EV Charging Infrastructure – An International Perspective

by Professor Vasco Sanchez Rodrigues

Since the number of electric vehicles is expected to rise, given the potentially massive number of vehicles involved, a reliable control of EV charging will be essential for its successful penetration into the power system (Mureddu et al., 2018), as uncontrolled electric vehicle charging leads to large load variations in the electrical grid and impacts the power quality of the distribution grid (Shafiee et al., 2013). If power distribution and infrastructure is not planned in a holistic manner included the whole electricity supply chain from energy generation to electricity user (businesses and citizens) in the long-term process of infrastructure development. Because, building EV charging infrastructure is very likely to have impacts on power grid performance and efficiency, such as overloading, reduced efficiency, power quality issues and disturbances, and voltage regulation, particularly at the distribution level, may significantly increase in the near future (Khalid et al., 2019). Such as huge venture needs to be undertaken with active support accurate science, government monitoring and private investment.

In a study published by Amry et al. (2022) on light-duty electric vehicles drivetrain power electronics and charging stations specifications found that integrated on-board chargers offer the possibility to optimize the use of traction/propulsion power converters and motor windings, but suffers from a long time to fully recharge EV batteries; nevertheless, , off-board chargers are high power chargers that require few minutes to recharge the EV batteries up to 80% state of charge (SOC); and, unfortunately, the massive usage of such equipment could have a negative impact on the utility grid and may cause PQ disturbances. Hence, every given should put in place thorough planning and delivery of infrastructure that align with their specific geographic, topographical, and socioeconomic realities.

Studies published based on various international contexts show a diverse range of results, plans and advice. the EV initiative is one of the few programmes listed by the International Energy Agency (IEA) that aligns with the IEA's net-zero emissions goals (Amara-Ouali et. al., 2023). According to a report published by IEA (2022), in 2021, China led global EV sales with 3.3 million units, tripling its 2020 sales, followed by Europe with 2.3 million units, up from 1.4 million in 2020; and, in just 2022, the U.S. market share of electric vehicles doubled to 4.5%, whereas electric vehicle sales in emerging markets more than doubled. Electric mobility development entails new needs for energy providers and consumers (Réseau de Transport d'Électricité. Futurs énergétiques 2050 (2022), and companies and researchers are proposing innovative solutions including pricing strategies and smart charging related to a range of solutions, e.g., grid integration of intermittent renewable energy sources using price-responsive plug-in electric vehicles (Dallinger & Wietschel, 2012), smart charging for electric

vehicles (Wang et al, 2016), optimal pricing to manage electric vehicles in coupled power and transportation networks (Alizadeh et al., 2017), smart charging strategy for electric vehicle charging stations (Moghaddam et al., 2018) and the opportunity for smart charging to mitigate the impact of electric vehicles on transmission and distribution systems (Crozier et al., 2020).

Even though there some positive evidence on progress in EV technology, there are still some concerns to road freight transport stakeholders that is inhibited investment on electric fleet rollouts (Ahmad et al., 2019), including scarcity in the availability of recharging stations, extended charging delay, coercion by underlying utility grid, and the most important is the inherent EV range anxiety (EVRA) problem (Franke & Krems, 2013).

Research on smart charging stations has advanced substantially in the last decade, though this report intends to show several cases from developed and emerging economies to inform the plans and future actions of the Colombian energy and transport sectors.

International evidence on plans and progress in EV charging stations

United States of America

According to a study published by PWC (2022), there has been incentives put in place by the US government that has caused growth in the number of EV charging infrastructure, including 7.5 billion investment in EV charging infrastructure, the Inflation Reduction Act provided tax credits for both new and used electric passenger vehicles as well as for commercial vehicles, and California announced it will ban the sale of new internal combustion engine-powered vehicles by 2035, which the two latter causing demand growth for more EV charging stations. As Figure 1 shows, PWC (2022) also reports that the number of charge points in the US is poised to grow from about 4 million today to an estimated 35 million in 2030, and these incentives play a major role in driving this sharp growth.

