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Penetration of Electric Vehicles in Gulf Region and Its Influence on Energy and Economy

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ABSTRACT Electric mobility seems to bring a paradigm shift in the road transport sector worldwide. Huge consumption of fossil fuels and ever-increasing traffic congestion have caused concerns over future energy consumption, economy growth, and greenhouse gas emissions in the Gulf Cooperation Council region's member countries. The introduction of electric vehicles (EVs) in the two most populous countries of the region, i.e., the Kingdom of Saudi Arabia and UAE is considered a promising option to address environmental pollution and future economy-related fears region. This paper presents key drivers for the countries to adopt electric transportation. This research study investigates the impact of EVs penetration on energy, economy, and environment of KSA and UAE through EV stockpile forecasting using linear regression analysis. The obtained results suggest that expected growth in KSA and UAE's power sector will enable them to keep up 5% and 30% EVs penetration by 2030, respectively. In this regard, a set of policies are proposed, which will enable the countries to pace up their efforts to achieve the intended greenhouse gases (GHG) emission reduction goals. Though the presented research is focused on the case study of KSA and UAE, the research findings are generalized enough to be applied to all other regions of the region. The suggested set of policies will serve as guidelines for the relevant stakeholders about the necessary measures required for sustainable road transport electrification in KSA and UAE.

INDEX TERMS Road transport electrification, forecasting, energy and economy, policy.

NOMENCLATURE

CB	Charging Business
DEWA	Dubai Electricity and Water Authority
DSCE	Dubai Supreme Council of Energy
ECEM	Eighth Clean Energy Ministerial
EEE's	Energy, Economy, and Environment
ESMA	Emirates Authority of Standardization & Metrology
EVs	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GHG	Greenhouse Gases
ICE	Internal Combustion Engine
INDC	Intended Nationally Determined Contribution
KSA	Kingdom of Saudi Arabia
OECD	Organization for Economic Cooperation and Development
PIF	Public Investment Fund
PPP	Public-Private Partnerships
R&D	Research and Development
RES	Renewable Energy Sources
RPPG	Research Projects Portfolio
RTA	Road Transport Authority
SASCO	Saudi Automotive Services Company
SASO	Saudi Standards, Metrology, and Quality Organization
SoH	State of Health
TEPCO	Tokyo Electric Power Company
TOU	Time of Use
UAE	United Arab Emirates
VAT	Value Added Tax

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VS	The number of vehicle sales in thousands
V2G	Vehicle to Grid
WHO	World Health Organization
x	Year

I. INTRODUCTION

Electric vehicle sales hit a record figure of 2.1 million in 2019, making the total EV strength worldwide to be 7.2 million [1]. Amongst signatories of EV30@30 (30% vehicle electrification by 2030), 64% EVs comprise of battery electric vehicles [2]. The fossil fuel reliant middle east countries like the Kingdom of Saudi Arabia (KSA) and United Arab Emirates (UAE) have power generation of more than 99% from fossil fuels. Therefore, oil being economic fuel for these countries enabled them to be prosaic, resulting in a monotonous power generation mix [3]. According to the Union of Concerned Scientists, KSA was amongst the top 10 CO_2 emitters worldwide by emitting a humungous 0.62 metric gigatons of carbon dioxide [4].

In contrast, UAE has significantly less CO_2 emissions being 115 million metric tons of carbon dioxide, but still, it is an alarming figure for all seven emirates as they aim to provide a clean environment for its citizens [5]. Considering the non-oil-based activities in KSA, the transportation sector plays a vital role in the economy as its contribution is 10.4% [6]. The transportation sector of UAE contributes 5.4% to its GDP, having a major contribution from Dubai [7]. The previous studies conducted in road transport electrification in KSA and UAE were focused on the impact of EV influx on the environment. They created a void for the proposal of effective guidelines considering the current standings of KSA and UAE to tackle environmental pollution using EVs. The research gap we are going to address in this article are as follows:

1) Why should fossil fuel-driven economies opt for road transport electrification?
2) Current standings of both countries concerning the goal of 30% vehicle electrification by 2030?
3) The potential impact of EV penetration on the Energy, Economic, and Environment of KSA and UAE is 30% road transport electrification.
4) Identification of policies and recommendations that will enable the realization of environmental sustainability goals via EV penetration.

The economic progress of any country lies in the growth of its transportation sector. The Government of KSA has invested a huge amount of USD 229 billion in the last five years in improving the country's transportation infrastructure [8]. Similarly, UAE has also invested USD 87.3 billion in enhancing the transportation sector by the end of 2017 [9]. However, the transportation sector investment resulted in a considerable increase in internal combustion engine (ICE) vehicles. The uncontrolled growth in ICE vehicles and oil-dependent economy resulted in a rampant environmental pollution in KSA and UAE. Therefore, it is deemed necessary to identify all the potential factors that propel these countries to shift towards renewable sources for power generation and clean transportation modes. Amongst numerous driving factors, one of the main reasons is the environmental sustainability goals of KSA and UAE. KSA must meet its Paris goal of curbing 130 million metric tons of carbon dioxide by 2030, while UAE has to uplift its renewable energy mix proportion to 24% under its COP21 goal [10], [11].

To lay the foundation of KSA and UAE's recommended policies, an in-depth analysis of the current EV market scenario and implemented policies is required. In Saudi Arabia, 13 battery charging stations have been deployed, and the government approved the import of 16 EVs from different manufacturers [12], [13]. UAE is quite ahead as only Dubai has 200 charging stations and 4000 EVs on its road network [14], [15]. The administration of both KSA and UAE has defined policies associated with the standardization of EV chargers and defined charger standards accordingly. However, both countries currently apply flat tariffs for EVs instead of hourly tariffs. To engage customers in a vehicle to grid, the introduction of an hourly tariff is necessary. Besides, a flat tariff would allow a huge influx of EVs during peak hours which overburdens the grid.

To measure the impact of EV penetration on EEE's (Energy, Economic, and Environment), it is necessary to delve into countries' future EV market goals. Thus, the EV outlook 2030 for KSA and UAE is elaborated in detail by mentioning the possible EV strength on roads and GHG emissions reduction corresponding to EV strength. The analysis of EV impact on EEE's suggests that if power sector growth in KSA and UAE remains consistent with previous trends, then KSA will sustain 5% EVs while UAE will sustain 30% EVs. Renewable sources would power these EVs; otherwise, they can support more vehicle electrification but using non-renewable energy sources. The analysis for EV strength sustainability is localized to renewables because of significantly reduced detrimental effects on the environment and enhanced well-to-wheel efficiency of EVs [16].

Although the governments of KSA and UAE are heavily investing in the realization of 30% EVs by 2030 but considering their current standings, many efforts need to be made to achieve the milestone. In the light of the current EV market scenario, policies and recommendations are proposed to enable them to escalate their pace towards EV-related goals of reduced GHG emissions alongside the smooth transitioning towards EVs. Moreover, some suggestions are derived from developed EV markets like China had a positive outcome after applying the recommended policies.

A major contribution of this article is as follows:

1) Identification of key driving factors for the deployment of EVs in KSA and UAE. The intent is to establish the need to switch towards EVs despite being oil-driven countries.
2) Forecasting of EV stockpile in 2030 for different market shares using linear regression analysis.

3) The analysis of how EV penetration could impact EEE's in KSA and UAE. It also elaborates that if the average growth rate in the power sector continues, will they be able to realize 30% EVs by 2030?
4) Policies and recommendations are proposed with an intent to have relevant stakeholders invest in the EV market of KSA and UAE. In addition, it boosts the EVs growth to enable mentioned middle east countries to meet their environmental goals well within a time.
5) KSA and UAE are selected to perform this research study as the two countries represent over 75% of the total population of the region. Thus, the research findings are generalized enough for the case of other countries.

The uniqueness of a manuscript is demonstrated by an attempt to identify the key drivers for the introduction of EVs in KSA and UAE despite having oil driving their economy. Also, no such attempts have been made to identify the impact of vehicle electrification on EEE's of KSA and UAE, which indicates whether the respective countries are on the right track to sustain 30% EVs or not? Policy recommendations are proposed considering voids in the EV market of KSA and UAE with an intent to escalate their efforts in meeting environmental sustainability goals alongside the diversification of their economy as EVs are set to take over conventional fossil fuel vehicles.

The manuscript consists of fourteen sections. The first section is an introduction to a research topic. The second section explains the methodology adopted in a study. The overview of energy, economy, and environment, existing EV landscape, and key drivers of KSA is mentioned in the third, fourth, and fifth sections, respectively. Similarly, the overview of energy, economy, and environment, existing EV landscape, and key drivers of UAE are mentioned in the sixth, seventh, and eighth sections, respectively. The KSA's future EV outlook and its impact on EEE's are mentioned in the ninth and tenth sections, respectively. Similarly, UAE's future EV outlook and its impact on EEE's are mentioned in the eleventh and twelfth sections, respectively. The appropriate policy recommendations are proposed in the thirteenth section. Finally, the paper is concluded in the fourteenth section.

II. METHODOLOGY

The assessment of EV market analysis in KSA and UAE requires an in-depth study of their current standings in the EV market. The efforts being made by the administration to curb environmental pollution by promoting EV dissemination and analysis of whether their current strategy will put them in a position to realize and sustain 30% vehicle electrification by 2030? If yes, then are these EVs will be entirely powered by renewable energy sources? To find the answers to all these questions, a four-stage-based methodology is adopted. These four stages are data collection, computation, results & analysis, and recommendations.

