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Strategies for Electric Vehicle Infrastructure of Cities: Benefits and Challenges

Murat Furat, İsra Karabiber and Senem Kocaoğlu

Abstract

The emerging technology, electric vehicles (EVs), has gained more attention due to the greenhouse gas (GHG) emission, climate change, and air pollution in the cities. The rising demand for EVs brings new benefits and challenges to the city life of citizens. Balancing the demand in the electrical energy distribution grid, charging scheduling, dynamic pricing, and different types of charging stations change the priorities of city life. In order to manage the new requirements and perform the permanent transition from gasoline-powered vehicles to EVs, a strategic plan must be prepared by the city authorities. Currently, a number of cities in different countries have published their strategic plans for the sense of perspective about reaching a 30% sales share for EVs by 2030. These plans focus on the solutions to maximize the benefits of EVs and the awareness of the citizens. In the present study, fundamental components of a strategic plan for both EVs and necessary infrastructure are outlined with different aspects.

Keywords: Electric vehicles, infrastructure, strategic plan, charge scheduling, grid management

1. Introduction

Different technologies and structural changes are coming to city life with EVs. The number of EVs has increased exponentially in the last decade because there are many benefits that EVs bring to their owners and the environment. According to the Electric Vehicles Initiative (EVI), the fourteen member countries have accelerated the development of EVs. Also, the EV30@30 Campaign was launched by the members of EVI to increase the EV market by 30% of the total of all vehicles until 2030 [1]. In addition to the countries, several companies have also supported the Campaign [2].

On the other hand, the cities and the citizens must be ready for the requirements of the emerging technologies [3]. Getting cities ready for the basic infrastructure of EVs will determine the permanent transition times of EVs from gasoline-powered vehicles. Therefore, understanding EVs and their infrastructure are crucial [4].

In order to make ready a city for EVs, a strategy must be determined which includes the following indicators:

- Education of citizens about EVs, their benefits and associated technologies,
- Optimum planning of the location and installing the charging/swapping stations,

- Planning necessary energy resources for charging stations,
- Establishing the essential infrastructure and maintenance,
- Establishing the essential communication networks of electric vehicles and charging stations,
- Defining the roles of the federal government, the city authorities, energy providers and EV users to collaborate with other cities to share experiences.

Obviously, a strategic plan can be shaped not only at the city level but also at the federal level with a host of incentives and initiatives [2, 3]. Also, the goals of the plan must be realistic and flexible to change for unpredictable future requirements. The strategic plans of many cities, published recently, have been considered within this framework. In addition, many countries have announced their roadmap for EVs and highlighted key policies [5]. Because EVs are not only electric cars. The EV term covers all transportation vehicles from bikes to busses, from heavy-duty vehicles to ships and aircrafts which are powered electrical energy. Therefore, a wide range of vehicles is about to transform into electrically powered vehicles.

In this chapter, information is given about the way to be followed to create the electric vehicle infrastructure of a city within the scope of these plans. There are several benefits and challenges for cities and citizens to be ready for them. In the next section, EVs are introduced. Then, a necessary strategic plan is outlined. Finally, the conclusion is provided.

2. Motivation

Electric vehicles are not an invention of today's technology. The first EV was seen in the 1800s. From the first EV to today's modern EVs, the evaluation of EV technology can be summarized as in **Figure 1** [6].

In the beginning, electric-powered vehicles were popular since they were quiet, easy to drive especially for women. Later, as gasoline stations available everywhere, the interest in gasoline-powered vehicles was increased. When the price of gasoline has risen, EVs were retaken into account. However, their small range and long charging time were still the main barriers in front of EVs. Whenever the ranges are increased and necessary infrastructures are constructed, the popularity of electric vehicles has gained more attention [7, 8]. According to [2, 9], it is clearly seen that the direction in the vehicle preference has been towards to EVs. In **Figure 2**, annual EV market growth is given [10].

According to [1], worldwide EV sales in 2017 was over 1 million and then two years later, it surpassed the 2 million mark in 2019. Technical improvements on EVs

Figure 1.
Timeline of the EVs.