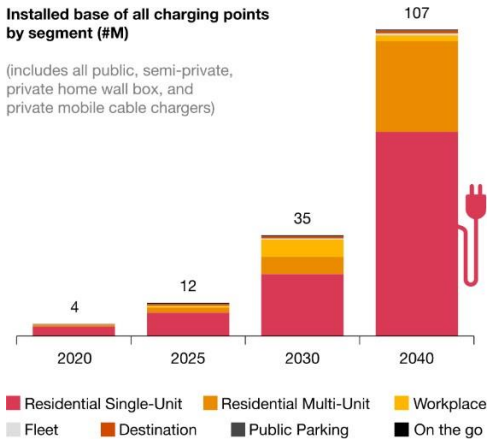


Figure 1: Estimated growth in EV charging stations
Source: PWC (2022)

However, the PWC (2022) study does not show significant growth in EV fast charging infrastructure, which is contradicted by a recent article published in Gran Value Research (2023), which estimates that EV fast charging infrastructure is expected to grow at a compound annual growth rate (CAGR) of 29.1% from 2023 to 2030. Also, the article reports that the development of technologies like portable charging stations, smart charging with load management, automated payment technology, and bi-directional charging is further expected to create new growth opportunities for the market over the forecast period. As Grand Value Research (2022) reports in Figure 2, most of the expected growth in the EV charging stations is driving by the fast EV charging markets, which is driving by longer distance trips from passage vehicles and EV freight vehicles that need to be fast charging for purely commercial and journey time sensitivity reasons.

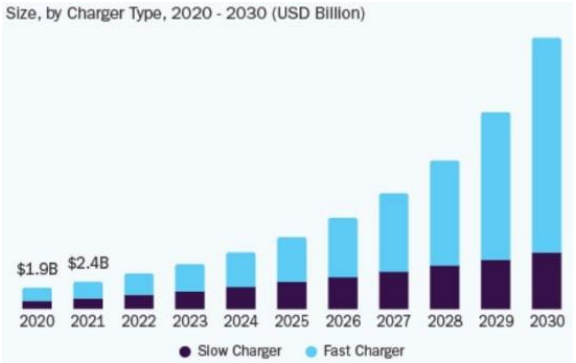
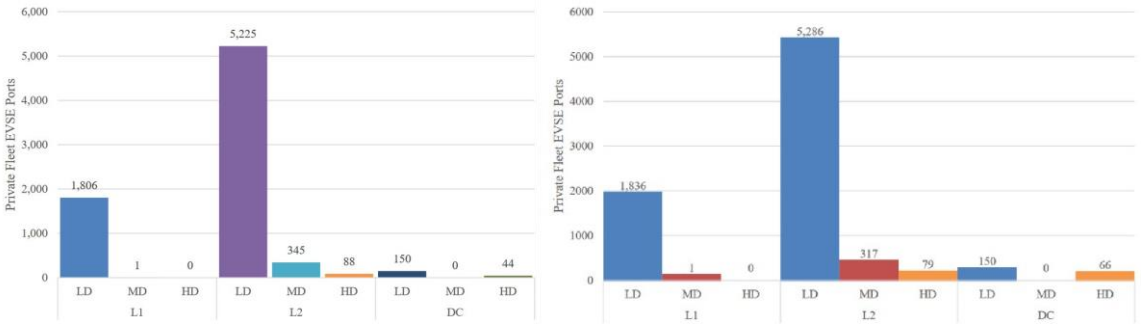


Figure 2: US Expected EV charging infrastructure growth
Source: Grand Value Research (2023)

Statistics from the US's National Renewable Energy Laboratory published in the first quarters of 2022 and 2023 by Brown et al. (2022, 2023), as shown in Figure 3, most freight EV charging stations are used by light duty vehicles, and most of the freight EVs currently using EV charging stations use level 2 charging stations, medium charging level, and very few uses fast direct current (DC) charging. This trend can be driven by the fact that EV charging L2 performed a full charge in a third of the time of EV charging L1 for more than half of the cost of a full charge than fast DC charging. The few freight EVs that are using fast DC charging are vehicles that are used for longer distance trips.



