Article

Forecast of the Demand for Electric Mobility for Rome-Fiumicino International Airport

Romano Alberto Acri [1], Silvia Barone [1], Paolo Cambula [2], Valter Cecchini [2], Maria Carmen Falvo [1], Jacopo Lepore [1], Matteo Manganelli [1,*], and Federico Santi [1]

[1] Department of Astronautic, Electrical and Energy Engineering, Sapienza University of Rome, Rome, Italy; {romanoalberto.acri, mariacarmen.falvo, matteo.manganelli, federico.santi}@uniroma1.it

[2] ADR, Atlantia Group, Rome, Italy; paolo.cambula@adr.it, ing.cecchini@gmail.com

* Correspondence: matteo.manganelli@uniroma1.com

Abstract: Following electrification of automotive transport, studies on the penetration of Electric Vehicles (EVs) are widespread, especially in defined contexts, e.g. cities. As major transport hubs, airports fall within contexts worth of interest. In this work, a forecast of the demand for electric mobility in an Italian international airport (Rome, Fiumicino) is presented. First, a wide review of proposed scenarios on the penetration of EVs at international and national level and available data on local automotive transport are presented, as preliminary study for the definition of reference scenarios for the local context. Then the methodology proposed is presented and applied to the specific case study. Finally, a preliminary sizing of the required charging infrastructure is reported. The proposed approach can be considered as reference for similar studies on electrical mobility in other airport areas around the world.

Keywords: electric mobility, electric vehicle, electrification, airport.

1. Introduction

Following energy and environmental concerns in road transports [1], the automotive industry is quickly evolving in the direction of Low-Emission Vehicles (LEVs) [2]. Electric Vehicles (EVs) are regarded as a suitable option. They can be classified as reported in **Figure 1** as: battery-powered electric drive alone, such as Battery Electric Vehicles (BEVs), or Full Electric Vehicles (FEVs), combined with thermal traction, such as Hybrid Electric Vehicles (HEVs), or BEV with range extender (Rex). Other low-emission technologies, like Fuel Cell Electric Vehicles (FCEV), are in the minority.
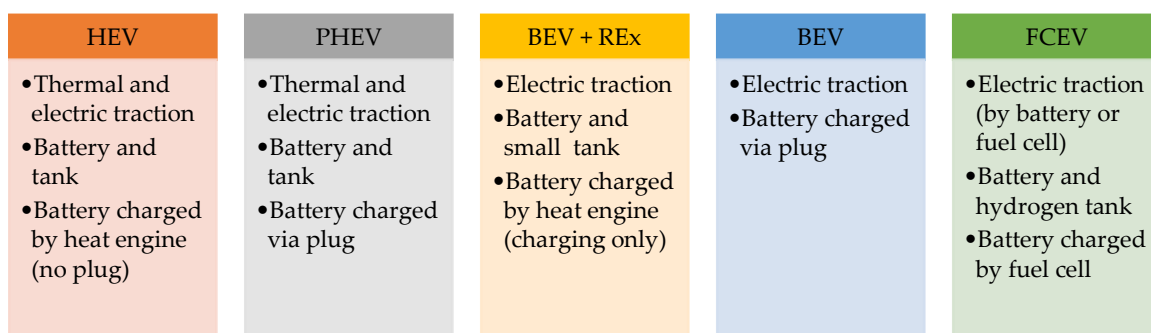
HEV	PHEV	BEV + REx	BEV	FCEV
•Thermal and electric traction •Battery and tank •Battery charged by heat engine (no plug)	•Thermal and electric traction •Battery and tank •Battery charged via plug	•Electric traction •Battery and small tank •Battery charged by heat engine (charging only)	•Electric traction •Battery charged via plug	•Electric traction (by battery or fuel cell) •Battery and hydrogen tank •Battery charged by fuel cell

Figure 1. Taxonomy of Low-Emission Vehicles (LEVs)

The international literature dealing with the topic of electrification of transport, and in particular the spread of EVs, is wide-ranging and approaching the subject from many different points of view. Just as examples, some references have been preliminary studied in details. Potential energy saving and emission avoidance via electrification of road transports is investigated e.g. by Uherek et al. [1] and by Gonzalez-Palencia et al. [3,4]. Drivers and strategies for the expansion of EV are investigated e.g. by Wesseling et al. [5] and for

Plug-In Vehicles (PEVs) by Gnamm et al. [6]. Examples of policies around the world are reported e.g. by Kong et al. [7] or by Trencher et al. [8]. Studies on the diffusion of EV in the world are e.g. by the Fraunhofer Institute [9] or the International Energy Agency [10].

The diffusion of EVs is strongly conditioned by the development of charging infrastructure, mandatory for their expansion and deployment. The EVs charging system has an unavoidable impact on the electrical grids. Studies on the implementation of charging stations and on the issues related the power systems are widely present in international literature. [11-13]. The diffusion of electrical mobility in cities is an investigated topic in many papers, e.g. [14-16].

The present work deals with a study made for forecasting of the demand for electric mobility for a specific area in Italy that is Rome-Fiumicino International Airport. Similar studies on the electrification of road transports to airports and the allocation of EVs charging in airports are included in [17,18]. The work takes its cue from the necessity to upgrade airports, as major transport hubs, to accommodate electrical mobility. The objectives of the work are:

- The forecast of EVs turnout at airport parking facilities at time horizon 2025-2030, for clusters of vehicles (chauffeurs, private cars, rental cars, and taxis);
- The estimation of charging points potentially required accommodating the forecasted EVs turnout.

For the purpose of a forecast at local level (airport area), it is necessary to elaborate forecasts at wider levels to extrapolate local results. In addition, given the specific context, analysis of other specific data (e.g., stop duration and vehicle age) is also necessary. It means that a specific methodology of forecast has to be formulated. The present paper wants to show the methodology formulated and the results obtained. The paper is organized as follows. Section 2 includes a description of the case study. Section 3 deals with the analysis of EVs development scenarios at the different levels and the definition of scenarios of the forecast at local level. In Section 4, the forecast of EVs turnout for the case study is carried out. In section 5, the preliminary sizing of charging infrastructure for the case study is performed. Section 6 concludes the paper.

2. The case study

The case study is the Rome–Fiumicino International Airport "Leonardo da Vinci", the major airport in Italy and 15th airport in Europe by passenger traffic in 2020 (43 532 573 passengers in 2019 and 9 486 161 Jan-Nov 2020) [19]-[20]. The landside mobility is organized in:

- Parking areas for passengers and operators;
- Sub-concession parking areas for car rentals, chauffeurs, and buses;
- Non-sub-concession parking areas for taxis, chauffeurs, buses, and shuttles.

Transport to the airport is organized as follows [21]:

- Public collective railway transport with the city of Rome: *Ferrovia Laziale FL1* local train, *Leonardo Express* nonstop service;
- Public collective railway transport major Italian cities: Trenitalia *Frecciargento* high-speed trains;
- Public and private collective road transport: shuttle buses by private companies;
- Public personal road transport: taxis;
- Private personal road transport: chauffeurs and car rentals.

The forecasting methodology is aimed to know the demand of electrical mobility in the airport area, split in the different categories of transport systems. For doing that the first steps are related to - the knowledge of the state of art of the EVs diffusion at national level and the analysis of EVs development scenarios at international and national level.

In reference to data on EV fleet and market in Italy, the market is expanding, but it is still limited. In 2019, approximately 39 000 EV and 17 000 were sold (less than 1% of two million cars sold) (**Figure 2**).
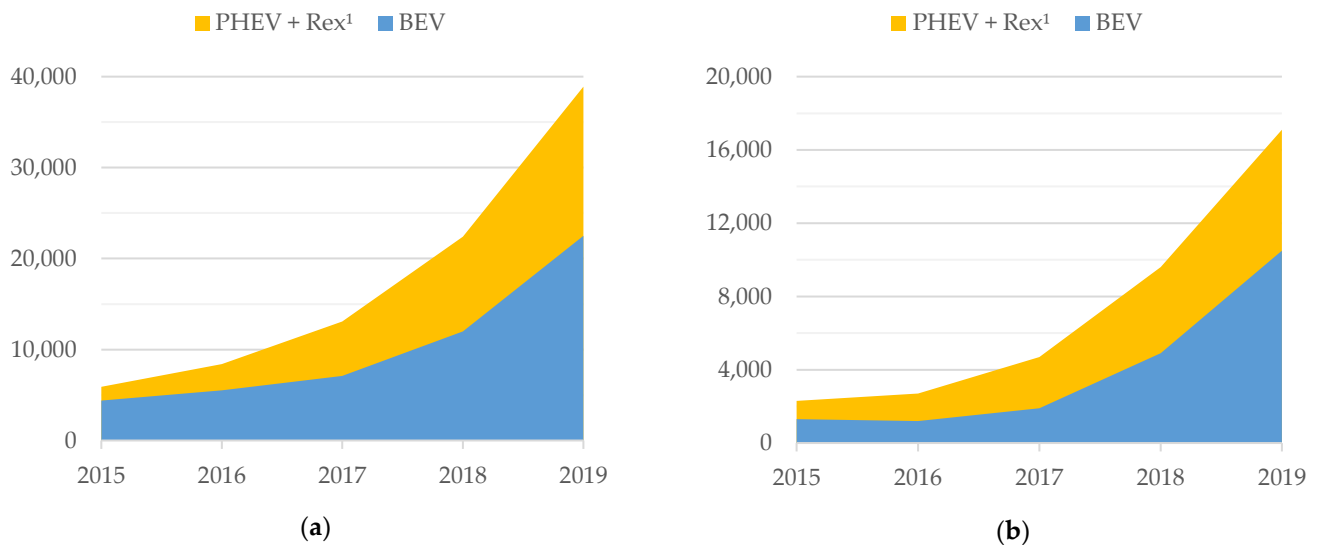

