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Article

Evolution of Hottest Research Topics in E-Mobility over Period of 20 Years and How It Will Help State of Kuwait in Catching Up

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Abstract: This article examines the evolution of the most extensively researched subjects in E-mobility during the previous two decades. The objective of this analysis is to identify the lessons that the State of Kuwait, which is falling behind other nations in E-mobility, can absorb in its efforts to embrace adoptions of electric vehicles (EVs). To strengthen the body of knowledge and determine the most effective and efficient route to an "EV-ready" nation, the authors compiled data on the latest developments in the EV industry. A bibliometric analysis was performed on 3,962 articles utilizing the VOSviewer software, which identified six noteworthy clusters that warranted further attention. Additionally, we examine the sequential progression of these clusters as follows: 1. The environmental ramifications of electric mobility; 2. Advancements in electric vehicle technology, including range extension and soundless engines; and capital (CAPEX) and operational (OPEX) expenditures of purchasing and operating EVs. 3. Concerns regarding effectiveness and durability of EV batteries, 4. Availability of EV charging stations and grid integration, 5. Charging time, and finally 6. Origin and source of the energy utilized in the development of e-mobility. We are of the opinion that by delineating the critical aspects of e-mobility development, policymakers and decision-makers in Kuwait will be better equipped to formulate timely and economical choices pertaining to sustainable transportation.

Keywords: cluster analysis; bibliometric analysis; EV battery performance; EV charging facilities

1. Introduction

1.1. Energy Efficiency of EVs Vs. ICE

Upstream and tailpipe emissions comprise the total Green House Gas (GHG) emissions in the transportation sector. Upstream emissions originate from power plants and analogous sources, while tailpipe emissions are produced by vehicles. When the upstream emissions are held constant, it becomes apparent that transitioning to Electric Vehicles (EVs) can effectively mitigate emissions, regardless of their proximity to the power plant. [1]. Transitioning to electric vehicles (EVs) is strongly advised to significantly reduce carbon dioxide (CO₂) emissions from the transportation sector on a global scale, which currently stands at 16%. Electric vehicles (EVs) are particularly well-suited to supplant Internal Combustion Engine (ICE) cars due to their superior energy efficiency and comparatively low energy losses in comparison to the systems that supply energy to ICE car energy transportation facilities. EVs are five times more efficient than internal combustion engine (ICE) vehicles at delivering energy to the axles, according to a German research think tank named Powerid. [2]. The think tank arrives at its conclusion based on two analyses, of which the well-to-tank, reveals a mere 6% power loss in comparison to the 45% power loss observed in gasoline sourcing. [3,4]. Combining well-to-tank and tank-to-wheel analyses reveals an even more pronounced efficiency gap

in favor of electric vehicles over internal combustion engines. Research on tank-to-wheel energy efficiency indicates that driving electric vehicles energies greatly supersedes diving internal combustion engine automobile whether it is powered by gasoline or diesel. One of the primary reasons for this glaring contrast between EVs and ICEs is that the ICE engine fails to fully utilize its energy value, converting most of the fuel energy value to heat rather than power to the wheels. [5] (See Figure 1) The enormous efficiency disparity between ICE and EV raises the question of whether ICE technology is obsolete and will soon be disrupted by electric power vehicles. An examination of E-mobility from well-to-wheel reveals a mere 23% energy loss or 77% efficiency, in contrast to the substantial 84% energy loss or mere 16% efficiency observed in transportation powered by liquid petrol/gasoline. The disparity in efficacy is nearly five times more astounding. As stated by Mr. Nasser Abu Dagg, the Director of Powerid, the disparity in efficiency is of such magnitude that the carbon footprint difference, which is contingent upon the source of electricity generation, assumes a subordinate position when juxtaposed with the efficiency difference. [6] Fuel efficiency of internal combustion engine (ICE) engines is projected to increase gradually until 2050. However, greater efficiency gains are anticipated from electric vehicle (EV) batteries, particularly with the advent of solid-state batteries, which are anticipated to represent a significant leap in efficiency from production to usage. [7]

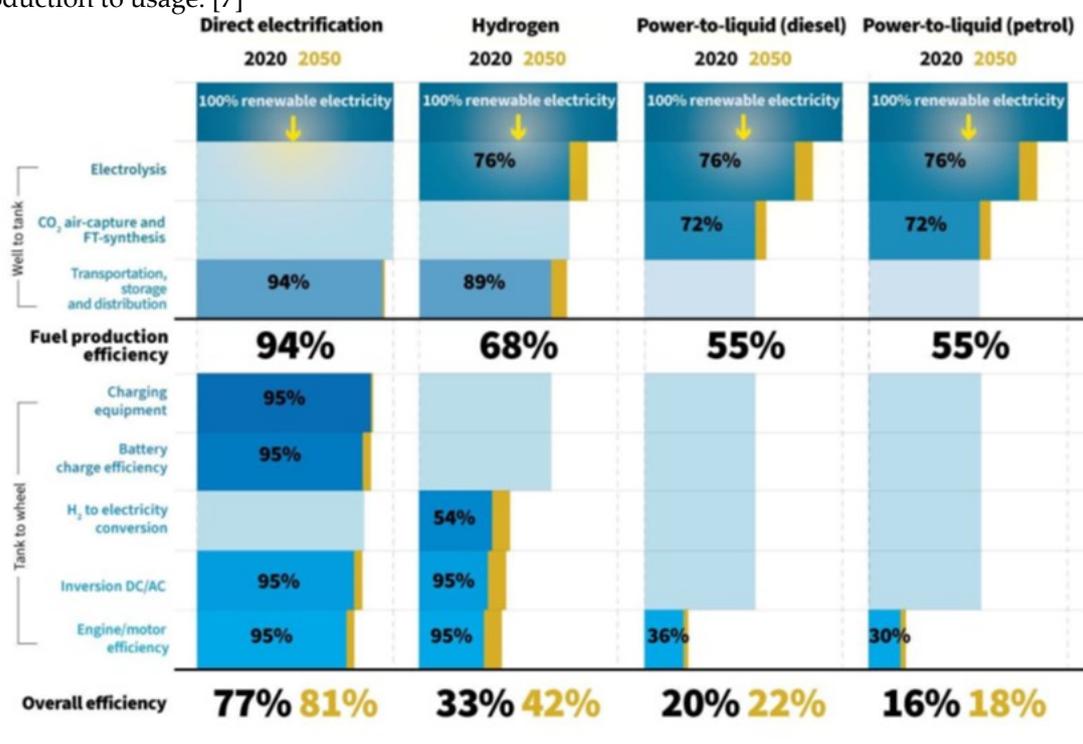


Figure 1. Vehicle fuel energy efficiency; source: Powerid. Printed with permission [1].

