energies

MDPI

*Article*

# Evaluation of the Power Generation Impact for the Mobility of Battery Electric Vehicles

**Javier Rey and Lázaro V. Cremades ***

Department of Project and Construction Engineering, Universitat Politècnica de Catalunya, 08028 Barcelona, Spain
* Correspondence: lazaro.cremades@upc.edu

**Abstract:** European institutions have decided to ban the sale of Internal Combustion Vehicles (ICEVs) in the EU from 2035. This opens a possible scenario in which, in the not-too-distant future, all vehicles circulating in Europe are likely to be Battery Electric Vehicles (BEVs). The Spanish vehicle fleet is one of the oldest and has the lowest percentage of BEVs in Europe. The aim of this study is to evaluate the hypothetical scenario in which the current mobility of ICEVs is transformed into BEVs, in the geographical area of the province of Barcelona and in Spain in general. The daily electricity consumption, the required installation capacity of wind and solar photovoltaic energies, and the potential reduction of $NO_x$ and particulate matter (PM) emissions are estimated. The daily emission reduction would be about 314 tons of $NO_x$ and 17 tons of PM in Spain. However, the estimated investment required in Spain to generate the additional electricity from renewable sources would be enormous (over EUR 25.4 billion), representing, for example, 5.5% of the total national budget in 2022.

**Keywords:** ICEVs; BEVs; mobility; electricity generation; wind energy; solar photovoltaic energy; renewable energy sources; vehicle fleet; pollutant emissions

check for updates

**Citation:** Rey, J.; Cremades, L.V. Evaluation of the Power Generation Impact for the Mobility of Battery Electric Vehicles. *Energies* **2023**, *16*, 5006. https://doi.org/en16135006

Academic Editor: Simone Barcellona

Received: 23 May 2023
Revised: 24 June 2023
Accepted: 26 June 2023
Published: 28 June 2023



## 1. Introduction

The 2015 Paris summit, COP21, ended with an agreement between all industrialized nations [1]. This agreement calls on the European Union (EU) to try to avoid a global temperature increase of more than 2 °C compared to pre-industrial levels. To achieve these goals, the European institutions have proposed to achieve climate neutrality, i.e., zero carbon dioxide ($CO_2$) emissions, so that no more greenhouse gases (GHG) are produced by human activity.

In order to contribute to these objectives, it is necessary to regulate vehicle transport. Member States have committed themselves to taking appropriate measures to achieve this objective, which is why the successive environmental permits for vehicle transport in the EU are becoming increasingly restrictive for internal combustion engine vehicles (ICEVs). However, the ultimate goal is to ban ICEVs in the medium and long term. Currently, in the absence of a final agreement with all Member States, European institutions have decided to ban the sale of internal combustion vehicles in the EU from 2035 [2]. Although this only affects the sale of new vehicles, major European cities are also restricting the circulation of ICEVs in low emission zones [3].

It is therefore foreseeable that the current vehicle fleet will be transformed at high speed in the coming years, and it is therefore important to study and analyze the following questions: Is it possible to transform the current vehicle fleet into a battery electric vehicle fleet? And if it is possible, how can the transition be made and what are the socio-economic costs?

Virtually since the popularization of the automobile at the beginning of the 20th century, all ground transportation has been powered by internal combustion engines. However, this form of mobility generates negative externalities that were not considered until the last few decades. ICEVs emit gaseous and particulate pollutants from the combustion process [4].

Successive environmental regulations have restricted the maximum value of each of the emissions or introduced a new restriction that was not foreseen in the previous regulations.

The EU has adopted and applied a series of environmental regulations, known as EURO regulations, which affect the homologation of vehicles, in an attempt to reduce the pollutant emissions of ICEVs. The EURO 6d regulation is currently in effect [5–7]. Each revision of these regulations has further restricted the maximum level of pollutant emissions and introduced new, more demanding type-approval tests based on real-world driving, such as the WLTP procedure or the Real Driving Emissions tests [5].

In order to comply with these regulations, vehicle manufacturers have developed technological improvements to meet the EURO regulations, such as particulate filters or Selective Catalytic Reduction (SCR) catalysts using AdBlue [8]. Now, with the foreseeable introduction of the next update of the EURO regulation, EURO 7 [5], European manufacturers are declaring that it will be impossible to comply with the new restrictions and make the necessary investments to adapt the existing technology while keeping it profitable, even more so when the sale of internal combustion vehicles is finally banned in the EU from 2035. It is therefore foreseeable that the introduction of electric vehicles will accelerate in the coming years.

There are several types of electric vehicle (Figure 1):

- Battery electric vehicle (BEV): They store chemical energy in a battery, which provides the electrical energy for consumption by the electric motor, which converts the electrical energy into mechanical energy. It is currently the main alternative to the conventional ICEV and is the main pillar of the new mobility. This is due to the fact that the use of the battery electric vehicles is considered to produce no polluting gases or particles, although this depends on the origin of the electrical energy and the entire life cycle of the battery electric vehicle.
- Hybrid electric vehicle (HEV): They combine an internal combustion engine with an electric motor. The internal combustion engine can operate in two ways. The combustion engine provides mechanical power directly to the transmission or to an electric generator. The generator feeds a battery, which feeds an electric motor. The electric motor provides mechanical power to the transmission. HEVs have seen significant development and uptake in recent years due to their lower fuel consumption, combined with a competitive price compared to the ICEV.
- Plug-in hybrid electric vehicle (PHEV): They are essentially HEVs that allow electricity to be supplied to the battery directly from the grid. The battery is smaller than that of a BEV. This makes it possible to provide driving modes using only the electric motor supplied by the battery, and therefore driving modes that are a priori free of polluting emissions. The main problem with PHEVs is that there is no guarantee that the user will recharge the battery and not constantly use the vehicle powered by the combustion engine, which is effectively equivalent to an ICEV.
- Fuel cell electric vehicle (FCEV): They use the electrical energy generated in a fuel cell, which uses the chemical energy stored in a pressurized tank, mainly from hydrogen. This electrical energy powers a smaller battery than in the BEV, to ultimately provide mechanical power to the drivetrain through the electric motor. FCEVs can become another alternative for zero-emission mobility and coexist with the BEV in the medium and long term. Currently, the purchase price of existing FCEVs, such as the Toyota Mirai [9] or the Hyundai NEXO [10], is high and the technology to produce green hydrogen from clean electricity is not yet developed enough to compete with ICEVs and BEVs. Finally, the refueling infrastructure is very poorly developed and free mobility with an FCEV is practically impossible [11].