(b) QT 12022 **(a)** QT 2023

Note: LD – light duty, MD – medium duty, HD – heavy duty, L1 – slow charging level 1, L2 – medium charging level 2, DC – fast direct current charging

Figure 3: Reported freight EV charging stations in QT1 2022 and QT2 2023 (Brown et al. (2022, 2023)

In addition, according to Figure 3, from QT1 2022 to QT1 2023, there was a light increase of about 1% in the total number of freight EV charging ports. However, this number is likely to increase with future introduction of new taxes and other incentives by the US government with the aim of driving freight EV sales.

European Union

In a recent article published in News European Parliament (2023), it is confirmed that the EU parliament successfully negotiated that for electric trucks and buses charging stations have to be provided every 120 km, these station should be installed on half of main EU roads by 2028 and with a 1400kW to 2800 kW power output depending on the road, as well as that EU countries have to ensure that hydrogen refuelling stations along core TEN-T network will be deployed at least every 200 km by 2031. Parliament's rapporteur on alternative fuels infrastructure Petar Vitanov (S&D, BG) said: "Using more sustainable, renewable, and efficient energy solutions in the transport sector will help reduce greenhouse gas emissions and air pollution, improve citizens' quality of life, and create new high-quality jobs. The new rules will also help to deploy more charging infrastructure and make it as easy to use as traditional petrol stations".

In another press release published by the European Union Commission (2023), the EU Science Hub confirms that the EU and the US have put in place several technical recommendations for the upgrade and expansion of charging infrastructure. These recommendations offer guidance to policy makers and implementing bodies on how best to improve and rapidly rollout smart charging infrastructure for EVs, and help set harmonised standards and remove trade barriers, while contributing to the integration of renewables, ensuring stability of power grids and greening the road transport.

These recommendations from the EU and US Governments include:

- The need for harmonised standards to minimise trade barriers.

- Manufacturers and suppliers in the EU and the US could benefit from international standards to cut costs and development times while maintaining their competitiveness across global markets and fostering innovation.
- Developing consumer- and grid-friendly charging solutions requires further pre-normative research and common testing methods.
- The need for joint research, development, and demonstration (RD&D) activities to optimise grid integration, reliability and the energy efficiency of smart chargers.

As stated in the recent report by EU Parliament (2022), there are a series of recommendations put in place by the EU to ensure the rapid development of EV charging infrastructure for light and heavy-duty vehicles, as outlines in Table 1.

Table 1: EU Parliament's recommendation on EV charging stations specific to light- & heavy duty vehicles

Key theme	Recommendation
Fast charging points for light-duty vehicles	Enough publicly accessible fast recharging points dedicated to light-duty vehicles should also be deployed to ensure full cross-border connectivity and allow electric vehicles to circulate throughout the Union. For each battery electric light-duty vehicle registered in their territory, a total power output of at least 1.5 kW is provided through publicly accessible recharging stations if a Member State's electric vehicles share of the total projected vehicle fleet for each year is greater than 5% and below 10%.
Fast charging for heavy-duty vehicles	Electric heavy-duty vehicles need a distinctively different recharging infrastructure than light-duty vehicles. Publicly accessible infrastructure for electric heavy-duty vehicles is almost entirely unavailable in the Union. Heavy-duty vehicles will require a longer development and deployment time than the infrastructure for light-duty vehicles. New charging infrastructure standards for heavy-duty vehicles are currently being developed. It is technically possible to ensure the upgradability of the physical connections and communication exchange protocols so that individual charging stations and charging points can be upgraded to a new standard at a later stage. It is technically possible for light-duty and heavy-duty vehicles to use the same infrastructure when this has been considered in the design of the maximum power output as well as other technical solutions.
Energy supply & demand	In portions of territories of member states where demand of EV charging varies, deploying a temporary mobile off-grid charging infrastructure could offer added flexibility and facilitate meeting seasonal demand without requiring the installation of fixed infrastructure. The use of smart metering systems in combination with smart recharging points can optimise recharging, with benefits for the electricity system and for the end user. Smart recharging points, as well as off-grid recharging points, in particular, can facilitate the integration of electric vehicles into the electricity system and reduce the impact of electric vehicles on the electricity distribution network. Measures to ensure grid connection and power capacity take into account the number of charging pools which can be expected in the future following the increasing fleet penetration of electric vehicles.
Access of electricity suppliers to charging stations	The access of Union electricity suppliers to recharging points should be without prejudice to the derogations under Article 66 of Directive.
Smart charging speed	Smart recharging can be realised at normal charging speeds as well as during fast charging through response to dynamic price signals or optimisation of power flow.

