V2MARKET

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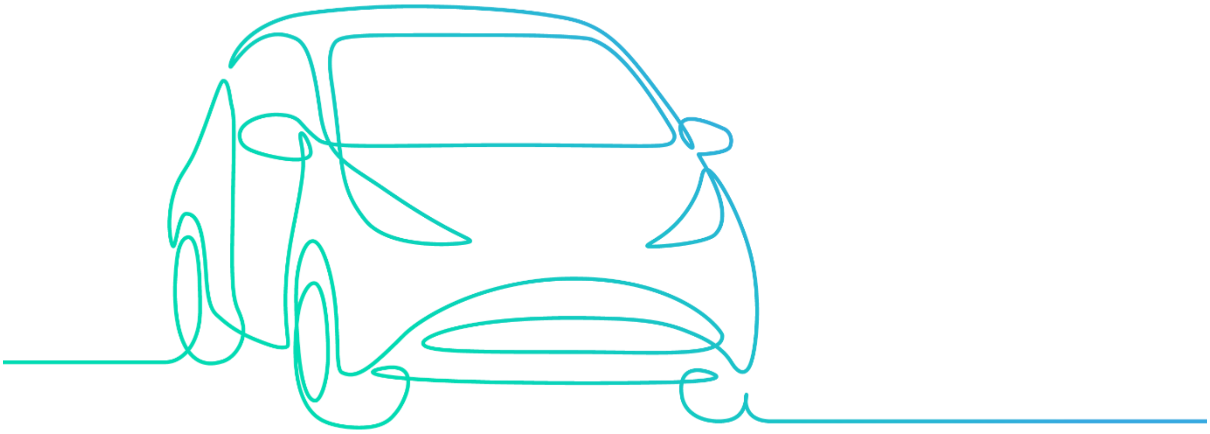

Training materials

D7.2

DECEMBER 2023

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AUTHORS

Author Name	Partner
Miquel Anglada Adrià Serarols	ECOSERVEIS

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Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Index

Version History ... 2
Index ... 3
1 Introduction ... 4
2 Target groups segmentation ... 5
2.1 Training structure ... 6
2.2 Schematic structure ... 8
3 Training content guide ... 9
3.1 General Webinar ... 9
Introduction ... 9
Renewable electricity in the grid concepts ... 14
Electricity markets overview ... 17
Vehicle to grid, vehicle to building and smart charging concepts ... 20
Why V2G, V2B and V1G? ... 22
3.2 Specific training 1 ... 24
Introduction ... 25
Objectives of the pilot ... 25
Usability of the vehicle fleet ... 26
Software usability module ... 27
3.3 Specific training 2 ... 31
Introduction ... 31
Battery as a service ... 31
How to benefit from V2X ... 33
Potential concerns ... 35
3.4 Specific training 3 ... 37
Introduction ... 37
Energy Supply Chain ... 37
Energy Balance ... 38
Electricity markets ... 40
Local flexibility markets ... 41
Electric vehicles and V2X ... 42

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Acronym list

AI	Artificial Intelligence
AMB	Barcelona's Metropolitan Area
CER	Renewable Energy Community
CCE	Citizen Energy Community
EU	European Union
EV	Electric Vehicle
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment
HVAC	Heating, Ventilation, and Air Conditioning
PV	Photovoltaic
RES	Renewable Energy Sources
SOC	State of Charge
V2B	Vehicle to Building
V2G	Vehicle to Grid
V2M / V2Market	It refers to V2Market EU collaborative project
V2X	Vehicle to everything

1 Introduction

This document presents the training materials regarding V2G usability, benefits, challenges and contexts for main interested users and stakeholders around Europe. It has been developed in the framework of the V2M project. These materials will be used for the delivery of trainings early in 2024, during the pilot implementation for the Barcelona Metropolitan Area. They will also be online and available for the general public and for other project activities until July 2024.

The V2M project has two pilots. Theses pilots are small scale initiatives built for the purpose of testing the feasibility of utilizing V2G and V1G technology in Spain. The pilots will utilize energy market indicators from the wholesale electricity market and local flexibility markets enabled by OMIE to enhance the use of V2G technology. Pilot 1 uses vehicles from the fleet of AMB (Public Administration in charge of Metropolitan Area of Barcelona), used by its staff to perform their duties (e.g. travel for maintenance work). While the vehicles are parked. Nuvve will act as the aggregator and ICT technology provider, to use the battery to provide V2G services. Pilot 2 is based on Holaluz's customers owning an electric vehicle. Holaluz is a

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Spanish electricity supplier and also PV installer for household self-consumption. Nuvve will perform energy advisory as a service based on predictive modelling of AstreaAI. As the Spanish regulation still does not provide room for aggregators and V2G services to participate in relevant markets, the AMB pilot will use simulated exchanges with the market, with different scenarios (such as normal day, day with high renewable generation, day with low renewable generation), while Holaluz's pilot will be a real day to day use of EVSE (chargepoint chargers) as normally operated by the end users.

This document is supported by some presentations that briefly outline in a more visual way the content in this document. The presentations are prepared according to the target audience: general, EV users, public authority owning a V2G car fleet, energy experts, aggregators, EV/V2G providers, energy communities, and policy makers, as described in more detail later in this document.

The content of this document is useful for stakeholders in other countries of the EU and EU level. The European Union has set a path towards electrification, decentralization and flexibility of the energy systems where electric vehicles can play a central role for the transition and decarbonization. In particular, the recast of the Electricity Markets Directive of 2019 (Directive (EU) 2019/944), and the proposed reform of 2023 puts on the table an important role for aggregators (either independent or as part of an energy community or a supplier). EU countries will go through the process of considering how to implement these changes. Many stakeholders, in the same segments identified in the next section, can benefit from the information and increased literacy on V2G that this course provides. Stakeholders can access this training directly, and organizations and projects wishing to replicate the V2G approach could adapt the content to their national context too. The document however is for a Spanish context, many aspects are common in the EU, but some of the examples are based on Spanish markets and regulators.

2 Target groups segmentation

The first step upon preparation of training materials for the usability of V2G in the proposed pilots is defining the target groups which the trainings are prepared for. The training materials have been developed to support the pilot. They will be used to prepare the metropolitan area of Barcelona (AMB) workers and users to fully understand the principles of V2G, V1G and V2B. This will grant their knowledge, supporting the successful completion of the V2M pilot in the metropolitan area of Barcelona (AMB).
The project has a second pilot, added above the one originally programmed in this project. This pilot is delivered based on a group of Holaluz's residential clients owning EVs. The project is thus considering them as a target of the training sessions. Therefore, the targeted actors involved in the training sessions are:

- AMB fleet manager, energy technicians and engineers.
- Other AMB vehicle users – V2G users of the pilot.
- General citizens – EV users – for the pilot with Holaluz (HL).

Moreover, two more target groups have been considered in V2M project for training purposes through webinars/self-trainings. Our aim for these target groups is to help to facilitate the

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replication of the V2M project. That is, the market uptake of V2X products, services and technologies. The target groups are as follows:

- Politicians – Policy makers: the training will help the case for the change of policies that create an enabling regulatory framework of these services. It will also target decision makers in terms of budget and transition dedicated for the topic, research activities, and change of public administration's fleets, and use of the servitization model.
- Aggregators, Battery/EV providers and Local Energy Communities (CER or CCE). For increasing knowledge of how to use EV in future V2G services and getting their buy-in in delivering those services.

2.1 Training structure

Considering the complexity of the target segmentation, as the target groups are diferent, and will be interested in different aspects, the open trainings are divided in two different blocks. The first block contains all the general knowledge and necessary background information, while the second block is made of 5 modules specific to the focused target group within the pilots (EV users from AMB and HL clients).

- **General webinar**: its content shall be open to all the aforementioned target groups, and it contains the general overview of the idea of V2X services. The summary of the content is as follows:
    - Introduction about Climate Change, its impacts, EVs, and the need of V2M as a solution to tackle emissions and promote renewable energy.
    - General overview of electricity markets and future renewable electricity grid.
        - Day ahead market
        - Intraday continuous market
        - Short term flexibility market
    - Grid flexibility in a renewable grid from the Demand side.
    - V2G, V1G, V2B main principles.
    - Why is V2X an opportunity for everyone, benefits and why it is necessary.
- **Specific training sessions:** they will target particular topics addressed to the 5 target groups identified, the first three for the pilot and and the two last for replication and extending the project beyond the pilot.
    - **AMB pilot users:** This group receives a specific training session on the usability of V2G/V2B for their fleet of vehicles, usability requirements, objectives of the pilot, risks of V2G as opposed to normal behaviour and other V2G aspects directly related to the pilot.
    - **EV general users (HL clients):** They are given a specific training session on the benefits of V2G, V2B and V1G for them in terms of energy bills, energy efficiency and battery behaviour. Battery as a service topic shall also be addressed in this specific training session as well as the potential risks of battery degradation and how V2G does (not) influence on it.

- **Municipality energy technicians:** A specific training session on electricity markets, especially intraday, day ahead, and local flexibility markets is given in this specific training session, along with general knowledge about electric vehicles.
- **Aggregators, Service Providers and Energy communities:** This specific training session includes knowledge about the value proposition of having V2G for aggregators and energy communities, along with the market opportunities for providers, considering battery as a service and general V2M concepts.
- **Policy makers:** This group receives a specific training on market needs and regulation needs for the proper implementation of V2G, V2B and V1G in all electricity markets. It thus inclued policy recommendations extracted from the previously performed market studies.

The training sessions that will take place during the pilot will be addressed to the he first three specific groups: AMB pilot users, EV general users, and municipality energy technicians. They are the main three actors involved in the pilot.
As for the specific trainings to aggregators and policy makers, they are not included in the present document as they will be part of another set of training material preparation, which will be published as a separate document: under work package 8, Delivarable 8.4, of hte current project.

The trainings to be done for the pilot in V2M project will be held at AMB headquarters during February 2024 in two sessions: the first one being the general training, as a webinar session; the second one being a face to face workshop targeted to a more technical audience to discuss deeper into the technicalities of V2G, its deployment and its performance.
The results on the attendance and evaluation of the participants regarding the training wil be collected on site during the training sessions.

2.2 Schematic structure

Regarding the contents to be explained to the different target groups, these are summarized in the next Figure. See that those related to WP7 are targeted to the pilot users, general end users of EV and local public administration, whereas the contents in WP8 are targeted to aggregators and policy makers:

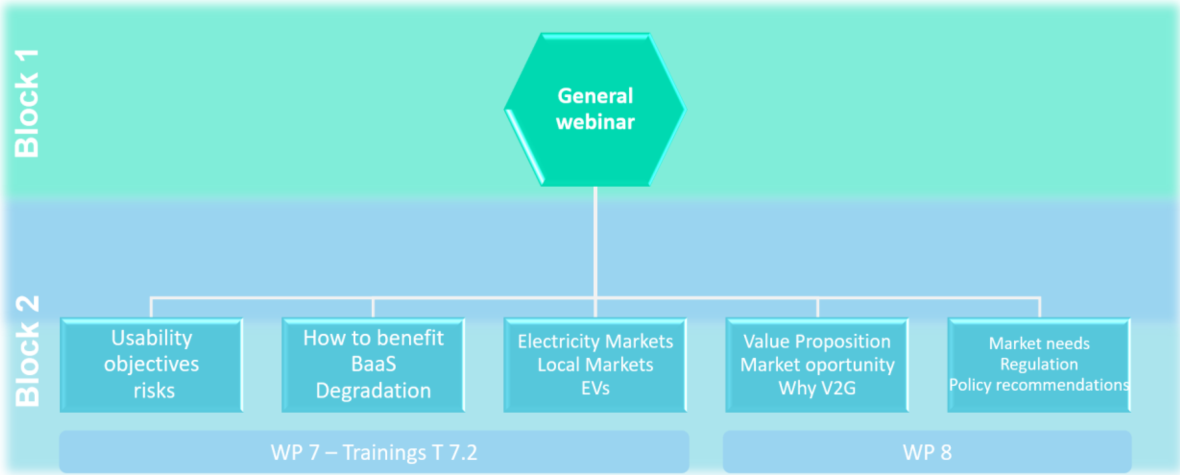

Figure 1: Schematic structure of the proposed trainings.

3 Training content guide

The following section includes all information about the content to be given during the training sessions for the pilot as well as for the self-training materials for V2X general users. It consists of general guidelines of the content that shall be used during the proposed trainings, allowing its replication in further trainings beyond the project.

3.1 General Webinar

Introduction

The webinar starts with a brief introduction about climate change, the greenhouse gas effect, CO2 emissions, its impact, and the need to take action to prevent increasing 1,5 ºC from global warming.