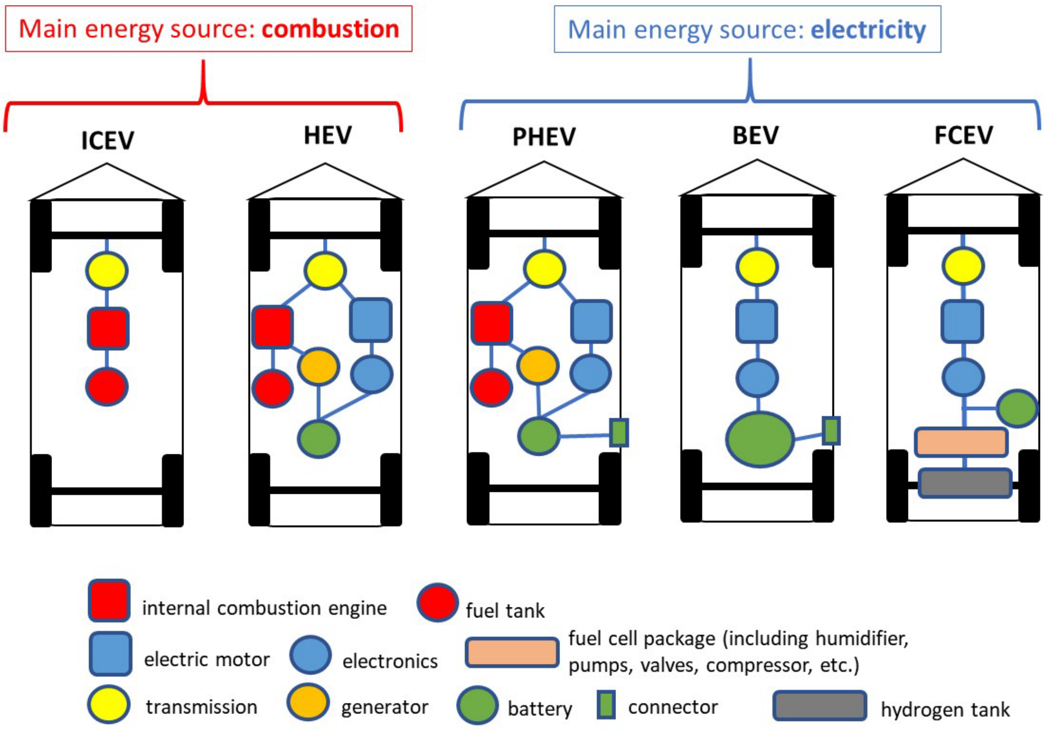


**Figure 1.** Types of vehicles (internal combustion and electric) and their main components. Modified from [12].

For the end user, the main difference between an ICEV and a BEV is the provision and storage of the energy needed to operate the vehicle. This difference is currently the main advantage of the ICEV, and therefore the main disadvantage of the BEV. In order to drive the BEV, the vehicle's battery needs to be charged. There are currently four possible modes of charging from the grid [13,14]:

- Mode 1. The vehicle is directly connected to the conventional grid without the need for any additional special equipment or systems. This mode is very practical for small vehicles such as bicycles or mopeds, but is not recommended for commercial vehicles.
- Mode 2. This mode provides a slow charge. This type of charging is single-phase with a voltage of 230 V and a maximum power of 3.7 kW. The BEV is connected to the mains via the appropriate plug/adapter to ensure the safety of the charging process.
- Mode 3. This mode provides semi-fast charging. The electric vehicle is connected to the alternating current grid via a dedicated BEV charging outlet. The most commonly used plug for this type of charging is Type 2 [15]. This mode allows single-phase or three-phase charging. Single-phase connections charge at 7.4 kW and three-phase connections charge at 22 kW.
- Mode 4. Its charging power is equal to or greater than 50 kW, allowing "super fast" and "ultra fast" charging. The latter is not recommended for daily charging, as it can damage the battery if used regularly. It is specifically designed for outdoor public use stations and could be similar to a gas station, where the vehicle can be recharged during long trips or in specific situations where passengers are short of time.

Mode 4 charging uses direct current (DC), as opposed to the previous modes that use alternating current (AC). The most commonly used plug for this type of charging is currently the CCS Combo, which combines a Type 2 plug with two extra terminals to allow DC power to pass through [15].

The main objective of this paper is to study the feasibility of transforming the current mobility of the vehicle fleet in Spain based on the use of fossil fuels (gasoline and diesel) in internal combustion engines (ICEVs) to a mobility based on the use of electricity from renewable sources for battery electric vehicles (BEVs). This feasibility is analyzed from a techno-economic and environmental point of view.

There are several papers in the literature that have examined the impact on the reduction of GHG and/or non-GHG emissions by substituting ICEVs with BEVs in specific regions, such as [16,17]. There are also those that performed life cycle analyses comparing ICEVs with BEVs, such as [18–20]. But none of them explored the feasibility of transforming the actual mobility of ICEVs into BEVs and its impact on electricity generation in Spain, as presented in this paper.

## 2. Method

In order to study the feasibility of this change, an in-depth analysis of daily mobility at different geographical levels and of the type of vehicle used for each trip was carried out, making it possible to estimate the amount of additional electrical energy that would need to be generated to make a fleet of vehicles made up entirely of BEVs feasible. However, to achieve a true environmental transition in vehicle transportation, the electricity needed to power a fleet of BEVs must come from renewable sources. This would require the installation of new solar and wind power plants, which would need to be located and installed somewhere in the territory, along the associated transportation network.

The following steps were taken to conduct the study (Figure 2):

(1) Collect available information on charging stations, vehicle fleet, actual mobility, certified electricity consumption of BEVs, electricity generation, and pollutant emissions of ICEVs according to vehicle age.
(2) Estimate the daily electricity consumption that would be required for the mobility of the vehicles if they were all BEVs.
(3) Determine the hourly availability for charging these vehicles based on the daily mobility data and energy source. Since photovoltaic (PV) solar energy can only be generated during daylight hours, the percentage of daily use of this source can be defined. The rest of the energy is assumed to come from wind.
(4) Estimate the required installation capacity of wind turbines and PV panels to provide the energy needed to charge the BEVs. Also estimate the investment required.
(5) Estimate the reduction in pollutant emissions from replacing ICEVs with BEVs.

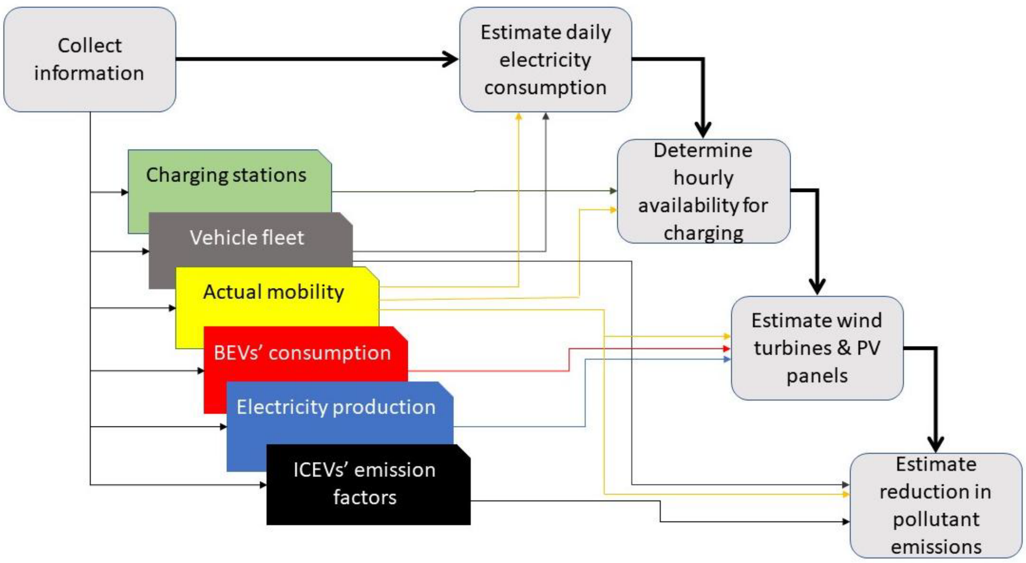


**Figure 2.** Schematic of the methodological steps followed in this study.

The fleet information was used to estimate the emission reduction of the ICEVs that would be replaced by BEVs, based on their age. However, the number of ICEVs to be replaced by BEVs was determined by the actual mobility. Vehicle mobility trips are assumed to correspond to the proportion of such vehicles in the fleet, both in terms of category and age.

The study, analysis and proposal to be carried out in this work mainly focused on the province of Barcelona (PB) (Spain), as there is a survey of actual mobility that is regularly carried out for this region [21]. However, the composition and age of the vehicle fleet have been obtained from data for Spain as a whole.

The results obtained for PB can be extrapolated to the whole of Spain, assuming that the mobility pattern is similar.