The first stage is executed by gathering publicly available data of annual vehicle sales and 2030 EV goals of both countries. Many EV market information have been retrieved from technical blogs due to a limited number of publications. Once the required data is collected, we enter stage two of computation. The computation stage involves the projection of vehicle sales in KSA and UAE by 2030. The vehicle sales data of both countries are available online from the year 2008 and onwards. Therefore, linear regression analysis is on vehicle sales from 2008 and onwards to forecast EVs stockpile of 2030. The results are gathered for each country based upon a trend in vehicle sales in previous years. It can be easily seen that there is no trend in vehicle sales, so appropriate best-fit plots are applied with some assumptions to predict vehicle sales till 2030. After having best-fit plots, we will add vehicle units sold in each year to determine the total vehicle stockpile till 2030, which gives us an estimate of EVs strength in 2030 if vehicle electrification goals are achieved by KSA and UAE. EVs strength will eventually give information about a potential reduction in GHG emissions. At this point, we will be in a better position to analyze that if the power sector in both countries grows as per previous trends, then is it possible for both countries to sustain 30% EVs? If yes are all these EVs would be powered by renewable energy sources? These questions would be better answered if we define the EV specifications, which enables a comparison between potential resources available in 2030 with the possible requirement in the EV sector. At this stage, work is ready to analyze the 30% EV impact on EEE's of both countries. Once, analysis is done, the final stage will put us in positions for appropriate recommendations to ensure maximum could be reaped by KSA and UAE. These recommendations would be directed towards policies that address the potential flaws in the current strategies of KSA and UAE. Moreover, it will indicate the potential deficiency of renewables installed capacity in 2030 if governments of respective countries will not take any action to enhance it. The deficiency indicates possible non-renewables utilization that barely decreases environmental pollution. The summary of an analysis conducted in this study is given in Fig. 1.

III. OVERVIEW OF ENERGY AND TRANSPORTATION SECTORS OF KINGDOM OF SAUDI ARABIA

There has been a modest increase in the gross domestic product (GDP) of KSA in 2019 compared to the past few years. Mere GDP growth of 0.2% occurred in 2019, which is significantly less than 1.6% growth in 2018 [17]. Although the growth of the oil sector is not expected in 2020, still improvement in non-oil sector activities led authors to conclude that GDP in 2020 grows by 2.1% [17]. Forecasting conducted in [18] yields an inflation rate of 0.9% in 2030, which points towards items and facilities being expensive.

The increased power consumption in recent years led towards enhanced oil sector activities. In 2017, 99%

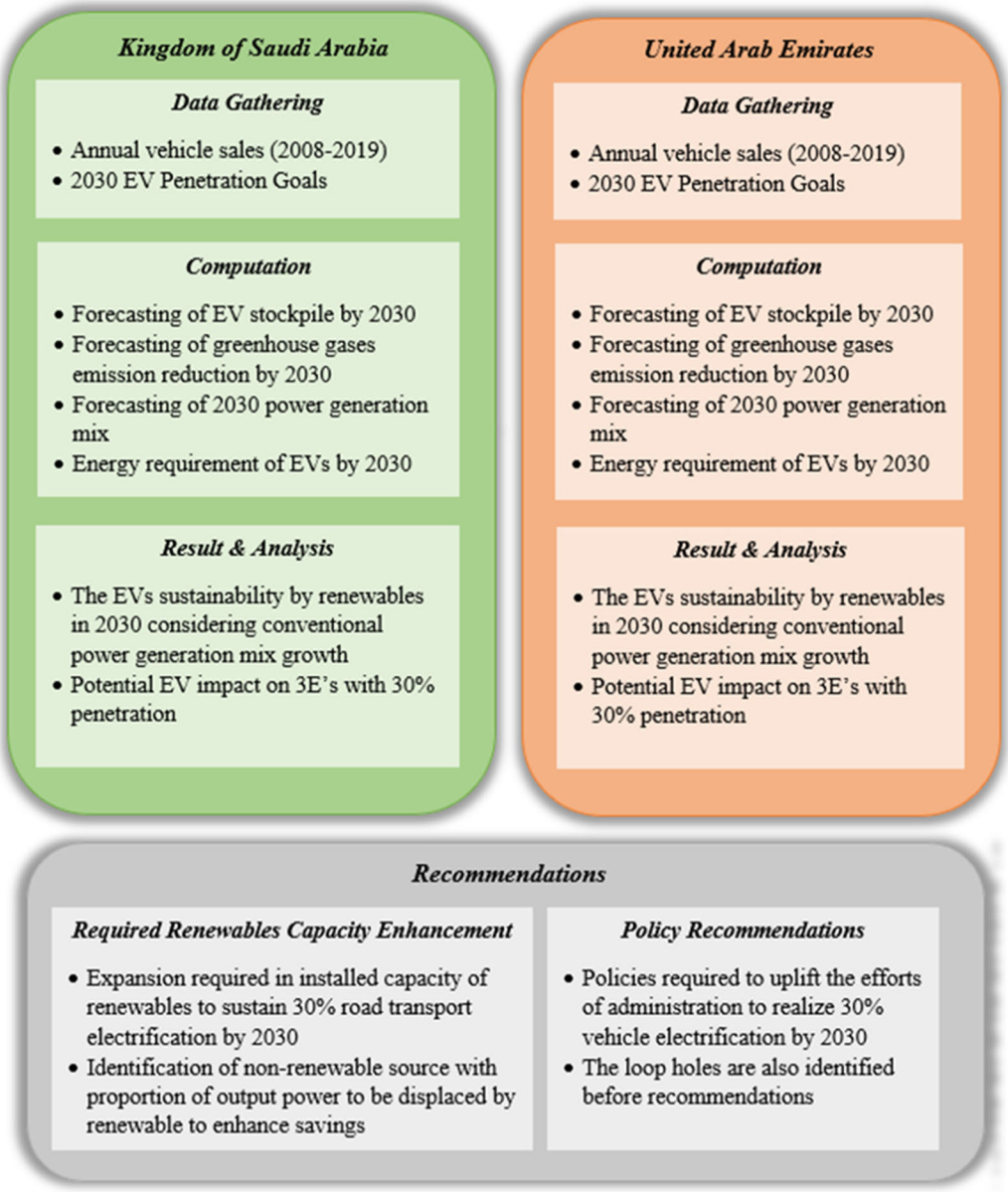

FIGURE 1. Proposed four stage method for EV market analysis in KSA and UAE.

of 375.6 TWh electricity production was generated from fossil fuels [10]. Fossil fuel dominates the energy mix of KSA despite an immense potential for exploiting resources for solar energy production. The electricity generation by fuel in 2017 is given in Fig. 2. 59% of electricity is generated using natural gas. A huge investment of USD 229 billion in the years 2015-2019 by the kingdom is rewarded with an average annual growth rate of 10% in the transportation sector [8]. The country aims to boost its railway infrastructure by investing USD 25 billion in 3 mega railway projects having a length of 3900 km [8]. The road network of a country is 200,000 km in length and registered vehicles strength is 18 million in 2019 [19]. 96% of vehicle stockpiles are comprised of cars and trucks. KSA had a 40% share in total vehicle sales in the middle east [20]. The market share of global vehicle brands in KSA is given in Fig. 3.

IV. EXISTING EV LANDSCAPE IN KSA

The Automotive industry in KSA records 40% sales in the Middle East, including sales of auto parts as well [20]. KSA imported almost 1 million vehicles in 2016, which includes light-duty trucks, commercial cars, and passenger cars [20]. The annual sales growth of vehicles in KSA is given in Fig. 4. Overall, there was no consistent trend in growth as frequent rise and fall of sales were experienced since 2008 and onwards. The largest rise in vehicle sales can be seen in 2019 with 31% growth, while the major fall in sales was back in 2017 with a −23.6% sales reduction [21].

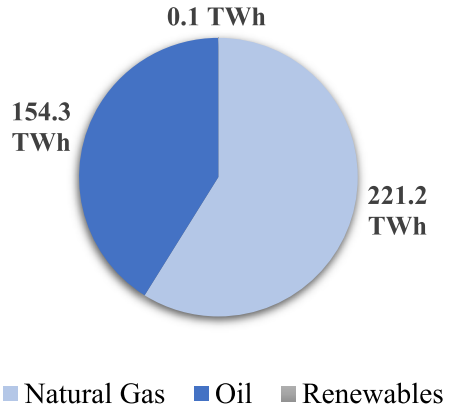

FIGURE 2. Power generation mix of KSA in 2017 [8].

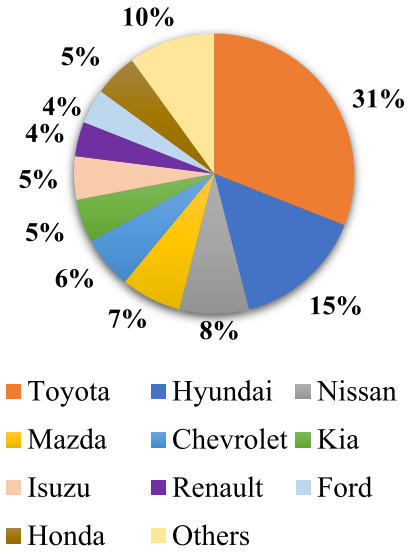

FIGURE 3. Global manufacturers market share in 2018 [20].

The transportation sector is booming in KSA, so insight on their current progress towards a green mode of transportation is necessary to understand the probability of achieving their future goals of a sustainable environment. The status quo of the electric vehicle industry in KSA is discussed in detail in this section.

Few charging stations have been deployed in KSA within the last couple of years. The first commercial charging station was deployed in Riyadh back in August 2019 at one of the petrol pumps of Saudi Automotive Services Company (SASCO) [22]. A total of 13 charging stations have been deployed within KSA, having 13 connectors in them and most of these connectors are Schuko (EU Plug) [12].

The EV market of KSA is in a fledgling stage and looks forward to boosting the number of EVs on roads in the future. 16 EV models have been approved by the Saudi Standards, Metrology and Quality Organization (SASO) to be imported into KSA [13]. The wealth fund of KSA, known as the Public Investment Fund (PIF), became partners with California-based startup Lucid Motors to manufacture EVs by pouring in a huge investment of USD 1 billion [23]. Moreover, PIF bought shares of tesla in 2018 but ended up selling all of its shares at the end of 2019 [23].

A. CURRENT EV POLICY

The initiation of EV penetration in KSA enables it to be on a track to diversify its economy by decreasing its dependence on oil. In 2017, SASO suspended the import of EVs due to pending EV regulations which came into effect back in June 2018 [24]. These regulations allowed the import of EVs for personal use, not for commercial purposes. Therefore, EV penetration at a commercial scale in KSA has yet to happen. In this subsection, we would highlight the existing EV policies issued by SASO to draft a set of recommendations in the later part of this study. Article 5 of the KSA constitution states that if any facility provides charging power to EVs, then it must be considered as a charging business (CB) [25]. These CBs must have a license from the relevant authority and comply with a defined set of regulations [26]. EV charging infrastructure comes under the umbrella of CB and would be subjected to all the laws associated with CBs.