Figure 2.
Annual EV market growth (%) by country from 2013 to 2020.

have been increased to the attractiveness of EVs. The demand for EVs is further increased if the cost of EVs is reduced and the travel range is increased. By the end of 2020, the number of electric vehicles worldwide, in the light-duty segment, exceeded 10 million [2]. Among the countries, the largest number of ELDVs was registered in China, with 4.5 million. China was followed by European countries with 1.4 million registered ELDVs. In addition, a number of EV manufacturers, such as Volvo, Ford, General Motors, announced that they only sell EVs from 2030 [2].

Not only in ELDV sales but also in EHDT and electric bus sales, China is the dominant country all over the world. In 2020, the number of electric busses was 600 thousand and the number of EHDT was 31 thousand [2]. According to the IEA, the global prediction on the number of EVs are summarized with the following **Table 1** [11].

Today, many governments around the world have focused on making all current vehicles electrified at a specific time in the near future. In addition, studies on the necessary infrastructure and the adoption of citizens are carried out within the framework of strategic plans.

A strategic plan should include a training section in which EVs' terminology and basic infrastructures are introduced. Therefore, in the present section, the fundamental information is given.

2.1 Classification of EVs

EVs do not have a unique structure. Depending on the energy source, EVs are classified as follows:

- *Battery Electric vehicles (BEVs) or all-electric vehicles (AEVs)* are vehicles powered only by electrical energy. The electrical energy is stored in the battery utilized in the vehicle. The battery is charged from the electrical energy distribution grid and partly from a regenerative braking system which recovers the lost energy when braking. The range of this type of vehicle is between 150 and 500 km. But, many manufacturers continue to improve the driving range.
- *Plug-in hybrid electric vehicles (PHEVs) or extended-range electric vehicles (EREVs)* use electrical energy for short driving ranges and turn into an internal combustion engine when the vehicle's battery is depleted. The range of this type of vehicle with only electrical power is between 25 and 85 km.

- *Hydrogen Fuel Cell Electric Vehicles (FCEVs)* are currently under development since their electrical energy is obtained from hydrogen. It is presently difficult to storage and refuels the hydrogen. A limited number of FCEVs are available between 500 and 600 km driving range.

2.2 Charging methods

Another classification can be performed for the Electric Vehicle Supply Equipment (EVSE) which is the charging facilities of the EVs as shown in **Figure 3**.

In order to charge an EV at home or at the office, Level 1 type charging stations are suitable since they can be used with home electricity provided by a standard AC wall outlet. It is ideal for EV owners who generally preferred to charge their vehicles at home [12]. Level 1 cord set is generally provided with most EVs.

Level 2 type charging stations provides faster charging and are commonly installed for public usage in car parks and supermarkets. 3 or 4 EVs can be charged a day by using this type of charging station [12].

Level 3 type charging stations uses 3-phase supply voltage for fast charge. It is suitable for EV owners who need quick charges such as commercial vehicles and taxis [12].

Level 4 charging stations, namely developed by Tesla, enable rapid charge for larger battery-powered EVs [12].

Induction charging or wireless charging is an emerging technology based on power transfer by an electromagnetic field [13, 14]. The efficient power transmission can be performed by a small space between the EV and inductive coils mounted on the ground. However, the space is directly related to the load on the vehicle and the clearance of the ground [15]. Protected connections without any cable and low infection risk are the main advantages of induction charging, while slower and inefficient charging makes it more expensive. The main benefit of induction charging can be seen on public transportation vehicles since charging the vehicle on the road reduces the total size of the battery for the trip. Therefore, wireless energy transfer to EVs is currently under development [16].

Pantograph is another solution for EVs especially commercial vehicles such as busses and trucks. More than 150 kW DC power can be supplied by a conductive charging system mounted at the top of the busses or trucks [17].

A patented approach to supply power to EVs is swapping batteries at battery swapping stations (BSS) [18, 19]. Consumer acceptance, non-standard batteries and technical challenges on SoC of the batteries are the main barriers to battery swapping.

2.3 Charging modes

Another technical detail of the EV charging is the charging modes which is defined by the reference standard is IEC 61851–1. There are four different charging modes as shown in **Figure 4**.

