in mines in the southern Katanga region on the DRC. This continues to be a practice utilised in cobalt mines in the DRC. In 2019, it was reported that child labour was still being used in the mining of cobalt for the production of electric vehicles [95,96]. The reports indicate that the ore was being sold to refineries in the People's Republic of China, which produces the most refined cobalt [95,96]. A report by the US Department of Labor also indicated that the DRC had made no advancement to ending child labour in the nation, with child labour also being utilised to mine copper and other metal ores [97]. While the report does note that some efforts have been made to eliminate child labour with new anti-trafficking laws and government bodies, it notes that children are still utilised in the mining of ores [97]. This does raise the issue of how companies and other organisations involved in using these materials for electric vehicle manufacture can combat this practice.

It is also reported that other "informal workers" mine cobalt outside of major mines, with reports of these workers dying in the smaller mines. This is due to both poor safety and the unregulated nature of "artisan" mining, a practice that is legal in the DRC [96,98]. Up to 30% of the DRC's cobalt comes from these artisan mines [96]. Alongside these deaths, several other ethical issues appear to arise aside from this practice. While many of the informal workers risk their lives for cobalt, most seem to undertake this hazardous work simply to survive, as some buyers have been supposedly trading the mined cobalt for food and shelter to the miners [96]. There is definite evidence of the exploitation of vulnerable people, and it also raises the question of what other options they have. Do they accept this work or do they decline and possibly suffer if no other option of employment or revenue is available?

Efforts to stop this practice have also been ethically questionable, such as a decision to move 600 villagers away from their homes due to the artisan miners digging in their back gardens [96]. The move was met with protests and was financed by a mining firm that was granted the right to buy all the cobalt and copper mined on the land [96]. However, the artisan mines were unsafe, and, as well as these mines causing injuries and deaths in the area, some mines forced a local road to close due to tunnels being dug in the foundations of the road [96]. The ethical stance of these mines is not clear as preventing the mined cobalt from entering the market would cut the numbers of these mines, leading to better safety and fewer deaths from accidents. However, it also denies an income source to a group of workers who may have few other options at present.

It will be difficult to have influence over the political regimes in the DRC or China, given that China's international influence exceeds most other nations and is the major consumer of the DRC's mineral products [99], so many of these practices are likely to continue. The target group for purchasing electric vehicles includes those interested in climate change and the environment. It is likely that they would also have an interest in politics and human rights and would view the conditions of cobalt mining in a negative light. Some companies have taken steps to tackle ethical issues with cobalt production, with Umicore producing a sustainable procurement framework for cobalt to assist in ethically sourcing its cobalt [100]. As part of this, the company produces a due diligence compliance report each year [101]. The latest report for 2019 details a number of aspects of their procurement framework, including a public grievance mechanism, a committee to ensure that the principles and guidelines of the framework are followed, as well as traceability systems for Umicore's supply chain [101].

Other industry groups have taken steps to tackle some ethical issues that arise from the production of raw materials, with conflict materials being another issue. In the context of the supply chain, conflict materials refer to materials, often minerals, that are mined by armed groups to fund the conflict they are participating in, with human rights violations often occurring during this process [100,102]. These are primarily the materials tin, tungsten, tantalum and gold, most of which are important or have prospects of being useful materials in battery production [103]. Gold is utilised in circuit board production to allow battery pack control, while tin and tungsten have shown promise as materials in lithium-ion battery production, which means conflict materials could be present in battery production supply chains [104,105]. This is concerning, especially as further demand for electric vehicles could increase the number of operations supplying conflict materials, potentially helping to fuel more instability in parts of the world. This is also present in the Congo, with some mines financing armed groups, so an increased demand in cobalt from battery production may funnel more funds to these groups [106].

Some organisations have attempted to tackle this by adopting several policies to ensure they act responsibly with the supply chain of materials and prevent conflict materials from being utilised within their supply chain. Alongside their compliance reports, Umicore has also implemented a number of policies to tackle this issue [100]. These policies have led Umicore to be certified as a responsible gold smelter by both the London Bullion Market Association and the Responsible Jewellery Council [100]. Other groups working against conflict materials include Avnet, which works to promote traceability and transparency of its supply chain [107,108], and non-profit organisations such as Global Witness, which also works to eliminate conflict materials [109,110]. Avnet has worked with a number of suppliers, including 3M and Panasonic, to ensure conflict materials remain out of its supply chain [107,108].

Meanwhile, Global Witness has exposed how some conflict groups, such as the rapid support forces (RSFs) in Sudan, a paramilitary militia, are financed by the minerals extracted [109,110]. The RSFs utilise a substantial amount of the Sudanese gold industry and use front companies and banks to finance itself [109,110]. This should show that taking precautions in supply chains to prevent unethically sourced materials from entering electric vehicles is possible, with the mentioned organisations possibly providing a framework for such procedures to other companies. Sharing this information may require monetary transactions to compensate the groups for the money they have spent developing their systems but could be useful to many different companies in the long term. Some groups have already begun implementing similar systems, with the OECD releasing a portal to help companies map their supply chains and the risks within them, which could be extended to cover conflict materials [111].