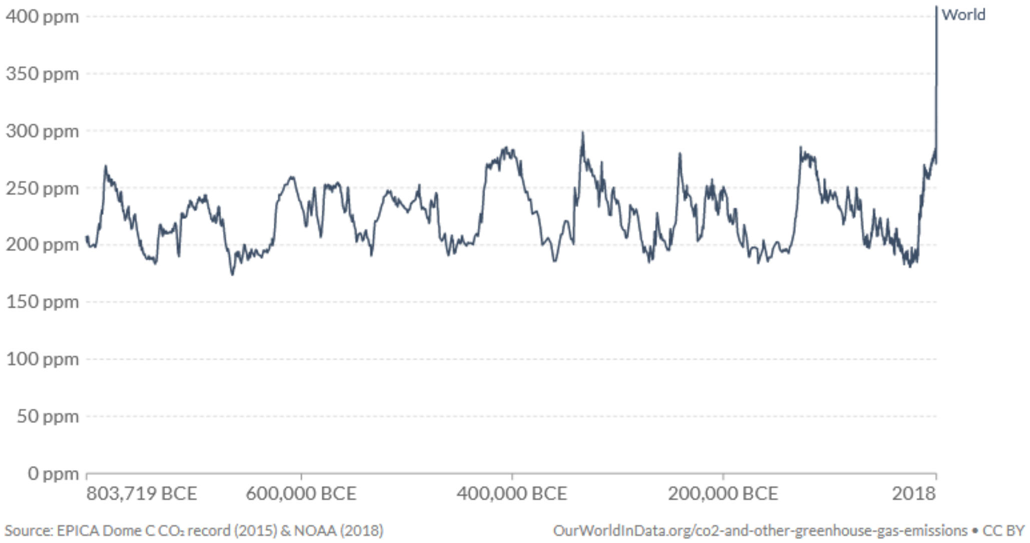

Figure 2 World CO2 emissions. Source: EPICA & NOAA

The atmosphere has a certain amount of greenhouse gases, which allow the solar radiation to reach the earth. As it bounces again to space, the atmosphere can retain some of that heat, so it is not lost, by keeping our planet in habitable temperatures, for biodiversity to live in it. However, if the concentration of those gases increases, due to human activity of the last century and beyond, then more heat is retained, and it breaks the natural equilibrium, leading to the so-called global warming. It has been proved that as greenhouse gas emissions and their presence in the atmosphere has increased, the average global temperature has increased too. This has numerous and dangerous potential environmental impacts that can affect us in many negative ways. This is particularly marked for CO2 emissions.

The energy transition objectives in Spain and the European Union have included for years many objectives related to mobility, which are starting to become today a real change in the sector. According to the governmental strategy *España 2050 (Spain 2050),* Spain aims to achieve a 100% renewable energy system by 2050, with the aim to fulfil European objectives of decarbonization to avoid the increase of global temperatures with respect to preindustrial values. The document estimates that by 2050 Spain will be much drier and warmer than it is today. It will also have a much more unstable climate, Spain being one of the most impacted countries in terms of water availability in Europe. This adds up to a continuous increasing hazard of forestall fire, which is estimated to be the highest in western Europe:

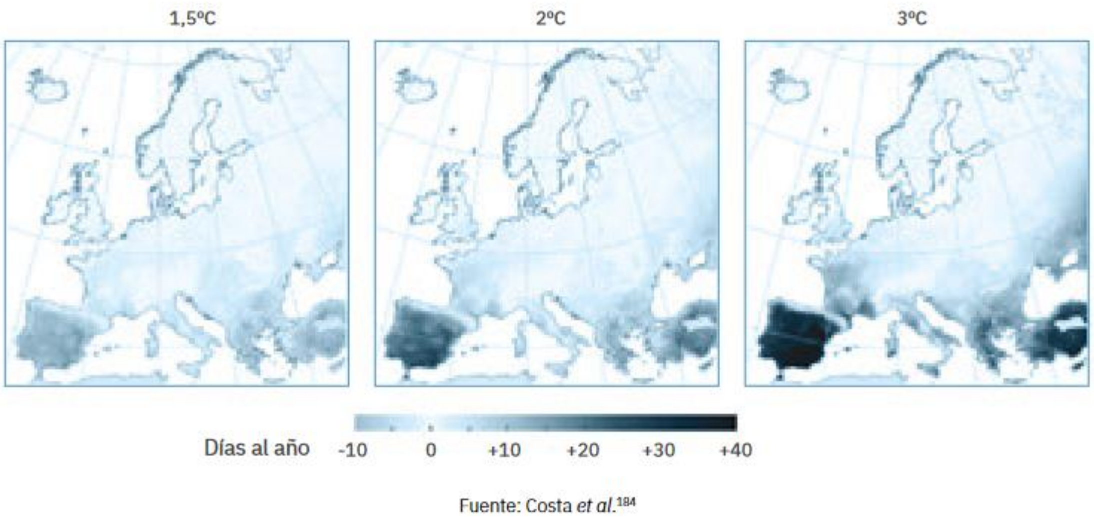

Figure 3: Days of risk of forestall fire in Europe with respect to global temperature increase.

Therefore, decarbonisation objectives are necessary and energy transition is an urgent matter for Spain. Especially with sight on a 100% renewable energy system, but also on the intermediate steps towards the final grid design. Efforts must be put on energy efficiency improvements, more conscient energy consumption habits and behavioural change. It is also key to develop a new electric smart grid, considering territorial flexibility, energy storage and energy inertia.

As renewable energy sources don't have the ability to be adapted to the demand, new actors, technologies, and services are going to be fundamental for the attainment of ambitious energy transition goals. For example, new forms of energy and electricity storage, or the increased use of hydrogen and biogas as energy vectors. An increasing fleet of electric vehicles with energy storage solutions shall inevitably become a key actor to achieve grid flexibility and optimize the production of energy in the new electricity system. [1]

Under the premise of this new mobility concept, additional revenue opportunities and business models will arise in order to use the common resource that will become a reality, which are EV batteries. Here is where our project, V2M, stands out. If we are planning to deploy renewables among the territory, but their availability of energy is uncertain or intermittent, what can we do? Can't we store the energy to use it when needed?
Unlike natural gas power plants, renewable power plants such as wind and solar PV are not switchable, so they generate electricity whenever the resource is available. The sun does not shine, and the wind does not blow only when we need them to. If we do not store or use what is generated, we lose it, and the plants can only be shut down or curtailed. In a renewable grid, one option is to have much more power installed than that demanded, so that enough power is available at all times. To match supply and demand of electricity at all times, energy

storage is necessary, so that the excess energy at peak production times can be stored, and used when the supply of electricity is not enough to match the demand.

Since a large uptake of electric vehicles in Europe will inevitably result in local, small, mobile, energy storage solutions integrated in each vehicle, it makes sense to use them as part of the electricity market, being able to absorb energy or deliver it depending on the needs.

How do Electric Vehicles work?

Let's briefly introduce the main principles for the audience that might not be very familiarized on what an electric vehicle is and how it works comparing to a conventional combustion car. The body, chassis and frame are very similar to those in the fuel-engine cars (Gasoline and Diesel).

As for the main parts of the engine and charging needs, we can differentiate 4 key elements:

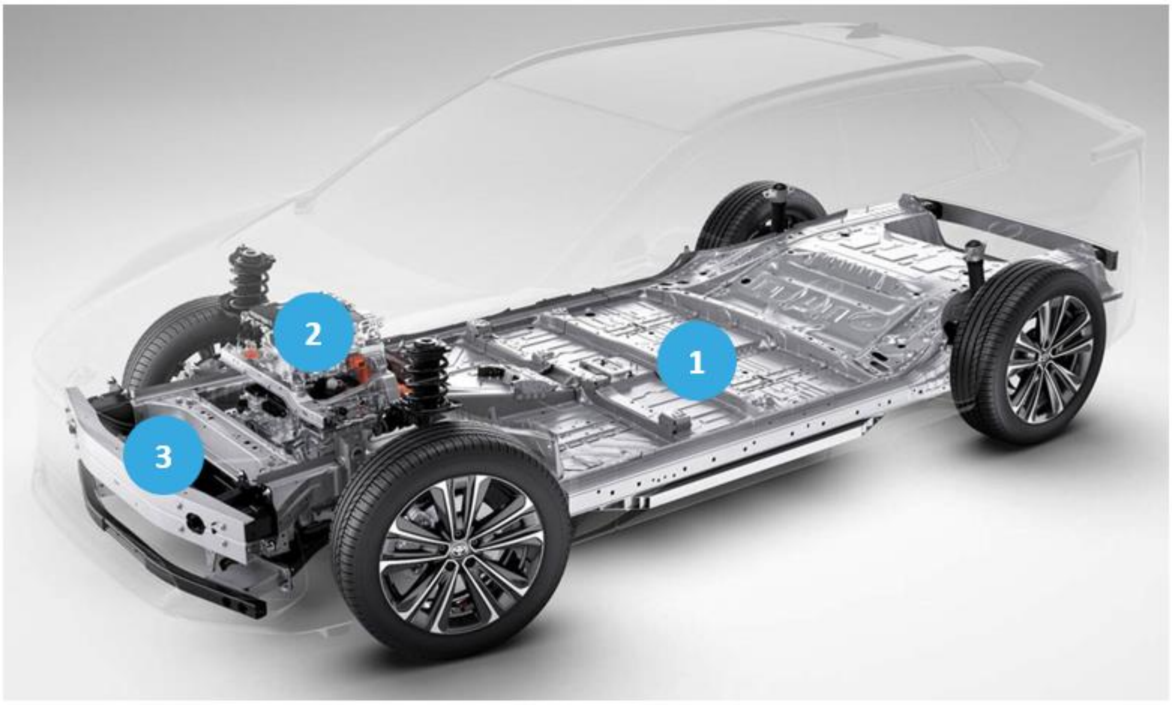

Figure 4 EV parts. Source: Eléctricos y Híbridos

- **Battery:** is the biggest component and the heaviest. The bigger it is, the more electricity it can store, resulting in more autonomy to travel further. In the commercially available cars, there are different vehicles with different capacity, and this is related with the car size. A common EV can have a battery of about 50 kWh, which is more or less the consumption of a family for 4 days, equivalent to 300 km approximately. Nowadays, the car which is known to have the largest autonomy it is expected to last for more than 700 km. Usually the batteries are constructed using Lithium among other metals, which are often found in countries outside the EU. This has an environmental, social, and economic impact. More information on this topic later.
- **Inverter:** located inside the car engine, they basically convert the electricity which comes from the grid from AC current to CC current, which is used to store the electricity into the battery. For our use case, the ABB EVSE (charger) is supplying DC (CC)

directly into the vehicle. The ChargePoint EVSE (charger) on the other hand is supplying AC and the vehicle and the AC/DC Converters inside the vehicle make the conversion to supply DC to the battery.

- **Charging point and motor:** usually in the front, there is the plug where the users can charge their vehicles. Every vehicle comes with its own cable, even though they are standardized into 2 or 3 types, sometimes depending on the speed of the charge (electric power). The motor is in charge of transforming the electricity to mechanical energy to move the car. Unlike conventional cars, electric motors don't require an engine torque, so they don't have gears either. Therefore, they are automatic.
- **Charging stations**: besides the vehicle itself, it is essential to take into account the charging stations, which are being deployed along the territory, in a similar way as a petrol station. The charger stations may have different power capacities, so the vehicles can be charged faster or lower. Chargers performing slow charge are usually installed at households. For the project that is being presented today and the new opportunities for EVs to **unfold in the coming years**, it is **necessary for** the EVSE Manufacturers to develop bidirectional capable products. It is imperative that auto manufacturers embrace V2G technology as well, a full stack of V2G capable technology is necessary for V2G and V2X to come into fruition.

An Electric Vehicle Communication Controller (EVCC) is a crucial component in an electric vehicle (EV) system. It serves as the interface that enables communication between the electric vehicle and the charging infrastructure.

- The EVCC plays several key roles:
  - **Communication Interface:** It facilitates communication protocols between the EV and the charging station. This allows the vehicle to interact with different types of charging stations and grids, ensuring compatibility and safe charging.
  - **Charging Control:** The EVCC manages the charging process by regulating the flow of electricity from the charging station to the vehicle's battery. It can negotiate the charging rate and manage power flow based on the vehicle's battery status, charging requirements, and grid conditions.
  - **Safety and Authentication:** The EVCC ensures safety by authenticating the charging station and verifying its credentials. It helps prevent unauthorized access to the vehicle's systems and protects against potential cybersecurity threats.
  - **Data Handling:** It collects and processes data related to charging sessions, such as energy consumption, charging duration, and charging rates. This data can be used for billing, monitoring, and analyzing the performance of the vehicle's battery and charging infrastructure.
- The importance of the EVCC in the EV system lies in its ability to standardize communication protocols, ensure interoperability between different charging stations and vehicles, and provide a secure and controlled charging process. It enables efficient and safe charging while allowing for smart grid integration and effective management of the electric vehicle fleet. Additionally, the EVCC contributes to the development of a robust infrastructure for electric mobility, supporting the widespread adoption of electric vehicles.