1.2. Other benefits of EVs over ICE

Additionally, higher energy efficient EVs have many advantages compared to Internal Combustion Engine (ICE) vehicles, such as no tailpipe emission/no pollutants, low noise, fewer moving parts which leads of significantly lower maintenance cost. Even though many developments are happening in appearance, performance, etc., according to International Energy Agency (IEA), only 9% of newly sold cars in 2021 were EVs [8]. Half of the EVs sold in 2021 were in China and another 40 % from the USA and Europe. The rest of the world combined, only bought about 10% of EVs sold in 2021. Many of the emerging market countries such as the State of Kuwait for example have close to zero contributions towards sustainable transport through electric transportation. Without involving all countries, achieving the IEA's target of 30% of new vehicles sold globally in 2030 as be EVs will be a complicated task. To escalate the EV market share in emerging markets to a

decent level need much planning and financial support, but as well as knowledge transfers and best practices from countries that are more far along in their EV transition. [9]

1.3. Reasons for Low EV Adoptions in Emerging Markets

The World Economic Forum identified four crucial reasons behind the low adoption of EVs in emerging markets. These four reasons were: Firstly, the new car purchasing cost difference of EV compared to purchasing new ICE vehicle. Secondly, fear of the risk of vehicle/EV battery fire. Thirdly, lack of support and dealership facilities. The fourth reason given for low adoption of EVs in emerging market was lack of charging facilities. [10].

In addition to the reasons given above, ten slightly more detailed reasons were presented at a conference on the Future of Sustainable Transportation in Kuwait, which where the results of a two-year exhaustive mixed method study. In-depth qualitative interviews were conducted with all automobile dealers who sold Electric Vehicles (EVs), 15 current proprietors of EVs in Kuwait were also questioned in-depth qualitatively, and a comprehensive survey of 600 participants was administered to determine the conditions under which they would purchase an EV as their next vehicle.

1) The findings of these studies indicated that the primary factor contributing to the low adoption rates of EVs was lack of fast-charging 300-500 kW Direct Current (DC to DC) public charging stations.

2) The second reason was Kuwaiti landlords' hesitancy to permit EV owners to install EV amplifier wall-boxes and charge their vehicles on their property for fear of fire and interference with household electricity, particularly the air conditioning units. This adamant opposition to EV home charging effectively prevented the around 75% expatriate populations from owning EVs, since real estate ownership in the State of Kuwait is restricted to Kuwait nationals only.

3) Thirdly, Kuwait has one of the most affordable retail petroleum prices in the globe. However, gasoline prices do not price high either due to the substantial subsidies provided for residential electricity. The cost of charging electricity is approximately one-fourth of that of gasoline, even though gasoline is priced as low as USD 0.3 per liter.

4) An additional factor contributing to the limited uptake of electric vehicles (EVs) in Kuwait was their prohibitively high purchase price, which was typically 30% higher than an equivalent internal combustion engine (ICE) vehicle with a comparable body. Notably, this substantial price differential is primarily attributable to the absence of a financial incentive program in Kuwait which gives no preference for EVs over ICE.

5) The fifth reason cited is that Kuwaiti consumers who are in the market for new vehicles are risk-averse in general and especially skeptical regarding the lithium battery's durability in Kuwait's extreme heat conditions.

6) Reason number six cited was the absence of an electric vehicle (EV) community. While Kuwaiti consumers typically seek guidance from their peer group prior to making significant purchasing decisions (e.g., purchasing a new car), it is difficult to find a reliable source of advice among friends and family for EVs, which comprise less than 1% of the total automobile body.

7) Existing EV owners in Kuwait primarily cited the seventh reason for low adoption: dealerships' reluctance to develop technical capacity due to minimal or nonexistent EV maintenance, which generates negligible to no profit.

8) Reason number eight was also derived from EV owners, who complained that exceptionally high speedbumps in residential areas to deter low-riding muscle cars from entering were particularly hazardous, or that the battery, the most expensive component of the vehicle, was positioned beneath it and could be damaged in areas where the ground clearance did not exceed the speedbump's height.

9) Lack or unavailability of designated EV facilities, such as priority lanes or designated parking, was the ninth reason for the low adoption of electric vehicles in comparison to other nations, excluding rapid charging stations. EV owners expressed dissatisfaction with the tendency for internal combustion engine (ICE) vehicles to park in specified parking areas or alternative current

charging stations, given that consequences for parking in EV facilities will cease to apply by the end of 2023. [11,12]

10) A lack of environmental zeal among policymakers and decision-makers, in contrast to other countries where numerous political parties are devoted to environmental causes, is the concluding rationale provided. Others note that the correlation between the participation of women in politics and government support for ecological initiatives is quite robust. The political participation of women is generally inadequate in most emergent market nations. [13]

2. Materials and Methods

2.1. What is Bibliometric Analysis

To assist emerging market nations such as the State of Kuwait in becoming "EV ready," the authors of this study determined which aspects of E-mobility received the most interest and, as a result, warranted priority in the development of an efficient and effective set of recommendations for EV laggards who are still in the process of establishing a sustainable transportation system. The process of identifying the subject matter that has received the most scholarly attention is referred to as Bibliometric Analysis (BA). BA, which is also referred to as bibliographic analysis, is a quantitative software application utilized by researchers to conduct literature reviews and identify emergent research trends within a specific field [14]. The utilization of its data mining, mathematical, and statistical functionalities enable researchers to systematically visualize trends. Numerous researchers employed this methodology to augment the knowledge base more efficiently and, in less time, compared to the conventional qualitative data analysis approach. Prior to undertaking an extensive literature review, scholars [15–29] employ bibliometric analysis to identify noteworthy domains that warrant their attention. Similarly, numerous researchers employed BA as an initial methodology in the execution of their investigations. The fifteen publishing houses and their affiliated partners that accepted articles for Scopus-indexed journals in 2021 are detailed in Table 1 [30].

Table 1. Articles on Bibliometric Analysis accepted by various publishers in 2021.

Publisher	No of articles
Elsevier	229
Springer	180
MDPI	174
University of Idaho Library	144
Frontiers Media S.A.	69
Institute of Electrical and Electronics Engineers Inc.	60
Emerald Group Holdings Ltd.	57
IOP Publishing Ltd	42
Taylor and Francis Ltd.	41
Routledge	38
SAGE Publications	37
John Wiley and Sons Inc	27
BioMed Central Ltd	26
Dove Medical Press Ltd	21
Hindawi Limited	19
Others	681

2.2. Methodology

Methodological process was designed and followed to obtain a clear vision (see Figure 2) In the subsection sections each step of the process is explained. For quality purposes we have selected and limited our search to Scopus accepted journals. The search was carried out in Scopus with the following criteria:

TITLE (electric AND vehicle) AND PUBYEAR > 2000 AND (LIMIT-TO (SUBJAREA, "ENER")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACTKEYWORD, "Electric Vehicle") OR LIMIT-TO (EXACTKEYWORD, "Charging (batteries)"))

The command can be read as a search for articles in the English language that is published after the year 2000 around energy, having "electric vehicle" in their title and either "electric vehicle" or "Charging (batteries)" as the keyword.