Governing bodies, including the US government and the EU Commission, have also enacted policies and laws to tackle conflict materials and mandate companies to avoid sourcing materials that finance conflict groups [103]. The EU regulation focuses on the import of 3TG, this representing tin, tungsten, tantalum and gold, as mentioned previously, and was fully enacted on 1 January 2021 [103,112]. It is still too early to see what impact these policies have on the trade of conflict materials, but they could be the basis of further regulations if they are successful in preventing these materials from entering European supply chains.

4. Conclusions and Policy Implications

EVs are rapidly developing to meet changing global requirements, with both consumer expectations and legislation designed to address climate change and emissions. It also attempts to fill the void expected to be left by conventional vehicles, with the decline in the availability of fossil fuels and the needs of consumers who wish to have ongoing private transport.

Political influences have a positive impact on the uptake of electric vehicles. However, some governments, such as Norway's, are more actively supportive of the industry, especially when compared with the UK government [37,38]. This is open to a change in UK policy, with new announcements to eliminate the sale of new fossil-fuel-based vehicles by 2030 being one advancement and new hybrid vehicle sales probably being ended by 2035 [113]. Current economic considerations mainly focus on production costs, particularly when looking at larger batteries with a longer range [53]. In most countries, the cost of an electric vehicle is significantly higher than a conventional vehicle, with components such as the battery costing the same as an internal combustion vehicle, which acts as a disincentive to purchase an electric vehicle over other vehicles [47]. However, reduced taxes from government on the vehicle could offer benefits, and overall running costs appear to be lower over the lifetime of the vehicle [54,56,57].

Some social factors, such as a lack of in-depth understanding of electric vehicle ownership and perceptions of safety and image, will also have a clear impact on potential buyers [58,59]. The industry could address these areas with educational and marketing strategies. The limitations of the current technology have also influenced how various companies have developed their range of electric vehicles, with the restriction of range by the batteries being one of the largest issues and one that has seen considerable attention from the industry [62].

The development of electric vehicles was partly in response to environmental concerns [78]. However, it should be emphasised that they do have their shortcomings in environmental emissions, although electric vehicles offer significant advantages compared with those that use fossil fuels. Coupled with the legal requirements and political actions being brought into force by international agreements, such as the Paris agreement, electric vehicles stand to be an important aspect of the transport industry going forward [79]. The development of electric vehicles is also considerably expensive, so patents with long time periods before expiry have been one legally based way in which companies are able to protect their investment, and they are a positive factor to encourage further development [90].

Ethical considerations mainly surround the conditions of workers who mine the scarce materials, with cobalt being of notable concern, needed for battery production. It may take international input to resolve these issues, given the political regimes in power in the countries involved in material production [99]. The issues surrounding artisan mining also need addressing as the safety risks to both human life and infrastructure clash with the possibility of denying an impoverished group an avenue of income [96]. Various international groups, ranging from the US Department for Labor to Amnesty International, have been examining these concerns and looking to how they can influence them [95,97]. This also extends to private companies, including Umicore, who have examined issues such as the prevalence of conflict materials and implemented new structures within their supply chain to prevent materials sourced in several unethical scenarios from entering their products [100].

From this analysis, several potential courses of action can be derived. There is clearly a need for further regulation and initiatives from governments and companies to help mitigate environmental and ethical issues that are currently present within the life cycle of electric vehicles. Nations producing or adopting similar legislation to that of the EU, relating to conflict materials, would be an example of positive regulation of the electric vehicle supply chain, as would companies looking to adopt a similar compliance reporting system as Umicore [100]. Further legislation and funding to expand and improve charging stations and other infrastructure projects needed for a larger presence of electric vehicles in the transport sector would also be beneficial [15,18,19]. Any compliance reporting system would need tailoring to a company and its suppliers to ensure it works as intended as well as likely needing the backing of senior staff and shareholders to be implemented. Having an established variation in the EU and Umicore will assist in producing these systems and regulations, and there is likely to be pressure groups and think tanks willing to support such initiatives [100,103,112].

Another possible initiative could be to create a shared pool of patented technologies, which some groups have worked to produce, for all automotive companies or electric vehicle part manufacturers to draw from to produce or improve their products [91,92]. This would remove some of the legal barriers some companies may have for producing better electric vehicles, but this would need to be balanced against what the companies that produced the patented technologies would lose from such a scheme. If such an initiative simply discouraged companies from developing technologies for electric vehicles, that would be a disaster. Further studies will need to be done to see how this could work as an initiative and what would be needed to resolve the issues that may arise from its introduction, which may include financial compensation to companies that willingly give up patents for it.

These examples would need to navigate the political and economic situations in each nation or company to become policy and be written to best fit the situation presented, demonstrating the importance of these two types of factors within the market. This is also shown by how many of the social, technological, environmental, legal, and ethical issues examined in this paper are directly tied to or significantly affected by factors within the political and economic spheres.

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