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Let's now discuss about the benefits, opportunities and challenges related to owning an EV:

Opportunities and Strengths:

- It can help integrate more renewable energy into the grid, and into our homes: it is an energy storage unit, so it is able to provide energy to our home or store some surplus from a photovoltaic installation if there is one for self-consumption. It improves the air quality as it does not have GHG emissions. However, only if the electricity feeding the car is produced using renewable technologies, it will not have emissions for its use. Ownership of the car is not the only option. Energy communities could have a shared EV or an EV fleet, as an interesting solution to maximise the self-consumption of collective renewable installations, and more economical. A battery can absorb peak renewable generation from the grid and give it to the grid when needed if the car is connected to a bidirectional charger.
- A V2G capable tech stack (EV + EVSE) can help defer costly investments necessary to the grid: The transportation and distribution grids are dimensioned based on the peak demand. If we electrify our energy use, such as using heat pumps instead of gas boilers, we risk increasing this peak demand. Significant grid upgrades will be necessary to adapt the increase capacity. This involves enhancing existing infrastructure and additional installation of transformers, substations and power lines to handle higher loads without overloading the system. However, with the use of Smart Grid Technologies, we can help manage the distribution of electricity more efficiently. we can avoid this peak demand to the grid going upwards and use the flexibility connected to our close network. The grid can remunerate directly or through credits to those allowing the use of their batteries for this service.

- It can help us safe money: In addition, as electricity is cheaper than gasoline or diesel, users will save money during the lifetime of their EVs. Finally, it is in line with the electrification planned for the next decades to remove pollutant sources of energy.

Challenges and Weaknesses:

- Environmental impact beyond emissions: as said before, we cannot omit the fact that the batteries are mostly produced using raw materials that are scarce, to the point that is not physically possible to change all the current vehicles to EVs. There are simply not enough materials in the world. There are steps to be done related to the life cycle of the batteries. Research and analysis of their life cycle, how many charging cycles and years they can last but also for a second life for other purposes, or how to recycle the materials.
- Financial cost: One of the challenges for switching to an electrical vehicle nowadays is still the affordability, as most of the vehicles can double the price compared to a conventional one. Although on the long term one can make up for the savings with a smart charging and lower cost of electricity, one still need to be able to make up the upfront payment (or access to advantageous financing options / loans). Lack of regulation for some of the possible features that could pay further lower the cost of

electric vehicles, such as V2G and the services to the grid, that is being discussed in this training, makes it less attractive economically.

- Range Anxiety: In addition, being used to the comfort that conventional cars provide, some users might be sceptic about changing to an EV. The main concerns are often related to the charging of the car, of not having a charging station available where (and when) needed, or the autonomy of the cars.
- Non V2G EV expansion will put excess strain on the grid inherent to typical “dumb” charging causing critical fluctuations and affecting grid voltage regulation, frequency levels and power factor drops.
- The transition to EVs requires a coordinated effort between government entities, utility companies, and stakeholders to ensure the grid can handle the increased demand while maintaining reliability and efficiency.

Renewable electricity in the grid concepts

Current electricity grid in Spain is the second in Europe in terms of renewable energy power installed, with wind energy being the highest with 29.3 GW installed, followed by hydropower with 20.3 GW and solar energy with 18.5 GW. This means that the current electricity system in Spain consists of 62 % of renewable power installed. In terms of generation, in 2022 classic thermal energy (natural gas, coal, oil) was the highest in Spain, followed by wind energy with 58.7 TWh and solar energy with 31.1 TWh, which add up to one TWh more than that produced with fossil fuels. Renewable energies in total represented almost 45 % of the total energy produced in the country, aiming at 100% in 2050. [2]

There is indeed a long way to go to implement more renewable facilities in Spain with new barriers arising with the substitution of inertial energy sources like nuclear power of natural gas combined cycle plants by solar or wind energy.

Electricity Supply Chain

Before going into detail, we must identify the main actors that take part in the electricity market and which are their roles, so we can then talk more deeply about the operation of the market on a daily basis.

Generators: they are responsible for transforming natural resources (which may or may not be renewable) into electrical energy. There are nuclear, hydroelectric, thermal power plants (through Gas, coal, or bio-fuels), wind and solar farms, etc. Until the beginning of the century, electricity generation has been developed mainly in a centralized way and outside the cities. Today, we are moving towards a distributed generation of electricity, since renewables and the possibilities offered by self-consumption modes make it possible to generate electrical energy on a small scale and in a much more local way.

Transport System Operator (TSO): its main function is to manage the transport of electricity in long distances, such as transporting electricities from the generation points to the cities or industrial areas, as the name suggests. In the case of Spain, throughout the whole peninsula, a single company, Red Eléctrica Española, is the TSO. This transport is carried out by raising the electricity to high voltage to minimize losses during the journey.

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Distribution System Operator (DSO): once the electricity reaches the cities, the distributors are responsible for the management and maintenance of the local grid. Depending on the territory, one company or another may be in charge, but mainly in Spain the DSOs are Endesa Distribución, Nedgia and Iberdrola, among others. Therefore, if, for example, someone considers making a photovoltaic installation connected to the grid, the distributor will have to verify that the grid is ready to accept the connection point. The distributor is also the one who manages the data from the digital meters and subsequently communicates the readings to the energy retailers in order to be able to make the bills each month.

Market operators (MO): Responsible of the operation of the electricity market, ensuring that all their markets are transparent and fair for all the participants, including V2G users. They give access to market platform to all the agents and guarantee the correct functioning of the systems, matching demand, and supply. The electricity market is in the centre of all the actors. Market operators are also in charge of nomination, receiving the bids, guarantees and carrying out the clearing and settlement processes.

Energy Retailers: they are the companies we pay the bills to. There are more than 600 of them in Spain and they offer different tariffs with different prices, sometimes variable and sometimes fixed, which we can choose according to what suits us the most.

In terms of market organisation, in 1998 the electricity markets in Spain were liberalised and unbundled. In very general terms, the concept is to bring as much competition as possible to the markets. Transmission and distribution are considered natural monopolies. That is, it does not make sense to have more than one network running in parallel. This infrastructure is ran by private organisations, but highly regulated. For example, through price controls, and how to set tariffs. They often have other functions than the pure cable and transformers, such as the ownership or management of the metering in our homes, and the management of the data of those metering points, centralising databases of customers so that accessing the relevant data for switching suppliers is swift, easy, transparent, and not undully blocked. As one can have the same companies running the commercial side and the monopolistic side, the management of both transmission and distribution networks has to be legally and functionally unbundled from commercial activities. That is, if such as in Spain, Endesa might run both generation, retail, and distribution, the distribution side has to be at “arm lengths” of the others to avoid priviledged treatment when compared to otehr retailers. Note that, historically, there has been a so-called vertical integration between retailers and generators in most EU countries. A traditional large retail company would own generation power plants, they would mostly sell what they produced and would, proportionally, barely buy or sell outside what they owned. This aspects of the market will also be changed with more distributed energy production, as the flows and ownerships will change.

That being said, it is worth mentioning that the conventional electricity supply chain, has been mostly centralized, producing the energy in large facilities, and then transporting the electricity to the cities, or the gas through pipelines. However, the trend is to move into a de-centralized electricity sector, where multiple producers using small renewable energy technologies can generate the energy close to their consumption points, reducing the need of transporting the

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energy (and also reducing such losses), and promoting a new model based on carbon neutral technologies.

Electricity Balance

Managing the electricity sector is a complex task. As we mentioned before, right now there is not a possibility to store electricity in a large scale. That's why the production of electricity always has to match the demand, at all times. Usually, electricity sources from thermal plants like coal and gas power plants, and to a much lower extent, nuclear plants, can adapt their production increasing it or reducing it to match the demand during the day. Moreover, these plants can provide stability to the grid: a sudden change of system frequency can be absorbed by a change in the rotation of the turbines of such power plants.

Energy inertia is a key concept for the stabilisation of the operation of electricity systems. Therefore, electricity systems' inertia is needed in order to maintain the operational frequency of 50 Hz of the electricity grid. Oscilations outside small margins around 50 Hz would not make the electircity grid function properly, so inertial electricity systems provide aid to stabilise the grid's frequency, when a missmatch occurs between electricity supply and demand.

Solar and Wind cannot provide this stabilisation, but fuel-based power plants can. Certain forms of storage can provide this service too. In a 100 % renewable electricity grid based in these technologies, electricity inertia will not be possible. No generating ressources could provide stability when a missmatch between supply and demand occurs. A vast amount of electricity storage solutions shall therefore be required in the near future electricity grid to counteract frequency imbalances led by supply and demand missmatches.

Electricity system flexibility

Energy Electricity system flexibility can be defined as the capacity of the system to adjust supply or demand to achieve an energy balance between the two. Flexibility nowadays can be provided mostly on the supply side: through stored natural gas, with rapid increase or decrease of production capability of natural gas power plants, or in hydroelectric power plants, using the stored water from the upper side to generate energy. Some level of demand-side exists in some countries such as Spain, by pumping water from down the river to the lake to increase the demand and then use a traditional hydroelectric plant generation when needed. In the future, flexibility may also be provided directly through electricity storage by converting it to other energy forms, like chemical energy (lithium-ion batteries or hydrogen), or kinetic energy (flywheels), among others. [3]

Although there is a historical tendency to achieve grid flexibility through an alteration on the supply side, such flexibility can be attained through the demand side as well. It can be brought by storage as we have seen, but technology can help incentivise behavioural changes in the demand side in order to achieve grid flexibility in a renewable grid. For example, through the internet of things and digitalisation of the grid, we can incentivise households to use more electricity at times of high renewable generation. With the increase of renewable technologies and the use of electricity as opposed to other sources (electric vehicles, heat pumps...) electric grids will inevitably become more decentralised and potentially unstable. Flexible and smart systems monitor electricity flows of the dispersed installed renewable sources to create signals that motivate behavioural shifts on the demand side achieving flexibility purposes. As flexibility brings value to the system, the system operators and market players can value them, creating markets for these assets. They are explained in more detail latter on in this document.

In this future energy grid, these markets will integrate smart meters and smart appliances becoming smart grids, which will be key for the development of a climate-neutral country (and continent) by 2050. [4]

Electricity markets overview

Large and rapid implementation of electric vehicles in Spain (or any country), will inebitably create a close relationship between mobility and electricity markets. The electricity market in Spain is liberalised since 1998, and since 2007 the wholesale side is integrated with the Portuguesse market in the Iberian Electricity Market (MIBEL).
Nowadays, the price of electricity is determined in the electricity pool, which is the wholesale market where retailers and producers offer to buy and sell electricity. There are markets at different levels, by means of being able to buy electricity several months ahead up to one hour before the delivery of the energy, for example.

The main wholesale spot market in Spain and Portugal is set as a day ahead market, together with intraday markets (with continuous intraday market and intraday auctions), as these three markets represent the majority of energy negotiated in Spain.

Forward / Future market and Power purchase agreements

Usually, large retailers don’t want to rely on the volatility of electricity market prices. As we have said, many retailers have their own power plants. For the rest, usually there are agreements between retailers and generators, so certain amount of energy will be produced for a certain period of time (sometimes set years in advance) and paid at a fixed price. This is what we call future markets. Usually large retailers buy part of their energy to be supplied in future markets, and the rest on the day ahead market and intraday market, to ensure certain stability of price. As you may guess, the larger the retailer, in terms of number of consumers an therefore volume of energy demand, the better the offers they can get. Another way to achieve this, which attendees to the training might have seen on the news, are power purchase agreements. These are long term contracts by which an indepenedent power plant will sell all or a portion of their generation to a single buyer for a number of years. For example, an energy supplier could buy all of the generation of a new solar power plant in the next 20 years. This can help independent project, or collective project, to come to fruition as they have a secured stream of revenue. Usually the retailers are able to predict a certain volume of energy that they can ensure that will be needed.

Day Ahead Electricity Market

The day ahead market includes cross-border European transactions to deliver electricity for the following day. Prices are determined with an algorithm named Euphemia in all the countries that are members of the Price Coupling of Regions (PCR) included in the Day Ahead

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Market. All market participants submit their offers until 12:00 of the previous day, by introducing the amount of energy that is intended to buy or sell, and the matching process starts. From the demand site, there is more consumption to fulfill during working hours, and specially at peak hours (lunch or dinner), and there is less demand during the night. We could say the demand curve is relatively stable (or inelastic). From the production site, renewable producers may be able to offer more energy at low prices when the weather is in favour, whereas other technologies rely on the primary energy price (coal, oil, gas, etc.).