Scenario/Year	2025	2030
Stated Policies Scenario	BEV ~ 30 million	BEV ~ 80 million
	PHEV ~16 million	PHEV ~44 million
	FCEV ~233 thousand	FCEV ~1.15 million
Sustainable Development Scenario	BEV ~ 41.5 million	BEV ~ 138 million
	PHEV ~21 million	PHEV ~61 million
	FCEV ~830 thousand	FCEV ~5 million

Table 1.
Global predictions of EVs with different scenarios.

Figure 3.
Charging facilities of the EVs.

Mode 1: This charging mode (Schuko mode) is generally used in two-wheel vehicles such as electric bikes and scooters. The household outlet is directly connected to the vehicles by an extended cable without any safety device. This is currently unpopular and also no longer used for EVs.

Mode 2: The electrical energy from the household outlet to the vehicle is transmitted over a control box which is also known as a portable EV charger. In order to fully charge a battery, the EV must be connected for up to 16 hours.

Mode 3: An AC power supply directly connected to the electric distribution network is used in this type of charging mode. The power supply is generally mounted a wall and is used in both public areas and residences. The typical charging duration in this mode is between 4 and 9 hours, depending on the battery size of the EV.

Mode 4: It is generally used in public areas due to its high cost. The charging station provides faster charging over an AC-to-DC converter mounted in the station. It takes less than 1 hour to charge an EV to 80%.

2.4 Essential energy phenomenon

As the battery capacity is increased to extend the range of electric vehicles, the required energy to charge the battery in a short time interval will pose a problem for

Figure 4.
Charging modes of the EVs.

the electrical energy distribution grid of the cities. In addition, the waiting time to charge EVs and waiting time for the available charging stations will be the problems of EV owners as the number of EVs on the roads increases [20].

In recent years, different solutions have been proposed for the rising problems. Scheduling of charging [21, 22], placement of charging stations [23], different pricing methodologies [24] and also integrating the renewable energy sources [25] are frequently studied to supply energy to the vehicles. These solutions also bring new habits the citizens. At the same time, it brings great responsibilities to local governments in the implementation of these solutions. In this sense, sharing experiences among the cities becomes more important to find appropriate policies, financial supports and also the adoption of citizens to the new technology. More than 100 cities come together for an initial period of 5 years in order to build a network for The Electric Vehicles Initiative Global EV Pilot City Programme (EVI-PCP) [26].

The necessary number of charging stations, either home type or publicly accessible, are installed proportionally to the number of EVs on the roads. Especially Level 3 and Level 4 charging stations play an important role in the amount of load on the electrical energy distribution grid. According to [2], these charging stations are increasingly installed in all regions. Necessary infrastructure for the charging station to provide parking areas and necessary electrification have to be planned. In order to meet the energy needs of electric vehicles continuously, a target has been set by Alternative Fuel Infrastructure Directive (AFID) which is 1 public charging station per 10 EVs [27]. There are also several patent studies to overcome the charging scheduling phenomenon of EVs [25–34].

In addition, renewable energies are also studied for this purpose [8, 35]. Although the main target is to provide sufficient public charging stations, electric busses and electric heavy-duty trucks, medium freight trucks (MFTs) and heavy freight trucks (HFTs) have also been on the roads. Therefore, the needed energy supply equipment for HFTs and necessary energy sources may be a big problem in cities with heavy commercial transport. This problem brings a new solution with megachargers of 1 MW which satisfies the need for HFTs [2]. A project on the clean transit corridor used by heavy commercial trucks started by West Coast Clean Transit Corridor Initiative to reduce the greenhouse gas (GHG) emission by the diesel trucks. Another project scope is the required amount of space to install EVSE for the heavy commercial trucks since these vehicles may need to be charged frequently [36].

Electric vehicles are considered not only for road transport but also for sea and air transport. In order to contribute to the reduction of GHG emission, shipping and flying vehicles are planned to power with electrical energy [37–41].

2.5 Reduction of greenhouse gases emission

Globally, over 20% of total GHG has been emitted by transportation vehicles [27, 42]. It is partially true that all types of EVs are considered a significant solution for reducing GHG emissions. EVs themselves do not emit GHG. Therefore, their contribution to air quality is undoubtedly in cities with heavy traffic. However, the required electrical energy is generated in power plants that emit GHG. All vehicles emit GHG in their lifecycle. But, the generated GHG by power plants for EVs is lower than the total amount of GHG emitted by gasoline-powered vehicles [43, 44]. A higher ratio of the electrical energy generated by renewable energy sources results in a further reduction in GHG emissions [42] which is the main reason to obtain zero-emission transportation.