The PB covers mobility that takes place in the region bordering the city of Barcelona. At the end of 2022, the PB had a population of 5,727,615 inhabitants [22] in an area of 7726 km$^2$, which corresponds to a population density of 741.2 inhabitants/km$^2$, of which 1,636,193 inhabitants correspond to the city of Barcelona, with a population density of 15,992.2 inhabitants/km$^2$, which acts as a dynamic center of socio-economic activity.

In this paper, clean electrical energy is defined as energy produced by renewable energy sources. Renewable energy is defined as energy that is consumed more slowly than it is produced. Therefore, in this study, only energy from solar and wind sources is considered to be clean electricity.

Available data from actual wind and PV solar farms in Spain were extrapolated to estimate the area and investment costs required to meet the estimated energy demand.

The optimal use of a BEV implies a usage model with recharging at a dedicated charging point and at a recharging rate that does not imply a sudden degradation of the battery system. For this reason, in the hypothetical case study of a ground transport BEV, it was assumed that the vehicle would not be charged in the usual way at a fast charging station.

## 3. Basic Data

### 3.1. Charging Points

In order to increase the use of BEVs, it is necessary to develop a network of charging stations with public access, in addition to the private charging points that each user can install at home.

Currently, the two most powerful public charging stations in Spain are located in the Basque Country and have been installed by Repsol [23]. The fact that a fuel company is installing charging stations shows a clear commitment to electrification. These four-terminal installations have a capacity of 400 kW, which corresponds to a charging time of between 5 and 10 min, similar to the refueling time of an ICEV.

However, according to the Spanish Association of Automobile and Truck Manufacturers (ANFAC) [24], the public access charging network in Spain is growing very slowly and is poorly distributed throughout the country. At the beginning of 2021, there were 11,517 public access charging points in Spain, 83% of which had power of less than 22 kW, which does not allow fast charging. While in the EU as a whole the average number of charging points per million inhabitants is 573, in Spain it is only 245. This is in line with the current low presence of BEVs in Spain.

### 3.2. Vehicle Fleet Composition

From the studies and statistics published by the *Dirección General de Tráfico* (DGT in Spanish) [25], it is possible to know the composition of the current vehicle fleet in each of the Spanish municipalities and, therefore, in the country as a whole.

On 31 December 2022, the total number of main categories of motor vehicles in Spain was 34,304,426, divided as follows:

- Passenger cars: 25,222,554 (73.5%);
- Motorcycles: 4,006,804 (11.7%);
- Vans: 2,617,145 (7.6%);
- Trucks: 2,457,923 (7.2%).

The DGT statistics also allowed us to classify each vehicle type according to its age, from 2022 backwards (Table 1), which allowed us to know its pollution potential according to the existing environmental approval in place at the time of its registration.

**Table 1.** Age of the Spanish vehicle fleet by vehicle type in 2022 [26].

| Vehicle | Age | Gasoline | % [1] | Diesel | % [1] | Others | % [1] | Total | % [2] |
|---|---|---|---|---|---|---|---|---|---|
| Passenger cars | <5 years | 3,242,568 | 62.7 | 1,739,699 | 33.6 | 190,474 | 3.7 | 5,172,741 | *20.5* |
| | 5–9 years | 1,813,269 | 38.6 | 2,859,712 | 60.8 | 26,896 | 0.6 | 4,699,877 | *18.6* |
| | 10–14 years | 1,150,761 | 29.1 | 2,802,644 | 70.8 | 3542 | 0.1 | 3,956,947 | *15.7* |
| | 15–19 years | 1,854,694 | 32.0 | 3,944,656 | 68.0 | 2511 | 0.0 | 5,801,861 | *23.0* |
| | >19 years | 3,689,507 | 66.0 | 1,899,161 | 34.0 | 2460 | 0.0 | 5,591,128 | *22.2* |
| Motorcycles | <5 years | 817,978 | 95.9 | 1398 | 0.2 | 33,988 | 4.0 | 853,364 | *21.3* |
| | 5–9 years | 612,144 | 99.0 | 1853 | 0.3 | 4625 | 0.7 | 618,622 | *15.4* |
| | 10–14 years | 644,651 | 99.5 | 922 | 0.1 | 2478 | 0.4 | 648,051 | *16.2* |
| | 15–19 years | 810,876 | 99.8 | 1186 | 0.1 | 118 | 0.0 | 812,180 | *20.3* |
| | >19 years | 1,073,538 | 99.9 | 645 | 0.1 | 404 | 0.0 | 1,074,587 | *26.8* |
| Vans | <5 years | 49,376 | 9.2 | 470,241 | 87.1 | 19,986 | 3.7 | 539,603 | *20.6* |
| | 5–9 years | 13,425 | 3.4 | 373,018 | 95.4 | 4400 | 1.1 | 390,843 | *14.9* |
| | 10–14 years | 13,616 | 5.2 | 249,505 | 94.5 | 795 | 0.3 | 263,916 | *10.1* |
| | 15–19 years | 36,964 | 7.9 | 430,543 | 91.9 | 778 | 0.2 | 468,285 | *17.9* |
| | >19 years | 302,203 | 31.7 | 651,928 | 68.3 | 367 | 0.0 | 954,498 | *36.5* |
| Trucks | <5 years | 11,108 | 3.7 | 275,904 | 92.8 | 10,405 | 3.5 | 297,417 | *12.1* |
| | 5–9 years | 5511 | 2.1 | 252,210 | 97.1 | 2106 | 0.8 | 259,827 | *10.6* |
| | 10–14 years | 3995 | 1.3 | 293,101 | 98.2 | 1331 | 0.4 | 298,427 | *12.1* |
| | 15–19 years | 18,085 | 2.3 | 777,168 | 97.7 | 402 | 0.1 | 795,655 | *32.4* |
| | >19 years | 38,597 | 4.8 | 767,888 | 95.2 | 112 | 0.0 | 806,597 | *32.8* |
| Total | | 16,202,866 | 47.2 | 17,793,382 | 51.9 | 308,178 | 0.9 | 34,304,426 | |

[1] Percentage of each fuel type in its age group; [2] percentage contribution of each age for the type of vehicle

Table 1 shows how the share of diesel passenger cars has fallen significantly in recent years, from 60 to 70% of the fleet to just 34% for cars less than 5 years old. This is largely due to the reputational crisis suffered by the diesel engine as a result of the so-called "dieselgate" in September 2015. It should also be noted that the sales of alternative vehicles ("Others" column in Table 1) compared to conventional vehicles have started to increase in recent years, but still represent a very small number. Furthermore, the age of the fleet is remarkable, as the number of vehicles 10 years old or more accounts for more than 60% in all categories.

Within PB, the total fleet of main vehicles in 2022 was 3,560,977, as follows [25]:

- Passenger cars: 2,417,620 (67.9%);
- Motorcycles: 696,678 (19.6%);
- Vans: 241,125 (6.8%);
- Trucks: 205,554 (5.8%).

Age and energy type distribution can be assumed to be similar to that of the Spanish fleet.

### *3.3. Mobility in the Barcelona Province*

According to the latest published survey on mobility in the Barcelona metropolitan area in 2021, there were 16,909,491 trips per working day in PB, which corresponds to an average of 3.5 trips per inhabitant per day [21,27]. These trips were made on foot (46.5%) or by bicycle/scooter (2.5%), public transport (14%), or private transport (37%), the latter including cars (86%), motorcycles (10.6%), and vans/trucks (3.4%). The total number of trips in 2021 was lower than it was in 2019 (19,259,471), in the pre-pandemic COVID-19 situation, but the distribution of trips by mode was similar [21].

On the other hand, the average distance of each trip by private vehicle in PB was as follows [27]: 8.9 km by car; 5.8 km by motorcycle, and 15.2 km by van/truck.

Multiplying each trip by the average distance per trip gives the total distance traveled per working day by each type of vehicle (Table 2).