United Kingdom

According to UK government (2023), in the UK, as of 1 April 2023, there were 40,150 public electric vehicle charging devices installed in the UK, fast charging – 56% and rapid charging 19%, the increase compared to April 20222 was 8%, and compared top April 2015 has been 1,500% (see Figure 4).

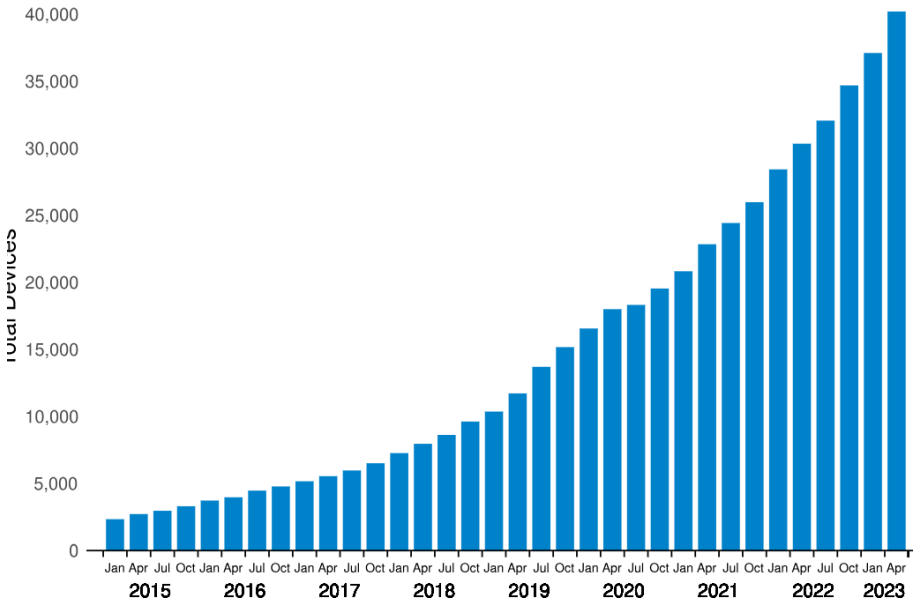


Figure 4: Installed UK public rapid charging or above devices, midnight, 1 of month, since 2015 (UK Government, 2023)

According to estimates by DfT (2023), in the UK, there will be about 10 million battery EVs on the road, which will need as a minimum 300,000 public charging points.

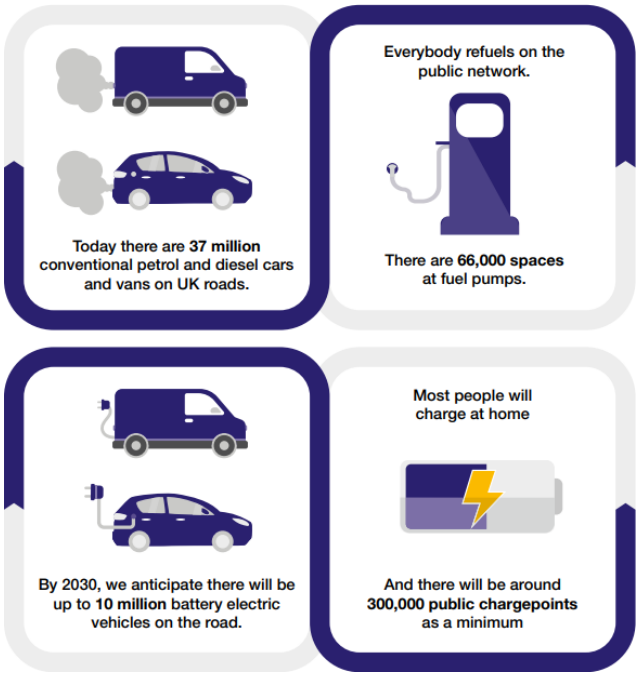


Figure 5: DfT vehicle statistics on EVs and charging points

One key aspect for road freight transport is having easy and convenient access to EV charging points in motorways, which for the electric cars the UK is leading in Europe, according to Transport & Environment (2020).