Accordingly, 3962 references were extracted from the search and exported to 19 Research Information System (.ris) files, which were later merged into a single file. The data represents studies conducted by researchers from 93 countries, with maximum contribution from China and the USA.

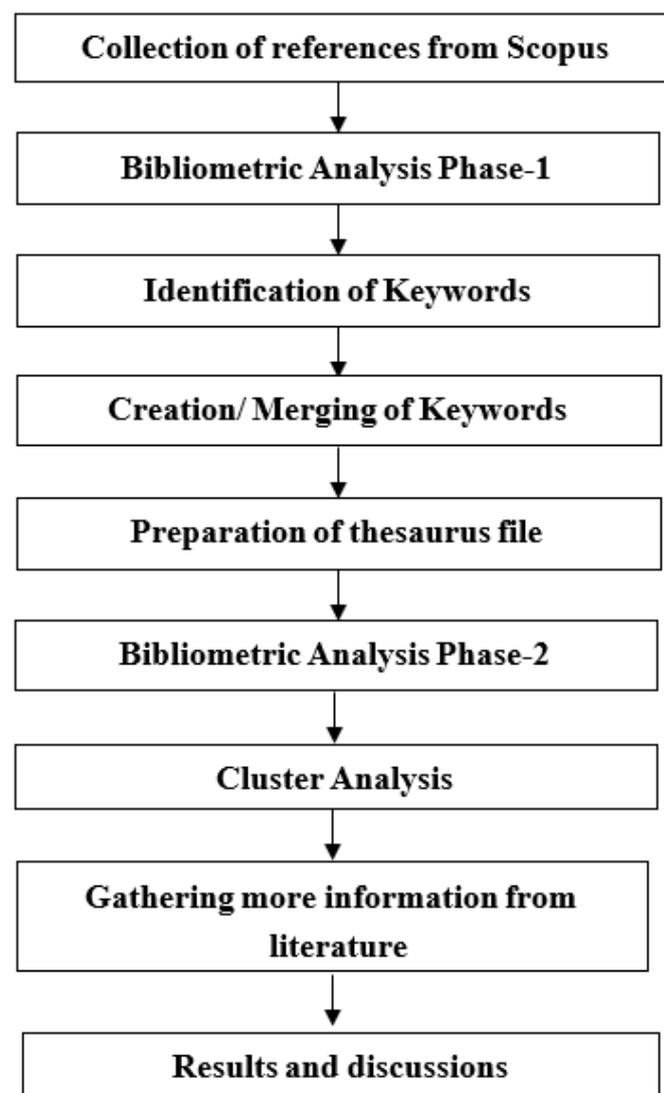


Figure 2. Methodological Steps used in the study.

In the next step the clubbed search results were uploaded to *VOSviewer - Ver 1.6.18*, a java-based software available free to the research community. With the help of this software, users can construct a network of various attributes of scientific publications. such as authors, keywords, etc. It accepts inputs as database files, reference manager files, and Application Programming Interfaces (API) [31].

To improve the readability, we have decided to club similar keywords together to avoid confusion due to the duplication of keywords. By doing so, we could reduce the keywords to 1000, the default number of keywords appearing in the VOSviewer software. The old and suggested keywords were listed in a thesaurus file to replace the existing keywords with the new ones. Examples of a few highly appeared sets of keywords (old and new) are presented in Table 6. The clubbing/ creation of new keywords was discussed in detail with all authors, who have spent a good quality time developing the thesaurus file.

Table 3. Example of keyword merging.

Old keywords	New keyword	Old keywords	New keyword
wireless charging wireless charging system wireless electric vehicles wireless energy transfers wireless power wireless power transfer wireless power transfer (WPT) wireless power transmission	wireless charging	ac/dc converter ac/dc converters ac-dc converter ac-dc converters	ac-dc converter
electric vehicles electric vehicle electric vehicle plug-in electric vehicles electric automobiles battery-electric vehicles battery-electric vehicle	electric vehicle	renewable energy renewable energy resources renewable energy sources renewable energies	renewable energy

By following the detailed and focused keyword reduction, we have limited the keywords to 1000 and prepared a thesaurus file in the format suggested by the user's manual [32]. Along with the thesaurus file, the phase-2 bibliometric analysis was carried out by inputting the original .ris file. The reduction in the keywords brought more clarity to the network map (Figure 4) compared to the previous one (Figure 3).

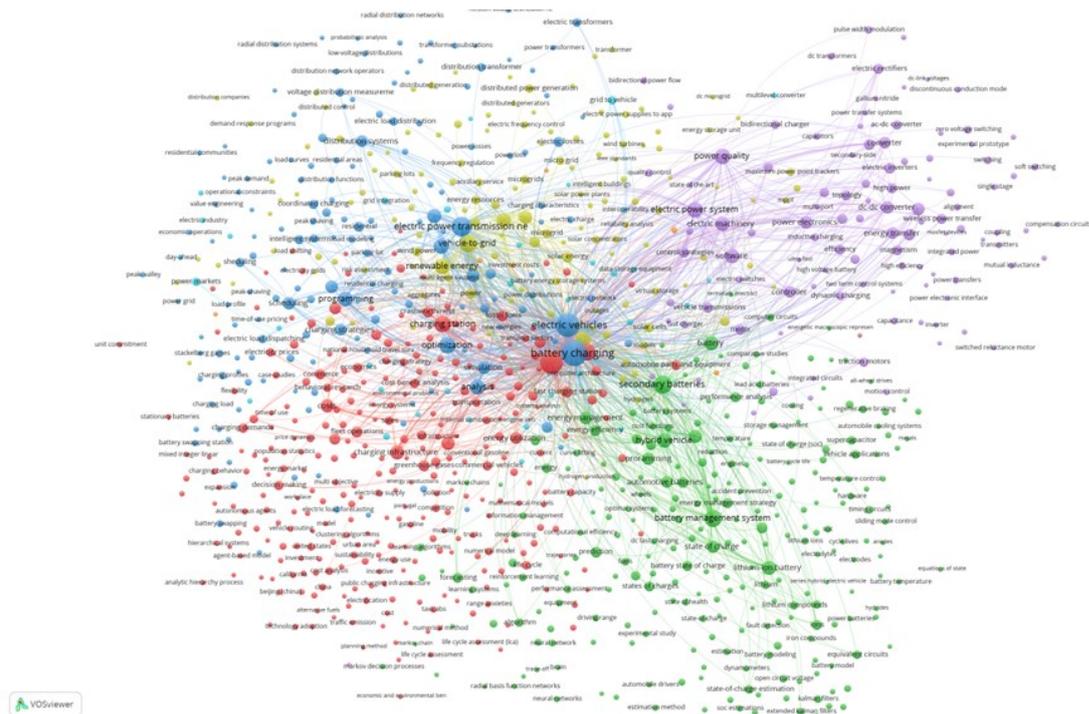


Figure 4. Refined map with 1000 keywords.