**Table 2.** Total daily distance traveled by type of vehicle in Barcelona province.

| Private Transport | Trips | km/Trip | Distance (km) |
|---|---|---|---|
| Car | 5,370,628 | 8.9 | 47,798,589 |
| Motorcycle | 664,715 | 5.8 | 3,855,347 |
| Van/Truck | 214,745 | 15.2 | 3,264,124 |
| Total | 6,250,088 | | 54,918,060 |

The total distance traveled by private vehicles was 54,918,060 km, which corresponds to a total of 9.6 km traveled per inhabitant per working day in a private vehicle.

Figure 3 shows the hourly distribution of private transport mobility during a weekday in PB. It follows a pattern of occupational mobility (work and/or study), as the largest number of trips was concentrated between 7 and 9 a.m. and 5 and 7 p.m., coinciding with the departure and return home.

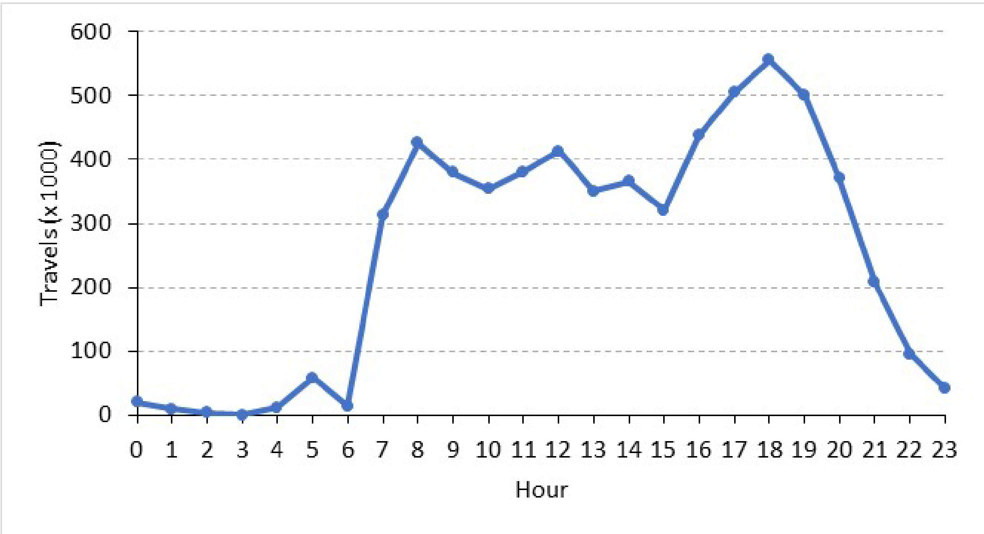


**Figure 3.** Private transportation trips in PB during the course of a workday. Based on [27].

### *3.4. Electric Vehicle Power Consumption*

In order to know the energy consumption of a fleet made up entirely of electric vehicles, the homologated consumption of models representative of the type of transport can be used as a basis for calculation. From the lowest to the highest electric energy consumption per kilometre traveled, the following models were selected:

- Motorcycles: Silence S01 [28]. This electric motorcycle is the number 1 seller on the Spanish market, with sales of 1433 units in 2022. It has a range of 133 km with a battery of 5.6 kWh of stored energy, giving an energy consumption per 100 km of 4.2 kWh/100 km.
- Passenger cars: Tesla Model 3 [29]. This car is the number 1 in the Spanish electric vehicle market, with sales of 2677 units in 2022. It has an approved energy consumption of 16.2 kWh/100 km.
- Vans: Peugeot Expert [30]. It is a mid-size van and therefore covers the entire range of this type of vehicle. In 2022, 722 units were sold on the Spanish market. It has an energy consumption of 20.5 kWh/100 km, slightly higher than that of a car.
- Trucks: DAF LF Electric [31]. The disadvantage of the battery electric vehicle market for trucks is the significant energy consumption required to move such a large

and heavy vehicle. Therefore, to achieve a homologated range of 280 km, a battery with 254 kWh of stored energy is required, resulting in an energy consumption of 110.2 kWh/100 km, more than five times higher than that of the reference van.

To disaggregate the van and truck mobility data in Table 2, we have assumed that 55% are vans and 45% are trucks. This proportion is about the same proportion as their share in the PB fleet (see Section 3.2).

### 3.5. Electric Power Generation

In 2022, a total of 276,316 GWh of electricity was produced in Spain, corresponding to an average daily production of 757 GWh [32]. Up to 44% of this energy came from renewable sources, i.e., around 330 GWh per day, mainly from wind, photovoltaics, and hydropower (Table 3).

**Table 3.** Electricity production by technology in Spain by 2022 [32].

| Generation Type | Source Category | Energy Generated (GWh) | % |
|---|---|---|---|
| Combined cycle | Pollutant | 60,652 | 24.66 |
| Wind | Renewable | 59,805 | 22.14 |
| Nuclear | No emissions * | 55,984 | 20.26 |
| Photovoltaic | Renewable | 27,283 | 10.08 |
| Hydropower | Renewable | 17,860 | 6.46 |
| Co-generation | Pollutant | 17,732 | 6.43 |
| Coal | Pollutant | 7687 | 2.81 |
| Other renewable sources | Renewable | 4646 | 1.69 |
| Solar thermal | Renewable | 4123 | 1.49 |
| Turbine pumping | Renewable | 3776 | 1.37 |
| Diesel engines | Pollutant | 2548 | 0.92 |
| Non-renewable wastes | Pollutant | 1761 | 0.69 |
| Steam turbine | Pollutant | 1207 | 0.44 |
| Renewable wastes | Renewable | 739 | 0.32 |
| Gas turbine | Pollutant | 657 | 0.24 |
| Hydro-wind | Renewable | 23 | 0.01 |
| TOTAL | | 276,316 | 100.00 |

* but radioactive wastes

### 3.6. Pollutant Emission Factors for ICEVs

To estimate the emissions of ICEVs, we used the European Environment Agency emission factors for road transport according to the Tier 2 methodology, which take into account the technology or legislation (age) of the vehicle [33]. We only considered the emissions of nitrogen oxides ($NO_x$) and particulate matter (PM). Table 4 shows the emission factors expressed in grams of pollutant emitted per kilometer driven, used in this study for both gasoline and diesel vehicles. The passenger car factors corresponded to mid-size passenger cars. The truck factors corresponded to trucks between 7.5 and 16 tons. And the motorcycle factors corresponded to four-stroke motorcycles between 250 and 750 $cm^3$.

In the absence of factors, the same values are assumed for gasoline trucks as for vans. Similarly, the PM factors for diesel motorcycles are assumed to be the same as for cars.