2.6 New habits and routines of citizens

Living with EVs will be different than living with gasoline-powered vehicles. As described above, EVs will bring new regulations to city life. In order to use EVs without any interruption, charging of the vehicles in any location might be predefined to the owners. The charging decision of an EV owner depends on the battery status of the EV. The battery power, driving characteristics, environmental and geographic conditions plays a significant role on the frequency of the charging EV. Meanwhile, the selection of charging type, duration and time is decided by the owner [45]. Driving and driver behaviors in the big data perspective were also discussed in the literature [46].

In the literature, different methods have been proposed to overcome the charging problems, such as waiting for a charging station and waiting for charging of the EV [21]. In order to maximize the benefits of EVs, the owners may need to follow new regulations [47]. Therefore, new habits and new routines get into the city life which the governments may previously explain. Currently, many cities and countries have implemented the necessary regulations and practices for electric vehicles. In order to permanent transition in a phased manner, a number of strategic reports are published by the governments [3, 12, 48–54].

2.7 Obstacles to the strategic plan

In the development stages of the vehicles, either gasoline-powered or electric-powered, there were different obstacles to both vehicles. Although EVs are technologically advanced, the infrastructure to fully replace gasoline-powered vehicles is not ready in many cities. There are obstacles that cities have to overcome in order to have the infrastructure [55]. A well-designed strategic report will play an important role in overcoming the following obstacles in front of the city authorities:

- Introduction of electric vehicles in all aspects
- Determining the necessary infrastructure
- Financial resources to cover the cost of infrastructure
- Determining the policies and their implementation the city life

EVs are still under development stage and each city has its own characteristics to adopt the EVs essentials. Because of this reason, currently, there is no specific result that describes the whole experience of a strategic plan. According to [55], the primary obstacles can be divided into sub-obstacles.

3. Methodology of strategic plan

The framework for a strategy report has been drawn in the previous section to overcome the multidimensional preparation problem that arises with the spread of electric vehicles. The critical sections in the structure of a strategic plan to prepare a city and its citizens determine how well perform a flawless transition to EVs (Figure 5).

The first section of a strategic plan is designed for the citizens unfamiliar with EV technology to motivate the citizens to have EVs. Therefore, the following topics can take place in this section:

- How an EV works?
- Charging of battery
- Environmental benefits of EVs
- Economic advantages
 - Taxation policy of the government
 - Running costs of EVs
- Local, federal and global trends in the EVs market

Figure 5.
Critical sections of a strategic plan.

- The objectives of the strategic plan
 - Future predictions about number of EVs
 - Rate of reduction in GHG emission
 - Increase the awareness of EVs by social media

The framework of the local and federal policies on EVs and their structure can be considered with the density of the population and their geographical characteristics of the cities. In the second section, the following related subsections can be given:

- Local and federal health policy
- Local and federal air quality policy
- Future plans to ban gasoline-powered vehicles
- Zero-emission policy for GHG

Funding of necessary infrastructure is a financial problem in front of the governments. The strategy that will be followed for deploying charging stations, charging parks, organization and also providing vital electrical energy can be explained in the third section as follows:

- Free or reduced cost of parking EVs
- Cost of infrastructure for electric busses
- Cost of installing renewable energy sources
- Running cost of EVSE
- Methods to increase cost recovery time

Supporting the installation of renewable energy sources significantly contributes the zero-emission target. Therefore, necessary plans should be put forward to research the city's renewable energy sources and add them to the electrical energy distribution grid. The steps to be taken in this regard should be included in a strategic plan as follows:

- Identifying the city's renewable energy sources
- Possibilities of integrating the renewable energy sources into the grid
- Feeding of charging stations from these sources
- Encouraging the EV owners to use private renewable energy sources

Another critical topic is the declaration of external stakeholders and strategic partnerships. Many countries and cities have come together to share their experiences. In order to inform the citizens, these partners can be explained in a section as follows:

- Working with EV manufacturers
- Coordination with energy providers
- Collaboration between the cities and countries around the world, such as EVI