The aforementioned algorithm matches the offers and determines energy prices and energy flows for each hour of the following day and for each biding zone. The algorithm is designed such that it optimises the consumer surplus, the producer surplus and the congestion rent across regions. The final step is the validation of the results by the Market Operator (OM) and by the transmission system operators (TSOs) to ensure that the obtained results are

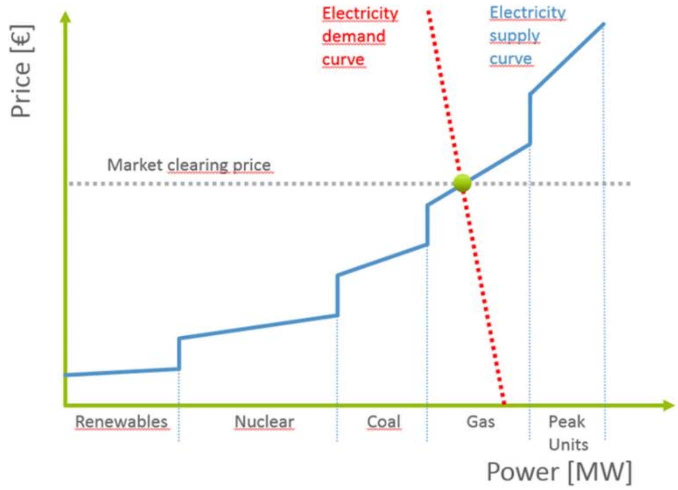

Figure 5 Demand and offer curves. Source: ResearchGate

technically viable in the electrical network. Therefore, the electricity price for each hour of the day is determined the day before through this auctionoffered to producers and consumers, hence the name.

Once the price is defined for every hour, it will be paid equally to all generators, regardless of the cost to produce the energy, as it is a marginal pricing auction.

Intraday Electricity Markets

These intraday markets are the tool for market participants to adjust their energy schedules from the day ahead market to make sure their real needs are fulfilled during the auctioned day. There are six auction sessions in Spain and Portugal.

The intraday auctions market auctions are also based on marginal pricing and, in order to participate, market participants are obliged to have submitted an offer in the day-ahead market. Each intraday auction has 60 minutes of auction time, in which participants have to submit their offers to buy or sell electricity. OMIE is the responsible part of matching the offers as market operator, by adjusting supply and demand. In case of internal congestion within the interconnections of Spain and Portugal, the resulted pricing of both regions is different.

On the other hand, the Intraday Continuous Market (or Single Intraday Coupling SIDC), has the aim of stablishing a common cross border continuous intraday solution across Europe. It serves the same purpose of allowing market participants to change their energy balance according to their real daily needs, and these adjustments are allowed until one hour before the energy delivery time.

Local Flexibility Electricity Markets

The introduction of small-scale distributed and intermitent renewable energy sources, transforms the generation side of the electricity market into a more variable and uncertain side, that must be addressed properly in order to ensure flexibility and grid stability. Moreover, consumers are switching towards more electrified forms of consumption, and their everyday life costs are much more linked to electricity, than they are to other fuels. Consumers will be more proactive in the electricity market with emerging types of loads like electric vehicles that shall be charged and discharged depending on market pricing signals and needs. Therefore, the new foreseen electricity grid shall include a locally managed market in order to address the needs of the electricity market in terms of flexibility and stability at all times in a local way.

Flexibility procurement is the responsability of distribution system operators according to the EU directive 2019/944, the article 42 of which advocates that *Member states shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services, including congestion management in their areas, in order to improve efficiencies in the operation and development of the distribution system*.

Therefore, local flexibility electricity markets, as the ones promoted by the Market Operator OMIE, will emerge as the solution to provide flexibility services to DSOs through providing demand reponse, electric vehicle storage management, and energy prosumers, in a local, distributed way. Moreover, the aggregation and real-time action of electricity markets represent an added value to energy prosumers and electric vehicle owners. This can usually be done by an aggregator.

But what is an aggregator?

An entity capable of managing several consumption points. Until now, aggregators have basically been interested in industrial consumption points, as they can manage larger amounts of energy, to aggregate them and find deals with the DSO or retailers, wether they can be related to flexibility services or finding energy purchase agreements. It is expected that in a near future there will be more interest in aggregating the storage capacity of the batteries within several Evs to do the same.

So, as a conclusion, an aggregator can be the bridge between end users and DSO, receiving the external needs from the grid and adapting the demand of the end-users to the requirements automatically, at any time, once a deal is agreed between all parts.

The flexibility is usually defined as a difference between the energy "baseline" curve, and the potential increase or decrease of demand at a given time. An upward flexibility is the refered term of an increase of demand (i.e when there is a surplus from renewable production, to avoid losing the energy), and a downward flexibility is the refered term used when the grid requires consumers to decrease their demand (i.e turning of HVAC, or compensate injecting the missing energy from storage units).

Given the situation, electric vehicles can play an important role in balancing the grid thanks to flexibility services that can be achieved while the vehicles are parked. This can make more interesting also for energy communities to buy shared EVs. In this training, the different applications for EVs will be introduced. There's actually a pilot in UK in which different technologies regarding flexibility through EVs are being tested.

In Spain, IREMEL project was the first approach to these local flexibility electricity markets developed by IDAE and OMIE. It aims to promote the participation in electricity markets of distributed renewable energy producers and consumers, as well as EV owners through battery management and V2G, charging control etc. This new type of market would ensure a decentralised flexibility management of the decentralised renewable energy grid, addressing congestion problems and grid stability situations in a local, decentralised way. The participation in local flexibility electricity markets results in more competitive prices due to the provided flexibility pushing for the integration of renewable energy sources and the empowerment of the electricity consumer.

Finally, as mentioned before, as the plan is to install more renewable energies in the future, to depend less on combustion technologies, storage will be key specially during non renewable energy production moments, to prevent the prices to ramp up due to the use of conventional energy sources. It is also worth mentioning that by 2035 EU is banning the sales of vehicles running with combustion engines, and more charging stations are being installed in parallel to facilitate the integration of EVs in the general vehicle stock.

Vehicle to grid, vehicle to building and smart charging concepts

Nowadays, transport sector in Spain represents 25 % of overall greenhouse gas emissions, with domestic transport representing, since 2016, the highest source of GHG emissions in Spain and the second in the EU-27, only after energy supply. European regulation sets to reduce 50% of GHG emissions from cars by 2030 and cut emissions from cars and vans by 2035. Therefore, a rapid change and revolution is expected in the automobility sector to adapt to the new reality, with an expected rapid growth in electric vehicle fleets in both the private sector and also the public transport fleets.

This not only opens the possibility for electric vehicle owners to become part of electricity markets by smart charging the battery and selling the energy stored when demand peaks occur, but it will also release the opportunity for electricity market operators to adapt to the new reality and find in the increasing fleet of mobile electric batteries an opportunity for the stabilisation of the grid. At the beginning of 2023, the European Commission already exposed that the Spanish electricity grid was not capable of adopting the large renewable capacity planned for the following years, with the transmission network not growing at the expected rates. The electricity grid then, is facing capacity and transmission problems due to the increasing capacity of renewable energies installed, lacking storage capacity and grid infrastructure.

Let's go deeply into the different modes in which EVs can contribute into the new energy scenario:

V1G – Unidirectional charging

It is the simplest way of implementing smart EV technology. It consists on charging the vehicle when prices are low, which can be checked through different websites or apps, and at the same time, avoid charging at peak prices. Smart charging would consist in integrated apps for the EV which indicate when is the best moment to charge the electric vehicle in order to optimize costs of charging. If the system dynamically reacts to price signals to charge the vehicle, it results in a minimization of charging costs for the user.

V2G – Vehicle to grid

V2G is based on the principle that a vehicle is statistically parked 95% of the time, and thus it deals with bidirectional charging technology for electric vehicles in order to not only charge the electric vehicle battery for transportation purposes, but also to use the battery as a mobile energy storage solution to compensate for imbalances in the grid. Therefore, the EV battery serves the purpose to provide a service to the electricity grid when needed to provide the necessary flexibility to the grid when the demand peaks over the generation capacity of the grid.

This technology requires specific charging stations, with auditable service render and a communication platform to control the V2G system in an optimal way. In order to properly use the EVs for grid flexibility and stabilisation purposes, a large aggregated amount of connected electric vehicles or fleets is required. If automatised, it allows to provide flexibility from both the supply side (electricity from EV battery to the grid), and the demand side (from the grid to the EV battery) optimizing charging and discharging to provide this needed flexibility to the grid, while optimising the cost of charging for final users.

V2B – Vehicle to building

In this case, V2B is also a bidirectional charging technology that connects the electric vehicle battery with the building itself. Therefore, not only can the car be charged at home, but it can also be discharged providing a service to the building's electricity consumption. The concept of V2H, or vehicle to home, is a related concept in which the electric vehicle provides a service to a home. This category is also refered to as *behind the meter* and it can be implemented with current regulation already, as it does not depend on electric market and thus it does not depend on current market regulation.

This way, the V2B technology provides an optimal charging/discharging option such that when the electricity prices are high the vehicle can be discharged, using its stored electricity for home consumption purposes, while at the same time, when the prices are low, the vehicle can be charged.

This technology can be combined with V2G by providing services both to the building/home or to the grid depending on price signals and demand peaks or grid imbalances. Moreover, the V2B/V2H technologies can generate an added value to the final user by reducing the bill, and if combined with a PV self-consumption installation, by maximizing the self-consumption coefficient, without having to install an external battery for the home supply, as the one from the car can be used in the same way, charging the vehicle when there is a surplus of production coming from PV, and using this energy during the night, for example.

V2X – Vehicle to everything

In general terms, vehicle to everything consists on the concept where electric vehicle batteries are used together with other electrical systems by providing them with electricity from the EV battery to comply with a certain service. Therefore, V2G, V2B and V2H are particular options of V2X technology, which can be combined and used at the same time when integrated in a dedicated software to manage the charging points.

Why V2G, V2B and V1G?

Benefits of V2X can be understood from both the perspective of final electric vehicle users, and the perspective of distribution system operators (DSOs), transmission system operators (TSOs) or the grid in general.

With regards to the grid, V2G can compensate congestions due to overloads or other stress moments, by providing energy storage solutions to the electricity system that can be charged or discharged depending on each moment's need. A big enough electric vehicle fleet could reduce or delay investments in transmission and distribution infrastructure such as transformers of power lines by enabling a more decentralised storage and distribution of energy. Moreover, the benefits received by final users could enhance and promote electric vehicle solutions, which would reduce the carbon footprint of the country if charged with an electricity mix mostly made up of renewable energy. As from the grid's perspective, the V2G capacity to ensure flexibility purposes to the grid is higher than other distributed energy resources, as it has a higher activation capacity.

On the other hand, final users can account for several benefits from opting for V2G or V2B technologies for the charging/discharging process of their electric vehicles.

- **Reduction of the final electricity bill**: V2B or V2H as well as an optimised smart charging with V1G, provide an efficient charge/discharge process to electric vehicle owners, allowing them to charge their vehicle when electricity has a lower price, and, with V2B and V2H, discharge it to power their building/home when electricity prices are high. At the same time, researchers found that with V2G technology being used, a **significant reduction of charging costs** would be observed as well.
- **Smart charging:** Included as part of V2G and V2B technologies, smart charging allows to automatically fulfill grid or building requirements by maintaining enough battery capacity for vehicles to be ready to go at all times, with enough capacity for their day-to-day activities and behaviours. Automatisation also allows for an optimal charge/discharge process reacting to electricity prices and grid requirements.
- **Protection against electricity prices spikes:** These technologies offer the ability of users to react to electricity price signals to modify their consumption behaviours to save energy when demand prices are high and consume it in moments when electricity is cheaper. EV batteries provide users with the ability to store more energy and adapt to each moment.
- **Promote self-consumption:** V2B/V2H and V2G and even V1G promote self-consumption installations but providing storage services and thus enhancing the self-consumption coefficient potential of the installation by ensuring a more cost-efficient usage. As the surplus of PV production can be stored and used later, it limits its injection to the grid (as sometimes the sale price is low for the end user) and prevents from buying energy (sometimes more expensive) at other hours when otherwise it wouldn't be possible to be fed by the PV installation.
- **Source of income:** V2G technology can provide an extra source of income for EV users which helps reduce the operational cost of electric vehicles. When the service is provided in the electricity markets, EV users receive an income for the energy supplied to the grid, which results in a net incentive for EV users to participate in flexibility electricity markets.
- **Easy controls over the vehicle state-of-charge:** Final users need to have control over the EV independently of V2G technology. Therefore, a serious tracking of the autonomy and state-of-charge of the vehicle is provided generally through apps developed by the technology providers. These apps usually allow to program trips to ensure a certain state of charge before using the vehicle.