**Table 4.** $NO_x$ and PM emission factors (in g/km) for ICEVs (European gasoline and diesel vehicles) taken from [33]. Values in italics are estimates used in this study.

| Technology/Regulation | Passenger Cars | | Vans | | Trucks | | Motorcycles | |
|---|---|---|---|---|---|---|---|---|
| | $NO_x$ [a] | PM [b] | $NO_x$ [a] | PM [b] | $NO_x$ [a] | PM [b] | $NO_x$ [a] | PM [b,c] |
| **Gasoline** | | | | | | | | |
| ECE (until 1977) | 2.53 | 0.0022 | *3.09* | 0.0023 | *3.09* | *0.0023* | *0.233* | *0.2* |
| ECE (1978–1980) | 2.40 | 0.0022 | *3.09* | 0.0023 | *3.09* | *0.0023* | *0.233* | *0.2* |
| ECE (1981–1985) | 2.51 | 0.0022 | *3.09* | 0.0023 | *3.09* | *0.0023* | *0.233* | *0.2* |
| ECE (1985–1992) | 2.66 | 0.0022 | 3.09 | 0.0023 | *3.09* | *0.0023* | *0.233* | *0.2* |
| Euro 1 (1992–1996) | 0.485 | 0.0022 | 0.563 | 0.0023 | *0.563* | *0.0023* | 0.233 | 0.2 |
| Euro 2 (1996–2000) | 0.255 | 0.0022 | 0.23 | 0.0023 | *0.23* | *0.0023* | 0.477 | 0.08 |
| Euro 3 (2000–2005) | 0.097 | 0.0011 | 0.129 | 0.0011 | *0.129* | *0.0011* | 0.317 | 0.04 |
| Euro 4 (2005–2010) | 0.061 | 0.0011 | 0.064 | 0.0011 | *0.064* | *0.0011* | 0.194 | 0.04 |
| Euro 5 (2010–2016) | 0.061 | 0.0014 | 0.064 | 0.0014 | *0.064* | *0.0014* | 0.194 | 0.01 |
| Euro 6 until 2016 | 0.061 | 0.0014 | 0.064 | 0.0012 | *0.064* | *0.0012* | *0.194* | *0.01* |
| Euro 6 2017–2019 | 0.061 | 0.0016 | 0.064 | 0.0012 | *0.064* | *0.0012* | *0.194* | *0.01* |
| Euro 6 2020+ | 0.061 | 0.0016 | 0.064 | 0.0012 | *0.064* | *0.0012* | *0.194* | *0.01* |
| **Diesel** | | | | | | | | |
| Conventional (until 1992) | 0.546 | 0.2209 | 0.87 | 0.356 | 8.92 | 0.3344 | *0.546* | *0.2209* |
| Euro 1 (1992–1996) | 0.690 | 0.0842 | 0.69 | 0.117 | 5.31 | 0.201 | *0.690* | *0.0842* |
| Euro 2 (1996–2000) | 0.716 | 0.0548 | 0.716 | 0.117 | 5.5 | 0.104 | *0.716* | *0.0548* |
| Euro 3 (2000–2005) | 0.773 | 0.0391 | 0.77 | 0.0783 | 4.3 | 0.0881 | *0.773* | *0.0391* |
| Euro 4 (2005–2010) | 0.58 | 0.0314 | 0.58 | 0.0409 | 2.65 | 0.0161 | *0.58* | *0.0314* |
| Euro 5 (2010–2016) | 0.55 | 0.0021 | 0.55 | 0.001 | 1.51 | 0.0161 | *0.55* | *0.0021* |
| Euro 6 until 2016 | 0.45 | 0.0015 | 0.45 | 0.0009 | 0.291 | 0.0008 | *0.45* | *0.0015* |
| Euro 6 2017–2019 | 0.35 | 0.0015 | 0.35 | 0.0009 | 0.291 | 0.0008 | *0.35* | *0.0015* |
| Euro 6 2020+ | 0.17 | 0.0015 | 0.17 | 0.0009 | 0.291 | 0.0008 | *0.17* | *0.0015* |

ECE = Economic Commission for Europe; [a] $NO_x$ = nitrogen oxides, expressed as $NO_2$; [b] PM = particulate matter, expressed as $PM_{2.5}$; [c] values for quadbikes.

## 4. Results

The total energy needed to cover the mobility in PB with a fleet composed exclusively of BEVs can be estimated by multiplying the homologated power consumption of each vehicle type selected in Section 3.4 by the total distance traveled by each vehicle in PB. The results are shown in Table 5.

**Table 5.** Daily energy consumption estimated for a fleet of BEVs in Barcelona province.

| Private Transport | Distance (km) | Power Consumption (kWh/100 km) | Total Daily Consumption (kWh) |
|---|---|---|---|
| Cars | 47,798,589 | 16.2 | 7,743,371 |
| Motorcycles | 3,855,347 | 4.2 | 162,310 |
| Vans | 1,795,268 | 20.5 | 368,030 |
| Trucks | 1,468,856 | 110.2 | 1,619,267 |
| TOTAL | 54,918,060 | | 9,892,978 |

In summary, the daily electrical energy required to switch from fossil-fuel-based ground transportation to clean electric transportation would be about 10 GWh. This amount would require a 3% increase in clean electricity generation. This increase seems more than affordable for Spain as a whole, with the exception of hydropower.

Traditionally, hydropower has been very important in electricity generation. The main problem with this energy source is that due to the drought situation in 2022, the total production of hydroelectricity in Spain has decreased by 39.7% compared to 2021. The foreseeable increase in droughts and the abandonment of the construction of hydroelectric dams in Spain means that an increase in hydroelectric capacity has not been considered.

Therefore, it seems reasonable to consider an increase in electricity generation capacity with only wind and PV solar energies.

Unlike nuclear power and combined cycle power plants, wind and solar energies cannot be controlled by existing human technology, but depend on the weather. This fact means that the installation of new electricity generation mechanisms must take into account: (1) the hourly schedules for charging BEVs, and (2) the hourly production of electricity for each technology.

The main characteristic of the BEV is the slowness of recharging the vehicle compared to refueling an ICEV. Since the BEV needs to be parked for a relatively long time to recharge, we propose relating the period of electricity generation needed to recharge the BEV fleet inversely proportionally to the mobility schedule in PB (Figure 3). That is, we assume that the fewer trips are made in PB, the more likely it is that the BEV will be recharging batteries in the standard recharge mode. With this assumption, the distribution of electric power throughout the day would be as shown in Figure 4. Therefore, most of the additional electricity generation to charge the batteries of the BEVs that would replace the current fleet would have to be generated at night.

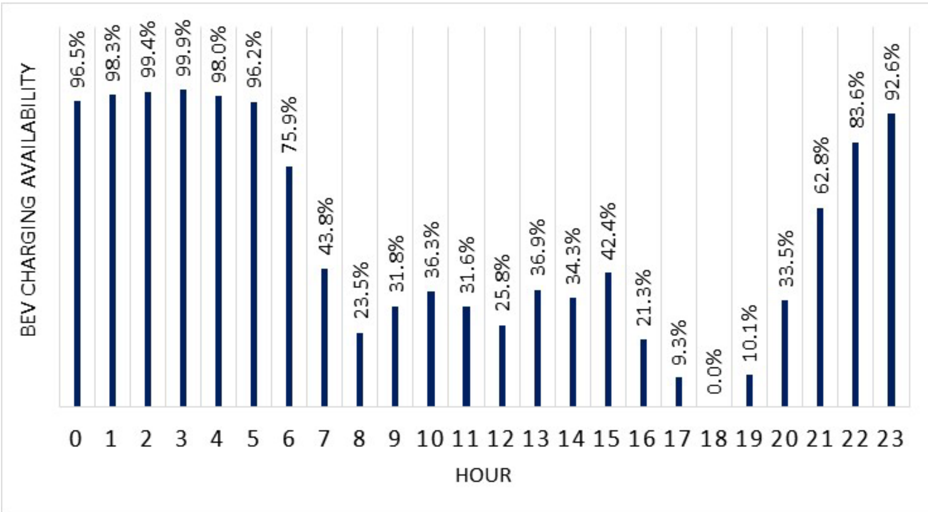


**Figure 4.** Estimated availability of electric power to recharge a BEV in PB.

A proposal to increase wind and PV solar power generation capacity is presented below.

### *4.1. PV Solar Energy*

Solar energy reaches its daily production peak in Barcelona between 10 a.m. and 5 p.m. [34]. In winter, approximately 90% of the total energy is produced in this hourly window. However, this is also the season with the lowest total production. In summer, about 70% is produced in this time window [34]. Therefore, it is estimated that 75% of the total energy production on an annual average is in this time window.