The charging fee of EVs is not regulated as the electricity tariffs. Therefore, calibrated and certified meters are installed separately to measure EV power consumption in Wh. It results in charging infrastructure paying power charges on the basis of charging time and avoids installation charges of certified meters. The time of use (TOU) hourly tariff is necessary to engage EV owners in vehicle-to-grid operation and shifting of peak hour loads. Otherwise, EVs can cluster at charging infrastructure during peak hours and may not feed power into a grid due to a lack of financial incentive by a flat tariff. The specific TOU charging tariffs for EV charging have not been drafted, and instead, regular electricity tariffs have been used to facilitate EV owners at charging stations in KSA.

1) STANDARDS FOR EV CHARGERS

SASO has already started the implementation of "IEC 60364-7-722 Low voltage electrical installations, Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles" and made it a standard for normal EVs chargers as SASO-IEC-60364-7-722. SASO has adopted various standards for quick chargers like IEC 61851-1 etc. However, there are two standards IEC 61851-23 and IEC 62196-1, that SASO did not opt, and they are necessary for the realization of quick charging. IEC 61851-23 and IEC 61851-24 are associated with fast DC charging. However, SASO only opted for IEC 61851-24, which allows communication between a fast DC charging station and EV for controlling DC power flow. However, IEC 61851-23 does not permit communication between the charging station and EVs. Still, KSA must adopt IEC61851-23 as it standardizes the charging methods. Similarly, IEC 62196-1 acts as a referential source for IEC-62196-3, and yet it is not adopted, and the later one is selected. The detail of quick charging standards opted by KSA are mentioned in Table 1.

TABLE 1. Quick charging standards adoption status [25].

S.No	Description	IEC Charging Standard	Requirements	Status of Adoption
1	Conductive EV charging – vehicle inlets, connectors, socket-outlets, and plugs.	IEC 62196-1	General Requirements	✘
2		IEC 62196-2	Interchangeability requirements and compatibility needs for contact tube accessories and AC pins	✓
3		IEC 62196-3	Interchangeability requirements and compatibility needs for AC/DC pins, DC pins, and contact-tube couplers	✓
4	EV conductive charging system	IEC 61851-1	General Requirements	✓
5		IEC 61851-21-1	On-board EV charger EMC requirements for conductive connection to AC/DC supply	✓
6		IEC 61851-21-2	Off-board EV charger EMC requirements for conductive connection to AC/DC supply	✓
7		IEC 61851-23	DC fast charging station	✘
8		IEC 61851-24	Communication for DC power flow between fast DC charging station and EV	✓

V. KEY DRIVERS TO DEPLOY ELECTRIC VEHICLES IN KSA

Transportation Sector Heavy Oil Consumption: It stems out from the fact that almost 25% of oil consumption within KSA is attributed to the transportation sector [23]. Therefore, if KSA manages to replace the significant strength of ICE vehicles with EVs, then promising results shall be expected in terms of the decline in GHG emissions. Therefore, the pace of approaching Intended Nationally Determined Contribution (INDC) goals would also be increased.

Economic Diversity: The key to achieving stability in the economy of any country is economic diversity. As per [27], KSA's economy is heavily dependent upon a single source (oil). Therefore, the country is investing in emerging sectors to make its economy risk-free. The government has decided to take the following steps for economic diversification, which are opting for renewable energy, carbon capture and utilization, gas utilization in the energy mix, efficient energy production and methane recovery, and flare minimization [27].

Paris and INDC Goals: The Government of KSA decided to curb their GHG emission by 130 million metric-tons of CO_2 equivalent by 2030 under Paris goal and INDC [10]. Their objective to achieve this goal is barely possible under their recent changes of domestic policies. Moreover, the Government of KSA also demanded the help of foreign countries, enabling them to emerge with a competitive industry that would compensate for financial loss due to a reduction in oil utilization at the national level [27].

Enhancing Oil Exports: Although Saudi Arabia wants to decrease its dependence on oil due to its increasing GHG emission levels, there is also another motive behind it. According to Tokyo Electric Power Company (TEPCO), the Government of KSA looks forward to enhancing its oil-exporting capacity by cutting down its oil requirements [23]. It would significantly compensate for the revenue generated by oil consumption locally. Moreover, as per [27], KSA can boost its economy and simultaneously

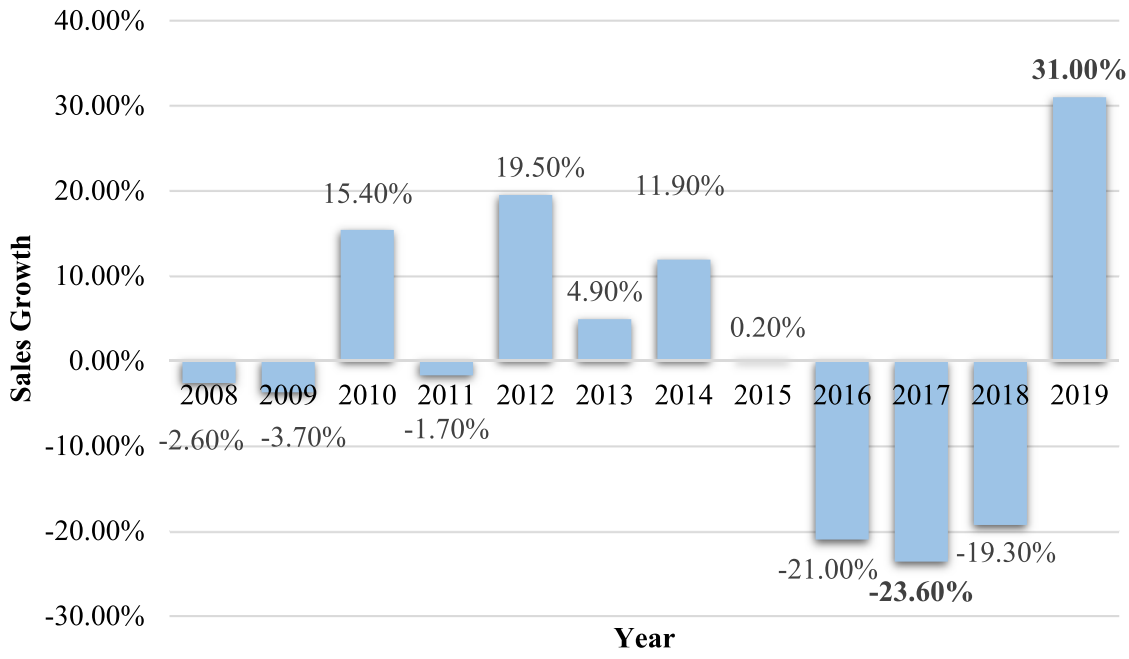

FIGURE 4. KSA annual vehicle sales growth 2008-2019 [21].

achieve its INDC goal of 2030 via revenue generation through oil exports. However, diligent efforts from the Government of KSA are required to find another source of revenue generation. Stage-wise planning is required to reduce their economic dependence on oil as exporting oil will simply shift GHG emissions from one country to another.

Potential Increase in Automobile Market: The legalization for a female to drive in September 2017 could potentially result in the growth of the automobile sector and eventually lead towards enhanced GHG emissions and oil consumption. According to the General Authority of Statistics, in 2017, there are approximately 9.1 million females in the age range of 15 to 29 [28]. At the age of 18, local citizens are eligible to apply for a driver's license [28]. The expected significant shift in the fossil fuel vehicle market influenced the Government of KSA to opt for EVs before environmental pollution and oil consumption by transport gets out of control.

VI. OVERVIEW OF ENERGY AND TRANSPORTATION SECTORS OF UNITED ARAB EMIRATES

The growth in the GDP of the UAE over the last few years has been consistently increasing at a steady pace, with a 2.4% increase in 2019 in comparison with 1.7% in 2018 [29]. Although the GDP growth rate slowed down to 1.7% in 2018, it was uplifted to 2.4% next year because of the significant contribution of the transportation sector in GDP [30]. The annual inflation rate in the year 2019 was -1.8% in comparison with 3.1% in 2018 [29]. The deflation in 2019 occurred as the consequence of the newly introduced value-added tax (VAT) of 5% in 2018, which was removed later on for the year 2019 [31].

The rapid economic growth enabled UAE's grid to reach its limits as installed generation capacity reaches 27 GW in 2017 [32]. Total energy consumption gets 127,000 GWh in 2017, which made UAE the largest electricity per capita consumer throughout the world [33]. A year later, an increase of 7.8% occurs in energy consumption, taking a total figure to 136.9 TWh (136,900 GWh) [34]. The power generation mix of UAE in 2018 is given in Fig. 5. It can be seen that country is heavily reliant upon natural gas, making almost 98% of the power mix. While less than 1% of power is generated using renewable energy sources (RES).

The transportation sector is vital for the economy of UAE as it contributes 5.40% in GDP [35]. According to World Health Organization (WHO), cars and light-duty four-wheelers possess a major chunk of a total 3.4 million vehicles registered in UAE [36]. The country secured an honor in 2017-18 for having one of the best road infrastructure networks in terms of road quality index [37]. The Government of UAE is heavily investing in railway networks known as Etihad railways. The authors in [43], [38] suggested that the railways network has the potential to reduce GHG emissions by 70 to 80%, and it can displace 300 diesel trucks from UAE's road networks. The registered vehicle composition is given in Fig. 6, and it states that cars and light-duty four-wheelers comprise 91.1% of total vehicles while all other vehicles combined would make less than 10% [39].

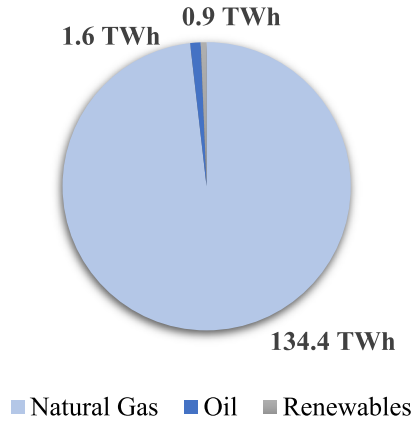

FIGURE 5. Power generation mix of UAE in 2018 [33].