Although the rapid chargers are developed, at least 30 minutes waiting time is required to charge an average ELDV. This problem will increase proportionally to the number of EVs in a city. A limited solution is to direct EV owners to charge their vehicles at home. As stated above, it does not fit EV owners who need quick charges such as commercial vehicles, taxis and HDTs. Coordination of charging stations to minimize waiting time, different methods have been proposed in the literature. Within the framework of a city's possibilities, the goal of coordination can be put forward with a strategy as follows:

- Collect all EV owner data in a database with the information of their EVs and charging characteristics
- Design a recommender system for the EV owners so that the system
 - Keeps the load balancing of the electrical distribution network
 - Follows the SoC of EVs
 - Recommends charging/swapping using a dynamic pricing methodology
 - Gets charging demand by a developed mobile phone application
- Determine optimal locations for additional charging stations in the light of collected data.

IoT-enabled smart applications for reducing the running cost of EVs have taken place from a daily life perspective of smart cities. As mobile communication devices are used widespread, smart EV and its infrastructure management systems have gained a great interest in the sense of IoT. Because of this reason, a section can be designed for the management of EV infrastructure with the following properties:

- Centralized load management of the electrical energy distribution grid
- Predicting and managing of charging operations of large-scale EVs
- Controlling the direction of energy flow in the grid
- Creating digital twins of EV owners (DToEVO)
- Performing different benchmark scenarios on the infrastructure by DToEVO

There are different approaches to model a real system to simulate. A DToEVO is a dynamically updated model of both EV and its owner. Therefore, data-driven modeling is appropriate to create and update DToEVO with the following properties:

- Model and age of EV
- Battery capacity of EV
- Charge frequency of EV
- Preferred SoC to charge the battery
- Average velocity per travel
- Maximum velocity per travel
- Travel duration and routes
- Resting duration and location

Finally, a section has been prepared for the activity schedule in order to realize the goals of the strategic plan in a phased manner [49].

Obviously, as the technological development on the EVs and essential infrastructure, these plans must be revised. There is no standard plan to fit all cities [56]. Every city has its own characteristics. In this sense, a collaboration between the cities increases the total benefits.

4. Conclusion

EV technology brings structural changes in city life. Therefore, city authorities and governments have important duties. In the present study, the outline of a city-scale strategic plan is explained. It is open to improvement since each city has its own specific requirements in the sense of EVs and their essential infrastructure. Analyzing the requirements, planning the activities and educating the EV owners result in an easy transition from gasoline-powered vehicles to EVs. In order to maximize the total benefits and overcome the challenges easily, experiences must be shared between the cities.

Conflict of interest

The authors declare no conflict of interest.

Nomenclature

AC	Alternating Current
AEV	All-Electric Vehicle
AFID	Alternative Fuel Infrastructure Directive
BEV	Battery Electric Vehicle
BSS	Battery Swapping Stations
DC	Direct Current
DToEVO	Digital Twin of Electric Vehicle Owner
EHDT	Electric Heavy-duty Truck
ELDV	Electric Light-duty Vehicle
EREV	Extended-range Electric Vehicle

EV	Electric Vehicle
EVI	Electric Vehicles Initiative
EVSE	Electric Vehicle Supply Equipment
FCEV	Hydrogen Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
HFT	Heavy Freight Trucks
IEA	International Energy Agency
MFT	Medium Freight Trucks
PHEV	Plug-in Hybrid Electric Vehicle
SoC	State of Charge