one of the significant features of VOSviewer is its capability to cluster the references based on their occurrences and co-occurrences. Cluster analysis is a blind data management model in which researchers must wait until the software gives its output [21,27]. Accordingly, the software arranged all 1000 keywords under six clusters. Even though the software did not suggest any names for the clusters, based on our understanding, we have named them as shown in Figure 5. Detailed elaboration of results is given in the following section.

Table 4. The details of the clusters.

Cluster Number	Most significant keywords	Other major keywords
1	Charging station	Emissions, Cost, Crashworthiness, Sustainable development
2	Battery Management System	Energy management, programming, Prediction
3	Battery Swapping	Charging Optimization, Electrical network, Simulation, Scheduling
4	Vehicle grid integration	Vehicle to Grid, Grid to Vehicle, Vehicle to Vehicle
5	Wireless charging	Converter, Power electronics, Inductive power transfer
6	Renewable energy	Solar energy, wind energy, grid integration

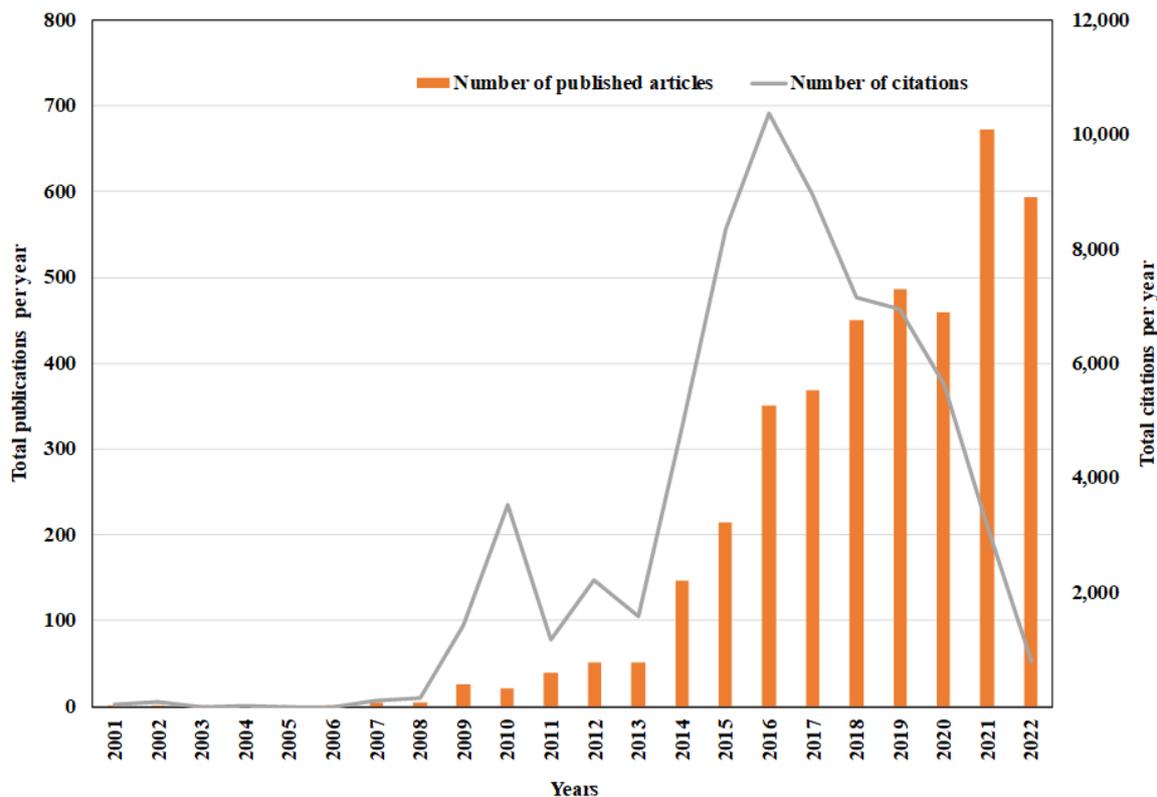


Figure 5. Distribution of articles and citations from 2000 to 2022.

3. Results and Discussions

The volume of EV-related articles published in Scopus-indexed journals is unmanageable. As a consequence, the outcomes were refined through the inclusion of a keyword proposed by Scopus, namely "Charging (Batteries)." Given the study's focus on infrastructure development for emerging electricity markets, we are adamant that the inclusion of this keyword will not have an adverse effect on the outcomes. We were ecstatic to discover that the number of search results was reduced to a level that was usable while preserving the study's context. The quantity of citations and the year of publication were entered into a table. To validate that the search results accurately reflected electric vehicle (EV) advancements during the designated years, a graph was produced. As depicted in Figure 9, the scientific community has conducted extensive research on EVs over the last two decades. The following: Subheadings may be used to divide this section. The document ought to offer a succinct and accurate account of the experimental findings, including their interpretation and any possible experimental conclusions.

3.1. Cluster Analysis

The concept of clustering aims to facilitate comprehension of large information sets through the categorization of them into distinct groups or labels. [33]. One example of cluster analysis that is readily comprehensible is the practice of dividing consumers into distinct categories to treat them differently. Although cluster analysis provides a comprehensive understanding of numerous fields and related subfields, the researchers retain the authority to choose their own areas of interest. A thousand keywords were categorized into six clusters and assigned names based on their frequency of occurrence, also with the assistance of the VOSviewer software. Each cluster is described in detail below.

to the battery giving power to the wheels. Two themes seem to emerge here. Firstly, the effectiveness and scalability of home charging using 380V wall box amplifier. The second, theme emerging is the speed of public Direct Current (DC to DC) fast charging. Interestingly the topic of battery swapping seems to gather a lot of attention as battery swapping seems to be the only technology now that can compete with the 5 minutes which is the time it takes to fill ICE vehicles of gasoline.