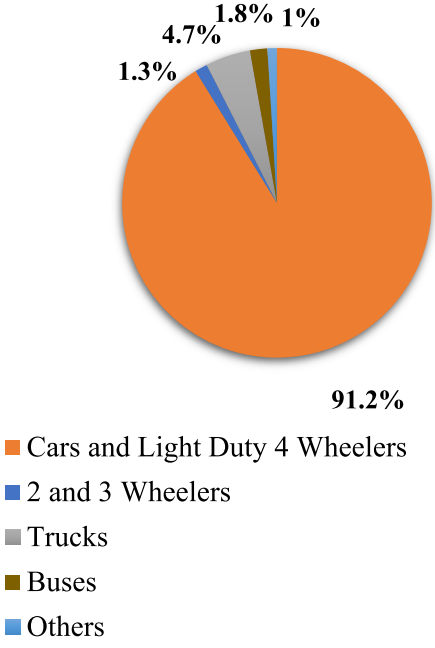

FIGURE 6. Registered vehicle composition of UAE in 2018 [39].

VII. OVERVIEW OF ENERGY AND TRANSPORTATION SECTORS OF UNITED ARAB EMIRATES

The transportation sector of UAE contributes a significant share of 5.40% towards the GDP of UAE [35]. The automotive trade of the Gulf Cooperation Council (GCC) reached USD 66.5 billion in 2014, and UAE achieved 39% of these exports with dominance in intra-GCC trade [40]. The humungous growth in annual vehicle sales of UAE resulted in a 1792.1% increase in 2019 in comparison with a growth of 8.6% in 2018, while the record lowest growth was recorded in 2017 with −93.6% [40]. The annual sales growth in UAE for a period of 2008-2019 is given in Fig. 7. Although the transportation sector is booming in UAE, an insight into their current progress towards a green mode of transportation is necessary to understand the probability of achieving their future goals of a sustainable environment. Therefore, the status quo of the electric vehicle industry in the UAE is discussed in detail in this subsection.

Although the EV market is in a nascent stage in UAE still the number of EVs on its roads is improving at a steady rate over the past few years. In 2016, 0.1% of the total vehicles sold were EVs which makes a sale of 311 EVs [41]. The sales of EVs within the UAE are much concentrated within Dubai because of the advanced development of charging infrastructure. It also resulted in the total strength of EVs in Dubai reaching 4000 by the end of 2018 [15].

Various charging stations have been deployed in UAE in the last five years. Dubai Electricity and Water Authority (DEWA) had doubled the number of charging stations in Dubai from 100 to 200 back in 2018 when they decided to install additional 100 chargers [14]. In Abu Dhabi, number of charging stations is almost ten times less than in Dubai. There are a total of 23 charging stations in Abu Dhabi with a total of 50 connectors in them, and a majority of these connectors are Tesla Dest Chargers [41].

A. CURRENT EV POLICY

The UAE is on a path to emerge as one of the leading EV markets in the world. Amongst all the seven emirates, Dubai has the potential to become a global leader in EV market. Dubai Clean Energy Strategy 2050 aims towards having 75% vehicle electrification in Dubai [23]. The administration across UAE has defined regulations for EVs and charging infrastructure networks. These regulations are mentioned as follows: The electric cars in UAE must mention performance labels on them having all values specified for an outdoor temperature of 45 degrees Celsius [42]. In addition, the vehicle range must be tested in compliance with the standard ISO 8714, and upon full charging, the vehicle at least provides a driving range of 150 km [42]. The length of cable connected with the charging connector shall not exceed 7.5m. The electric vehicle supply equipment (EVSE) shall provide the facility of interlock, which de-energizes the cable upon uncoupling of a connector from EV. The voltage and current rating of EVSE shall not exceed 250V and 50A. It is necessary for staff working at charging infrastructure to be trained in accordance with the following procedures: Risk assessment before electrical installation, strict adherence to wearing protective equipment, awareness of preventive actions, and must be articulate in communicating to customers about the use of EV and its maintenance measures.

Similar to KSA, a flat tariff has been applied by DEWA for charging infrastructure, which results in EV clustering during peak hours and reduced consumer participation in a vehicle to grid. DEWA has applied a flat tariff of 29 fils/kWh until 2020 for commercial consumers only, while the charging fee is waived off for non-commercial users [43]. This tariff is expected to continue till the end of 2021. TOU hourly tariff is necessary to reap maximum profits due to road transport electrification; otherwise, the road to a reduction in environmental pollution by EVs may result in overburdening of the grid. It may also lead to a worst-case scenario of the utilization of non-renewables for meeting EV power requirements.

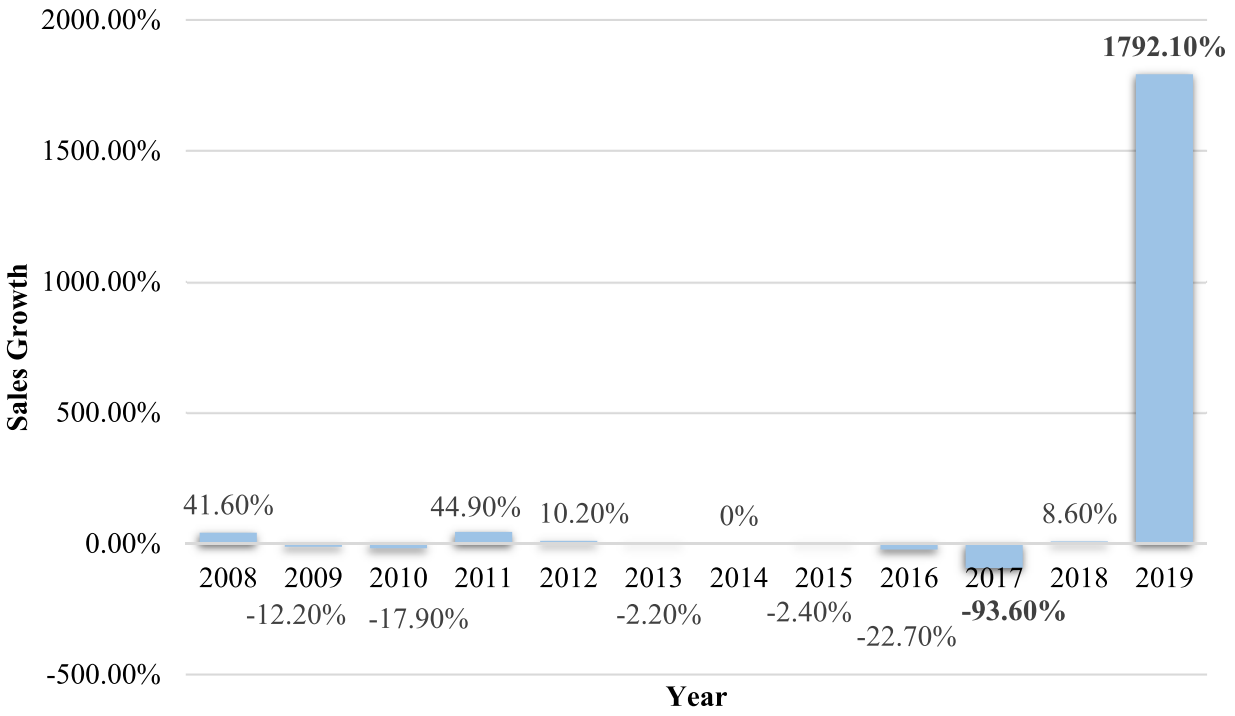

FIGURE 7. UAE annual vehicle sales growth 2008-2019 [40].

1) STANDARDS FOR CHARGERS

The Emirates Authority of Standardization & Metrology (ESMA) proposed the charging standard for both slow and fast charging. However, there are two standards in infant stages, namely IEC 62196-1 and IEC 62196-2. IEC 62196-1 is associated with DC charging, and it is under revision, while IEC 62196-2 is associated with requirements for dimensional interchangeability for AC pins and contact tube accessories is under development. The detail of charging standards opted in UAE is given in Table 2.

VIII. KEY DRIVERS TO DEPLOY ELECTRIC VEHICLES IN UAE

Increased Transportation Sector GHG Emissions: The transportation sector of UAE contributes the second-highest share of 22% in UAE's GHG emissions [45]. It led authorities to opt for an alternative clean mode of transportation in the form of EVs to meet their quota of reduction in GHG emissions defined under the Kyoto protocol and COP21.

Kyoto Protocol and COP21 Goal: UAE being the signatories of the Kyoto protocol and COP21 goal, intends to reduce GHG emissions for a sustainable long-term future via production of 24% electricity through RES [11]. The Government of UAE intends to fulfill these goals by defined KPIs to monitor its targets, and they have also launched some initiatives to reduce GHG emissions. Moreover, the Ministry of Climate Change and Environment drafted a national climate change plan [44] of UAE which would serve as a roadmap for how to achieve their defined targets.

Declining Cost of Electric Vehicles: The strength of electric vehicles has been increasing on road networks of UAE. The consistent increase in EV numbers over the past five years enabled a decreasing operational cost to settle at \$0.34/km for Tesla 3 at the current electricity tariff [45]. This cost is comparable to both petrol and diesel-based vehicles. In the light of these events, it is expected that EVs cost will continue to drop further, which makes its position stronger in the market.

10% Electric Vehicles in Dubai: Dubai has defined a target of having 10% electric or hybrid vehicles on its roads by 2030 [46]. The motive behind this target is to green the economy as the Government of UAE intends to enhance the research and development (R&D) related to green technologies to bolster institutional and behavioral foundations to ensure its effective adoption [47]. In 2011, a mere budget of 0.49% was spent by UAE in R&D, which is significantly less than the average spending of other member states of the Organization for Economic Cooperation and Development (OECD). Therefore, the country plans to increase it to 1.5% under UAE Vision 2021 [47].