Figure 2. Share of EVs in car fleet (a) and car sales (b) in Italy 2015-2019. [1]Range extender.

The analysis of EVs development scenarios at international and national level has been referred to different sources and the results of the wide analysis and comparison is reported in the next section. From these scenarios, two reference scenarios have been defined at national level, as starting point of the forecasting methodology proposed in Section 4.

3. Analysis of EVs development scenarios at different levels

3.1. Global level

The development scenarios on global level are developed by international agencies operating in energy, mobility, and environmental sectors, such as:

- Boston Consulting Group [22], where the analysis led to a single scenario, presented here as BCG;
- Bloomberg NEF [23] under the assumption that in 2025 combustion engine cars and EVs will reach economic parity and presented here as BNEF;
- IEA [10] which proposes two scenarios: IEA New Policy Scenario (NPS), this is the most conservative scenario and includes the impact of announced policy ambitions, and a more ambitious one, IEA 30@30, which accounts for the pledges of the EVs EV30@30 Campaign to reach 30% market share for electric vehicles by 2030.

The mentioned reports are compared with reference to the penetration index of new EVs registrations, where this index is defined as the ratio between the number of EVs and the total number of vehicles expressed in percentage. In particular, the EVs considered are only BEV or PHEV, while the timeframe examined includes the years: 2020, 2025 and 2030. **Figure 3** shows the results of the comparison among the scenarios before listed in terms of estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at world level.
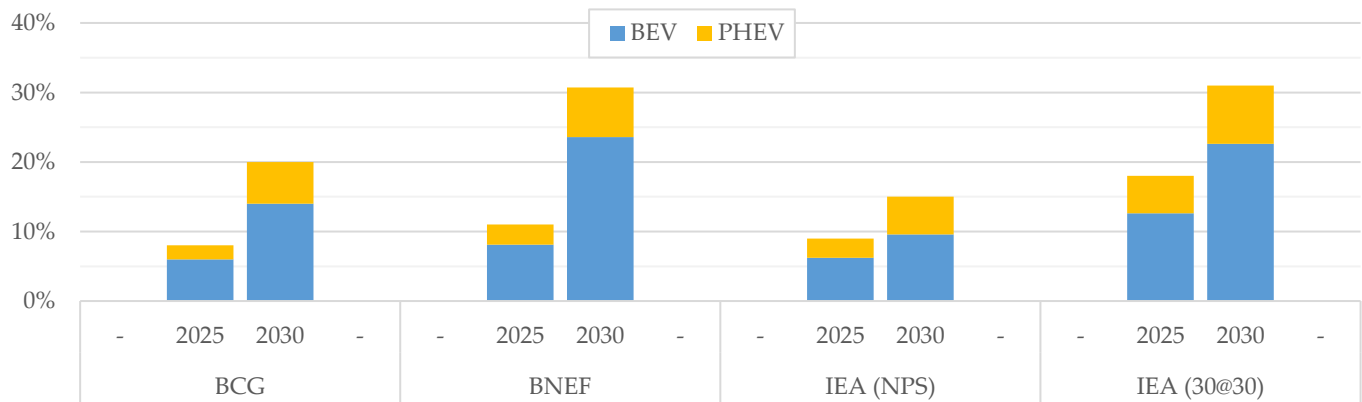
Figure 3. Estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at world level, based on different forecasting scenarios.

With global sales of new electric cars reached 2.1 million units in 2019, the actual global penetration index remains slightly more than 2%. According to the results showed, this value could rapidly increase up to 2030. Indeed, whilst the sales shares for BEV models vary between 10 to 24% by 2030, for PHEV ones the forecasts indicate a value between 5% and 9%.

3.2. European level

The projected scenarios on European level were developed by some international agencies operating in energy, mobility, and environmental sectors, such as:

- Boston Consulting Group [22] (BCG);
- Cambridge Econometrics [24] that develops a set of three scenarios, each assuming a different decarbonization pathway taken by most major car manufacturers to meet EU CO2 emissions reduction targets. The scenarios are presented as: CAM, CAM (Tech PHEV) and CAM (Tech OEM);
- Transport & Environment [25] that defined five scenarios, based on the incremental fuel efficiency upgrade of future ICE car fleet. The scenarios are presented as: TRA&ENV (b), TRA&ENV (lICE), TRA&ENV (hICE), TRA&ENV (BEV) and TRA&ENV (PHEV);
- IEA [10] which proposes only NPS Scenario to forecast new electric vehicles sales in Europe.

According to CAM (Tech) scenario ambitious deployment of fuel efficiency-technologies allowed new cars sales mix to reach emissions target, with a predominance in BEV sales. A variant of this scenario, where PHEV emerges as dominant segment, is represented by CAM (Tech PHEV); while in CAM (Tech OEM) was supposed a more ambitious deployment for advanced powertrain, in line with recent OEM announcements.

Starting with the central scenario TRA&ENV (b), Transport & Environment supposes different strategies adopted by carmakers to improve the average fuel efficiency. In TRA&ENV (lICE) (low ICE Improvement) scenario carmakers choose not to invest in the incremental efficiency gains of ICE engine while in TRA&ENV (hICE) (High ICE Improvement) more hybrid vehicle sales is assumed to improve average fuel efficiency of cars fleet. Further scenarios are: TRA&ENV (BEV) where carmakers focus on selling BEVs and TRA&ENV (PHEV) with an equal distribution between BEV and PHEV up to 2030.

Additional hypothesis, such as future declining of battery cost, growing incentive policy announcements and increasing of shared mobility are just some of the bases of BCG and IEA NPS scenario that led to following predictions.

Figure 4 shows the results of the comparison among the scenarios before listed in terms of estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at European level.
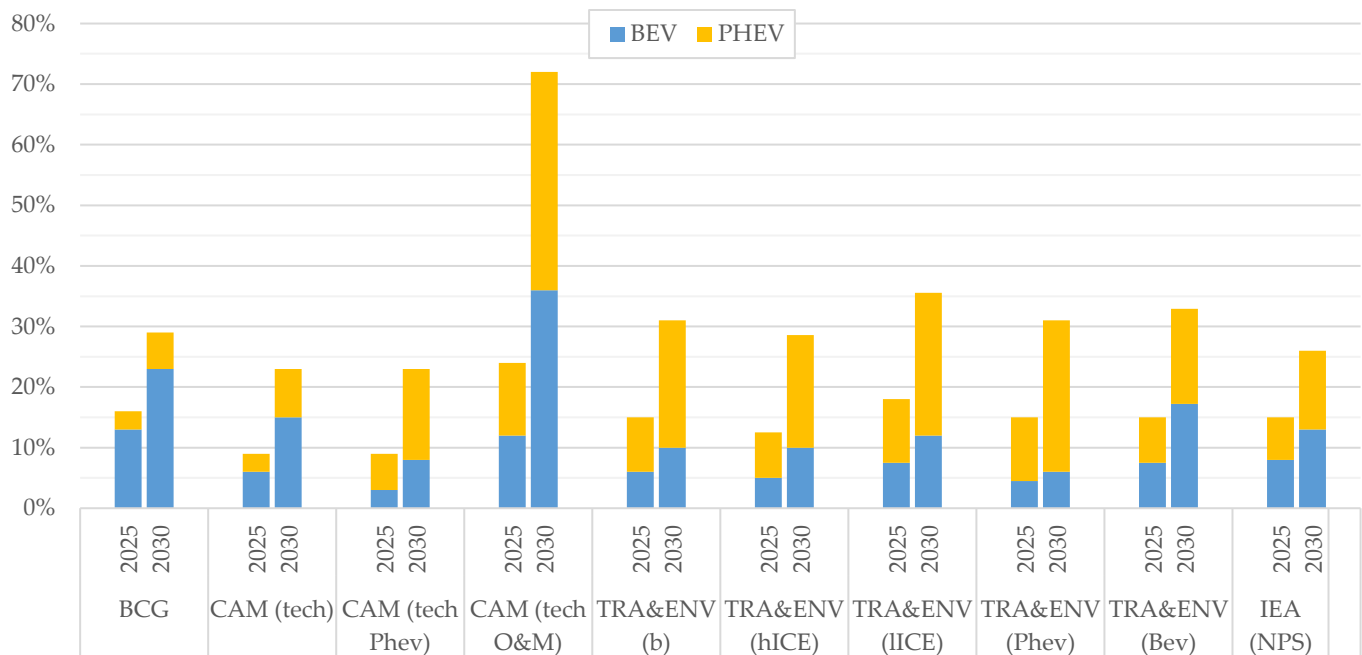

Figure 4. Estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at European level, based on different forecasting scenarios.