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References

- [1] “Global EV Outlook 2020,” *Glob. EV Outlook 2020*, 2020, doi: 10.1787/d394399e-en.
- [2] “Global EV Outlook 2021,” *Glob. EV Outlook 2020*, 2020, doi: 10.1787/d394399e-en.
- [3] D. Garas, G. O. Collantes, and M. A. Nicholas, “City of Vancouver EV infrastructure strategy report,” no. December, 2016, [Online]. Available: <https://escholarship.org/content/qt0w90c61t/qt0w90c61t.pdf>.
- [4] H. S. Das, M. M. Rahman, S. Li, and C. W. Tan, “Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review,” *Renew. Sustain. Energy Rev.*, vol. 120, no. November 2019, 2020, doi: 10.1016/j.rser.2019.109618.
- [5] International Energy Agency, “Global EV Policy Explorer,” 2021.
- [6] “Timeline: History of the Electric Car | Department of Energy.” <https://www.energy.gov/timeline/timeline-history-electric-car> (accessed May 25, 2021).
- [7] F. J. Soares, D. Rua, C. Gouveia, B. D. Tavares, A. M. Coelho, and J. A. P. Lopes, “Electric Vehicles Charging: Management and Control Strategies,” *IEEE Veh. Technol. Mag.*, vol. 13, no. 1, pp. 130-139, 2018, doi: 10.1109/MVT.2017.2781538.
- [8] J. A. Peças Lopes, F. J. Soares, P. M. Almeida, and M. Moreira Da Silva, “Smart charging strategies for electric vehicles: Enhancing grid performance and maximizing the use of variable renewable energy resources,” *24th Int. Batter. Hybrid Fuel Cell Electr. Veh. Symp. Exhib. 2009, EVS 24*, vol. 4, no. February 2014, pp. 2680-2690, 2009.
- [9] M. Muratori *et al.*, “The rise of electric vehicles—2020 status and future expectations,” *Prog. Energy*, vol. 3, no. 2, p. 022002, 2021, doi: 10.1088/2516-1083/abe0ad.
- [10] J. A. Sanguesa, V. Torres-Sanz, P. Garrido, F. J. Martinez, and J. M. Marquez-Barja, “A Review on Electric Vehicles: Technologies and Challenges,” *Smart Cities*, vol. 4, no. 1, pp. 372-404, 2021, doi: 10.3390/smartcities4010022.
- [11] “Global EV Data Explorer – Analysis - IEA.” <https://www.iea.org/articles/global-ev-data-explorer> (accessed Jun. 11, 2021).
- [12] Warwickshire County Council, “Electric Vehicle Charging Infrastructure Strategy 2017-2026,” no. November, 2017, [Online]. Available: <https://api.warwickshire.gov.uk/documents/WCCC-930-349>.
- [13] X. Lu, P. Wang, D. Niyato, D. I. Kim, and Z. Han, “Wireless Charging Technologies: Fundamentals, Standards, and Network Applications,” *IEEE Commun. Surv. Tutorials*, vol. 18, no. 2, pp. 1413-1452, 2016, doi: 10.1109/COMST.2015.2499783.
- [14] A. Zakerian, S. Vaez-Zadeh, and A. Babaki, “Efficiency Maximization Control and Voltage Regulation for Dynamic Wireless EV Charging Systems with Mutual Induction Estimation,” *IECON Proc. (Industrial Electron. Conf.)*, vol. 2019-Octob, pp. 4298-4303, 2019, doi: 10.1109/IECON.2019.8926940.
- [15] A. Marinescu *et al.*, “The way to engineering EV wireless charging: DACIA electron,” *2017 Electr. Veh. Int. Conf. EV 2017*, vol. 2017-Janua, pp. 1-6, 2017, doi: 10.1109/EV.2017.8242094.
- [16] S. Sharma, “China is the New Hub for Wireless Charging Technology.”

<https://www.ipwatchdog.com/2020/07/06/china-new-hub-wireless-charging-technology/id=123032/> (accessed May 23, 2021).

[17] “OppCharge - Fast charging of electric vehicles.” <https://www.oppcharge.org/> (accessed May 23, 2021).

[18] F. Adegbohun, A. von Jouanne, and K. Y. Lee, “Autonomous battery swapping system and methodologies of electric vehicles,” *Energies*, vol. 12, no. 4, pp. 1-14, 2019, doi: 10.3390/en12040667.

[19] I. J. R. Dahn, T. Van, and N. Westminster, “United States Patent [191 [11] Patent Number : US5998963A,” vol. 2, no. 19, pp. 1-7, 1990.

[20] T. S. Bryden, G. Hilton, B. Dimitrov, C. Ponce De León, and A. Cruden, “Rating a Stationary Energy Storage System Within a Fast Electric Vehicle Charging Station Considering User Waiting Times,” *IEEE Trans. Transp. Electrification*, vol. 5, no. 4, pp. 879-889, 2019, doi: 10.1109/TTE.2019.2910401.