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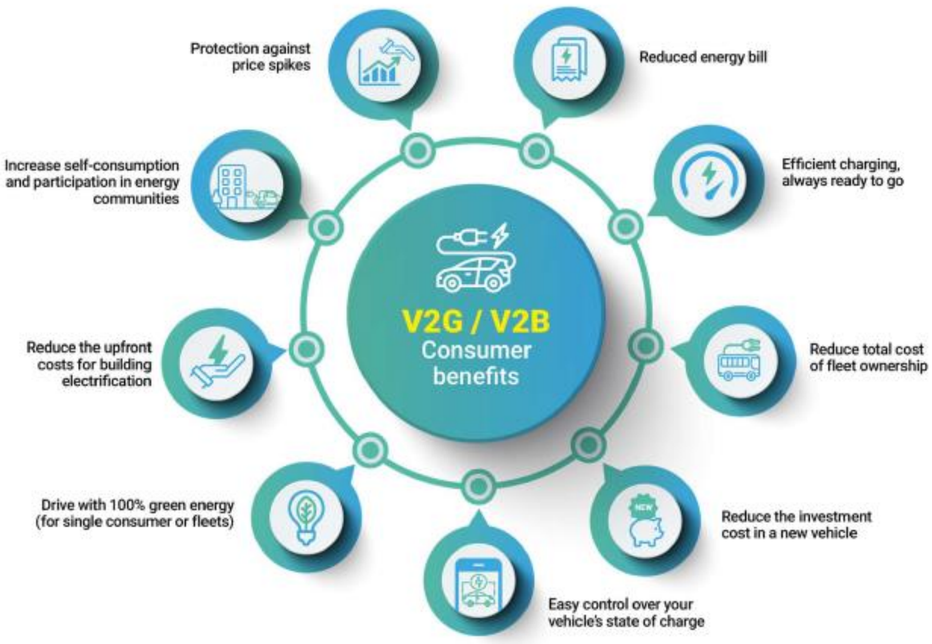

Figure 6 Consumer benefits. Source: V2M (Owned)

- **RES promotion:** When offering energy storage capacity through EV batteries, the grid can deploy easier the penetration of renewable energy sources (RES). When RES are locally available resources and governance models for their exploitation respond to citizen empowerment and increased democracy, environmental and social impacts from traditional energy sources to RES are positively affected.

3.2 Specific training 1

The first specific training session is addressed specifically to AMB vehicle fleet users, who are ultimately to be the first pilot users. It is open, however, to any particular group or individual interested in the content to be dealt with throughout the training session. The session is divided among three great blocks:

- **Usability**:
  - Dealing with basically how the incorporation of bidirectional V2G chargers and the V2G technology may affect the usability of the fleet of vehicles from a worker's perspective.
  - Software used (Fleetbox Platform)
- **Objectives of the Pilot**:
  - Variables to be measured
  - Testing
- **Concerns and risks**:
  - Battery capacity

- Improvisation and urgent vehicle use

The last part of the training includes a question-and-answer section in which all the members of the AMB staff are invited to provide their concerns and discuss how viable the use of V2G technology is for their daily activities.

Introduction

In the current situation of climate change, energy transition is currently in the centre of many political debates. What seems clear is that in 20-30 years, many EU countries, including Spain, have committed to have the national electric grid to be 100% renewable, and the vehicle fleet will mostly consist in battery electric vehicles. Vehicle to grid and vehicle to building technologies seem to appear as a solution to connect these two changing actors to ensure a stable grid of the near future.

Companies and administration with electric vehicle fleets like AMB have an opportunity to combine the renewable energy (potentially in the form of self-consumption as well) and the mobile energy storage solutions present in their electric vehicles to improve the energy efficiency of their buildings, and to provide them with an extra income from the use of their electric vehicle batteries' energy to supply the grid in case of necessity and grid imbalances, as well as more independency from the grid by optimizing the self-consumption possibilities.

In the framework of V2Market project, two pilots are organised to serve as testing periods for the V2X technologies and the usability of the electric vehicle fleets combined with V2G technology. Under this premise, AMB electric vehicle fleet is chosen to be the first testing period for the project, with which vehicle to grid shall be tested.

This way, electric vehicles used by AMB workers are to be connected to the grid at all times when parked, so that the bi-directional charge can be tested through a simulation of the local flexibility market involved in the operation.

Objectives of the pilot

The pilot part of V2Market project consists in testing the V2G technology in AMB facilities using AMB electric vehicle fleet. The testing period will run by the responsible involved parties – AMB, OMIE (for energy market communication testing), and Nuvve. The main objective is to test the V2X technologies through the use of bi-directional chargers in the controlled environment of the AMB electric vehicle fleet.
On the other hand, the pilot will serve to test the software responsible of managing the different charging points, to provide V2G services without interfering the usual usage of the vehicles.

The performance of the V2X service is to be collected in technical factsheets, in which involved actors of the testing period are to include technical, administrative, and legal barriers found during the pilot. An evaluation survey is also included at the end of the testing period in order to gather all the information and experience from the users' perspective so that the ICT tool can be better adapted to improve in terms of usability.

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Usability of the vehicle fleet

So, after discussing about the possibilities of V2X, some concerns may rise when it comes to adopting such technologies on the vehicle fleets. The main ones identified are related to the usability and the potential alteration of normal behaviours when it comes to the vehicle fleet use. For example:

- Can I use my car normally?
- What about battery degradation?
- Is this all automatic? How much time or effort does it require from the user side?

This chapter describes the main usability features of the Nuvve software so that EV fleet users can easily adapt to the incorporation of V2X technologies.

Trip schedule

The Trip Schedule feature in the bi-directional software control within Nuvve's Fleetbox software enables users to plan when their vehicle will be used. It allows setting a predetermined departure time, ensuring the electric vehicle is adequately charged for the required range. This feature complements the safety range, ensuring the vehicle is always ready while aiming for a specific state of charge (SoC) at the scheduled departure time. Additionally, users can schedule recurrent trips, removing the need for programming each one separately.

Range Anxiety

Nuvve's V2G Technology platform follows electricity market signals and user desired range inputs to adapt the charge and discharge controls of the EVSE. One of the modes of operation Nuvve specializes optimizes economic benefits by flattening demand peaks and adapting to supply surpluses while considering the battery related variables of range of vehicle determined by SoC and the vehicles battery capacity.

Range of battery charging for better conservation: With lithium-ion batteries, degradation of the battery will be sped up by elements such as temperature of the vehicle, the use of fast DC charging, and the driving habits such as sudden accelerations. An important factor is whether the battery is completely charged and completely depleted, if they are maintained in a range of partial charging. Many experts consider the battery will degrade less if its only charged at 80% and only discharged at most 20%, but this depends on actual battery manufacturer. This is linked to good practices for conservation. A lower range is also relevant for conservation if the battery is not in use for long periods of time. (Which can also occur with prolonged periods of fully discharged battery. Nuvve´s software considers the range of charging in which the battery can operate (the degradation range). Battery safety thresholds are established to keep the battery's health a priority.This way the battery shall never be charged higher than a certain level nor discharged to a state of charge lower than a certain level. In conclusion, the degradation of the electric vehicle battery is not negatively affected by the participation in the electricity market while plugged. Some EVs may also come with these limits established as a baseline setting for charging capacity, and so do some of the battery management systems. Note that the number of charging and discharging cycles linked with V2G, if done within the

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conservation parameters, do not degrade or deteriorate the battery significantly according to most recent studies and tests.

Moreover, another key feature determined by the software used by Nuvve's bi-directional charging software is the *safety range* which is a distance range (in km) that can either be predetermined or defined by each user. It sets a threshold in the available battery state of charge. This ensures a minimum autonomy range for the electric vehicle at all times in case of emergency or unexpected electric vehicle need. This way, electric vehicles are always available for its use independently of the current electricity market participation.

Software usability module

Let's introduce how the software developed by Nuvve operates:

Fleetbox
The fleetbox software allows electric vehicle users to preset their trip details and schedule, so that the vehicle can be ready for them. The V2G operation is automatically deployed once user agreements are in place. These agreements are based typically between Nuvve and another party (usually the fleet manager or fleet owner). The software has six main tabs:

Overview
The overview tab serves as a summary of the fleet of electric vehicles connected to the grid through the bidirectional chargers. In the case of the AMB facilities, there are three chargers located in building A. Thus, the overview tab shows the total amount of power from the grid to the cars, and the total amount of power from the car to the grid at all times, plotting the power balance curve as well. It also summarises the number of chargers charging vehicles, the number of chargers taking electricity from vehicles to the grid, the number of plugged chargers, available chargers, and offline chargers.

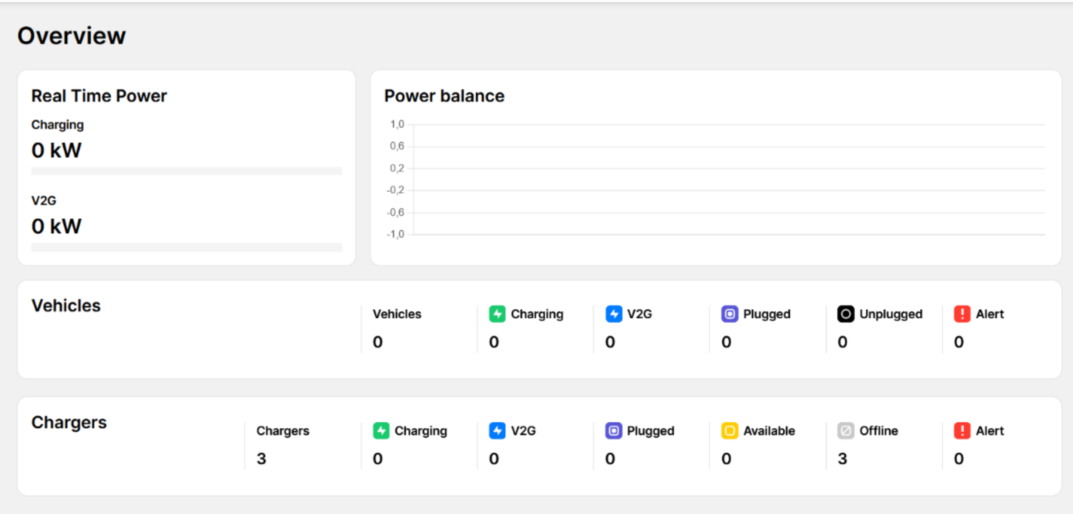

Figure 7: Screenshot of the overview tab of Nuvve Fleetbox platform.

Vehicles

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In the vehicle tab, one can find information regarding the status of each vehicle (plugged, unplugged, etc.), the state of charge of the vehicles, the charger, the site in which they can be found, and their trip schedule. It is, therefore, a summary of the basic information of each vehicle and the planned usability of each of them.

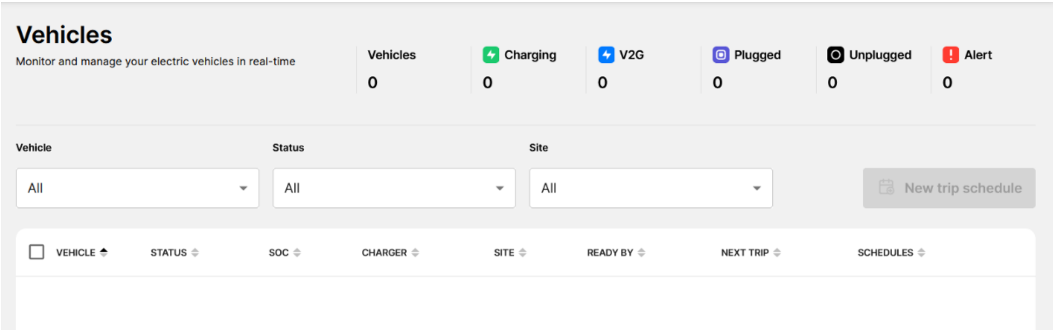

Figure 8: Screenshot of the vehicles tab of Nuvve Fleetbox platform.

Trip Schedule

This tab allows to plan the required trips for the vehicles so that the bidirectional chargers have the information of when the vehicles are to be 100% ready and with the desired state of charge.