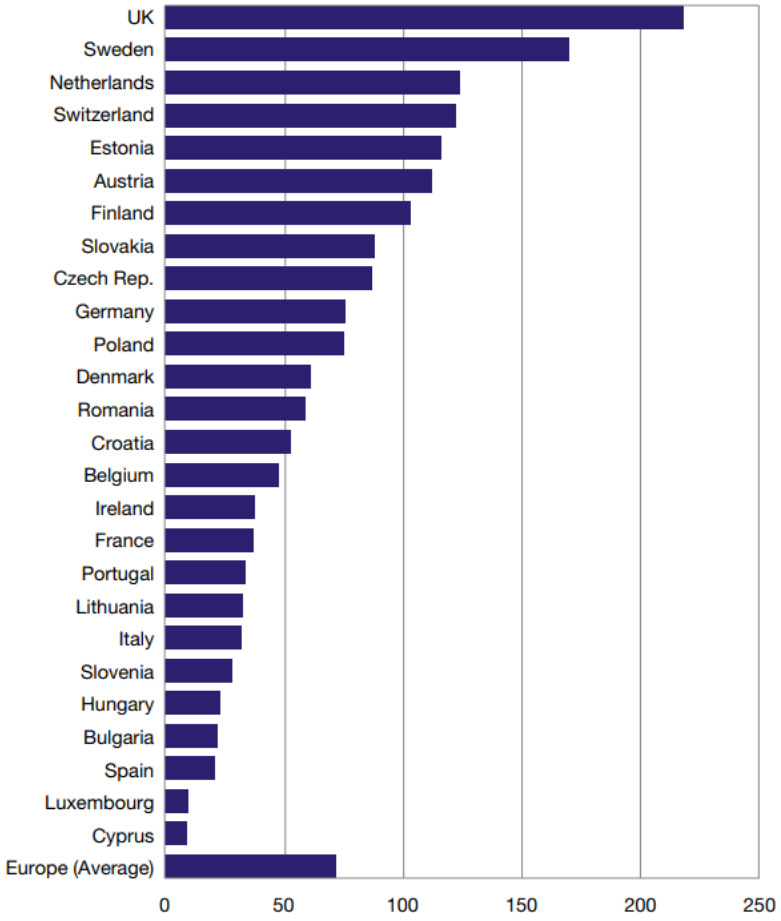


Figure 6: Number of charging points per country in 2020 (Transport & Environment (2020)

Despite this statistics, RAC's Head of Roads Policy Nicholas Lyes said: "It's all well and good having a zero-emission vehicle mandate for car manufacturers but if public charging isn't keeping pace with EV registrations, then drivers will quickly become disillusioned and frustrated. Data already shows a record number of electric vehicles per public charging point, so we strongly urge the Government to introduce annual installation targets and do whatever it takes to make it easier for operators to install new charging hubs". This tendency is showing the need for UK EV charging infrastructure developers to put in place much fast charging stations to ensure supply satisfies demand year on year. As DHL (2022) recommends, to smoothly transition to EVs, governments need to examine the drawbacks of EVs and design different solutions specific to their country's needs, including factors such as the average length of journeys (in both miles and hours), the ratio of chargers to vehicles, and the availability of expertise in maintaining the vehicles and stations.