Immense Vehicle to Grid Potential: It is estimated that if Dubai remains on course to achieve 10% EVs by 2030, then a total power of 3 GW can be injected by EVs into a grid via vehicle to grid (V2G) services whenever required, and it has a potential to generate a revenue of USD 100 million per year [46]. Therefore, the UAE's administration would not have to invest huge sums in thermal power generation and stationary battery energy storage systems. However, V2G yet has various problems to address, like the degradation of lithium-ion batteries [48].

TABLE 2. Charging standards adoption status [42].

S.No	Description	IEC Charging Standard	Requirements	Status of Adoption
1	Conductive EV charging – vehicle inlets, connectors, socket-outlets, and plugs.	IEC 62196-1	EV charging up to 250A ac and 400A dc	✘
2		IEC 62196-2	Interchangeability requirements and compatibility needs for contact tube accessories and AC pins	✘
3	EV conductive charging system	IEC 61851-1	General Requirements	✓
4		IEC 61851-21	Electric vehicle requirements for conductive connection to an a.c./d.c. supply	✓
5		IEC 61851-22	AC electric vehicle charging station	✓
6		IEC 61851-23	DC fast charging station	✓
7	Low voltage switch and control gear	IEC 61439 series	Assemblies	✓
8		IEC 60947-1	General rules	✓
9		IEC 60947-2	Circuit-breakers	✓
10		IEC 60947-3	Switches, disconnections, switch-disconnections, and fuse-combination units	✓

IX. FUTURE OUTLOOK OF EVS AND VEHICLE SALES IN KSA

The EV30@30 campaign aims to have 30% of vehicles electrified by 2030, and it was initiated back in 2017 at Eighth Clean Energy Ministerial (ECEM) [49]. The International Energy Agency forecasts the global EV stockpile under EV30@30 scenario to 228 million by 2030. The EV30@30 signatories are expected to realize 30% EV market share, excluding two-wheelers.

The Government of KSA, under its vision 2030, aims to invest in environmental sustainability for increasing the expected age of its citizens from 74 to 80 [50]. Vision 2030 also intends to diversify the economy of KSA as oil is a depleting resource and poses a high risk to the country's economic stability [50]. Therefore, the Government of KSA invested USD 1 billion in Lucid Motors for EV manufacturing [23].

There is very limited data available for vehicle sales in different regions of KSA. Riyadh city is the only exception as the Ministry of Economy, Trade and Industry of Japan gathered the data of registered vehicles in Riyadh city with the help of the General Directorate of Traffic in KSA to make EV projections against various EV market shares [25]. The passenger vehicle sales in Riyadh in 2015 is 83,873, while commercial vehicles were recorded at 31,058 in 2015. Moreover, 114,931 private vehicles were sold in Riyadh in 2015. The EV market size is estimated for three different scenarios, which are as follows:

- EV share in sales gets 5% by 2030
- EV share in sales gets 10% by 2030
- EV share in sales gets 30% by 2030

We will use it to estimate the strength of EVs in KSA after ten years. The total vehicle stockpile of KSA in 2030 is forecasted to be 16,493,320. Therefore, a 5% EV market

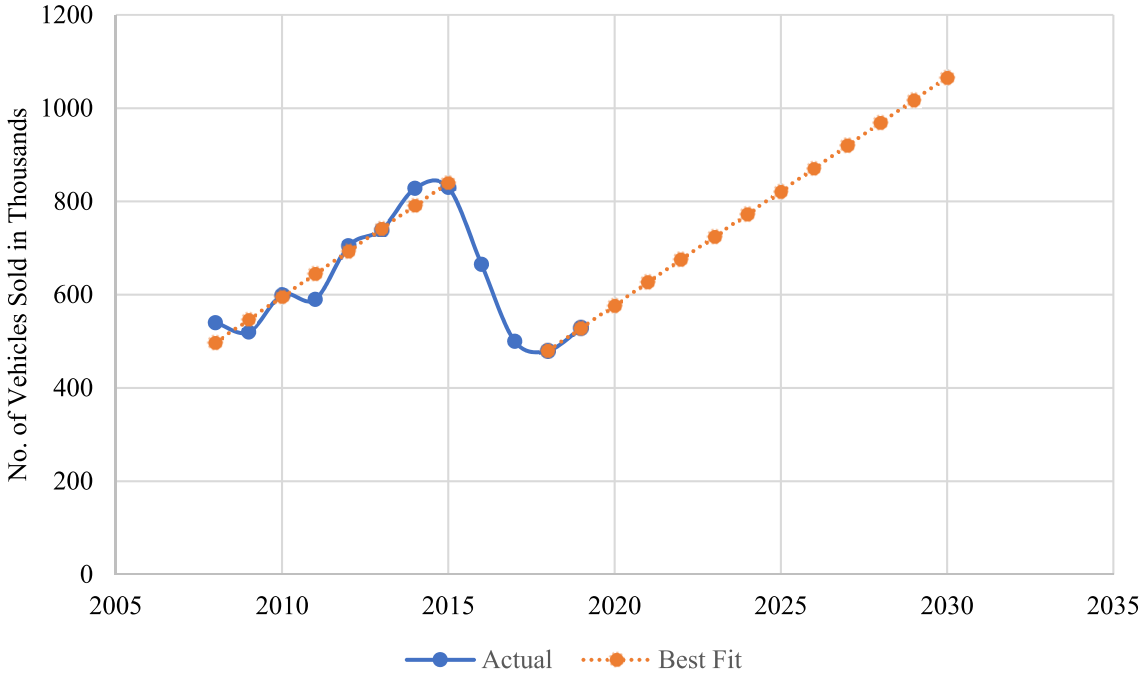

FIGURE 8. Actual and best fit plot of KSA annual vehicle sales (2008-2019).

TABLE 3. Annual vehicle sales in KSA.

Year	Vehicle Sales	Year	Vehicles Sales
2008	233,590	2014	263,110
2009	205,090	2015	256,710
2010	168,330	2016	198,510
2011	243,990	2017	12,800
2012	268,910	2018	13,900
2013	263,110	2019	263,000

share will result in 824,666 EVs. Similarly, 10% and 30% EV share results in 1,649,322 and 4,947,996 EVs respectively.

A. FORECASTING OF ANNUAL VEHICLE SALES IN KINGDOM OF SAUDI ARABIA

The annual vehicle sales data for KSA is given in Table 3. It can be easily seen that a particular trend is being followed from 2008 to 2015, which is a consistent increase in sales. Following 2015, sales were dropped rapidly till 2018 and the drop in sales can be attributed to economic uncertainties and tight liquidity prevailing in the market. In 2019, a promising increase in vehicle sales was observed, and the legalization of females driving vehicles is one of the major reasons behind it. Although in the future, numerous factors like COVID-19 pandemic can affect vehicle sales, but in our study, it is assumed that if Saudi Arabia is on the right path towards achieving their vision 2030, then a similar increase in sales trend could be experienced from 2019 till 2030.

Considering the data of vehicle sales from 2008 to 2015, we have analyzed that a forecasting method of simple linear regression analysis is appropriate to forecast KSA annual vehicle sales till 2030. It is because its sum of squares is least with linear best fit plot in comparison with a nonlinear best fit curve. The equation of a best-fit curve is linear, and our primary objective is to find the value of A as given in (1) to determine the gradient of the linear trend line from 2019 to 2030. The number of vehicle sales in thousands is given by VS and year is mentioned as x. The value of A and B would be determined by linear regression solver using best fit based on a minimum residual square error in data. The best fit plot is given in Fig. 8 results in the value of A being 48.86.

If we add data of vehicle sales of 2019 and computed value of A in (1), the resulting value of B comes out to be 480.02. The updated trend equation is given in (2), and its plot is given in Fig. 8. The trend equation forecast the sale of 1066340 vehicle sales in the year 2030, and accordingly total vehicle stockpile of KSA would be 16,493,320.

$$VS = A(x - 2007) + B \tag{1}$$

$$VS = 48.86(x - 2018) + 480.02 \tag{2}$$

X. EVs IMPACT ON ENERGY, ECONOMY, AND ENVIRONMENT IN KSA

The effects of EV penetration can be communicated with better clarity if we compare the parameters under two different scenarios being with and without EV penetration. The EV parameters are defined in Table 5. In order to achieve precise results for EEE's (Energy, Economy, and Environment) outlook in 2030, and it is necessary to use medium-duty EV specifications. Medium duty specifications evade the extremes results of light and heavy-duty EVs. The specifications of the electric transit bus correspond to

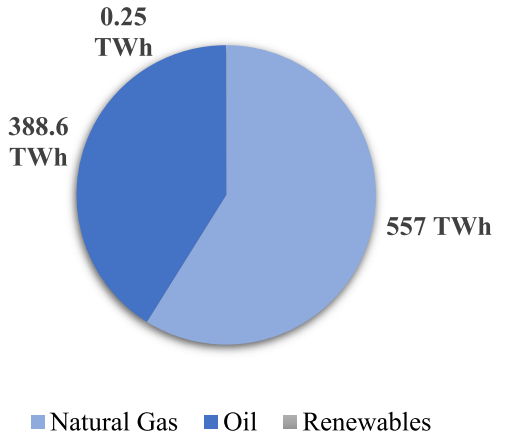

FIGURE 9. Power generation mix of KSA in 2030.

medium-duty EV. The strength of EVs used in the analysis is taken from the aforementioned forecasted results for different EV shares. Moreover, the primary purpose for the uptake of EVs is to reduce GHG emissions. Therefore, we will analyze the impact on EEE's given that renewable sources of energy power all EVs.

A. ENERGY

The impact on the energy sector by EV penetration is elaborated using a comparison of results for with and without EV penetration. If there is no EV penetration in KSA by 2030, their power generation mix is anticipated to look like Fig. 9. The statistics in Fig. 9 are calculated by using an average annual increase in power demand of KSA. According to the past trend in the growth of the power sector, the average annual growth in KSA settles at 8% [51]. Considering further growth in EV market share over the next ten years in KSA, the energy requirement to sustain corresponding EV strength would vary. Fig. 10 illustrates the energy requirement of EVs having specifications mentioned in Table 5 against particular EV strength in 2030 corresponding to market share growth.