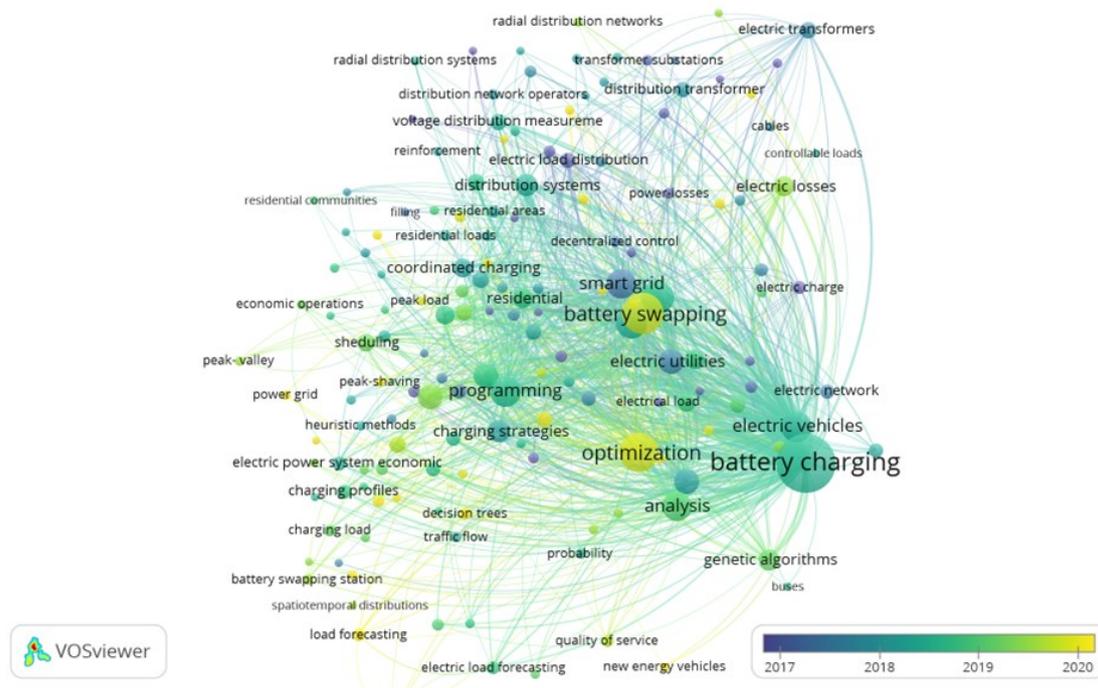


Figure 7. Cluster 3: EV Battery issues.

3.4. Cluster 4: Vehicle Grid Integration

EVs connected to the grid are called Gridable EVs (GEV)[38]. Vehicle to Grid Integration (VGI) can be both ways, energy transfer from the grid to the vehicle or vehicle to the grid. A VGI-enabled vehicle can receive electricity from the grid and supply it to the grid if required [41]. In a typical scenario, such VGI vehicles can charge the battery fully during nighttime and utilize the charge for driving during the daytime. Such facilities should be aligned with demand response programs so that the EV owner may get extra revenue in addition to their free commutation. Demand response programs are one way of managing the demand by involving end-users [42] Similarly, EV owners can also support each other in case of emergency by charging and discharging. Recent literature pointed out many benefits of VGI, such as less range anxiety, incentive, backup power for home, emission control, and other social aspects. Different strategies are being followed by involving VGI. They are Grid to Vehicle (G2V), Vehicle to Grid (V2G), and Vehicle to Vehicle (V2V) [43].

Typical G2V connections can be of two types: AC and DC. DC charging is comparatively faster than AC charging. The chargers placed inside the EV are called on-boards, while those placed outside are called off-boards. On-board chargers come in different variations, such as single-stage, two-stage, integrated and multifunctional. Likewise, off-board chargers are classified into bidirectional AC to DC converter, unidirectional AC to DC converter, bidirectional DC to DC conductor, and unidirectional DC to DC converter.

In the V2G scenario, EVs act as virtual power stations [44] and are implemented differently. The most promising one is related to charging the EVs from RE sources when EV is not running and in a static position in either parking lots or other locations where it has access to charging. The excess energy stored in the EVs can be exported to the grid during peak hours, generally managed through software. Studies suggest that a fully charged EV can power up a house for five hours [45]. According

to the projection made by [46] in 2025, if appropriately implemented, California will have half a million EVs, which could provide a 1GW of storage capacity.

In the V2V scenario, EVs are charged from the adjacent donor vehicle, either in a conductive or inductive manner. Even though it is used during emergencies, where electric charging stations are not nearby, the potential of using this method in other areas is still being studied. From Figure 8, the prominence of VGI can be visualized.

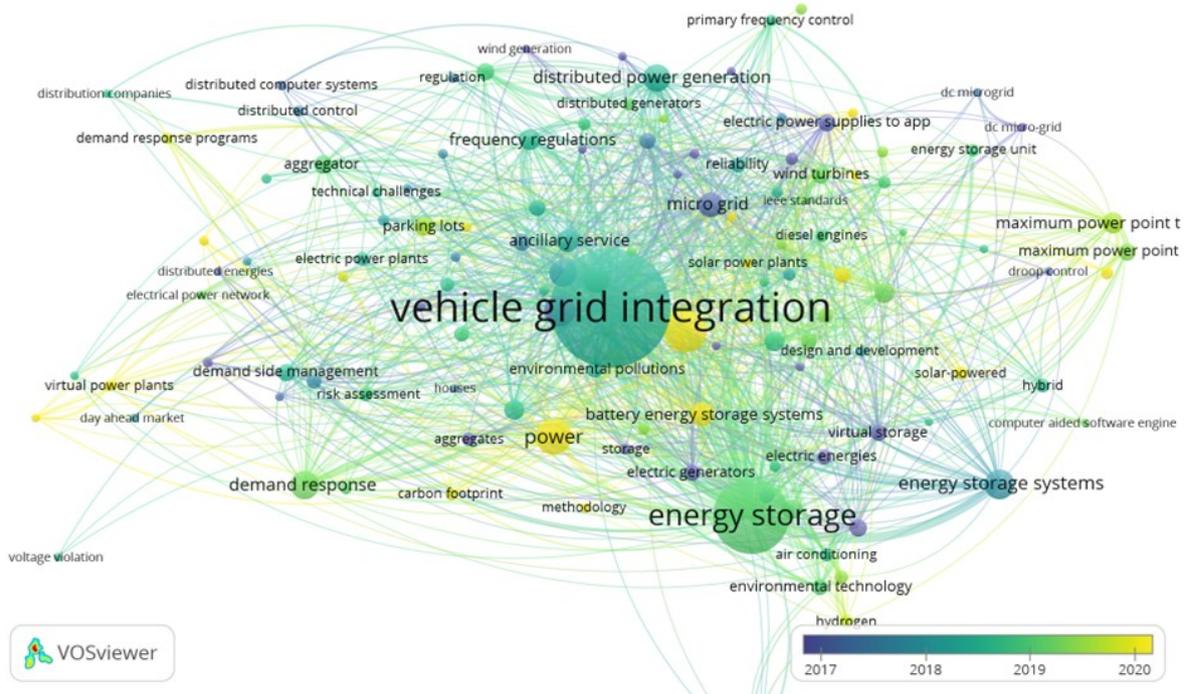


Figure 8. Cluster 4: Vehicle grid integration.