From Figure 4, it can be deduced that there would be an average of 29.7% charge availability in this period. To achieve this charging scenario, it is necessary to find a compromise between the recommendation of charging the BEV with non-fast charging and the availability of using PV solar energy. Therefore, in order to maximize the possibilities of producing 100% of the electrical energy from clean sources, it seems reasonable to consider that 30% of this energy can come from PV solar power.

The installed PV capacity in Spain in 2022 was 19,348 MW [35]. Therefore, its load factor $L$ can be calculated as follows:

$$L = \frac{E}{P \cdot t} \quad (1)$$

where $E$ is the total annual energy generated by photovoltaic source, i.e., 27,283 GWh (see Table 3); $P$ is the installed PV capacity, and $t$ is the number of hours per year available for

PV generation, i.e., 2557 h. Applying Equation (1) with these values gives a load factor of 55.1%.

Then, the additional PV power, $P_A$, to be installed for only BEV charging in PB during the period between 10 a.m. and 5 p.m., i.e., 7 h, can be estimated as follows:

$$P_A = \frac{f \cdot E_C}{L \cdot t_c} \tag{2}$$

where $f$ is the fraction of energy from PV solar power, i.e., 0.3; $E_C$ is the total daily consumption of energy, i.e., 9893 MWh (see Table 5); and $t_c$ is the number of charging hours, i.e., 7 h. Applying Equation (2) with these values gives $P_A$ = 770 MW.

As a reference, there are currently 196 PV park projects in Catalonia, with the construction of PV modules planned to occupy 4977 hectares (ha), with a total PV solar power of 2888 MW [36]. This corresponds to an average power of 0.58 MW/ha. Applying the same ratio to the additional power of 770 MW, at least 1327 ha of land would need to be covered with solar panels.

As a reference for estimating the investment required to install this amount of electricity, we have extrapolated the budget of the Ancar II PV solar farm [37]. This farm, located in the province of Teruel, has a nominal capacity of 41.58 MW, generated by 116,032 PV generation modules covering an area of 106.53 ha. The budget for the Ancar II PV solar park is EUR 21.2 M, of which the cost of the solar panels represents 62% [37]. Assuming the same cost per hectare, an investment of around EUR 265 M would be required to install 1327 ha.

If we extrapolate these calculations to the whole of Spain, assuming that the mobility of private transport in Spain as a whole follows a behavior similar to that of PB, as shown in Figure 3, it would be necessary to occupy an area of approximately 14,000 ha with an investment of around EUR 2800 M.

### *4.2. Wind Energy*

The remaining 70% of the electrical energy to be produced would come from wind.

The installed capacity of wind energy in Spain in 2022 was 29,417 MW [35]. When we applied Equation (1) to the data for wind power (i.e., $E$ = 59,805 GWh, $P$ = 29,417 MW, $t$ = 8766 h), the load factor of the entire wind power generation grid was only 23.2%.

As shown in Figure 4, there is virtually 100% hourly availability for BEV charging between 0 and 6 a.m. Therefore, the additional wind power to be installed for only BEV charging in PB can be estimated by applying Equation (2) with $f$ = 0.7, $E_C$ = 9893 MWh, $L$ = 0.232, and $t_c$ = 6 h. The result is $P_A$ = 4976 MW, or about 5 GW.

There are currently 45 wind farm projects in Catalonia (region in the northeast of Spain where PB is located), with 207 wind turbines in the pipeline, representing a total capacity of 1184 MW [36]. This corresponds to an average capacity of 5.72 MW per wind turbine. Applying the same ratio to the additional 5 GW of wind power, at least 870 turbines would need to be installed.

To estimate the budget of this proposal, we can extrapolate the actual budgets of existing wind farms. For example, the budget of the Cabigordo wind farm in the province of Teruel (Spain) is EUR 32.6 M, of which the main budget item is the purchase and installation of the wind turbines, which amounts to EUR 22 M [38]. This wind farm consists of nine wind turbines with a total capacity of 50 MW. Considering a similar cost for the wind turbines, the total cost of just installing the 870 wind turbines, without considering all the other costs of the project, would be approximately EUR 2127 M.

At the country level, assuming the same mobility pattern as in PB, it is estimated that approximately 9240 turbines would need to be installed at a cost of around EUR 22,600 M.

### *4.3. Reduction of Pollutant Emissions*

Table 6 shows the estimated $NO_x$ and PM emissions in kg/day that would be avoided if the ICEVs currently circulating in PB were replaced by BEVs. For this purpose, it was assumed that the mobility envisaged in Figure 3 is composed of ICEVs of the four categories analyzed (cars, motorcycles, vans, and trucks) and grouped in five age periods (up to 1993, 1994–2008, 2009–2013, 2014–2018, and 2019–2022) in the proportions that exist in the current Spanish fleet (see Table 1). The emission factors in Table 4 have been applied to each category by averaging the factors for the specified periods. These factors are multiplied by the daily distance traveled by each category of ICEV, as shown in Table 5.

**Table 6.** Estimated pollutant emissions from ICEVs in PB (kg/day).

| Vehicle | Age | Period | Gasoline | | Diesel | |
|---|---|---|---|---|---|---|
| | | | $NO_x$ | PM | $NO_x$ | PM |
| Passenger cars | <5 years | 2019–2022 | 375 | 10 | 1045 | 9 |
| | 5–9 years | 2014–2018 | 210 | 5 | 1546 | 6 |
| | 10–14 years | 2009–2013 | 133 | 3 | 1232 | 37 |
| | 15–19 years | 1994–2008 | 789 | 6 | 2424 | 184 |
| | >19 years | up to 1993 | 15,283 | 15 | 4321 | 1067 |
| Motorcycles | <5 years | 2019–2022 | 153 | 2 | 134 | 1 |
| | 5–9 years | 2014–2018 | 114 | 1 | 265 | 1 |
| | 10–14 years | 2009–2013 | 120 | 4 | 350 | 10 |
| | 15–19 years | 1994–2008 | 231 | 33 | 538 | 41 |
| | >19 years | up to 1993 | 283 | 186 | 638 | 158 |
| Vans | <5 years | 2019–2022 | 2 | 0 | 6 | 0 |
| | 5–9 years | 2014–2018 | 1 | 0 | 4 | 0 |
| | 10–14 years | 2009–2013 | 1 | 0 | 5 | 0 |
| | 15–19 years | 1994–2008 | 6 | 0 | 17 | 2 |
| | >19 years | up to 1993 | 553 | 0 | 162 | 49 |
| Trucks | <5 years | 2019–2022 | 0 | 0 | 2 | 0 |
| | 5–9 years | 2014–2018 | 0 | 0 | 2 | 0 |
| | 10–14 years | 2009–2013 | 7 | 0 | 5 | 0 |
| | 15–19 years | 1994–2008 | 3 | 0 | 48 | 1 |
| | >19 years | up to 1993 | 62 | 0 | 164 | 6 |
| Total | | | 18,325 | 265 | 12,910 | 1572 |

According to these calculations, more than 31 tons of $NO_x$ and almost two tons of PM would be avoided daily.

Assuming that the mobility pattern throughout Spain is similar to that of PB, it can be estimated that the daily emission reduction would be about 314 tons of $NO_x$ and 17 tons of PM in Spain.

## 5. Discussion

The methodology used could be applied to other regions or countries where the vehicle fleet is mainly composed of ICEVs and for which disaggregated mobility information is available.

To understand the scale of the challenge of installing the required wind power capacity, we can compare it with the current situation of existing wind farms. The total number of wind turbines currently operating in Catalonia is 846 [36]. These turbines are mainly located in four areas where the wind tends to blow with greater intensity and frequency. As a result, project proposals in Catalonia are concentrated in these areas [39]. However, this may foreshadow a land use problem, as the best sites are limited. For this reason, there is a first wind farm project, called Tramuntana Park, directly in the sea, on the coast of the Gulf of Roses, which foresees an initial installation of 35 wind turbines [40]. This would make it possible to take advantage of the high wind speeds in this area, although it is expected to have a negative impact on the ecosystem.