Comparing the expected renewable energy generation of 0.25 TWh given in Fig. 9 against energy requirements for all scenarios, KSA will only be able to sustain 5% EV penetration by 2030 powered by renewables. Therefore, if KSA has to achieve the milestone of 30% EV penetration by 2030, the electricity generation by renewable sources must be 1.48 TWh. The expected 0.25 TWh generation by renewables in 2030 is six times less than the requirement of 30% EV penetration. Therefore, the government of KSA needs to invest heavily to enhance renewable sources' contribution. Otherwise, they may lag behind their goal of a sustainable environment under vision 2030

B. ECONOMY

The total power generation capacity of KSA is expected to rise by 570.25 TWh in 2030. The contribution of natural gas and oil in this increase is immense, being 335.8 TWh and 234.3 TWh, respectively. The average operational cost involved in producing electricity from gas and oil-fired power

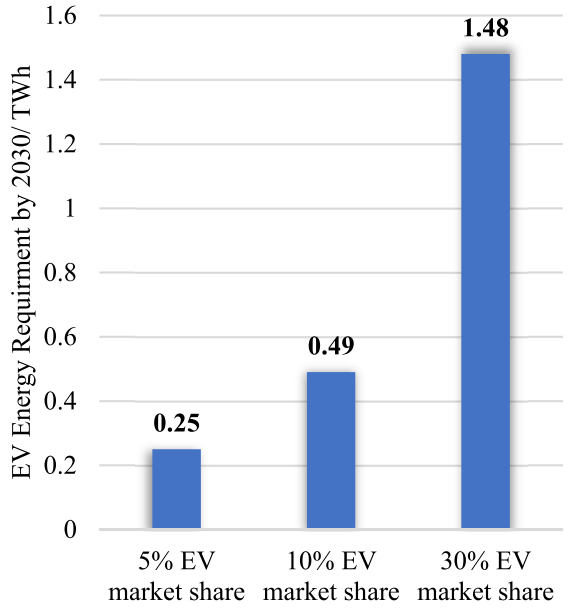

FIGURE 10. Energy requirement against different EV penetration in KSA by 2030.

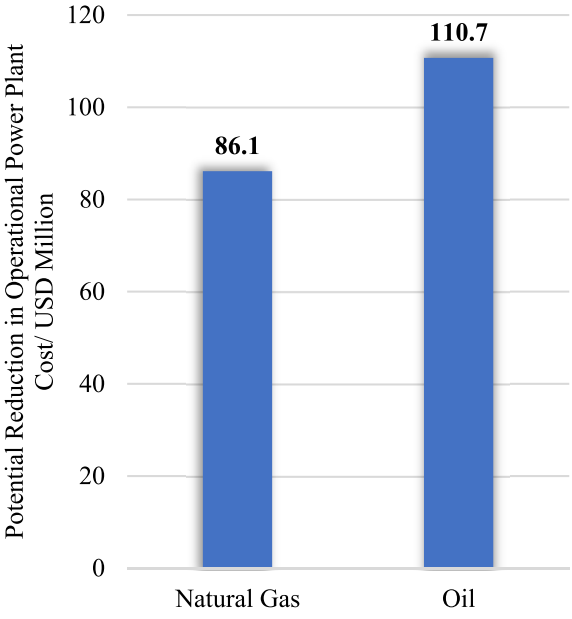

FIGURE 11. Power generation operational cost reduction.

plants is 8 cents/KWh and 10 cents/kWh, respectively, while renewables like solar and wind would incur 1 cent/kWh [52]. As we have already established in Fig. 9 that KSA is already on a trajectory to almost sustain 5% EV penetration by 2030, so we will analyze the economic benefit for 30% EV penetration. The 30% EVs in KSA would require an additional 1.23 TWh renewable energy if compared with the forecasted power generation mix in Fig. 9. considering that the total forecasted power of 2030 stays the same, and government of KSA has to accommodate 1.23 TWh electricity production by

TABLE 4. Diesel bus specifications.

S.No.	Parameter	Quantity
1	No. of Buses	1
2	Annual Distance Covered (Km)	150,000
3	Mileage (L/Km)	0.3
4	Fuel Consumption (Liters)	45,000
5	Annual GHG Emissions (Kg CO_2)	215,370

TABLE 5. Electric bus specifications.

S.No.	Parameter	Value
1	Maximum Range (Km)	375
3	Battery Size (kWh)	300
4	Charging Efficiency	90%
5	Charging Power (kW)	100
6	Annual Distance Covered (Km)	150,000
7	Consumption (kWh/km)	0.8
8	Annual GHG Emissions (Kg CO_2)	132,480

renewables at the stake of curbing output from either natural gas or oil. The different amounts of reduction in operational charges can be achieved by curbing output from different sources. The potential reduction in operational charges is mentioned in Fig. 11. The statistics in Fig. 11 reveals that higher savings can be achieved by decreasing oil utilization as a decrement of 1.23 TWh in oil-fired power production yields savings of USD 110.7 million.

C. ENVIRONMENT

The authors in [53] analyzed that the average ghg emissions for electricity generation in KSA is 1,104g CO_2/kWh. It is an emission resulting from electricity generation via non-renewable sources. The in-depth analysis is conducted in [54] looked into GHG emissions by ice vehicles in KSA via a comparative study of gulf course countries. Their result states that 9 million registered vehicles in KSA emitted 56 million tons of CO_2, corresponding to the consumption of 10,182,000 tons of oil equivalent. It makes average ice emissions of 4786g CO_2/liter of fossil fuel. The comparison of 1,104g CO_2/kWh with 4786g CO_2/liter of fossil fuel indicates that EVs contribution to GHG emissions is 4th in comparison with ICE vehicles if both vehicle technologies have similar electricity and fuel consumption respectively. To analyze the GHG emissions reduction, we would use the specifications of diesel and electric buses mentioned in Table 4 and Table 5, respectively. The potential GHG emissions reduction for different EV market shares is given in Fig. 12. however, GHG emissions reduction can be further enhanced if EVs are powered by renewable energy sources.

The comparative analysis of the potential GHG emission reduction is given in Fig. 12 if all EVs are powered by renewable or non-renewable energy sources. The different bus technologies emissions analysis conducted in [16] states that the average well-to-wheel GHG emissions of an electric bus are 20 gCO2 eq/km if powered by renewable energy sources. If the annual distance covered by electric bus is

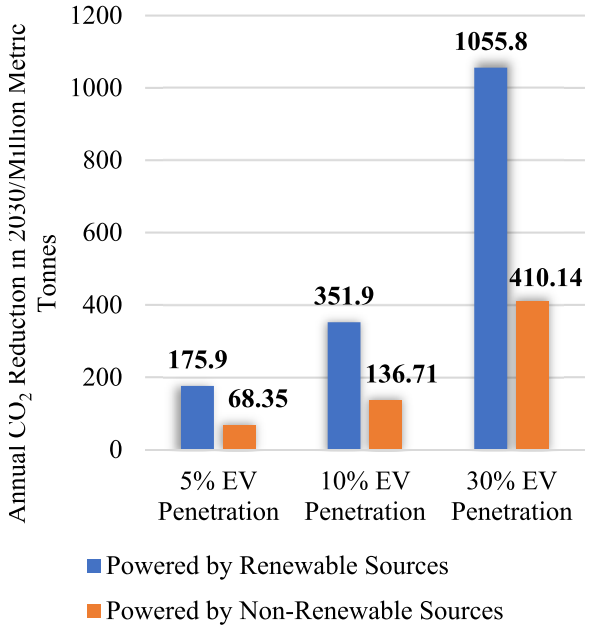

FIGURE 12. Comparison of KSA GHG emissions reduction in 2030.

150,000 km, as mentioned in Table 5, then its CO2 emission would be 3 tons CO2 eq. If we simply multiply this emission value with forecasted EV strength for different market share, then we can have annual GHG emissions of EVs powered by renewables. Then we can take its difference from annual GHG emissions of diesel buses to compute potential emission reduction.

XI. FUTURE OUTLOOK OF EVS AND VEHICLE SALES IN UAE

The strength of EVs on UAE roads is increasing, and eventually, it will knit electricity and transportation sectors. Currently, recharging EVs and refueling ICE vehicles almost costs the same with some minor differences. However, due to the increased competitiveness of EVs in the UAE, their cost of ownership is expected to drop lower than ICE vehicles in the

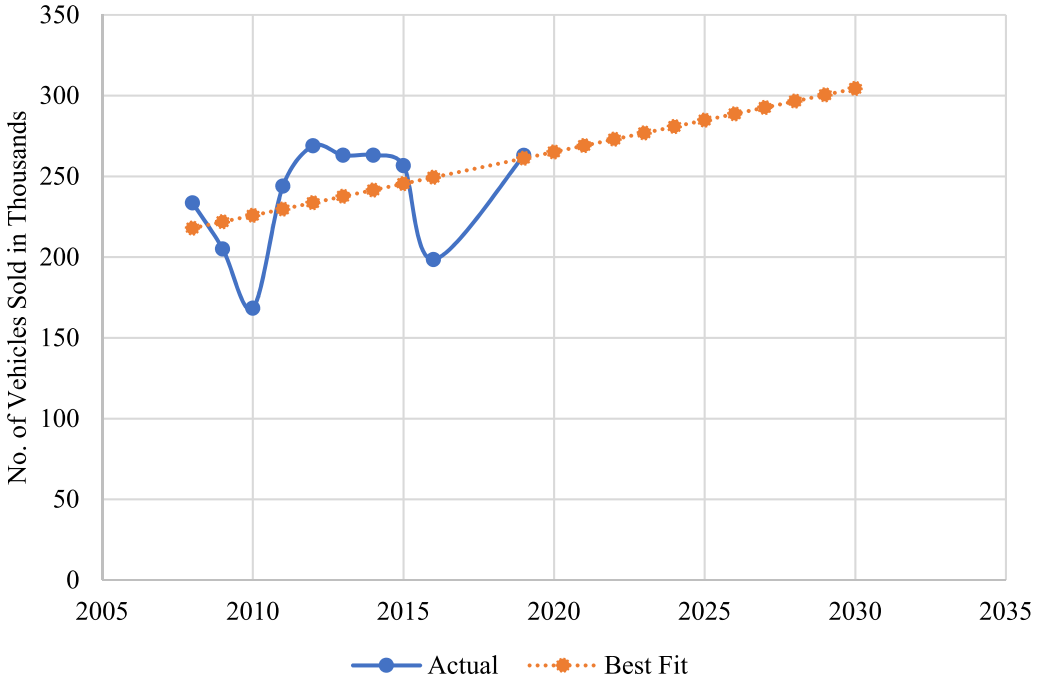

FIGURE 13. Actual and best fit plot of UAE annual vehicle sales (2008-2019).

coming years. The Dubai autonomous transportation strategy aims to have 25% of vehicles electrified in the UAE [55].