The results show an improvement on market sales at 2030 both for BEV and for PHEV segment, which account a total share between 6 to 36%.

2.3. Italian level

The forecasting scenarios on national level are developed by some national and international agencies operating in energy, mobility and environmental sectors, such as:

- Cambridge Econometrics [24], from which are extracted two main scenarios, following presented as CAM (Tech) and CAM (Tech Rap);
- Politecnico di Milano [26], with three scenarios classified as: POLIMI (b – base), POLIMI (m – moderate) and POLIMI (a – rapid);

CAM (Tech) scenario allows to reach the average fuel emission target set by European directive (DAFI) while, with a faster deployment of advanced powertrain achieved in CAM (Tech Rapid) scenario, new cars registration in 2030 meet 25 CO_2/km emission.

The report by Politecnico di Milano presented an analysis based on vehicle stock gained for each forecasting years. POLIMI (b) assumes a total volume of 2 million cars in circulation in 2030 whereas the future fleet for the other scenarios increase up to 5 million and 7.5 million, respectively for POLIMI (m) and POLIMI (a).

Figure 5 shows the results of the comparison among the scenarios before listed in terms of estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at Italian level.
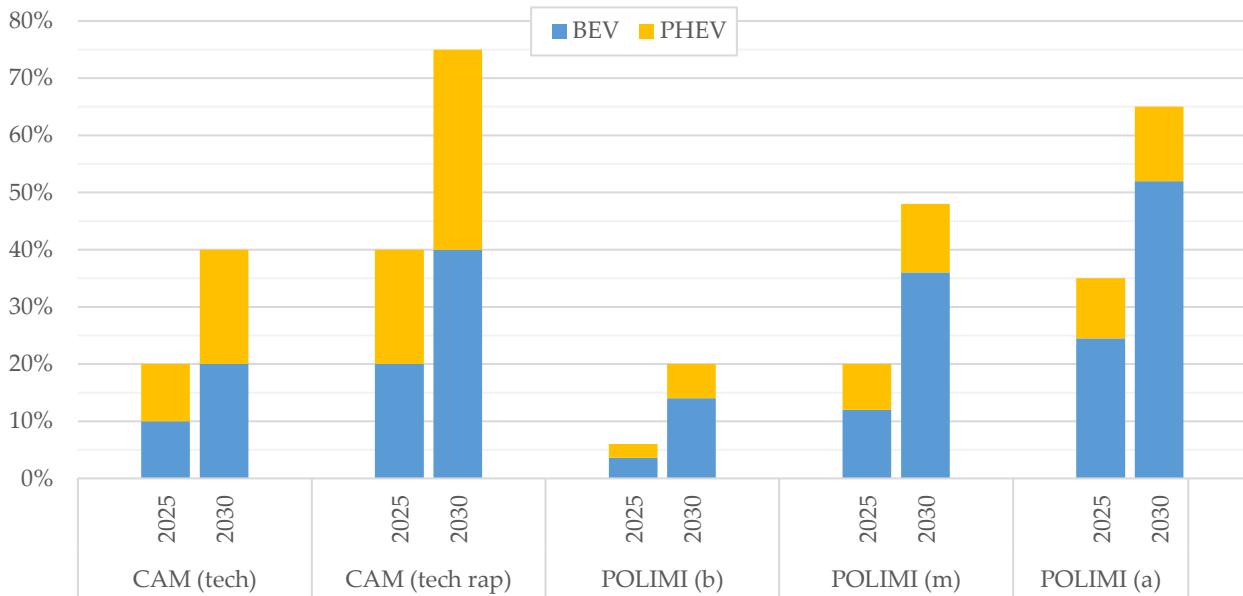
Figure 5. Estimated average BEV and PHEV penetration index on car sales, for 2025 and 2030, at Italian level, based on different forecasting scenarios.

The sales shares for BEV models in Italy vary between 14 to 54% by 2030, for PHEV ones the forecasts indicate a value among 6 to 34%.

3.4. Definition of reference forecasting scenarios for the case study

Two scenarios have been identified as reference taking in consideration the studies listed above. Given the number and variability of studies, it is necessary to condensate forecasts into a range in which the demand of local electric mobility is presumed to vary. The range is delimited by two scenarios making up the envelope in which electric mobility is forecasted to vary in the 2030 horizon, so defined:

- Conservative scenario: significant incentive policies are not considered, and it is in line with the basic one of the Politecnico di Milano study [26], which envisages the least expansion;
- PNIEC scenario: it is in line with the objectives on electrical mobility included in Italian *Integrated National Plan for Energy and Climate* (*Piano Nazionale Integrato per l'Energia e il Clima 2030*, PNIEC) [27] (to have 6 000 000 EVs circulating in 2030), consequently, it is the upper limit for the demand for Italian electric mobility in 2030.

The conservative scenario considers a total of 2 000 000 EVs circulating in 2030, of which 1 200 000 BEVs and 800 000 PHEVs. **Figure 6** shows the estimated average BEV and PHEV penetration index on car sales from 2020 to 2030 at Italian level. Therefore, the conservative scenario envisages a market share on sales of approximately 15% for BEVs and 10% for PHEVs by 2030, having assumed constant annual sales equal to 1.95 million vehicles per year. **Figure 7** shows the estimated average BEV and PHEV penetration index on car fleet from 2020 to 2030 at Italian level, with values equal to approximately 2.7% of BEV and 1.7% of PHEV.
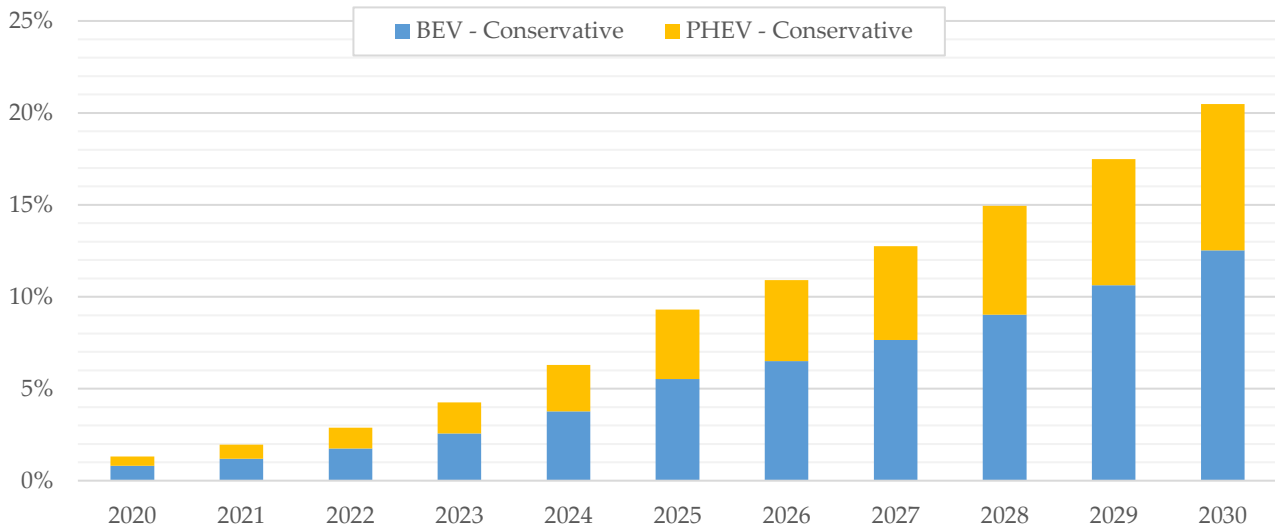
Figure 6. Estimated average BEV and PHEV penetration index on car sales from 2020 to 2030 at Italian level (conservative scenario)
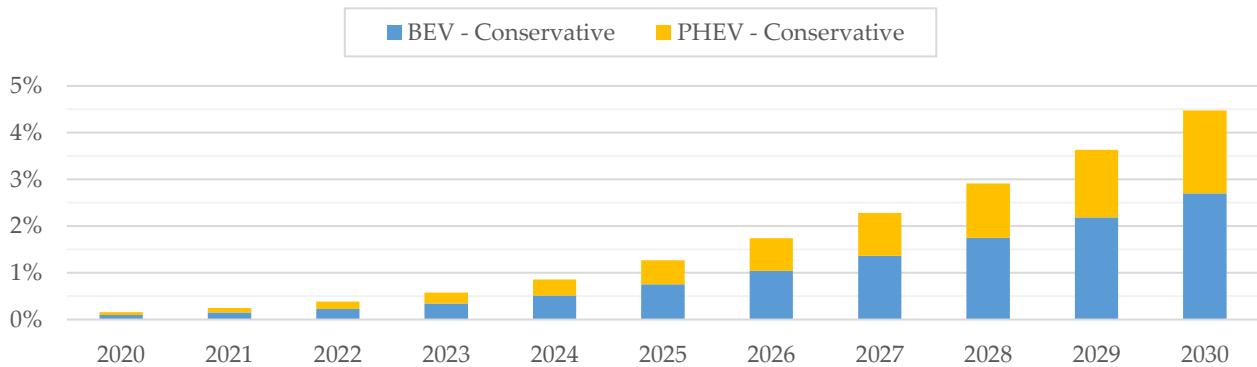