3.5. Cluster 5: Wireless Charging

Even though power quality is equally predominant under this cluster (Figure 9), we have chosen wireless charging as the primary keyword by seeing the subject's importance. Wireless power transfer (WPT) is another alternative to regular charging stations. WPT mainly uses inductive, capacitive, radio frequency, and laser-based technologies. However, magnetic resonant chargers (inductive) have only managed to become famous and commercially available now. WPT's advantages are that it is safer as no physical wiring is required, it can be used while EV is in static or moving condition, less supervision is required, etc.[47].

Inductive WPT works on the same principle as a transformer. In this case, the receiver converts AC to DC and feeds the battery with sufficient power. However, for effective charging, it is required to maintain the resonance frequency of both the donor and the acceptor. It is done through proper compensation networks. Charging systems are typically divided into two: static and dynamic. There are three types of WPTs: capacity WPT, permanent magnetic gear WPT, and inductive WPT. In capacitive WPT, the EVs are recharged while they are parked. The WPT occurs through the changes in the electric field between the transmitter and receiver. In permanent magnetic gear WPT, both transmitters and receivers are made up of synchronous windings and armature windings. In inductive WPT, mutual induction creates a magnetic field between the coil of the receiver and that of the transmitter. When AC power is given to the transmitter point, changes are observed in the magnetic field, generating power [48].

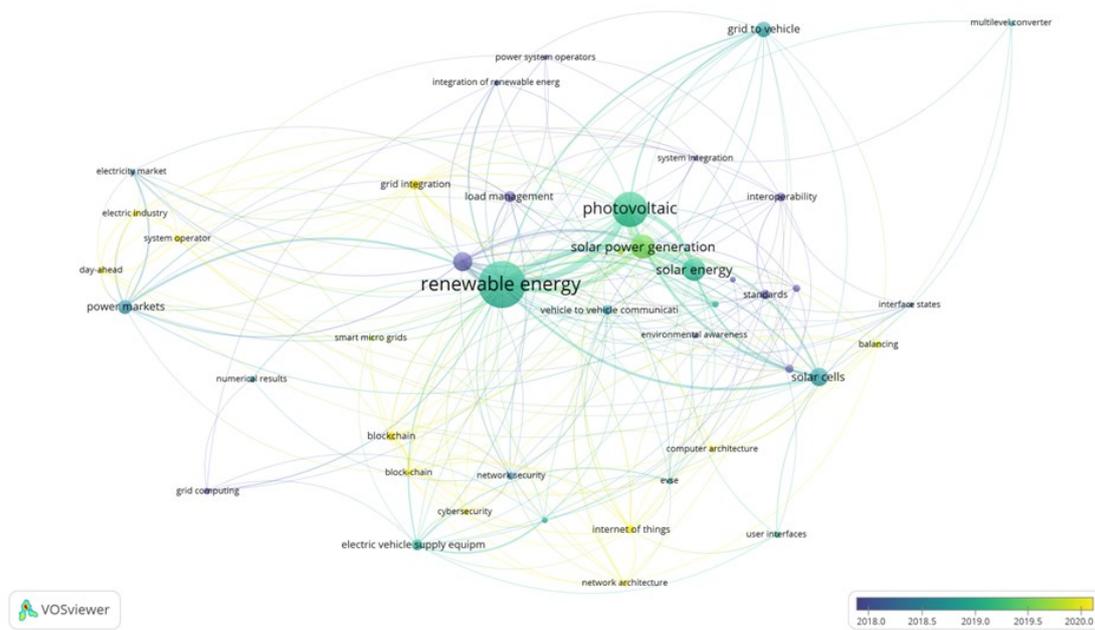


Figure 10. Cluster 6: Renewable energy.

3.7. Summary of Cluster Analysis

The six areas discussed under the cluster analysis benefit any electricity/transport sector globally. Many technologies are available in the market to charge EVs, with pros and cons. The large-scale adoption of EVs will demand more power capacity, and if fossil fuel-based power plants meet the demand, the objective will be ruined. To meet the ultimate purpose of using EVs, somehow RES-supported supply-side management is unavoidable.

The clustering of keywords may vary based on the nature and depth of reference documents collected. However, the probability of the presence of the above-discussed keywords in any of the bibliometric analyses related to the EV is high. Hence in this section, the significant parameters are discussed about a case study conducted by us in Kuwait to know the country's status without comparing it with any other countries.

4. Takeaways for Emerging Marketing Countries like the State of Kuwait

4.1. Most researched topic in Kuwaiti context – Charging Stating and Battery Performance

Kuwait is recognized globally for its substantial energy subsidies [50–57]. In order to fulfill sustainable development goal (SDG) 13.1, Kuwait is compelled to substantially mitigate its carbon dioxide (CO₂) emissions, given that the majority of its power facilities operate on fossil fuels. To put it another way, attaining SDG 3.7, which pertains to mortality caused by pollution, is not a trivial accomplishment for Kuwait [58]. Recent research [59] examined the "charging anxiety" that consumers may experience as a deterrent to purchasing electric vehicles. In Kuwait, approximately fifty diploid Alternative Current stations, which are frequently located in conjunction with retail centers, can be completely charged within five hours. However, no public rapid charging Direct Current (DC) station with an approximate 20-minute charging duration has been installed. The cluster 2 analysis reveals that this subject is similarly of utmost significance for Kuwait. The duration of battery charging and the distance a vehicle can travel on a single charge are aspects that are of specific relevance. The national laboratory, the Kuwait Institute for Scientific Research (KISR), selected a Chevrolet Chevy Bolt, one of the first electric vehicles (EVs) to arrive in Kuwait, for the purpose of evaluating its range and charging capabilities for a period of two years, from 2019 to 2021

(with the exception of the lockdown period during Covid-19). The EV's specifications are detailed in Table 5.

Table 5. Key specifications of the selected EV.