DfT (2023) also states that the UK road freight transport are a significant part of our transition to EVs, including delivery and freight vehicles, buses, emergency service vehicles, service sector vehicles, car-clubs, and business pool cars; and there are businesses that have a couple of vehicles, while others have many thousands, and such a variety of EV freight users require a wide range of charging solutions that will be most appropriate for each fleet, based on their usage patterns, mileage and how long they are parked in a typical day. Fleet operators and local highways

authorities need to share information on their prospective fleet needs to inform local planning, as well local electricity network operators will need to consider future fleet charging requirements as part of their network planning. The priorities of the UK government in relation to EV charging infrastructure suitable for road freight transport, as reported by DfT (2023), are:

- Regularly assessing current and future charging needs, identifying potential clusters of needs (whether depot or home based).
- Sharing information on key charging locations and requirements when requested by local authorities and electricity network operators as part of strategy development.
- Liaising with electricity network operators and charge-point operators on innovative, smart systems for scheduled charging that can reduce costs at depots (or other sites with multiple vehicles).
- Collaborating locally and nationally to improve charge-point utilisation rates and efficiency, and create “win-wins”, for example, by providing access to other fleets with different usage patterns or to local residents.

Conclusions

This report aims to inform the main actors within the Colombian road freight transport sector on the recent developments, advancements and plans published in the industry and academic literature on EV charging infrastructure. Evidence that features in this report include all aspects of EV charging infrastructure development, i.e., electricity demand and supply, matching EV demand with the number of charging stations and carefully geographical planning of the location of EV charging points. However, there is not evidence that the deployment of EV charging stations is being developed with the same place of EV sales; hence, public policy makers need to work with all key stakeholders to ensure that both freight and private EV users can have access to a suitable, convenient, and reliable EV charging network.

All actors with the Colombian road freight transport sector, including electricity providers, EV charging infrastructure developers & providers, freight and private EV users and the Colombian government must work together to draw a RoadMap to ensure the adoption of EVs is not hinder by insufficient progress on EV charging infrastructure development, one of the crucial elements of the decarbonisation of the Colombian road freight transport,

References

Ahmad, F., Alam, M.S., Shariff, S.M., et al.: ‘A cost-efficient approach to EV charging station integrated community microgrid: A case study of Indian power market’, IEEE Trans. Transp. Electrif., 2019, 5, (1), pp. 200–214.

Alizadeh, M., Wai, H.-T., Chowdhury, M., Goldsmith, A., Scaglione, A., and Javidi, T. Optimal pricing to manage electric vehicles in coupled power and transportation networks. IEEE Transactions on Control of Network Systems, 4(4):863–875, 2017.

Amara-Ouali, Y., Goude, Y., Doumèche, N., Veyret, P., Thomas, A., Hebenstreit, D., Wedenig, T., Satouf, A., Jan, A., Deleuze, Y., Berhaut, P., Treguer, S., Phe-Neau, T. Forecasting Electric Vehicle Charging Station Occupancy: Smarter Mobility Data Challenge, Cornell University Publication Repository. 2023, under review, June 2023.

Brown, A., Cappellucci, J., White, E., Heinrich, A., Cost, E. (2023). Electric Vehicle Charging Infrastructure Trends from the Alternative Fueling Station Locator, National Renewable Energy Laboratory. First Quarter 2023. https://afdc.energy.gov/files/u/publication/electric_vehicle_charging_infrastructure_trends_first_quarter_2023.pdf [Accessed on 22/08/2023]

Brown, A., Cappellucci, J., White, E., Heinrich, A., Cost, E. (2022). Electric Vehicle Charging Infrastructure Trends from the Alternative Fueling Station Locator, National Renewable Energy Laboratory. First Quarter 2022. https://afdc.energy.gov/files/u/publication/electric_vehicle_charging_infrastructure_trends_first_quarter_2022.pdf [Accessed on 22/08/2023]

Crozier, C., Morstyn, T., and McCulloch, M. The opportunity for smart charging to mitigate the impact of electric vehicles on transmission and distribution systems. Applied Energy, 268: 114973, 2020.

Amry, Y.; Elbouchikhi, E.; Le Gall, F.; Ghogho, M.; El Hani, S. Electric Vehicle Traction Drives and Charging Station Power Electronics: Current Status and Challenges. Energies 2022, 15, 6037.