Figure 7. Estimated average BEV and PHEV penetration index on car stocks from 2020 to 2030 at Italian level (conservative scenario)

The PNIEC foresees the effectiveness of investments in electric vehicles in 5-7 years, hence an overall diffusion of roughly 6 million of EVs, of which 4 million of pure EVs (BEV) and 2 million of hybrid EVs, by 2030. Assuming this target is achieved, there will be 44 million vehicles circulating with 14% made up of EVs (BEV or PHEV) in 2030. The trend for the intervening years has been calculated by interpolating data with a logistic curve (sigmoidal), whose equation is:

$$f(x) = \frac{Y}{1 + e^{-\frac{x-\mu}{s}}}$$

The assumptions assumed to uniquely determine the equation are as follows: the choice of the horizontal asymptote, represented by the constant Y, is carried out imposing for every typology a saturation level in the new registration in line with the values pre-sented in the analyzed reports, for which the phase-out year in the sale of conventional technology is set at 2040 with a ratio of BEV to PHEV equal to 2:1.

- the cars sold in 2019, for every typology, is obtained from the historical analysis;
- the cars sold in the horizon year 2030 is such as to make the fleet in circulation reach the corresponding value for the scenario considered.

As shown in **Figure 8**, the PNIEC scenario envisages a penetration index of sales of about 50% of BEV and 25% of PHEV, having assumed the total annual sales as constant

and approximately equal to 1,95 million of vehicles/year. The penetration index on the car fleet is shown in **Figure 9** and it is about 9% of BEV and 4.5% of PHEV.
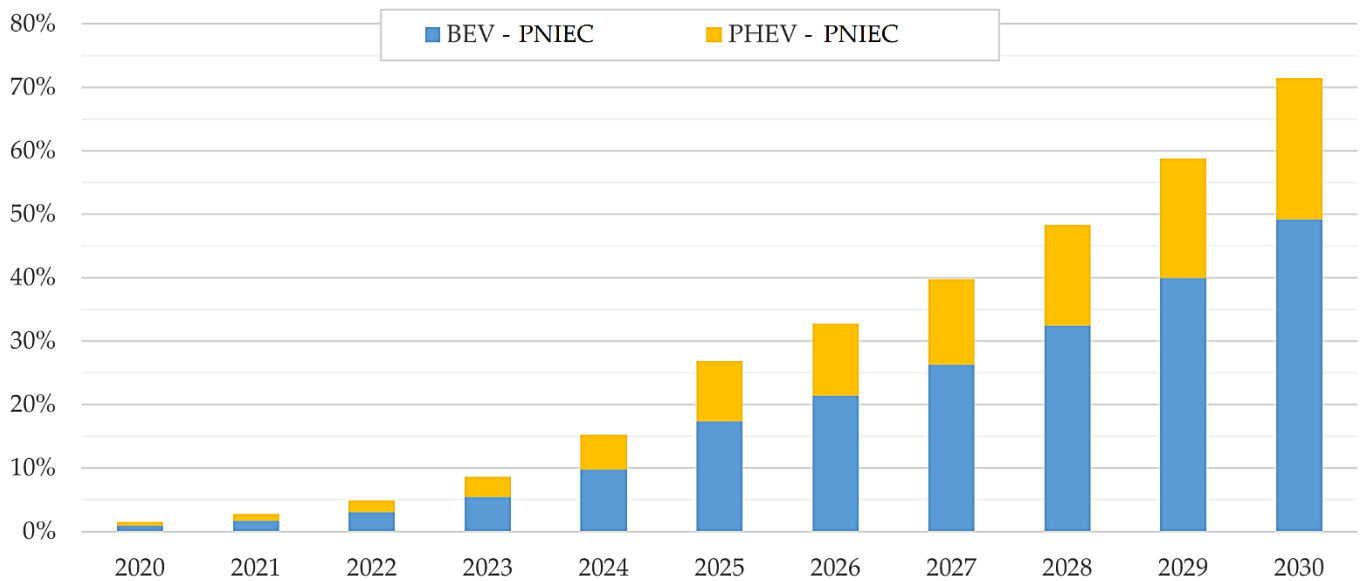

Figure 8. Estimated average BEV and PHEV penetration index on car sales from 2020 to 2030 at Italian level (PNIEC scenario).
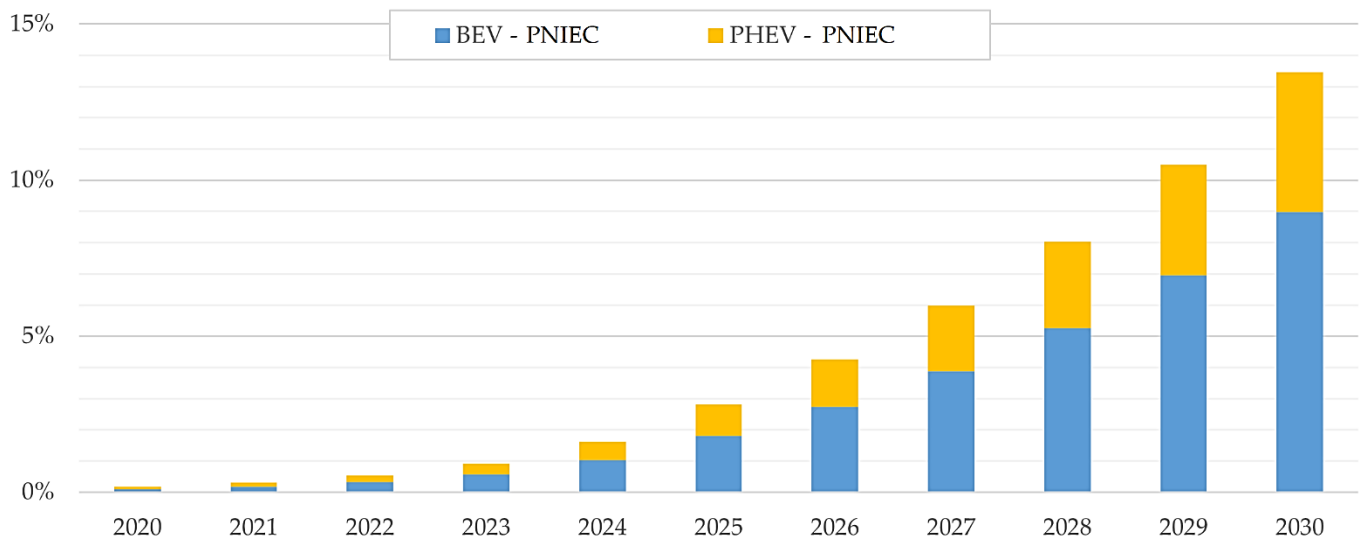

Figure 9. Estimated average BEV and PHEV penetration index on car stocks from 2020 to 2030 at Italian level (PNIEC scenario).