There is very limited data available for vehicle sales for all seven emirates of UAE. Dubai is the only exception as its government is actively involved in the flourishing EV industry. They have also declared their current state of the EV industry and their future goals in technical reports. Dubai has a target of achieving 10% EVs and hybrid EVs by 2030 [46]. DEWA has installed 200 charging stations in Dubai, having 4000 EVs on its roads [15]. However, our analysis for the EV market of UAE can certainly not be localized to Dubai, so that we will be using data of annual vehicle sales data in the UAE indicated by an actual plot in Fig. 13. The EV market size for UAE is estimated for three different scenarios, which are as follows:

- EV share in sales gets 5% by 2030
- EV share in sales gets 10% by 2030
- EV share in sales gets 30% by 2030

We will use it to estimate the strength of EVs in UAE after ten years against different market shares by considering the forecasted sales value in 2030. The total vehicle stockpile of UAE in 2030 is forecasted to be 5,523,519. Therefore, a 5% EV market share will result in 276,175 EVs. Similarly, 10% and 30% EV share results in 552,351 and 1,657,055 EVs respectively.

A. FORECASTING OF ANNUAL VEHICLE SALES IN UNITED ARAB EMIRATES

The annual vehicle sales data for UAE is given as blue line plot in Fig. 13. It can be easily seen that a particular trend is being followed from 2008 to 2016, which is a consistent increase in sales. Following 2016, sales were dropped rapidly till 2018. In 2019, a huge increase in vehicle sales was observed, which bring sales figure back onto the same trajectory of 2008-2016. The sales in 2019 hike up due to the stabilization of the automotive industry in UAE. Although in the future, numerous factors like Covid-19 pandemic can affect vehicle sales, but in our study, it is assumed that if UAE is on the right path towards achieving its vision 2030, then a similar increase in sales trend could be experienced from 2019 till 2030.

Considering the data of vehicle sales from 2008 to 2016 and sales in 2019, we have analyzed that a forecasting method of simple linear regression analysis is appropriate to forecast UAE annual vehicle sales till 2030. It is because its sum of squares is least with a linear best fit plot in comparison with a nonlinear best fit curve. The primary objective is to find values of A and B as given in (1) to determine the linear trend line from 2019 to 2030. The number of vehicle sales in thousands is given byVS and year is mentioned as x. The resulting best fit plot equation is given as (3) and its plot given in Fig. 13. The best fit plot is further interpolated to 2030, as given in Fig. 13. The results indicate an annual vehicle sale of 304420 units in 2030. The total vehicle stockpile by 2030 would be 5,523,519.

$$VS = 3.93(x - 2007) + 214.03 \tag{3}$$

XII. EVs IMPACT ON ENERGY, ECONOMY, AND ENVIRONMENT IN UAE

As in the case of KSA, we will be analyzing EV penetration impact under two different scenarios of with and without EV penetration. Similarly, we will also be using EV specifications given in Table 5 alongside mentioned assumptions for

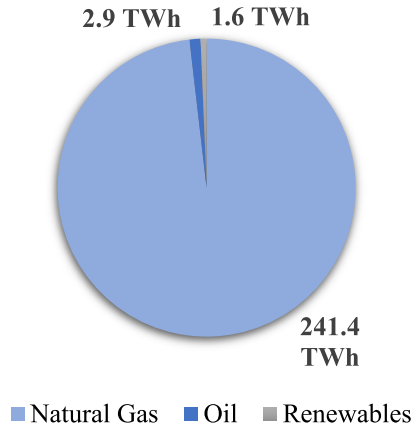

FIGURE 14. Power generation mix of UAE in 2030.

quantifying EV effects on energy, economy, and environment of UAE.

A. ENERGY

The impact on the energy sector by EV penetration is elaborated using a comparison of results for with and without EV penetration. If there is no EV penetration in UAE, then by 2030, their power generation mix will look like Fig. 14. The statistics in Fig. 14 are calculated by using an average annual increase in power demand of UAE. According to past trends in the growth of the power sector, the average annual growth in UAE settles at 5% [56]. Considering further growth in EV market share over the next ten years in UAE, the energy requirement to sustain corresponding EV strength would vary. Fig. 15 illustrates the energy requirement of EVs having specifications mentioned in Table 5 against particular EV strength in 2030 for each market share growth.

Comparing the expected renewable energy generation of 1.6 TWh given in Fig. 14 against energy requirements for all scenarios, UAE will be in a commanding position to sustain more than 30% EV penetration powered by renewable energy sources. However, the Government of UAE intends to roll out 42,000 EVs by 2030 [23]. It corresponds to less than 1% vehicle electrification by 2030. Therefore, proper planning and appropriate policies need to be adopted by the Government of UAE to head towards a right direction of 30% EV penetration. This set of policies will be discussed in detail later in this study.

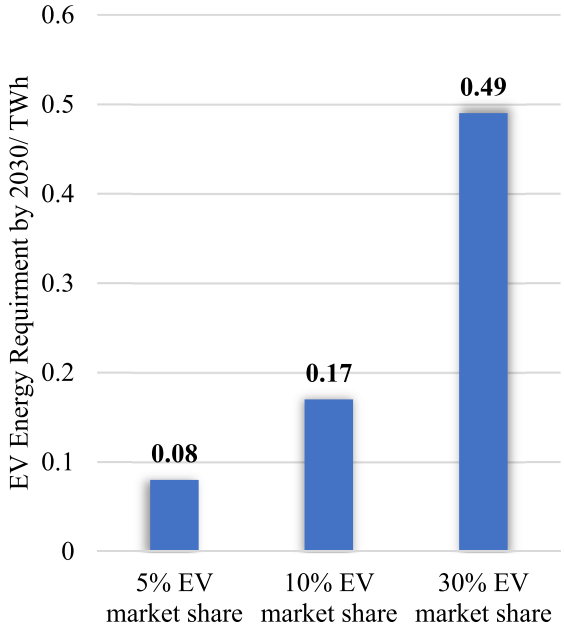

FIGURE 15. Energy requirement against different EV penetration in UAE by 2030.

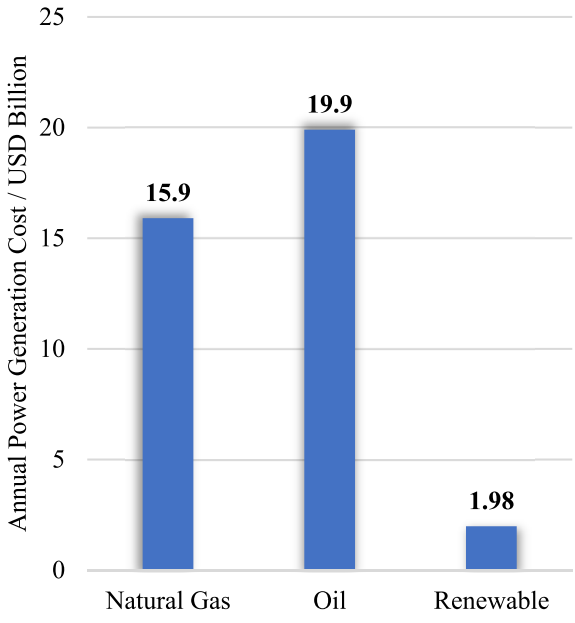

FIGURE 16. Power generation cost for 30% EV penetration in UAE.

B. ECONOMY

The total power generation capacity of the UAE is expected to rise by 109 TWh in 2030. Natural gas contributes a share of almost 98% (107 TWh) while renewables contribute 0.7 TWh in increment of power generation. As discussed earlier, the UAE's goals are only permitting less than 1% vehicle electrification by 2030. It will put UAE far behind the nations striving to achieve EV30@30 goals. Therefore, we will perform a comparative analysis of the operational cost involved in powering 30% EVs by oil, natural gas, and renewables. As discussed before, the average operational cost involved in producing electricity from gas and oil-fired power plants is 8 cents/kWh and 10 cents/kWh, respectively, while renewables like solar and wind would incur 1 cent/kWh [52]. It results in operational charges, as given in Fig. 16. The result indicates at least USD 14 billion could be saved by powering EVs with renewable sources.