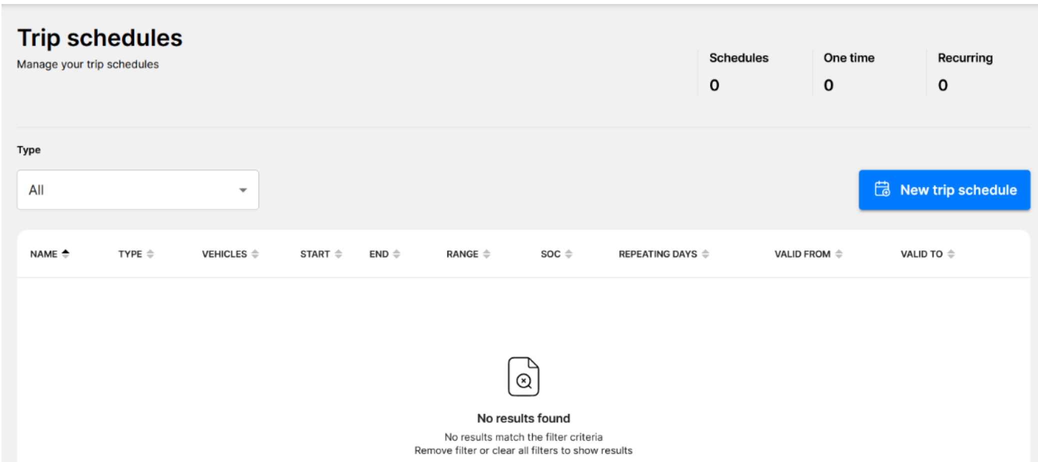

Figure 9: Schreenshot of the trip schedule tab of Nuvve Fleetbox platform.

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It has an option to add a new trip schedule in which the dates and times are to be selected along with the vehicle to be used. Down below appears a summary of all the schedules for the day with the start and end date and time, and their recurrency. The trip schedules can be one-day trips or recurring trips.

Chargers
The *Chargers* tab is used as a summary of the three chargers available at the AMB facilities. It provides users with information about the charging/discharging state of each charger, the status of the chargers (plugged, available or offline) and any possible alert. It also provides information about the vehicles plugged in each charger, with information about the next planned trip, hence information about the future availability of the chargers, and the next charging window.

Currently the three chargers appear offline as they are to be started once the pilot begins. It also includes the information about the location of the bidirectional chargers, which in this case are located all at the same site in building A. There are also optional filters to be applied to see particularities in the system.

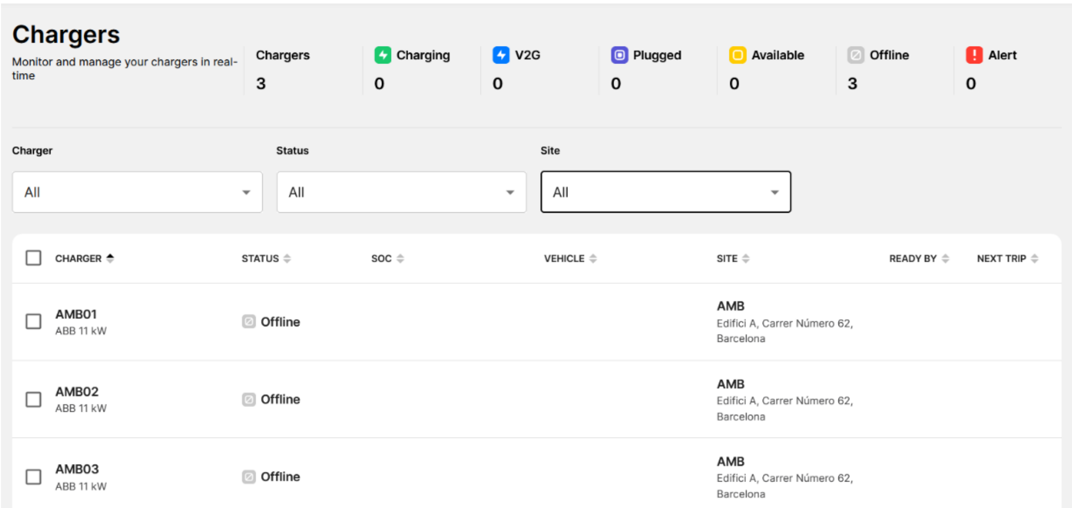

Figure 10: Screenshot of the chargers tab of Nuvve Fleetbox platform.

Sites and reports
The sites tab provides a summary of the information of each charger but separated among sites. In this case, there is only one site, so the tab might be repetitive. However, when more than one site with bidirectional chargers is available, this tab separates the information among different sites.

Finally, the *reports* tab, is where any available report of issues or activity can be found in the platform.

Fleetbox App

Apart from the Fleetbox platform there is an additional mobile app that provides users with the same information from their smartphone devices.

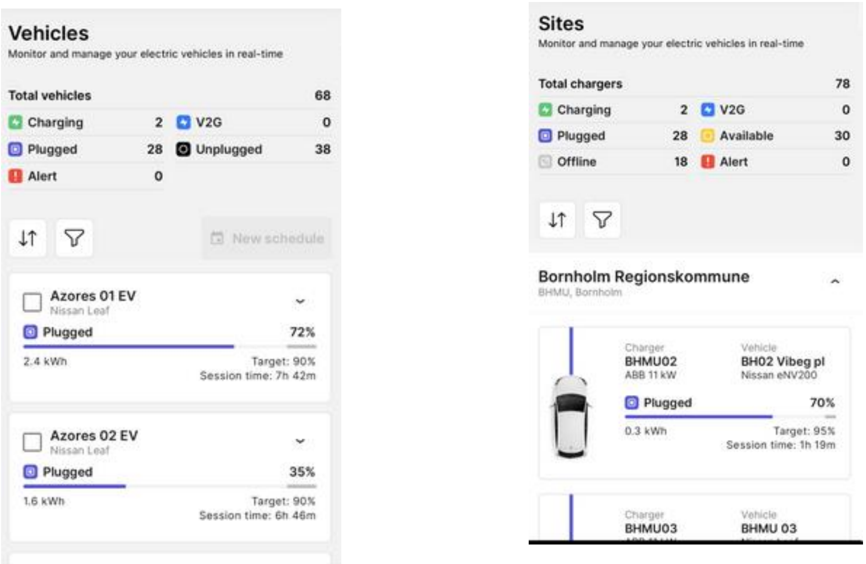

Figure 11:Screenshots of the vehicles and sites tabs of the Fleetbox app.

As shown in figure 7, the app has a similar appearance and usability as that of the platform, with little changes. It also allows users to plan their scheduled trips, see the availability and SOC of the plugged cars and chargers, and the planned charging window, desired final SOC, and the power balance between EV charging and V2G.

Reports on energy usage and discharge can be easily generated with a simple click in the “Generate Report” blue button on the reports tab of the app. The trip scheduling section is operated similarly to that of the platform, selecting whether it consists of a single or recurring trip, the duration of the trip, and the desired range of autonomy of the selected electric vehicle.

There are similar platforms/software available in the market, presented in the last slide, such as Hive power – Flexo, SYNOP or Driivz.

3.3 Specific training 2

The specific training 2 contains information dedicated specifically to electric vehicle users, although, again, it is open to any group interested in the content of the training. The training is divided among three main blocks:

- **How to benefit from V2X:**
    - Smart charging
    - V2B and price signals
    - V2G and economic compensation
- **The concept of battery as a service**
- **Potential concerns from users:**
    - Battery degradation
    - Battery ready to be used

The last part of the training is organised as an open discussion session with all participants in order to identify their particular concerns, opinions and objectives for a better understanding of the user perspective in order to properly identify their needs and concerns for the better development of the project.

Introduction

We find ourselves in a situation of both climate emergency and energy crisis. The climate emergency is caused by climate change and an uncontrolled amount of GHG emissions being sent to the atmosphere ever since industrial revolutions. The transportation sector represents in Spain up to 25% of their total greenhouse gas emissions, being one of the highest GHG sources of the country. Electric vehicles, although probably not the only one, it is one of the technological solutions proposed to avoid this great amount of greenhouse gases being emitted to the atmosphere. Moreover, electric vehicles are way more efficient than traditional ones, with efficiencies of up to more than 90%, resulting in less energy required for their use.

Electric vehicles by themselves are not the solution of the current problem, but they open up many possibilities to take into account when thinking about the electricity system of the future, in which EVs will potentially play a key role.

Battery as a service

Before going into detail about the flexibility services V2M project is testing, it is worth introducing the concept of Battery as a Service, as a complementary measure that can be considered when owning an electric vehicle.
We are typically used to own our vehicle, as with most of our daily things. However, society is moving towards the so-called “servitization” of things. It consists of paying for the use of something, but without having to own it entirely.
Regarding electric vehicle’s batteries, some manufacturers are starting to offer subscription plans for batteries, for example. It can be a way to “rent” somehow the battery, and only pay for the use of it, not for the battery itself.

This reduces the price of owning an electric vehicle, making it a more attractive alternative and accessible to a larger population.
Usually, these services include the replacement of the battery after a couple of years without having to pay an extra fee. It is a way to ensure the car runs at good performance at all times.

In addition, some motorbike manufacturers who have a considerable fleet, allow the users to replace the battery in certain hubs or headquarters every time they want instead of charging it, so the user doesn't have to charge it and it can continue its journey in less than a minute. However, this is mostly possible in big cities, but it might not be feasible in small villages.

Figure 12 Servitization. Source: V2M (Owned)

Battery as a Service usually is paid by end users by a monthly or annual subscription and formalized through an agreement when buying the vehicle.

How to benefit from V2X

Smart charging

EV owners can avoid peak prices of electricity for their vehicle with smart bidirectional chargers, following market-guided price signals that favour flexibility purposes in the grid from the demand side, and thus, by adjusting to the price signals, charging the vehicle for lower prices, while maintaining enough battery capacity for the vehicles to be ready to go at all times, with enough capacity for their day-to-day activities and behaviours.

Let's imagine the price curve for a random day is the following:

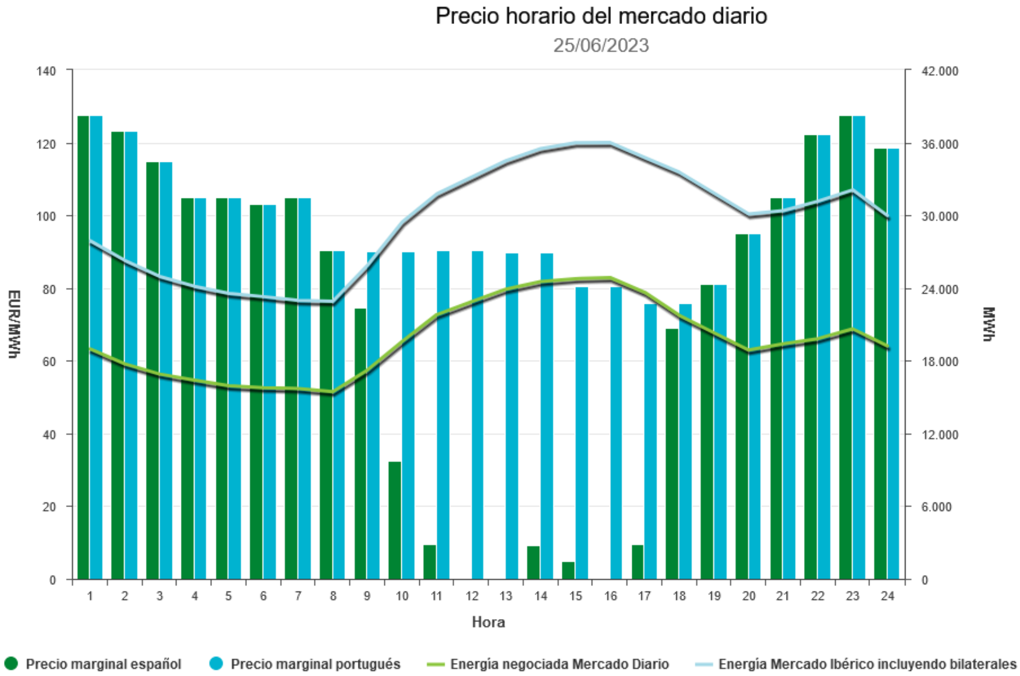

Figure 13 Daily market price in Spain. Source: OMIE

This is the daily wholesale electricity price from the day ahead electricity market of a particular day in Spain (green) and Portugal (blue). Taking Spain as a good example of what the electricity price curve will look like in an 100% renewable energy grid, the most expensive hours would have a price around 110 €/MWh, while the cheapest prices have a price of nearly 0, let's assume 10€/MWh. Charging an electric vehicle with a battery capacity of 50 kWh, from 20 to 80% would cost 3.3 € if done during the expensive hours of the particular day shown in the previous plot, but it would cost 0.3 € if done during the cheap hours. Smart bidirectional charging technologies can allow for our vehicle to optimise the charging and discharging processes of the battery in order to charge it in the most economically efficient way, obtaining direct economic savings from it.

Vehicle to building

The same principle applies for the vehicle to building or vehicle to home technologies. Having an electric vehicle connected directly to our home, ultimately means having a large capacity energy storage solution integrated to our homes. Therefore, if used in a smart way, following the price signals, the same way it can be charged during the cheap hours, it can also be partially discharged during the expensive hours.