The market share of BEVs and PHEVs in the two developed scenarios is, for the years between 2020 and 2030, in **Figure 10**, where a comparison with the various literature scenarios is also reported.
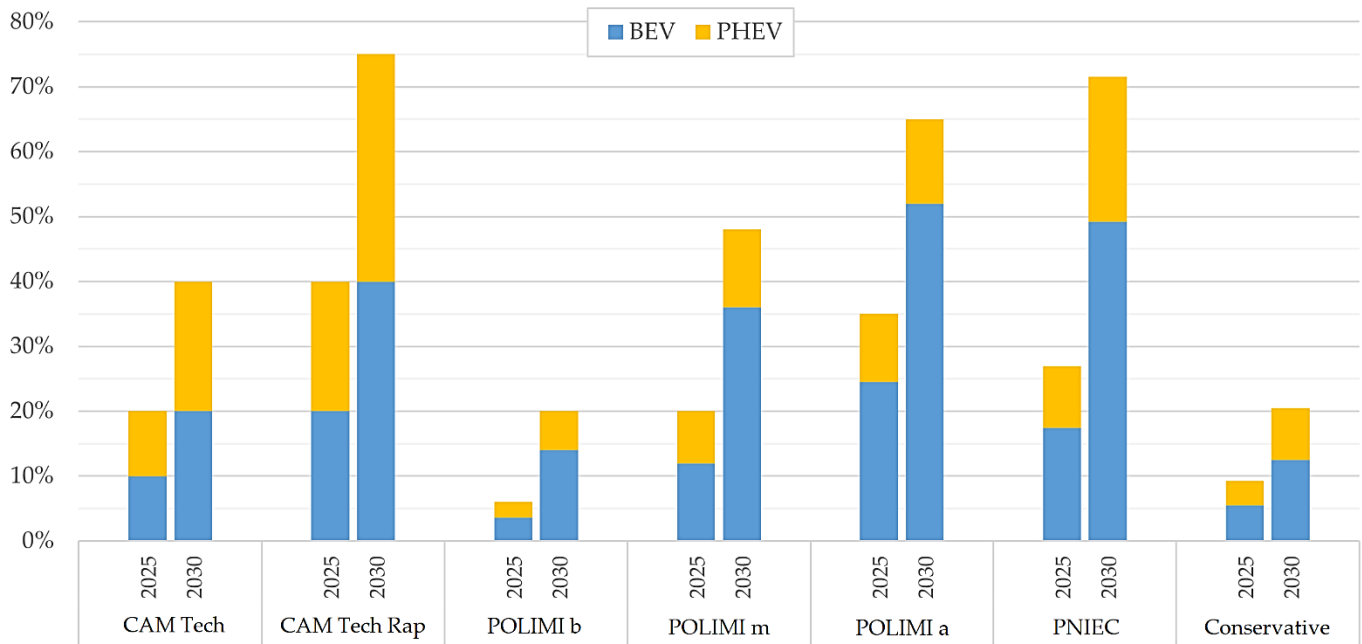
Figure 10. Comparison of estimated average penetration index on Italian car sales in 2025 and 2030, for the different scenarios,

4. Forecasting of Rome-Fiumicino airport EVs development scenarios

4.1. Data and methodology

From the scenarios defined for the international and national level, a methodology is defined to deduce the evolution of landside mobility for the Rome-Fiumicino airport. The context is peculiar due to the different distribution of vehicle clusters (private vehicles, taxis, chauffeurs, buses) compared to national data.

Supplemental data are used to support the analysis, which are as follows:

- Characterization of parking areas (via satellite imaging of public domain);
- Identification of internal collective transport lines (shuttles);
- Identification of public transport line;
- Data on stops in 2019 (duration, number of vehicles, and registration plates);
- Hourly detection of private traffic flows.

The main steps of the methodology are as follows:

- Analysis of the consistency of parking areas (via identification of areas from satellite imaging and allocation to cluster of users) to allocate charging points;
- Analysis of the duration of stops (from data provided by ADR) to allocate type of charging points (slow/fast charging);
- Analysis of vehicle age distribution (from license plate data provided by ADR) to estimate the renewal rate by cluster and the consequent EV penetration;
- Estimation of EV access number by cluster; obtained by combining the age distribution profiles with the sales forecasts derived from the analysis of the scenarios.

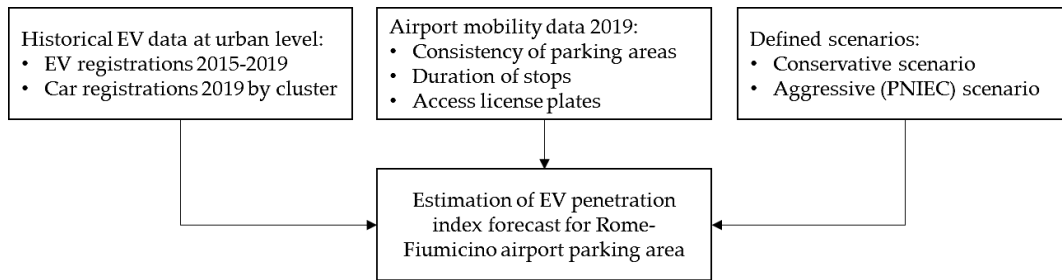A block diagram summarizing the main steps of the methodology is in **Figure 11**.

Figure 11. Summary of forecast methodology

Access data on license plates and duration of stops are provided by AdR Mobility [28] for multi-story and long stop car parks, while data on car parks for employees are not available. Data include license plate, duration of stop, and date and time of entry and exit.

Only the first two letters of license plates (in the Italian format AA 000 AA) were acquired for the sake of privacy. Registration date was then estimated via linear interpolation on registration of license plates. Results show a concentration of stops shorter than 30 minutes for cars newer than one year, which is ascribed to rental cars crossing the multi-story parking: To filter data, only stops longer than 30 minutes are considered.

Combining the age distribution profiles and EV sales forecast for the two reference scenarios, the percent of EV accessing airport car parks in the time horizon can be estimated, as follows:

$$P = \sum_{i=1}^{n} p_i \, q_i$$

where: p_i is the number of EV registered in the year I, q_i is the number of vehicles, registered in the year i, in the car parks; and n is the time horizon, chosen as 10 years. A similar forecast is performed for other clusters (chauffeurs, taxis, and rental cars), assuming:

- An expected life of 5 years for taxi cars;
- An expected life of 2.5 years for a rental car;
- The same age profile for airport operators' vehicles as those of passengers;
- Saturation of the logistic curve 5 years forward for taxis and chauffeurs compared to private cars.

4.2. Results

Parking areas can be divided by type of users (employees or passengers) or by duration (long or shortstop). Passenger parking areas are the multi-story car parks (A to D), the long stay car park, and the kiss-and-go car park. Other parking areas are the chauffeur buffer, the taxi buffer, the bus buffer, the car park for employees, and the car park for rental cars. The distribution of parking areas by type is reported in **Figure 12**.
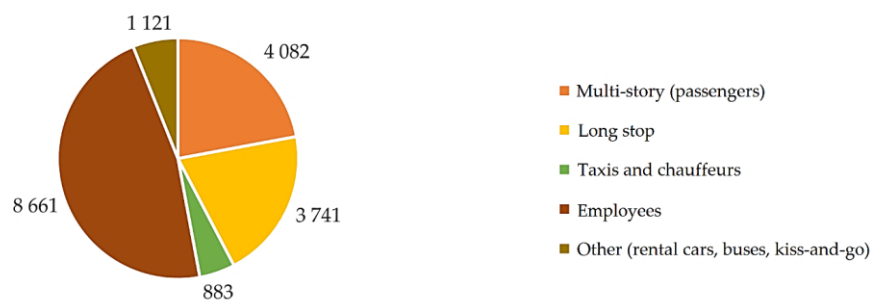