Model No	Range (Km)	Energy Consumption Wh/Km	Battery (kWh)
Chevrolet Chevy Bolt	383	156.6	60

We have diligently documented all critical parameters in a data log page, encompassing distance covered, energy consumption, recharge time, and more. We identified two critical performance-related issues during data analysis, which are described in detail below:

4.2. Variation of performance with seasons

A basic data analysis was conducted on the gathered information in order to ascertain the distance traveled per unit of energy (Km/KWh), as illustrated in Figure 3. Nonetheless, Kuwait, similar to numerous other developing nations, experiences temperatures well below the ideal 25 degrees Celsius in the absence of both heating and air conditioning systems. Pre-summer is depicted in the figure as spanning the months of October to November, summer as June to September, pre-winter as March to May, and winter as December to January. The figure illustrates how temperatures in the summer and winter impact the performance of the electric vehicle. The magnitude of the impact is greatest in the summer and moderate in the winter. The period preceding summer is characterized by optimal performance (Figure 11). It is worth noting that the range will decrease significantly in the summer due to the battery management system necessitating increased cooling and constant operation of the air conditioning at maximum capacity.

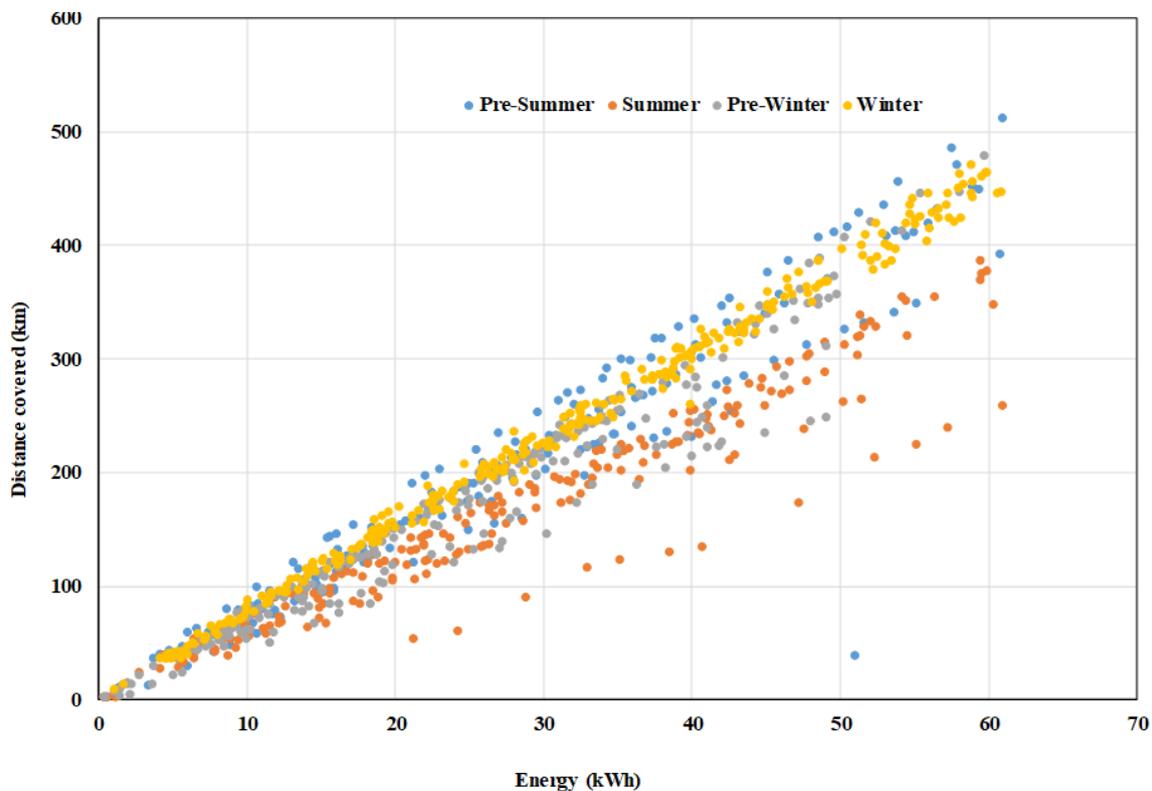


Figure 11. Variation of performance in different seasons.

4.3. Variations in charging time in different seasons

The time necessary for recharging electric vehicles (EVs) fluctuates, mirroring the similarities and differences in performance between seasons. Despite deviating slightly from the ambient

temperature pattern, its influence cannot be disregarded. The charging duration varies by approximately three hours between the summer and winter seasons, resulting in an approximate forty percent increase in charging time (Figure 12)..

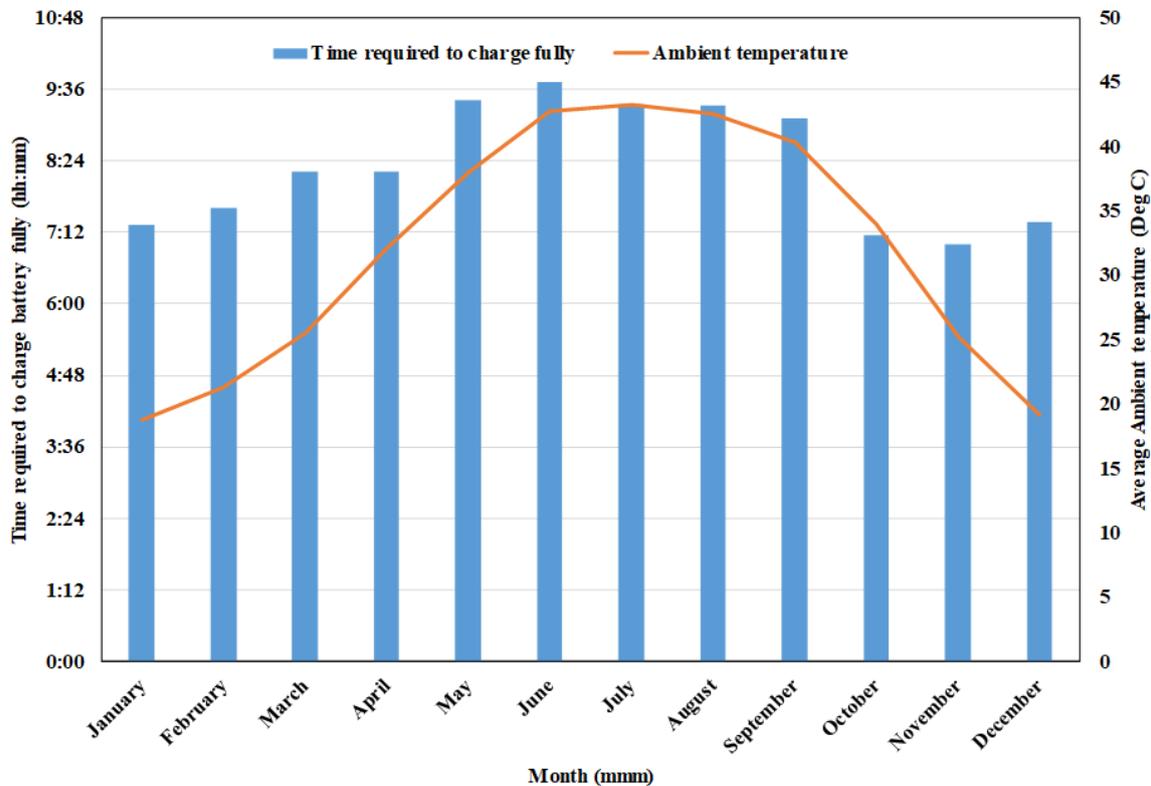


Figure 12. Variation in the charging time in different months of the year.