In terms of the estimated demand for solar energy, the 1327 ha of land required is equivalent to 1858 soccer fields, or 13.1% of the surface area of the city of Barcelona. The requirements to meet this demand appear to be lower than those for wind energy because, on the one hand, the surface area to be installed is relatively small, since only 30% of the electrical energy would be covered by PV solar energy, and, on the other hand, there are not as many restrictions on the location of the solar panels.

In the case of wind energy, the occupied area would be much smaller. For example, the total area occupied by nine wind turbines and foundations at the Cabigordo wind farm site is 65,413 $m^2$ [38]. We can then estimate that 870 turbines would occupy an area of about 63 ha. The impact on the land would therefore be small compared to that of a PV solar installation with a similarly rated output. However, the environmental impact generated by wind turbines is not harmless, as it mainly affects birds [41].

The cost per unit of installed power is lower for PV solar farms (EUR 0.34 M/MW) than for wind farms (EUR 0.43 M/MW). The main issue in achieving an effective use of clean energy for a BEV fleet is the need to ensure the production of clean energy at night. For this reason, it is essential to prioritize electrical energy produced by wind power, as it is not possible to produce electrical energy from PV solar sources during the night.

In addition to this investment in electricity generation, there is the cost of the infrastructure required to distribute and install the charging points. This cost is very variable because it depends on many factors, such as the price of the chosen charging point, the charging power, the distance to the meter or electrical panel, and the location of the charging point, as well as the auxiliary work that needs to be carried out to supply the charging point. However, as a guideline, the cost of installing one charging point can range from one to several thousand euros [42].

In terms of environmental benefits, the significant reduction in pollutant emissions that would be achieved during vehicle operation is noteworthy. The estimated values are relatively higher than those published in other studies, such as the one carried out for the urban areas of Berlin and Stuttgart [17]. This is probably due to the high age of the Spanish vehicle fleet, which is one of the oldest in Europe, with an average age of more than 13.5 years, compared to the European average of 11.5 years [43]. Likewise, the Spanish fleet has one of the lowest percentages of BEVs (3.8% [44]) in Europe (average 14.2% [45]).

In conclusion, if the assumptions made in the calculations are accepted, the resulting estimates allow us to state that the impact of the mobility transformation would be positive in terms of reducing pollutant emissions during the service life of BEVs. However, the environmental impact of the rest of the life cycle of the vehicle (extraction of raw materials, production, and recycling) would have to be taken into account.

The estimated investment required in Spain to generate the additional electricity from wind and PV solar power is enormous (more than 25.4 billion euros), representing, for example, 5.5% of the total national budget in 2022. On the other hand, the installation of the estimated quantities of wind turbines and solar panels, although important, would not be able to meet the electricity needs alone, unless they are accompanied by other auxiliary sources to meet demand when the weather is unfavorable.

Estimated energy requirements could be reduced if batteries with higher energy densities than those currently available are developed in the future. Another possibility for the future, perhaps in the longer term, is to advance the development of hydrogen production/use technology from renewable sources to make the use of FCEVs competitive.

**Author Contributions:** Conceptualization, J.R. and L.V.C.; methodology, J.R. and L.V.C.; validation, L.V.C.; formal analysis, J.R. and L.V.C.; investigation, J.R. and L.V.C.; data curation, J.R.; writing—original draft preparation, L.V.C.; writing—review and editing, J.R. and L.V.C.; visualization, J.R. and

L.V.C.; supervision, L.V.C.; project administration, L.V.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** Not applicable.

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

## References

1. United Nations Climate Change. The Paris Agreement. 2023. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement (accessed on 19 April 2023).
2. News European Parliament. EU Ban on the Sale of New Petrol and Diesel Cars from 2035 Explained. 2023. Available online: https://www.europarl.europa.eu/news/en/headlines/economy/20221019STO44572/eu-ban-on-sale-of-new-petrol-and-diesel-cars-from-2035-explained (accessed on 23 April 2023).
3. Eurocities. Low Emission Zones: Challenges and Solutions. 2021. Available online: https://eurocities.eu/latest/low-emission-zones-challenges-and-solutions/ (accessed on 29 April 2023).
4. Krajinska, A. Electric Vehicles Are Far Better than Combustion Engine Cars When it Comes to Air Pollution. Here's Why. 2021. Available online: https://www.transportenvironment.org/discover/electric-vehicles-are-far-better-than-combustion-engine-cars-when-it-comes-to-air-pollution-heres-why/ (accessed on 29 April 2023).
5. EUR-Lex. Commission Regulation (EU) 2017/1151 Supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council on Type-Approval of Motor Vehicles with Respect to Emissions from Light Passenger and Commercial Vehicles (Euro 5 and Euro 6). Available online: http://publications.europa.eu/resource/cellar/7d1c640d-62d8-11e7-b2f2-01aa75ed71a1.0006.02/DOC_1 (accessed on 29 April 2023).
6. Motorway. Euro 6 Compliance and Emission Standards—The 2023 Guide. 2023. Available online: https://motorway.co.uk/sell-my-car/guides/euro-6-emission-standards-compliance (accessed on 29 April 2023).
7. BUYACAR. What Are Euro 6 Emissions Standards? *Why You Need to Know*. 2022. Available online: https://www.buyacar.co.uk/cars/euro-6-emissions-standard-cars/522/what-are-euro-6-emissions-standards-why-you-need-to-know (accessed on 29 April 2023).
8. Brzezanski, M.; Sala, R. The influence of AdBlue dosage on the process of selective catalytic reduction of nitrogen oxides. *ResearchGate* **2013**, *154*, 1032–1037.
9. Toyota. 2023 MIRAI. 2023. Available online: https://www.toyota.com/mirai/ (accessed on 29 April 2023).
10. Hyundai. NEXO. 2023. Available online: https://www.hyundai.com/worldwide/en/eco/nexo/because-of-you (accessed on 29 April 2023).
11. Albatayneh, A.; Juaidi, A.; Jaradat, M.; Manzano-Agugliaro, F. Future of Electric and Hydrogen Cars and Trucks: An Overview. *Energies* **2023**, *16*, 3230. [CrossRef]
12. McKinsey & Company. EVolution. *Electric Vehicles in Europe: Gearing Up for A New Phase?* 2014. Available online: https://www.mckinsey.com/featured-insights/europe/electric-vehicles-in-europe-gearing-up-for-a-new-phase (accessed on 29 April 2023).
13. Schneider Electric. Electric Vehicle and EV Charging Fundamentals. 2021. Available online: https://www.electrical-installation.org/enwiki/Electric_Vehicle_and_EV_charging_fundamentals (accessed on 29 April 2023).
14. go-e. The 4 EV Charging Modes You Need to Know about. 2022. Available online: https://go-e.com/en/magazine/charging-modes-electric-car (accessed on 29 April 2023).
15. Wallbox. EV Charging Connector Types: What You Need to Know. 2023. Available online: https://wallbox.com/en_catalog/faqs-plug-types (accessed on 29 April 2023).
16. Lewison, T. Full fuel cycle emissions reductions through the replacement of ICEVs with BEVs. In *Climate Change 2-Canadian Technology Development Conference*; Canadian Nuclear Society: Toronto, ON, Canada, 2001.
17. Fournier, G.; Boos, A.; Wörner, R.; Jaroudi, I.; Morozova, I.; Nemoto, E. Substituting individual mobility by mobility on demand using autonomous vehicles—A sustainable assessment simulation of Berlin and Stuttgart. *Int. J. Automot. Technol. Manag.* **2020**, *20*, 369–407. [CrossRef]
18. Li, M.; Zhang, X.; Li, G. A comparative assessment of battery and fuel cell electric vehicles using a well-to-wheel analysis. *Energy* **2016**, *94*, 693–704. [CrossRef]
19. Choma, E.; Ugaya, C. Environmental impact assessment of increasing electric vehicles in the Brazilian fleet. *J. Clean. Prod.* **2017**, *152*, 497–507. [CrossRef]
20. Held, M.; Schücking, M. Utilization effects on battery electric vehicle life-cycle assessment: A case-driven analysis of two commercial mobility applications. *Transp. Res. Part D Transp. Environ.* **2019**, *75*, 87–105. [CrossRef]