Figure 12. Allocation of car park spaces

Figure 13 reports the distribution of stop durations. The data show about 2.2 million stops in 2019, resulting in a total duration of about 23 million hours. The number of very short stops is due to rental cars and kiss-and-go stops.
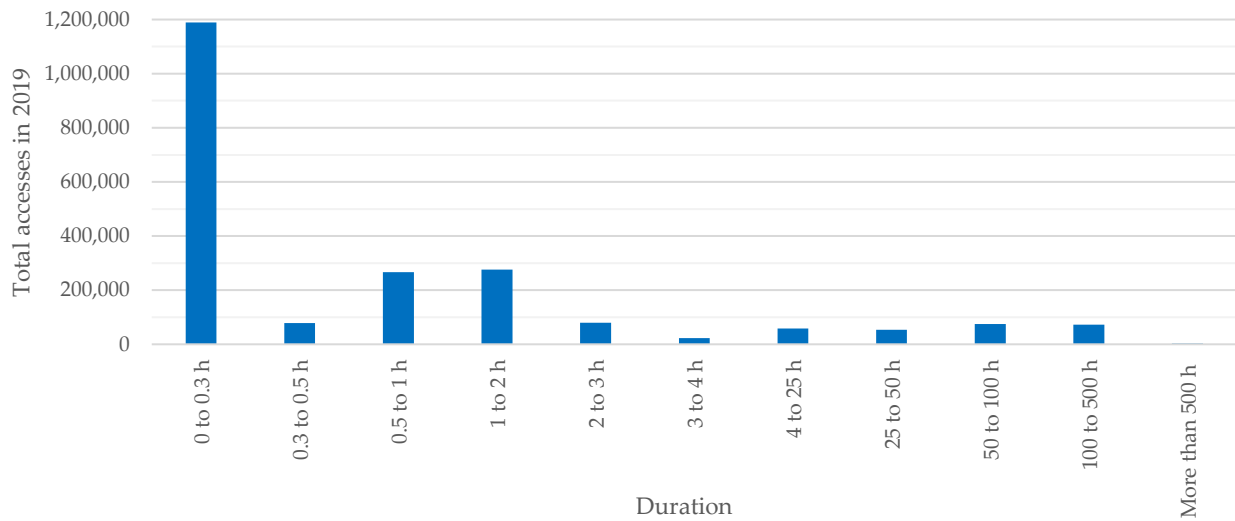

Figure 13. Stop duration distribution

Vehicle age distributions for the airport and the province of Rome are compared in **Figure 14**. The difference is due to two causes:

- Vehicles accessing airport car parks (particularly the multi-story car park) are often company cars which are usually replaced more frequently than private cars;
- Old cars travel less kilometers per year, while users travelling much are forced to replace car frequently due to wear, thus newer cars are likely to be a significant part of airport car park use.

The comparison shows that the age profile of car stock differs from that of vehicles accessing the airport. Thus, a preliminary sizing of charging infrastructure cannot be carried out simply based on car fleet data, but the specific context must be considered.

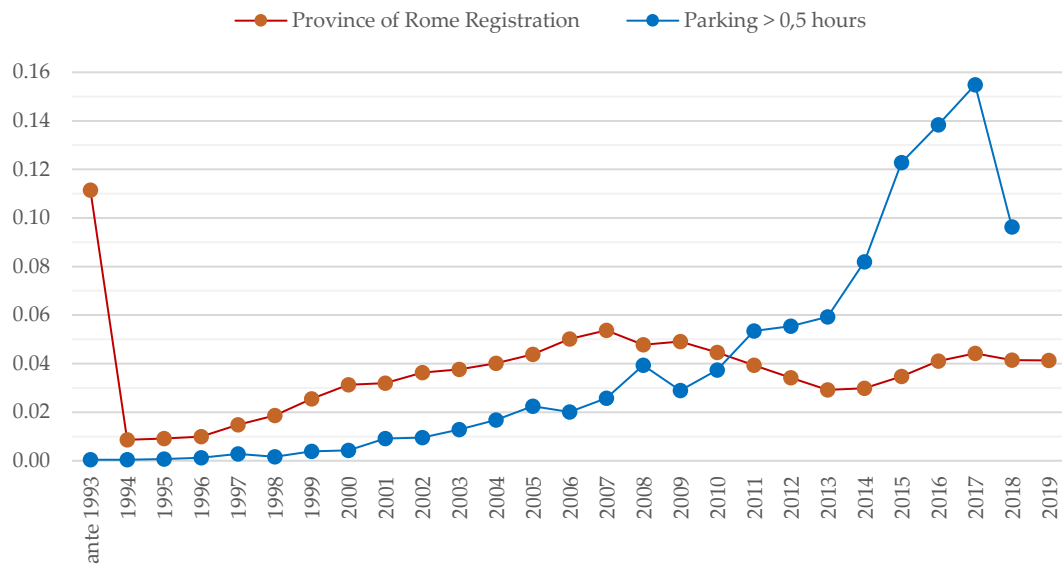**Figure 15** reports the distribution of stop durations by vehicle age.

Figure 14. Comparison of vehicle registration distribution (Rome-Fiumicino airport vs province of Rome)
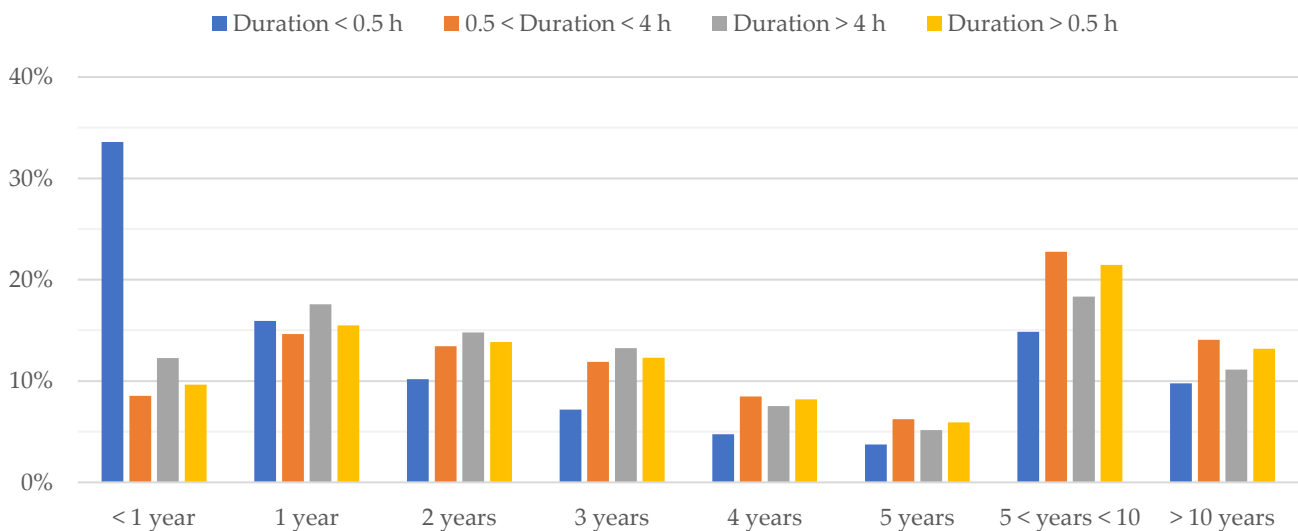

Figure 15. Distribution of stop duration by vehicle age.