The study's findings caution policymakers about the potential hazards associated with the importation of electric vehicles (EVs) and recharge stations without appropriately adapting them to the ambient conditions and other influencing factors of the destination country. Furthermore, it emphasizes the importance of self-reliability in a multitude of critical components, including the battery, charging system, BMS, and so forth.

4.4. Wireless Power Transfer for EVs vs. cooling problem for charging stations in Kuwait

Even though our cluster analysis indicates that research is beginning to focus on wireless charging, we deem these alternatives to be too advanced for electric vehicle (EV) laggard nations such as Kuwait, which is still in the process of implementing its first rapid charging stations. A representative from the Ministry of Electricity and Water stated at the recent Sustainable Transport Conference in Kuwait that the current air- and water-cooling mechanisms are incapable of regulating the heat in Kuwait. During charging, the temperature under the vehicle can reach 70 degrees Celsius, posing a fire hazard that could be particularly severe if the electric vehicle battery catches fire and causes a chemical reaction. The Ministry asserts that solid-state batteries for electric vehicles are eagerly anticipated due to their noncombustible characteristics. Evaluations indicate that rapid charging stations in Kuwait are only capable of operating at a capacity of approximately one-third due to the inability of existing charging mechanisms to withstand the extremely high temperatures in Kuwait. Additionally, dust in Kuwait can be a significant annoyance, according to ChargedKW, which has a charging station in Kuwait. They assert that particulate filter replacements are significantly more expensive than in other locations where the same rapid charging station is operational. [11]. Due to these factors, wireless charging will lag once the issue with rapid charging has been resolved. Nevertheless, once such charging station solutions are identified, we can

contemplate the dynamic EV charging (DEVIC) concept, which entails the implementation of WPT on highways. Even if the vehicle is traveling at 100 km/h, a hundred-meter-long WTP track can transmit up to 25 kW of energy to an EV [60]. This amount of power is sufficient to propel the vehicle for an impressive 150 to 200 km. Nonetheless, a substantial financial investment is necessary for the implementation. However, this can be intelligently applied to congested highways, roundabouts, and traffic signals. Such a configuration may extend to the most rudimentary degree of mobile V2V functionality.

4.5. Renewable energy supported VGI

Exceptions notwithstanding, the presence of an abundance of fossil fuels and extremely generous government subsidies that finance most of their power transport to companies and individuals discourages mass-scale energy and fuel transition initiatives, except for marginal image projects for solar and wind energy. Even though most Kuwaitis do not utilize public transportation, it is unlikely that petroleum-powered buses will be replaced with sustainable alternatives. Nevertheless, the literature reviewed for this investigation elucidated that the fleet of buses operating for public transportation systems possesses a considerable capacity for conversion into electric vehicles. Since most of their operations occur during the day, it would be a good notion to install RE power antennas in every bus station. When the enterprise reaches bus terminals, the pantographs that have been installed can be affixed to the antennas to recharge the batteries. Every parking lot, train included, has the potential to function as virtual power facilities. By establishing charging stations powered by solar energy, all electric vehicle (EV) batteries can be charged during the day and discharged during prime hours. To achieve this, an appropriate software-controlled system must be developed. Kuwait could still achieve this utopian future if the ruling aristocracy prioritized it above all else.

4.6. Battery Swapping

This "charging" alternative is particularly intriguing and could potentially represent a paradigm shift in consideration of the cooling challenge associated with rapid charging station operation. In comparison to other alternatives, battery swapping would be a viable option in terms of establishing a new infrastructure, given the shorter delay time for EV owners. Consequently, it is necessary to establish the battery manufacturing facility in the appropriate nation and ensure that the design specifications align with the prevailing environmental conditions. The foundation of the system will be a BMS-enabled, high-quality, custom-designed battery charging facility with a substantial capacity for recharging batteries, backed by effective supply chain management. As the process can be completed in a matter of minutes, the implementation of exchanging stations strategically placed will allow patrons to replace their batteries at a rate equivalent to or even surpassing that of refueling a gasoline-powered vehicle.

4.7. Environmental analysis of driving Electric Vehicle

Notably absent is a discussion of the environmental impact of electric vehicle (EV) operation; this leads us to the conclusion that editors and publishers have no longer shown interest in this subject matter, as it has been extensively covered and discussed previously. However, this subject remains pertinent for emergent market nations due to the relatively recent transition to renewable energy and fuel alternatives.[61] Emerging market countries will continue to find environmental impact analysis to be a pertinent subject, and we sincerely hope that editors will maintain their interest in this area.

5. Conclusions

Bringing every nation under the "EV ready" rubric requires considerable effort from a variety of stakeholders. It is imperative that nations maintain self-sufficiency in supplying all consumables and spare parts necessary to ensure uninterrupted operation of electric vehicles. Considering the findings

derived from the bibliometric analysis and case study, end-users are compelled to accept a performance compromise when EVs and related hardware are imported into their respective nations without undergoing country-specific modifications. Addition of electric vehicles (EVs) to the transportation network, if not executed properly, could result in increased demand outpacing supply, thereby failing to achieve its intended goal of reducing greenhouse gas emissions. Undertaking a study such as the present one, which investigates research interests in the domain of electric vehicle (EV) research, is especially crucial for a nation like Kuwait, which is striving to catch up to the rest of the world in its sustainable transportation system transformation and could use all the assistance it can get. These studies are especially beneficial in identifying the four distinct categories of the known and unknown. That is widely recognized and understood to be the issue at hand, and solutions are readily available and implementable. The second category, referred to as known/unknowns, pertains to matters that are within our awareness but for which we do not readily possess a solution. The third category consists of unknowns, which are occasionally referred to as "wicked problems" because we know what is wrong but not necessarily what caused it or how it evolved; therefore, these unknowns must be investigated prior to attempting to find a solution to the root cause. The fourth category, referred to as "unknowns," comprises unforeseen matters, concerns, and problems that we were not cognizant of prior to commencing the investigation but became apparent during the course of the study—through an epiphany, "aha!" moment, or "genius moment"—and as a consequence, we concluded the exploratory study considerably more informed.

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