[21] W. Jiang and Y. Zhen, “A Real-Time EV Charging Scheduling for Parking Lots with PV System and Energy Store System,” *IEEE Access*, vol. 7, pp. 86184-86193, 2019, doi: 10.1109/ACCESS.2019.2925559.

[22] Z. Moghaddam, I. Ahmad, D. Habibi, and Q. V. Phung, “Smart Charging Strategy for Electric Vehicle Charging Stations,” *IEEE Trans. Transp. Electrification*, vol. 4, no. 1, pp. 76-88, 2017, doi: 10.1109/TTE.2017.2753403.

[23] C. Luo, Y. F. Huang, and V. Gupta, “Placement of EV charging stations-balancing benefits among multiple entities,” *arXiv*, pp. 1-10, 2018.

[24] Z. Moghaddam, I. Ahmad, D. Habibi, and M. A. S. Masoum, “A coordinated dynamic pricing model for electric vehicle charging stations,” *IEEE Trans. Transp. Electrification*, vol. 5, no. 1,

pp. 226-238, 2019, doi: 10.1109/TTE.2019.2897087.

[25] P. Mesarić and S. Krajcar, “Home demand side management integrated with electric vehicles and renewable energy sources,” *Energy Build.*, vol. 108, pp. 1-9, 2015, doi: 10.1016/j.enbuild.2015.09.001.

[26] “EVI Global EV Pilot City Programme – Programmes and partnerships - IEA.” <https://www.iea.org/areas-of-work/programmes-and-partnerships/evi-global-ev-pilot-city-programme> (accessed May 25, 2021).

[27] “DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure.” <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014L0094&from=en> (accessed May 26, 2021).

[28] A. Deshpande and P. Murali, “Managing Electric Vehicle (EV) Charging Station Usage Pub. No.: US 2015/0032516 A1,” *Patent*, vol. 1, no. 19, 2015.

[29] S. Kawano *et al.*, “Charging Management System Pub. No.: US 2015 / 0158393 A1,” *Patent*, vol. 1, no. 19, 2015.

[30] T. K. Paul and H. Aisu, “Electric Vehicle Charging Scheduling System Pub. No: US 9,112,382 B2,” *Patent*, vol. 2, no. 12, 2015.

[31] M. Ramezani, H. Vogt, and H. Braun, “Vehicle Electric Charging Schedule Selection and Evolution Based on Multiple Weighted Charging Objectives Pub. No.: US 2013/0054045 A1,” *Patent*, vol. 1, no. 19, 2013.

[32] S. B. Pllack and W. Bridges, “Systems and Methods for Smart Charging Techniques, Value and Guarantee Pub. No.: US 2013 / 0184886 A1,” *Patent*, vol. 1, no. 19, 2013.