The EV penetration forecast is reported for private cars (**Figure 16**), taxis and chauffeurs (**Figure 17**), and rental cars (**Figure 18**).
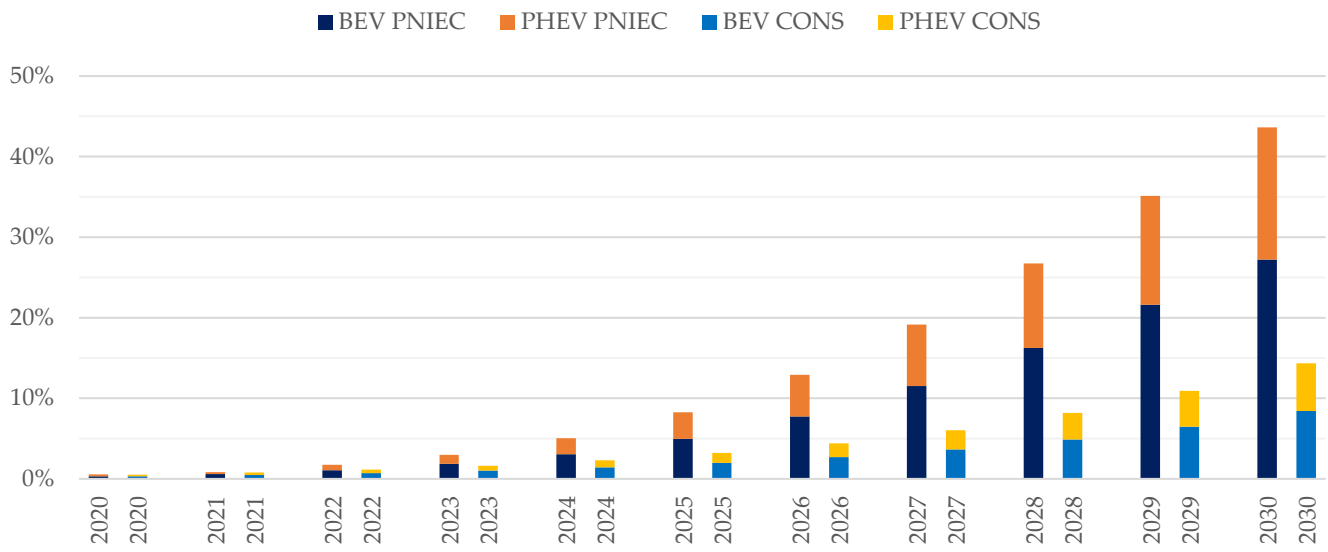
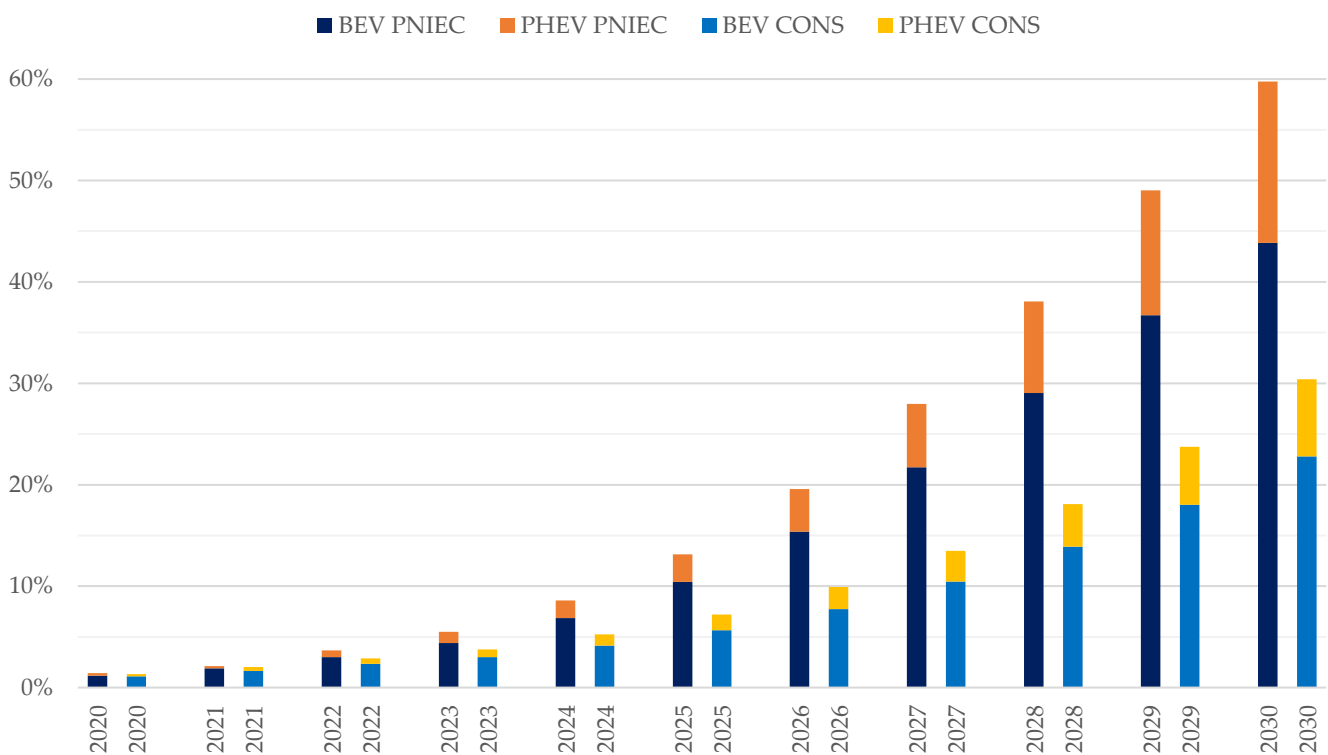**Figure 16**. EVs penetration index forecast for Rome-Fiumicino airport for private cars.

Figure 17. EVs penetration index forecast for Rome-Fiumicino airport for taxis and chauffeurs.
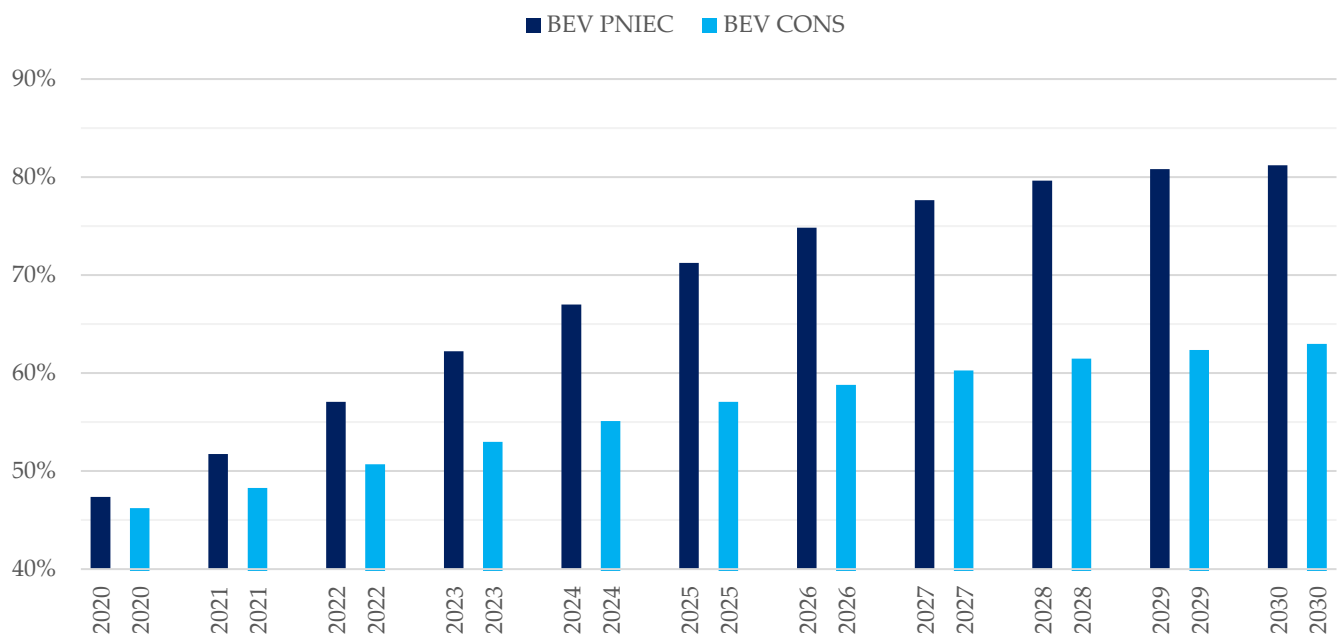
Figure 1813. EV penetration index forecast for Rome-Fiumicino airport for rental cars.

5. Preliminary sizing of charging infrastructure

The total number of charging stations can be calculated according to the following formula:

$$N_{CS} = N_{PSp} \cdot f_{EV} \cdot f_{UT\,Park} \cdot f_{UtChSt}$$

Where N_{PSp} is the total vehicle capacity of the parking area, f_{EV} is the percentage of BEV and PHEV vehicles on the total number of vehicles, $f_{UT\,Park}$ is the ratio between the recorded or estimated maximum occupancy of the parking and its total vehicle capacity (in a preliminary analysis this can be considered 1), f_{UtChSt} is the share of EVs that actually uses the charging infrastructure. Evaluating the last is more complex, since there are no data on typical EVs owner charging behavior in airport parking yet. The best approach, in this case, is to start with a conservative value of 1 and perform periodic evaluations of the parameter once the infrastructure deployment starts and real data become available. Given the predicted steep rise in the number of EVs, even a significant oversizing of the initial deployment can be easily compensated by slightly delaying the following phases of infrastructure deployment.

For passenger vehicles, it is also possible to differentiate between fast and slow charging station. The proposed method is to use the data of parking area usage by class of park duration, for this purpose, only two clusters are relevant, that of parking lasting less than two hours and that of parking lasting more. The analysis of data allows getting the share of share of total parking spot usage by duration reported in **Table 1**.

Table 1. Share of total parking spot usage by duration

Parking duration	Share of total parking spot usage*
< 2 h	2,8%
> 2 h	97,2%

*Parking spot usage is the product of the number of parking spots and their duration of usage

Combining this data with the prospected share of BEVs and PHEVs, the total share of fast charging stations can be calculated as:

$$S_{FastCharge} = BEV_\% \cdot SP_\%$$

where $BEV_\%$ is the share of BEVs, $SP_\%$ is the share of total parking spot usage by vehicles parking less than 2 hours. The main assumptions are that no PHEV uses fast charging stations and that only BEVs parking for less than 2 hours are potential users of fast charging stations (P>22kW). It is also assumed that parking spaces reserved for long stays will only have slow charging stations. The results in terms of EVs charging stations number forecasting are summarized in **Table 2**.