Let us take the plot of electricity prices from above. If the vehicle is fully charged during the cheap electricity hours (from 12 to 17h), it could be used to provide electricity to our appliances during the expensive hours. For instance, let us imagine we want to use the electric cooking stove at 9pm to prepare dinner. Considering the use of an electric induction stove, with medium power (around 1 kW) during an hour, would consume 1 kWh. If done during the expensive electricity price hours (9pm) this would cost around 0.1 €, but if the electricity stored in the vehicle is used, it would cost around 0-0.01 €, so around 10 times less. Extrapolating this value monthly, at the end of the month, cooking directly with electricity from the grid would cost 3 €, while doing it with the electricity from the vehicle would represent 0.3 €.

Therefore, vehicle to building and vehicle to home technologies, allow for the electric vehicle owner to avoid peak electricity price hours and maximise the use of the electricity provided during cheap hours, obtaining a more economically efficient management of the electricity, and hence, a direct economic saving.

Vehicle to grid

The vehicle to grid principle is based on the fact that cars are stationed for around 95 % of the time, meaning that it is a portable electric unused battery most of the time. Imagining a future with a large electric vehicle fleet, connected all the time when parked, with V2G technology, it would represent a large energy storage solution for the renewable energy grid of the future.

This way, the intermittent renewable energy grid could benefit from the large number of portable electricity storage solutions connected to the grid, to alleviate congestions and also provide electricity to the grid when necessary, achieving the so called and so desired grid flexibility.

From the electric vehicle owner's point of view, the benefit from vehicle to grid technologies is a direct revenue from the use of energy of their vehicle. In terms of contractual agreements, it is the aggregator who owns the recharging point to which the EV is connected, and therefore it is the aggregator who sells the electricity provided by the car (it has a deal with the DSO or an energy retailer) and is responsible of contracting and obtaining the necessary electricity to recharge the battery. The electric vehicle owner allows the aggregator to use the EV battery for its own benefit, while receiving an economic compensation from the aggregator for the use of the battery.

To sum up, from the use of V2G technologies, the electric vehicle owner would benefit from a direct economic income (compensation) for the electricity that has been provided to the grid, ensuring flexibility purposes. Moreover, the overall electricity prices will see a general decrease due to the shift of supply and demand.

Hybridise with PV installations

Another extra interesting advantage of the V2X technology is the hybridisation with home PV self-consumption installations. Currently, the cost of photovoltaic solutions has dropped, and they have become an interesting solution for many households. A self-consumption installation

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might require, or be more interesting with a storage solution, as it allows to maximise the self-consumption coefficient from household's consumption. However, electric batteries are expensive and could even duplicate the overall cost of the self-consumption installation.

Having an electric vehicle, as mentioned above, means having a large portable electric battery. The same way as the electric vehicle battery could be charged during cheap hours and discharged during expensive hours in a smart way, it could also be charged during self-consumption hours, so with the solar energy generated in the rooftop, at cost 0, and discharged during the expensive hours. This would ultimately convert the electric vehicle into the storage solution of the self-consumption installation, obtaining a higher self-consumption coefficient, and optimising the use of the PV installation, reducing the overall cost of electricity bills, and thus getting a lower payback of the installation.

Potential concerns

From the electric vehicle owner's perspective, three potential concerns have been mainly identified. First, there is the phenomenon defined as range anxiety from electric vehicle owners. Range anxiety is defined as a stressful experience from which electric vehicle owners as a result of a fear of running out of energy before being able to recharge the battery. [5] Let's discuss how managing the charge of the battery through V2X services can prevent this from happening.

Usability of the vehicle at any time

With the use of V2G, V2B or V2H, electric vehicle owners might be afraid of not being able to fully use their vehicles because of the discharging process performed by aggregators when the battery is connected. However, in the contractual agreements between aggregators and EV owners, there is a key definition to be determined, which is a minimum state of charge (SoC) of the electric vehicle battery after the V2G operation. So, aggregators cannot fully discharge a battery, which would result in the EV owner not being able to use the vehicle. There is then, a contractual definition of a minimum autonomy that must be ensured in the electric vehicle at all times. A desired SoC is also defined in the contractual agreements between aggregator and owner as the ultimate SoC that the vehicle ought to be at the end of the operation.

Added charging costs

V2G has been presented as an economically optimal solution for EV owners by receiving an economic compensation for the electric battery use by aggregators. However, as bidirectional smart chargers partially discharge the battery, they are also responsible for recharging it after the operation, ensuring at least the minimum state of charge defined in the contract. The battery is fully charged towards the desired SoC defined, only if the electricity price is not higher than the maximum electricity price determined in the contract. This way, it is avoided that added charging costs surpass the economic benefit from the V2G technology for the EV owner.

Battery degradation

Another identified key concern from EV owners when considering V2X technology is battery degradation. As part of the contractual agreements between aggregators and EV owners, it is

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of utmost importance then that the owner is informed and protected from problems related to battery degradation which could be directly related to the V2X technology. A warranty is then defined as part of the contract when the battery is user-owned, providing degradation security to the electric vehicle owner. On the other hand, if the battery is owned by a third party, through servitization contracts, it is considered that all the maintenance/replacement conditions ought to be properly determined.
Besides, the software in charge of performing V2G services performs not the only considering the economic benefits, but always ensuring a charge or discharge will not compromise the battery's lifespan, so it may decide whether or not to charge the vehicle according to different variables.

Moreover, a study by Dai Wang et al [6], shows that battery degradation if the vehicle SoC is always kept between 20 to 80% is minor. Another consideration to be considered is the type of charge. Battery degradation is higher when the charge is performed with rapid DC chargers, while it is much lower if performed with slow AC chargers (usually home-like chargers). Therefore, if grid services do not overcome the aforementioned SoC range, and it is performed with slower chargers, so with slow charges and discharges, the extra degradation of the battery ought to be much lower than with the use of fast chargers. [8]

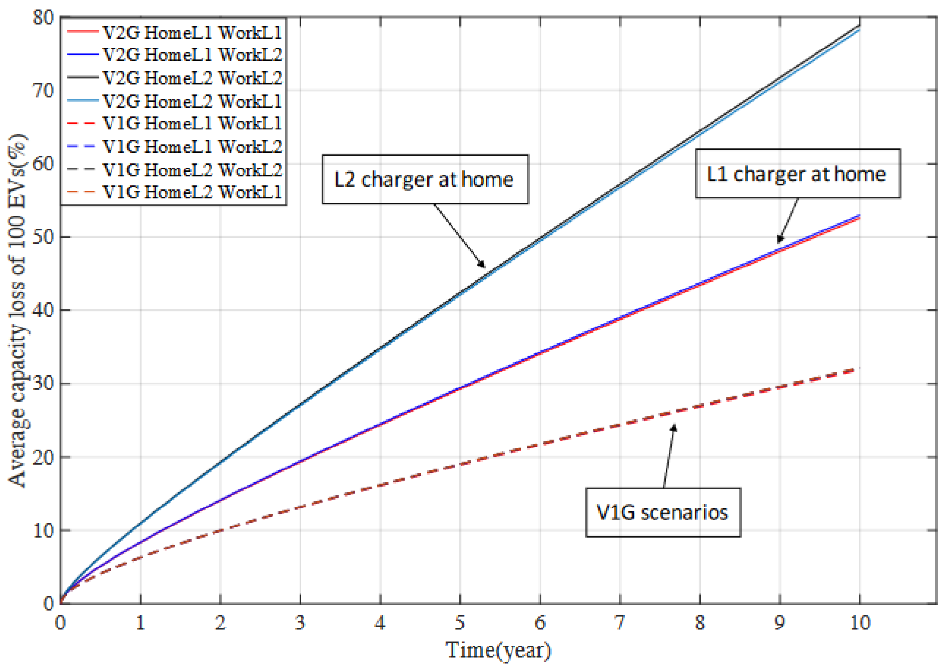

Figure 14 Electric Battery Degradation. Source: Quantifying electric vehicle battery degradation from driving vs. vehicle-to-grid services

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3.4 Specific training 3

The specific training 3 contains information dedicated specifically to municipality technicians, although, again, it is open to any group interested in the content of the training. The training is divided among three main blocks:

- **Electricity markets:**
  - Relevant market actors
  - Data flow
  - Energy communities
- **Local flexibility markets:**
  - Renewable grid needs
  - Flexibility
  - Local markets
- **Electric vehicles:**
  - Battery degradation
  - Battery ready to be used

Introduction

In the current situation of climate emergency and energy crisis, we find ourselves in a situation of rapid energy transition being required. Energy transition, as conceived as the transition from a traditional energy sources like fossil fuels, towards renewable energy sources like solar energy or wind energy. This energy transition will ultimately require a change of model away from traditionally conceived energy system towards a new, more distributed, and decentralised energy system, with smaller, distributed energy sources all over the territory.

Energy Supply Chain

Before going into detail, we must identify the main actors that take part of the electricity market and which are their roles, so we can then talk more deeply about the operation of the market on a daily basis.

Generators: they are responsible for transforming natural resources (which may or may not be renewable) into electrical energy. There are nuclear, hydroelectric, thermal power plants, wind and solar farms, etc. Until the beginning of the century, the generation has developed mainly in a centralized way and outside the cities. Today, we are moving towards a distributed generation of electricity, since renewables and the possibilities offered by self-consumption modes make it possible to generate electrical energy on a small scale and in a much more local way.

Market operators (MO): Responsible of the operation of the electricity market, ensuring that all their markets are transparent and fair for all the participants, including V2G users. They give access to market platform to all the agents and guarantee the correct functioning of the

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systems, matching demand, and supply. The electricity market is in the centre of all the actors. Market operators are also in charge of nomination, receiving the bids, guarantees and carrying out the clearing and settlement processes.

Transmission system operator (TSO): TSOs are the responsible actors to transport electricity from the generation sites to regional or local electricity distribution centres through the use of high voltage electrical grid. TSOs are responsible for maintaining, operating, and planning a cost-efficient electricity network. They are also responsible of ensuring security of supply to all consumers, and to maintain stability in the grid. In Spain, the transmission system operator is *Red Eléctrica Española* (REE).

Distribution system operator (DSO): DSOs are the electricity system actors that distribute the electricity transported by the TSOs towards each consuming point. They are managers, and sometimes owners, of the distribution networks, and they distribute the electricity in low or medium voltage levels. They include bi-directional readings of the energy flow with real-time communication in order to rapidly restore the supply of energy if interrupted [8]. There are five main distribution system operators in Spain, depending on the region: *Endesa*, *Iberdrola*, *EDP/HC*, *Nedgia*, and *Viesgo*.

Energy Retailers: they are the companies we pay the bills to. There are more than 600 of them in Spain and they offer different tariffs with different prices, sometimes variable and sometimes fixed, which we can choose according to what suits us the most.

Energy Balance

Usually, energy sources like coal and gas plants, as well as nuclear plants, can adapt their production increasing it or reducing it to match the demand during the day. On the other hand, renewable energy technologies as solar or wind, are intermittent energy sources, meaning that there is no control over the amount of energy supplied, as energy is generated depending on the weather (when there is sun or wind), so the production cannot be increased when desired; windimills, for example can only be shut down in order to avoid producing energy surpluses, which are not needed and they may not be able to be stored.

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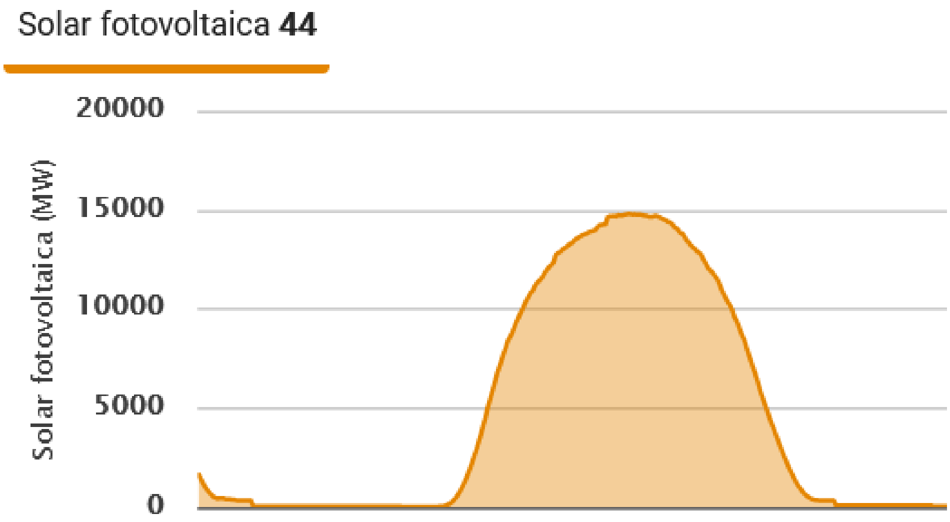

*Figure 15: Solar energy generation profile. Source: **REE***

Figure 9 shows the typical solar energy generation profile. Imagining an electricity grid fully composed of solar energy, it would mean that all the energy would be generated between 9-10 AM until 18-19 PM. On the other hand, the demand profile is more similar to what is shown in Figure 10. Traditional energy sources are easily adaptable to the demand side, so that a match between supply and demand is always achieved. In a 100 % renewable energy grid, this match between supply and demand must still be ensured. One way to achieve this match is through large amounts of energy storage facilities, storing the excess electricity generated in the peak hours, in order to supply it during the hours with no renewable energy generation or with a demand profile higher than the generation.