C. ENVIRONMENT

The in-depth analysis conducted in [57] states that GHG emissions of the power sector in UAE are 34.2 million metric tons CO_2 against power generation of 52.6 TWh

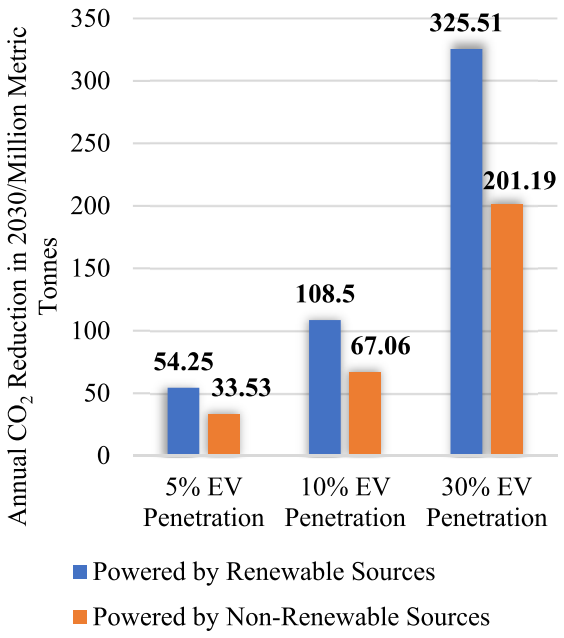

FIGURE 17. Comparison of UAE GHG emissions reduction in 2030.

in 2005. therefore, it corresponds to GHG emissions of 650.2g CO_2/kWh from power generation. The annual fuel consumption of UAE was 9807 kilotons of oil equivalent [58]. As per the report of the world bank, the registered number of vehicles in UAE by 2005 was approximately 1.46 million [59]. The study on GHG emissions impact in UAE states that, on average, 44.25 million metric tons of CO_2 is emitted annually by UAE's transportation sector [60]. Collectively, the above-mentioned information makes ICE vehicle emission of 4432g CO_2/liter of fossil fuel. The comparison of 1,104g CO_2/kWh with 4432g CO_2/liter of fossil fuel indicates statistics clearly indicate that EVs contribution to GHG emissions is almost 4th in comparison with ICE vehicles if both vehicle technologies have similar electricity and fuel consumption respectively. To analyze the GHG emissions reduction, we would use the specifications of diesel and electric buses mentioned in Table 4 and Table 5, respectively. The potential GHG emissions reduction for different EV market shares is given in Fig. 17 if EVs are powered by renewable or non-renewable sources. In this subsection, we will perform a comparative analysis of the potential GHG emission reduction if all EVs are powered by renewable or non-renewable. A similar methodology for comparative analysis in GHG emission reduction is used here, as mentioned in section x. The result suggests that GHG emissions reduction can be further enhanced if EVs are powered by renewable energy sources.

XIII. POLICY RECOMMENDATIONS

The effective proliferation of EVs on roads of KSA and UAE requires appropriate policy and guidelines to put them in a position for achieving their targets of environmental sustainability. These policies must be directed towards the identification of charging infrastructure requirements, EV user incentives, safety, reduction of pollutants in the environment, and profitability of investors. Following are the suggested set of policies that demands strict adherence from concerned bodies within KSA and UAE for seamless transitioning towards road transport electrification.

A. ENVIRONMENTAL POLLUTION

The saturation of fossil fuels in the power generation mix of UAE and KSA poses a huge threat of environmental pollution. Stage-wise planning is required to shift from oil to a renewable economy-based economy. As discussed earlier, that KSA will be far behind EV30@30 signatories to realize environmental sustainability goals if they do not plan to enhance their renewable sources share in the power mix. UAE needs to redefine its goals of road transport electrification as it will be in a position to sustain 30% EV penetration powered by renewables.

B. PRIVATE SECTOR PARTICIPATION

The Governments of KSA and UAE have been progressive towards expanding the EV market by attracting investment in the EV market. The PIF enabled KSA to own half of the California-based EV startup Lucid Motors by investing USD 1 billion [23]. A mandate has been issued that from 2020 and onwards, at least 10% government's investment in new vehicles must be spent on electric or hybrid vehicles [61]. However, a huge initial capital cost is required for the development of renewable energy-based charging infrastructure. The lack of investment from the private sector would put financial pressure on the government. Therefore, the governments of both countries should draft policies to attract investments from private sectors. These investments could be in the form of tax exemption, subsidy, etc.

C. RENEWABLE ENERGY SOURCE UTILIZATION

One of the main objectives for road transport electrification is a reduction of GHG emissions in the environment. It is only possible if power generated from renewable sources is used to power EVs. The share of renewables in the power generation mix is less than 1% for both countries, as indicated in Fig. 2 and Fig. 5. It means diligent efforts are required by concerned bodies in KSA and UAE to uplift the installed capacity of renewable sources to meet their desired goals of environmental sustainability by 2030. Strict policies must be enforced by respective countries to encourage power producers to shift towards renewable sources. In addition, they should also introduce incentives for renewable sources based IPPs to attract the interests of private investors.

D. THERMAL MANAGEMENT SYSTEM

KSA and UAE both have desert climates having very mild winters but unbearable hot summers. The temperature in KSA can go as high as 47 °C in summers, while different regions of UAE experience a maximum temperature of 43°C

in summer [62], [63]. Li-ion batteries are popular in modern EVs, and as per the study conducted in [64], the temperature variation in the domain of −10 °C to 70 °C has a significant impact on the state of health (SoH) of batteries. The optimal temperature of li-ion batteries is 25 °C, but if the temperature drops below 0 °C or exceeds 40 °C, then a considerable reduction in SoH of batteries can be witnessed, leading towards dropped range on fully charged batteries [64]. The batteries will no longer offer a range as per the expectations of customers. Therefore, charging infrastructure must be equipped with a facility of battery thermal management system so that the life of a battery can be preserved when they are being charged/discharged at the charging station. The policies associated with the battery thermal management system must be enforced by the administration of both countries. In case of non-compliance, charging infrastructure owners must be heavily fined, or in a worst-case scenario, their license to conduct business shall be canceled.

E. INCENTIVES

KSA is in the early stages of EV adoption and has yet to devise its incentive system like UAE [23]. UAE has its own incentives in place to encourage ICE vehicle owners to shift towards EVs. Dubai Supreme Council of Energy (DSCE) approved various policies, which include free charging of DEWA registered EVs at public charging stations in 2019, free parking, exemption from Road Transport Authority (RTA) registration fee, Salik's tag fee exemption, RTA renewal fee exemption, etc. Similarly, KSA can follow in the footsteps of the UAE to come up with its own incentive system for EVs. However, the incentives for a vehicle must be not be limited to financial incentives. KSA and UAE must also introduce a variety of non-financial incentives like separate lanes in toll for EVs, free or discounted parking, transit lane access, waivers in toll charges, and licensing incentive. The licensing incentive of a vehicle must ensure that EV gets registered in less time than an ICE vehicle. Moreover, the issuance of a driving license should also be quicker than the conventional vehicle.

F. PUBLIC-PRIVATE PARTNERSHIPS

KSA has faced numerous challenges in enforcing public-private partnerships (PPP) for different projects. However, the Ministry of Health successfully realized the first PPP project in KSA in a long time, reviving the administration's interest in PPP projects [66]. In addition, out of seven emirates in UAE, only Dubai and Abu Dhabi have defined laws of PPP. Therefore, the concerned bodies in KSA and UAE must fortify the laws and policies associated with PPP projects to facilitate the implementation of projects having higher initial capital outlay. They can follow a case study of China where a project named ''Anqing Charging Infrastructure PPP Project'' was successfully executed [65]. The results of the case study suggest that sharing of rewards and risks associated with the project resulted in the eradication of all potential delays [65].

G. SAFETY STANDARDS

To progress the EV industry, the provision of a safe working environment in charging stations is necessary. The administration of both countries shall draft safety protocols for the workers of charging infrastructure to avoid frequent mishaps. Moreover, the extremely flammable nature of li-ion batteries poses an additional risk for EVs and charging infrastructure owners. One of the major failures of li-ion batteries is thermal runaway which occurs due to violation of current and voltage bounds while charging. Therefore, strict policies must be laid down to ensure the optimality of critical parameters associated with batteries. In addition, Li-ion batteries can also get faulty due to non-technical reasons like internal short circuits due to mechanical abuse. Governments of KSA and UAE must come up with the policies linked with design standards of batteries and ensure that batteries approved from authentic testing labs will enter the charging infrastructure. In this regard, it is recommended that both countries can either follow the safety guidelines of matured EV markets like China or take assistance from li-ion battery manufacturers like Hilti Corporation. Hilti Corporation has defined scenario-based remedies for hazardous li-ion batteries accidents in their report [66].

H. RESEARCH AND DEVELOPMENT

KSA and UAE have shown a progressive approach in the adoption of EVs by investing in renewable energy sources and EVs. The universities in both countries have dedicated research groups for EVs in assisting administration to fulfill EV dissemination goals. The Government of KSA has put in extra effort by introducing EV research in the public sector. Saudi Electric Power Company initiated a research group under the name of Research Projects Portfolio Group (RPPG), working on quick EV charging infrastructure [67]. However, both countries have limited research contribution in EV and Li-ion battery manufacturing. It must be noted that they are importers of EVs and li-ion batteries. If both countries stay an importer, it will affect their economy significantly. Therefore, governments of KSA and UAE must invest heavily in mentioned areas with an intent to initiate local production of EVs and batteries. The local production will result in declined EV and battery prices.

I. ELECTRIC ROAD TRANSPORTATION AUTHORITY

The Transport General Authority in KSA and Road Transport Authority in UAE is responsible for managing road vehicle matters by monitoring service quality and approval of sector demands. It is believed that adding an extra responsibility on them in the form of managing EVs could lead to delays in approvals required for charging infrastructure networks. Besides, it can also lead to infrequent checks and balances on a maintenance schedule of charging stations. Eventually, it results in relevant stakeholders' discontent with the industry and ineffective EVs functionality. Therefore, an independent body under the name of Electric Road Transportation

Authority must be introduced to look after EV and charging infrastructure matters. It will bridge the communication gaps between government and charging infrastructure owners.

XIV. CONCLUSION

This research study has presented forecasting of annual vehicle sales in KSA and UAE to determine whether they will be able to keep up 30% EVs influx by 2030 or not. The key drivers for both countries are highlighted to establish the need for EV penetration. The impact on EEE's are also determined if both countries will achieve 30% EV penetration by 2030. Accordingly, policies are suggested for both countries, which enables them to be at par with EV30@30 signatories by 2030. The obtained results suggest that if the historic power sector growth continues till 2030, it will lead KSA and UAE to bear EVs penetration levels of 5% and 30%, respectively. However, the goals of the UAE are not aligned with their potential of EV penetration, and they are focusing on 1% EV diffusion by 2030, which is way below the signatories of EV30@30 having the aim to realize 30% vehicle electrification by the year 2030. The power generation mix of both countries are saturated with fossil fuels, and significant improvement efforts and political will is required to uplift renewables contribution in the power sector.

The future work must focus incorporation of the roadmap for both countries, which include measures that need to be taken for 30% EV penetration by 2030. It is recommended that the roadmap must be segregated into maturity levels in different domains. These domains shall include a technical section in which the selection of renewable sources and its integration with the charging infrastructure of EVs should be considered. Similarly, developments required in organizational structure, workforce training, regulatory strategy, and operations shall be highlighted.

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