Table 2. EVs charging stations number forecasting

	Horizon	Parking category	Slow charging stations	Fast charging stations
Conservative Scenario	2025	Multi storey park	354	14
		Long stay park	270	0
	2030	Multi storey park	1.494	56
		Long stay park	1.137	0
PNIEC Scenario	2025	Multi storey park	645	26
		Long stay park	492	0
	2030	Multi storey park	2.939	108
		Long stay park	2.235	0

Evaluating the impact on the airport power systems and the need of upgrading the present electrical infrastructure is the subject of ongoing research.

Concerning free shuttles for passengers and employees, the present electrification plan already envisages the implementation of 10 charging stations, 88 kW each, with total power 880 kW, assuming unitary simultaneity factor.

6. Conclusions

The electrification of the automotive industry is ongoing, as a mean to reduce environmental impact of transports. Being airports major transportation hubs, operators are interested in forecasting the demand for electrical mobility associated with airport operation, to be prepared for the adaptation of the infrastructure. In this work, the authors proposes a methodology for estimating the evolution of the demand for electric mobility in an international airport (Rome-Fiumicino, Italy) in the near future and the consequent demand for charging infrastructure. First, a wide review of proposed scenarios on the penetration of EVs at international and national level and available data on local automotive transport are presented, as preliminary study for the definition of reference scenarios for the local context. Then the methodology proposed is presented and applied to the specific case study. Finally, a preliminary sizing of the required charging infrastructure is reported. The proposed approach can be considered as reference for similar studies on electrical mobility in other airport areas around the world.

Author Contributions: Conceptualization, P.C., V.C., M.C.F. and F.S.; methodology, R.A. and M.M.; validation, P.C., V.C.,, M.C.F. and F.S.; formal analysis, R.A., M.C.F., M.M. and F.S.; investigation, R.A., S.B., J.L, and M.M.; resources, R.A., M.M., P.C. and V.C.,; data curation, R.A., S.B., J.L., and M.M.; writing—original draft preparation, R.A., S.B., J.L., and M.M.; writing—review and editing, M.C.F. and F.S.; visualization, J.L.; supervision, ,P.C., V.C., M.C.F. and F.S.; project administration, P.C., V.C., M.C.F. and F.S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Uherek, E.; Halenka, T.; Borken-Kleefeld, J.; Balkanski, Y.; Berntsen, T.; Borrego, C.; Gauss, M.; Hoor, P.; Juda-Rezler, K.; Lelieveld, J., et al. Transport impacts on atmosphere and climate: Land transport. *Atmospheric Environment* **2010**, *44*, 4772-4816, doi:https://doi.org/10.1016/j.atmosenv.2010.01.002.

2. Yuan, X.; Li, X. Mapping the technology diffusion of battery electric vehicle based on patent analysis: A perspective of global innovation systems. *Energy* **2021**, *222*, 119897, doi:https://doi.org/10.1016/j.energy.2021.119897.

3. González Palencia, J.C.; Nguyen, V.T.; Araki, M.; Shiga, S. The Role of Powertrain Electrification in Achieving Deep Decarbonization in Road Freight Transport. *Energies* **2020**, *13*, doi:10.3390/en13102459.

4. González Palencia, J.C.; Araki, M.; Shiga, S. Energy consumption and CO2 emissions reduction potential of electric-drive vehicle diffusion in a road freight vehicle fleet. *Energy Procedia* **2017**, *142*, 2936-2941, doi:https://doi.org/10.1016/j.egypro.2017.12.420.

5. Wesseling, J.H.; Faber, J.; Hekkert, M.P. How competitive forces sustain electric vehicle development. *Technological Forecasting and Social Change* **2014**, *81*, 154-164, doi:https://doi.org/10.1016/j.techfore.2013.02.005.

6. Gnann, T.; Stephens, T.S.; Lin, Z.; Plötz, P.; Liu, C.; Brokate, J. What drives the market for plug-in electric vehicles? - A review of international PEV market diffusion models. *Renewable and Sustainable Energy Reviews* **2018**, *93*, 158-164, doi:https://doi.org/10.1016/j.rser.2018.03.055.

7. Kong, D.; Xia, Q.; Xue, Y.; Zhao, X. Effects of multi policies on electric vehicle diffusion under subsidy policy abolishment in China: A multi-actor perspective. *Applied Energy* **2020**, *266*, 114887, doi:https://doi.org/10.1016/j.apenergy.2020.114887.

8. Trencher, G. Strategies to accelerate the production and diffusion of fuel cell electric vehicles: Experiences from California. *Energy Reports* **2020**, *6*, 2503-2519, doi:https://doi.org/10.1016/j.egyr.2020.09.008.

9. Plötz, P.; Gnann, T.; Wietschel, M. Modelling market diffusion of electric vehicles with real world driving data—Part I: Model structure and validation. *Ecological Economics* **2014**, *107*, 411-421.

10. IEA. *Global EV Outlook 2019*; IEA: 2021.

11. Liu, X.; Bie, Z. Optimal Allocation Planning for Public EV Charging Station Considering AC and DC Integrated Chargers. *Energy Procedia* **2019**, *159*, 382-387, doi:https://doi.org/10.1016/j.egypro.2018.12.072.

12. Liu, J.-p.; Zhang, T.-x.; Zhu, J.; Ma, T.-n. Allocation optimization of electric vehicle charging station (EVCS) considering with charging satisfaction and distributed renewables integration. *Energy* **2018**, *164*, 560-574, doi:https://doi.org/10.1016/j.energy.2018.09.028.

13. Pal, A.; Bhattacharya, A.; Chakraborty, A.K. Allocation of electric vehicle charging station considering uncertainties. *Sustainable Energy, Grids and Networks* **2021**, *25*, 100422, doi:https://doi.org/10.1016/j.segan.2020.100422.

14. Ajanovic, A.; Siebenhofer, M.; Haas, R. Electric Mobility in Cities: The Case of Vienna. *Energies* **2021**, *14*, 217.

15. Ruggieri, R.; Ruggeri, M.; Vinci, G.; Poponi, S. Electric Mobility in a Smart City: European Overview. *Energies* **2021**, *14*, doi:10.3390/en14020315.

16. Sanguesa, J.A.; Torres-Sanz, V.; Garrido, P.; Martinez, F.J.; Marquez-Barja, J.M. A Review on Electric Vehicles: Technologies and Challenges. *Smart Cities* **2021**, *4*, 372-404, doi:10.3390/smartcities4010022.

17. Xiang, Y.; Cai, H.; Liu, J.; Zhang, X. Techno-economic design of energy systems for airport electrification: A hydrogen-solar-storage integrated microgrid solution. *Applied Energy* **2021**, *283*, 116374, doi:https://doi.org/10.1016/j.apenergy.2020.116374.

18. Silvester, S.; Beella, S.K.; van Timmeren, A.; Bauer, P.; Quist, J.; van Dijk, S. Exploring design scenarios for large-scale implementation of electric vehicles; the Amsterdam Airport Schiphol case. *Journal of Cleaner Production* **2013**, *48*, 211-219, doi:https://doi.org/10.1016/j.jclepro.2012.07.053.

19. Wikipedia - List of the busiest airports in Europe. Availabe online: https://en.wikipedia.org/wiki/List_of_the_busiest_airports_in_Europe (accessed on Jan 2021).

20. Assaeroporti. Statistiche Dati di Traffico Aeroportuale Italiano. Availabe online: https://assaeroporti.com/statistiche/ (accessed on Jan 2021).

21.   Italian Civil Aviation Authority. Rome-Fiumicino Master Plan. **2016**.

22.   Mosquet, X.; Dinger, A.; Xu, G.; Andersen, M.; Tominaga, K.; Zablit, H. *The Electric Car Tipping Point*; 11 Jan 2018, 2021.

23.   BloombergNef. *BNEF EVO Report 2020*; @BloombergNEF: 2021.

24.   Cambridge Econometrics. *Low-carbon cars in Europe: A socio-economic assessment*; Feb 2018.

25.   Bannon, E. *Electric surge: Carmakers' electric car plans across Europe 2019-2025*; Transport & Environment: 2021.

26.   Politecnico di Milano. *E-MOBILITY REPORT 2018 - Le opportunità e le sfide per lo sviluppo della mobilità elettrica in Italia*; Politecnico di Milano,: Sep 2018.

27.   Italian Ministry of Economic Development; Italian Ministry of the Environment and Protection of Natural Resources and the Sea; Italian Ministry of Infrastructure and Transport. Piano Nazionale Integrato per l'Energia e il Clima 2030. Italy, 2019.

28.   AdR Mobility. 2020.