Dallinger, D., and Wietschel M. Grid integration of intermittent renewable energy sources using price-responsive plug-in electric vehicles. Renewable and Sustainable Energy Reviews, 16(5): 3370–3382, 2012.

Department for Transport. Taking charge: the electric vehicle infrastructure strategy. January 2023. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1065576/taking-charge-the-electric-vehicle-infrastructure-strategy.pdf [Accessed on 29/08/2023]

DHL. The future of EVs goes beyond vehicles, 22nd July 2022. https://lot.dhl.com/the-future-of-evs-goes-beyond-vehicles/ [Accessed on 29/08/2023]

European Union Parliament. Report on the proposal for a regulation of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council (COM(2021)0559 – C9-0331/2021 – 2021/0223(COD)). Released on 4/10/2022. Committee on Transport and Tourism. A9-0234/2022. https://www.europarl.europa.eu/doceo/document/A-9-2022-0234_EN.html [Accessed on 24/08/2023]

Franke, T., Krems, J.F.: 'What drives range preferences in electric vehicle users?', Transp. Policy, 2013, 30, pp. 56–62.

International Energy Agency. Trends in electric light-duty vehicles. Global EV Outlook 2022. https://www.iea.org/reports/global-ev-outlook-2022/trends-in-electric-light-duty-vehicles [Accessed on 15/08/2023]

Khalid, M.R.; Khan, I.A.; Hameed, S.; Asghar, M.J.; Ro, J.S. A comprehensive review on structural topologies, power levels, energy storage systems, and standards for electric vehicle charging stations and their impacts on grid. IEEE Access 2021, 9, 128069–128094.

Mureddu, M., Facchini, A., Scala, A., Caldarelli, G., and Damiano, A. ''A complex network approach for the estimation of the energy demand of electric mobility,'' Sci. Rep., vol. 8, no. 1, p. 268, 2018.

Moghaddam, Z., Ahmad, I., Habibi, D., and Phung, Q.V. Smart charging strategy for electric vehicle charging stations. IEEE Transactions on Transportation Electrification, 4(1):76–88, 2018.

News European Parliament. MEPs adopt new rules for more charging stations and greener maritime fuels. Press Release Plenary Session 11-07-2023. https://www.europarl.europa.eu/news/en/press-room/20230707IPR02419/meps-adopt-new-rules-for-more-charging-stations-and-greener-maritime-fuels [Accessed on 24/08/2023]

Price Water Cooper (2022), The US electric vehicle charging market could grow nearly tenfold by 2030: How will we get there? https://www.pwc.com/us/en/industries/industrial-products/library/electric-vehicle-charging-market-growth.html [Accessed on 22/08/2023]

Réseau de Transport d'Électricité. Futurs énergétiques 2050 : les scénarios de mix de production à l'étude permettant d'atteindre la neutralité carbone à l'horizon, 2022. https://www.rte-france.com/analyses-tendances-et-prospectives/bilan-previsionnel-2050-futurs-energetiques#Lesdocuments. [Accessed on 15th August 2023]

RAC. DfT report reveals that the UK is struggling to provide enough EV chargepoints for drivers. January 2023. https://www.rac.co.uk/drive/news/electric-vehicles-news/dft-report-reveals-uk-is-struggling-to-provide-enough-ev-chargepoints/ [Accessed on 29th August 2023]

Shafiee, S., Fotuhi-Firuzabad, M., and Rastegar M. ''Investigating the impacts of plug-in hybrid electric vehicles on power distribution systems,'' IEEE Trans. Smart Grid, vol. 4, no. 3, pp. 1351–1360, Sep. 2013.

Transport & Environment (2020). Recharge EU: How many chargepoints will Europe and its Member States need in the 2020s. Updated based on data from EAFO and Eurostat (2021). http://www.indiaenvironmentportal.org.in/files/file/Recharge-EU-charge-points-Europe-2020s.pdf [Accessed on 29/08/2023]

Wang, J. Q. Liu, X., Du, J., and Kong, F. Smart charging for electric vehicles: A survey from the algorithmic perspective. IEEE Communications Surveys & Tutorials, 18(2):1500–1517, 2016