21. Autoritat del Transport Metropolità. Enquesta de Mobilitat en Dia Feiner (EMEF). 2023. Available online: https://www.atm.cat/comunicacio/publicacions/emef (accessed on 11 May 2023). (In Catalan).
22. Padron.com.es. Población de Barcelona (Provincia). 2023. Available online: https://padron.com.es/barcelona/ (accessed on 14 May 2023). (In Spanish).
23. Repsol. Repsol Opens the Most Powerful Electric Vehicle Charging Station in Europe. 2019. Available online: https://www.repsol.com/en/press-room/press-releases/2019/repsol-opens-the-most-powerful-electric-vehicle-charging-station-in-europe.cshtml (accessed on 29 April 2023).
24. ANFAC. Mapa de Infraestructuras de Recarga de Acceso Público en España Para 2021–2030. 2021. Available online: https://anfac.com/publicaciones/mapa-de-infraestructuras-de-recarga-de-acceso-publico-en-espana-a-2021-2030/ (accessed on 29 April 2023).
25. Dirección General de Tráfico. Parque de Vehículos—Tablas Estadísticas 2022. 2023. Available online: https://www.dgt.es/menusecundario/dgt-en-cifras/dgt-en-cifras-resultados/dgt-en-cifras-detalle/?id=00866 (accessed on 29 April 2023). (In Spanish).
26. Dirección General de Tráfico. Parque de Vehículos—Tabla Estadística Auxiliar 2022. 2023. Available online: https://www.dgt.es/menusecundario/dgt-en-cifras/dgt-en-cifras-resultados/dgt-en-cifras-detalle/?id=00867 (accessed on 2 May 2023). (In Spanish).
27. Institut d'Estudis Regionals i Metropolitans de Barcelona. Enquesta de Mobilitat en Dia Feiner 2021 (EMEF 2021). 2022. Available online: https://omc.cat/documents/662112/1025112/EMEF+2021_Informe+SIMMB_juny2022+%281%29.pdf/17ff87aa-7005-193e-ad0e-e08330798c53?t=1666599585086 (accessed on 12 May 2023). (In Catalan).
28. Silence. Silence S01. 2023. Available online: https://www.silence.eco/lang/en/s01/ (accessed on 11 May 2023).
29. Tesla. Model 3. 2023. Available online: https://www.tesla.com/en_eu/model3 (accessed on 11 May 2023).
30. Peugeot. Peugeot e-Expert. 2023. Available online: https://www.peugeot.es/gama/expert-furgon.html (accessed on 11 May 2023).
31. DAF. DAF LF Electric. 2023. Available online: https://www.daf.es/es-es/descubra-los-camiones-daf/alternativas-de-combustibles-y-cadenas-cinematicas/vehiculos-electricos-de-bateria/daf-lf-electric (accessed on 11 May 2023). (In Spanish).
32. Red Eléctrica de España. Generación Total. 2023. Available online: https://www.sistemaelectrico-ree.es/informe-del-sistema-electrico/generacion/generacion-de-energia-electrica/generacion-total-de-energia-electrica (accessed on 15 May 2023). (In Spanish).
33. European Environment Agency. EMEP/EEA air pollutant emission inventory guidebook 2019. In *European Monitoring and Evaluation Programme (EMEP)*; European Environment Agency (EEA): Copenhagen, Denmark, 2019.
34. Red Eléctrica de España. Península—Seguimiento de la Demanda de Energía Eléctrica. 2023. Available online: https://demanda.ree.es/visiona/peninsula/demandaqh/total/2023-03-07 (accessed on 16 May 2023). (In Spanish).
35. Red Eléctrica de España. Potencia Instalada. 2023. Available online: https://www.sistemaelectrico-ree.es/informe-del-sistema-electrico/generacion/potencia-instalada (accessed on 16 May 2023). (In Spanish).
36. Generalitat de Catalunya. Visor Sobre el Estado de Tramitación Ambiental de los Proyectos de Energías Renovables en Catalunya. 2023. Available online: https://mediambient.gencat.cat/es/detalls/Articles/visor (accessed on 16 May 2023). (In Spanish).
37. Gobierno de Aragón. Planta Fotovoltaica Ancar II en los Término Municipales de Alfambra y Orrios (Teruel). 2023. Available online: https://www.aragon.es/-/planta-fotovoltaica-ancar-ii (accessed on 16 May 2023).
38. Gobierno de Aragón. Parque Eólico Cabigordo en los Términos Municipales de Corbalán, Cedrillas y El Pobo (Teruel). 2023. Available online: https://www.aragon.es/-/parque-eolico-cabigordo?p_l_back_url=%2Fbuscador%3Fq%3Deolico%2Bcabigordo%26category-td%3D466682%26category%3D465154%26type%3Dcom.liferay.journal.model.JournalArticle (accessed on 16 May 2023). (In Spanish).
39. Generalitat de Catalunya. Hipermapa. *Sol·Licituds de Parcs Eòlics*. 2023. Available online: https://sig.gencat.cat/visors/hipermapa_antic.html#param=param&color=vermell&background=topo_ICC_grisos&BBOX=134915.697674,4485000,659084.302326,4752000&layers=ENERGIA_PARCSEOLICS_MULTIPUNT,ENERGIA_PARCSEOLICSSOLARS_LIN,ENERGIA_PARCSSOLARS_MULTIPOLI (accessed on 16 May 2023).
40. Parc Tramuntana. Parc Tramuntana. *Una Oportunidad Azul Para la Sostenibilidad Del Empordà i Girona*. 2023. Available online: https://parctramuntana.com/es/inicio/ (accessed on 16 May 2023). (In Spanish).
41. Miao, R.; Ghosh, P.N.; Khanna, M.; Wang, W.; Rong, J. Effect of wind turbines on bird abundance: A national scale analysis based on fixed effects models. *Energy Policy* **2019**, *132*, 357–366. [CrossRef]
42. Chargeguru. Cuánto Cuesta la Instalación de un Punto de Recarga Para Vehículo Eléctrico? 2023. Available online: https://chargeguru.com/es/2021/09/17/cual-es-el-precio-de-la-instalacion-de-un-punto-de-recarga-para-vehiculo-electrico/ (accessed on 15 May 2023). (In Spanish).
43. ANFAC. La Antigüedad del Parque de Automóviles en España Sigue al Alza y Alcanza Los 13,5 Años de Edad Media. 2022. Available online: https://anfac.com/actualidad/la-antiguedad-del-parque-de-automoviles-en-espana-sigue-al-alza-y-alcanza-los-135-anos-de-edad-media/ (accessed on 15 May 2023). (In Spanish).

44. ANFAC. Vehículo Electrificado. *Informe Anual 2022*. 2023. Available online: https://anfac.com/wp-content/uploads/2023/04/2022_Informe_electrificados-Anual.pdf (accessed on 15 May 2023). (In Spanish).
45. Rodríguez, M. Electric Vehicle Sales in Europe in the First Quarter of 2023. 2023. Available online: https://www.electromaps.com/en/blog/electric-vehicle-sales-europe-first-quarter-2023 (accessed on 15 May 2023).