- [33] E. D. Tate and S. A. Tarnowsky, "Electric Charging Station Reservation System and Method Pub. No.: US 2012/0233077 A1," *Patent*, vol. 1, no. 19, 2012.
- [34] S. Smullin, M. J. Stefik, D. E. Schwartz, and D. H. Greene, "Computer - Implemented System and Method for Managing Interchangeable EV Charging - Capable Parking Spaces Patent No.: US 9,779,365 B2," *Patent*, vol. 2, 2017.
- [35] C. Goeltner, "Solar Powered, Grid Independent EV Charging System Pub. No.: US 2010/0181957 A1," *Patent*, vol. 1, no. 19, 2010.
- [36] "West Coast Clean Transit Corridor Initiative." <https://westcoastcleantransit.com/> (accessed May 27, 2021).
- [37] N. Shakeri, M. Zadeh, and J. Bremnes Nielsen, "Hydrogen Fuel Cells for Ship Electric Propulsion: Moving Toward Greener Ships," *IEEE Electr. Mag.*, vol. 8, no. 2, pp. 27-43, 2020, doi: 10.1109/MELE.2020.2985484.
- [38] H. Liu, Y. Wang, and D. Gao, "Research on control strategy of hybrid electric ship based on minimum equivalent fuel consumption," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 632, no. 3, 2021, doi: 10.1088/1755-1315/632/3/032029.
- [39] M. Macdonald, J. Rheume, Y. Khakpour, and C. Lents, "Transient cooling approach for a mhr class hybrid electric propulsion system battery pack," *AIAA Scitech 2020 Forum*, vol. 1 PartF, no. January, pp. 1-7, 2020, doi: 10.2514/6.2020-0120.
- [40] M. Crittenden, "Ultralight batteries for electric airplanes," *IEEE Spectr.*, vol. 57, no. 9, pp. 44-49, 2020, doi: 10.1109/MSPEC.2020.9173903.
- [41] "Electric ships: the world's top five projects by battery capacity." <https://www.ship-technology.com/features/electric-ships-the-world-top-five-projects-by-battery-capacity/> (accessed May 27, 2021).
- [42] K. J. Dillman, Á. Árnadóttir, J. Heinonen, M. Czepkiewicz, and B. Davíðsdóttir, "Review and meta-analysis of EVs: Embodied emissions and environmental breakeven," *Sustain.*, vol. 12, no. 22, pp. 1-32, 2020, doi: 10.3390/su12229390.
- [43] "Reducing Pollution with Electric Vehicles." <https://www.energy.gov/eere/electricvehicles/reducing-pollution-electric-vehicles> (accessed May 28, 2021).
- [44] "Alternative Fuels Data Center: Emissions from Hybrid and Plug-In Electric Vehicles." https://afdc.energy.gov/vehicles/electric_emissions.html (accessed May 28, 2021).
- [45] J. C. Spoelstra, "Charging behaviour of Dutch EV drivers," *MSc. Thesis*, 2014, [Online]. Available: <https://dspace.library.uu.nl/handle/1874/297327>.
- [46] R. Terzi, S. Sagiroglu, and M. U. Demirezen, "Big Data Perspective for Driver/Driving Behavior," *IEEE Intell. Transp. Syst. Mag.*, vol. 12, no. 2, pp. 20-35, 2020, doi: 10.1109/MITS.2018.2879220.
- [47] Z. Le Hong and N. Zimmerman, "Air quality and greenhouse gas implications of autonomous vehicles in Vancouver, Canada," *Transp. Res. Part D Transp. Environ.*, vol. 90, no. December 2020, p. 102676, 2021, doi: 10.1016/j.trd.2020.102676.
- [48] City of Vancouver, "Vancouver's EV Ecosystem Strategy," no. November, pp. 1-78, 2016, [Online]. Available: <https://vancouver.ca/files/cov/EV-Ecosystem-Strategy.pdf>.
- [49] "Calgary's Electric and Low-Emissions Vehicles Strategy," [Online]. Available: https://solaralberta.ca/wp-content/uploads/2020/10/Calgarys-Electric-Low-Emission-Vehicle-Strategy_0.pdf.

[50] Cidade de Edmonton, “Edmonton’s Electric Vehicle Strategy,” no. September, 2018, [Online]. Available: https://www.edmonton.ca/city_government/documents/PDF/EdmontonElectricVehicleStrategy.pdf.

[51] “Tompkins County Plug-in Electric Vehicle Infrastructure Plan: Charging Station Implementation Strategies,” 2017.

[52] London Borough of Richmond-upon-Thames, “Electric Vehicle Recharging Strategy 2016-2026,” no. December, pp. 1-23, 2016.

[53] T. Council, “Town of San Anselmo Electric Vehicle Strategy,” pp. 1-11, 2018, [Online]. Available: <https://www.townofsananselmo.org/DocumentCenter/View/23894/San-Anselmo-EV-Strategy>.

[54] W. E. Forum, “EV-Ready India Part 1 : Value Chain Analysis of State EV Policies,” no. October, 2019, [Online]. Available: http://www3.weforum.org/docs/WEF_EV_Ready_India.pdf.

[55] P. K. Tarei, P. Chand, and H. Gupta, “Barriers to the adoption of electric vehicles: Evidence from India,” *J. Clean. Prod.*, vol. 291, p. 125847, 2021, doi: 10.1016/j.jclepro.2021.125847.

[56] J. Gardner, “Creating Ev-Ready Towns and Cities: a Guide To Planning and Policy Tools Electric Vehicle Supply Equipment Support Study,” no. November, 2012, [Online]. Available: https://www.transportationandclimate.org/sites/default/files/EVSE_Planning_and_Policy_Tool_Guide.pdf.