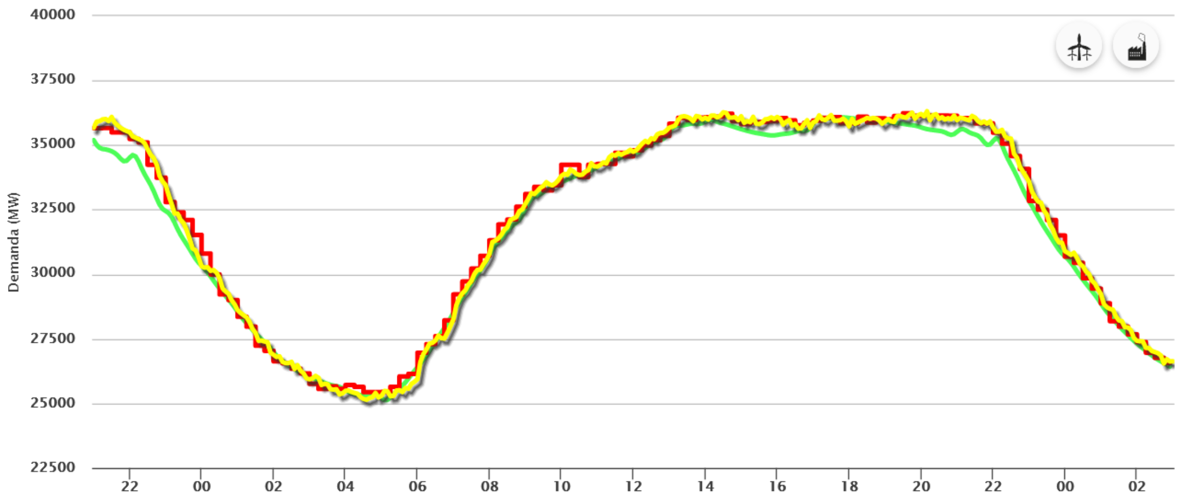

*Figure 16: Daily demand profile in Spain - 27th of june 2023. Source: **REE***

Therefore, the electricity model of a country transitioning towards a 100% renewable energy grid based mainly on solar and wind energies ought to properly adapt to these new changes. At the same time, a mobility transition is occurring, transitioning from petrol-based vehicles, towards electric vehicles. Most electric vehicles are known as BEV, meaning battery electric vehicles, and thus, incorporate a large battery in them to provide the necessary electricity to the engines. So, in the grid of the future, electric vehicles might emerge as a key actor to provide the necessary amounts of electricity storage required for the proper grid functioning. V2X technologies aim to introduce this concept of perceiving electric vehicles as portable electricity batteries providing a service to both buildings and the grid itself.

Electricity markets

The electricity market in Spain is liberalised since 1998, and since 2007 it is integrated with the Portuguesse market in the Iberian Electricity Market (MIBEL).
Nowadays, the price of electricity is determined in the electricity pool, which is the wholesale market where retailers and producers offer to buy and sell electricity. There are markets at different levels, by means of being able to buy electricity several months ahead upto one hour before the delivery of the energy, to buying certain amount of electricity every hour, for example.

The main wholescale spot market in Spain and Portugal is set as a day ahead market, together with intraday markets (with continuous intraday market and intraday auctions), as these three markets represent 92% of the total amount of energy negotiated in Spain.

In the current electricity system of Spain, there are mainly two electricity markets to be introduced, day-ahead market, and the intraday market. It is, however, interesting to first know all the main involved actors in the electricity sector.

Market operator
There is one or more nominated electricity market operator (NEMO) in each country or region, which is the responsible of managing the day-ahead and intraday electricity markets. They actively participate, together with the other designated NEMOs of other countries or regions in connecting the wholescale electricity markets in the European Union. For the case of the Iberian Peninsula (Spain and Portugal), the responsible for the operation and management of the electricity market is OMIE.

Aggregators
An entity capable of managing several consumption points. Until now, aggregators have basically been interested in industrial consumption points, as they can manage larger amounts of energy, to aggregate them and find deals with the DSO or retailers, wether they can be related to flexibility services or finding energy purchase agreements. It is expected that in a near future there will be more interest in aggregating the storage capacity of the batteries within several Evs to do the same.
So, as a conclusion, an aggregator can be the bridge between end users and DSO, receiving the external needs from the grid and adapting the demand of the end-users to the requirements automatically, at any time, once a deal is agreed between all parts.

Local flexibility markets

In a renewable energy grid, as seen previously, the generation of electricity is intermittent, uncontrollable, and variable. Therefore, in order to ensure security of supply, large energy storage solutions are required. Flexibility of the energy system might be an interesting option for DSOs, responsible of ensuring the security of supply, rather than reinforcing a more robust electricity system.

Flexibility has been typically achieved through the use of traditional power plants, like for instance natural gas co-generation power plants. These traditional power plants allow for the adaptation of supply to match the demand at all times. In the future renewable grid, natural gas power plants will not be a possibility anymore, and renewable based grid is more intermittent, and thus hard to alter in order to match demand. In this renewable grid then, flexibility will be achieved from the supply side through, for instance, energy storage, but also through the demand side, through price signals, adaptation, and electric vehicles.

Flexibility markets are an opportunity for distribution system operators to obtain flexibility and grid stabilisation, which can be more cost effective than grid reinforcement or maintenance in the distribution grid. According to article 32 of the European electricity Directive, *network development plans must include demand response, energy efficiency, energy storage or other resources that the distribution system operator is to use as an alternative to system expansion.* Also stating that their decisions ought to follow TOTEX instead of CAPEX only.

Flexibility markets are also the opportunity for DSOs to adapt to the new reality of a more decentralised scenario in which they might not be able to expand the grid as fast as new resources and new demand figures appear. Therefore, they are key for proper stabilisation of 100% renewable decentralised grids.

In order to promote a consumer-centric market incentivising their participation actively in electricity market transactions, proper flow of information is of utmost importance. Electricity consumers and prosumers ought to have full availability to their consumption and production (if any) data and transfer it to third parties. This way, consumers, prosumers, and thus, electric vehicle owners, can be part of demand management programs and thus obtain a benefit in their electricity bills.

Energy communities

There are two types of energy communities: Citizen energy communities (CEC, coming from Directive 2019/944) and renewable energy communities (REC, coming from Directive 2018/2001). Both entities are governed by their stakeholders and members and can participate within all the electricity sector, such as generation, aggregation, distribution, EV charging, V2X, etc. It still lacks regulation on the activity of local energy communities, although it is expected that within 2024, a more robust regulatory framework shall exist.

Nevertheless, energy communities create a framework of local energy generation and distribution contributing to the decentralisation of the electricity network and facilitating the access to renewable generation to every citizen locally. Directive 2019/944, the framework upon which CECs are based, states that energy communities can participate in the electricity market through the figure of aggregator, and thus, they emerge as an option for decentralised V2X technologies to be operated locally through the existence of energy communities.

Electric vehicles and V2X

Electric vehicle battery capacities range from 15-25 kWh capacities for short-range vehicles like the Nissan Leaf, up to 60-80 kWh for long-range vehicles like the Tesla Model 3 or the Volkswagen ID3. Assuming a usual household may use around 10 kWh per day, this can give us an idea of the capacity of car batteries. Let's go deeply into the different modes in which EVs can contribute into the new energy scenario:

V1G – Unidirectional charging

It is the simplest way of implementing smart EV technology. It consists on charging the vehicle when prices are low, which can be checked through different websites or apps, and at the same time, avoid charging at peak prices. Smart charging would consist in integrated apps for the EV which indicate when is the best moment to charge the electric vehicle in order to optimize costs of charging. If the system dynamically reacts to price signals to charge the vehicle, it results in a minimization of charging costs for the user.

V2G – Vehicle to grid

V2G is based on the principle that a vehicle is statistically parked 95% of the time, and thus it deals with bidirectional charging technology for electric vehicles in order to not only charge the electric vehicle battery for transportation purposes, but also to use the battery as a mobile energy storage solution to compensate for imbalances in the grid. Therefore, the EV battery serves the purpose to provide a service to the electricity grid when needed to provide the necessary flexibility to the grid when the demand peaks over the generation capacity of the grid.

This technology requires specific charging stations, with auditable service render and a communication platform to control the V2G system in an optimal way. In order to properly use the EVs for grid flexibility and stabilisation purposes, a large aggregated amount of connected electric vehicles or fleets is required. If automatised, it allows to provide flexibility from both the supply side (electricity from EV battery to the grid), and the demand side (from the grid to the EV battery) optimizing charging and discharging to provide this needed flexibility to the grid, while optimising the cost of charging for final users.

V2B – Vehicle to building

In this case, V2B is also a bidirectional charging technology that connects the electric vehicle battery with the building itself. Therefore, not only can the car be charged at home, but it can also be discharged providing a service to the building's electricity consumption. The concept of V2H, or vehicle to home, is a related concept in which the electric vehicle provides a service to a home. This category is also refered to as *behind the meter* and it can be implemented with current regulation already, as it does not depend on electric market and thus it does not depend on current market regulation.

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This way, the V2B technology provides an optimal charging/discharging option such that when the electricity prices are high the vehicle can be discharged, using its stored electricity for home consumption purposes, while at the same time, when the prices are low, the vehicle can be charged.

This technology can be combined with V2G by providing services both to the building/home or to the grid depending on price signals and demand peaks or grid imbalances. Moreover, the V2B/V2H technologies can generate an added value to the final user by reducing the bill, and if combined with a PV self-consumption installation, by maximizing the self-consumption coefficient, without having to install an external battery for the home supply, as the one from the car can be used in the same way, charging the vehicle when there is a surplus of production coming from PV, and using this energy during the night, for example.

V2X – Vehicle to everything

In general terms, vehicle to everything consists on the concept where electric vehicle batteries are used together with other electrical systems by providing them with electricity from the EV battery to comply with a certain service. Therefore, V2G, V2B and V2H are particular options of V2X technology, which can be combined and used at the same time when integrated in a dedicated software to manage the charging points.

Utrecht bi-directional charging station is an example of a large V2G power station project that can help stabilise the grid in a local way. This V2G bi-directional charging power station is located in a solar powered car park with an expected annual solar generation of between 850 and 1,000 MWh. It is expected to include 500 bi-directional chargers that shall add up to the already existing over 1,000 bi-directional chargers in the city. From the project's perspective relating to a study by the University of Utrecht, it is expected that 10,000 bi-directional electric vehicles would be enough to balance peak power demand locally in Utrecht, and up to 20,000 would be enough to cover the winter night power use. [9]

Battery degradation

Th main identified key concern from EV owners when considering V2X technology is battery degradation. As part of the contractual agreements between aggregators and EV owners, it is of utmost importance then, that the owner is informed and protected from problems related to battery degradation which could be directly related to the V2X technology. A warranty is then defined as part of the contract when the battery is user-owned, providing degradation security to the electric vehicle owner. On the other hand, if the battery is owned by a third party, through servitization contracts, it is considered that all the maintenance/replacement conditions ought to be properly determined.
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References

[1] Oficina Nacional de Prospectiva y Estrategia del Gobierno de España (2021). España 2050: Fundamentos y propuestas para una Estrategia Nacional de Largo Plazo. Madrid: Ministerio de la Presidencia. Gobierno de España.

[2] Informe de Red Eléctrica Española, Power Generation: https://www.sistemaelectrico-ree.es/informe-del-sistema-electrico/panorama-europeo/generacion

[3] National Grid ESO, What is energy Flexibility: https://www.nationalgrideso.com/document/189851/download

[4] European Comission, Energy Department. Flexibility markets: https://energy.ec.europa.eu/topics/research-and-technology/flexibility-markets_en

[5] Rauh, N., Franke, T., & Krems, J. F. (2015). Understanding the impact of electric vehicle driving experience on range anxiety. *Human factors*, *57*(1), 177-187.

[6] Wang, D., Coignard, J., Zeng, T., Zhang, C., & Saxena, S. (2016). Quantifying electric vehicle battery degradation from driving vs. vehicle-to-grid services. *Journal of Power Sources*, *332*, 193-203. https://www.sciencedirect.com/science/article/abs/pii/S0378775316313052

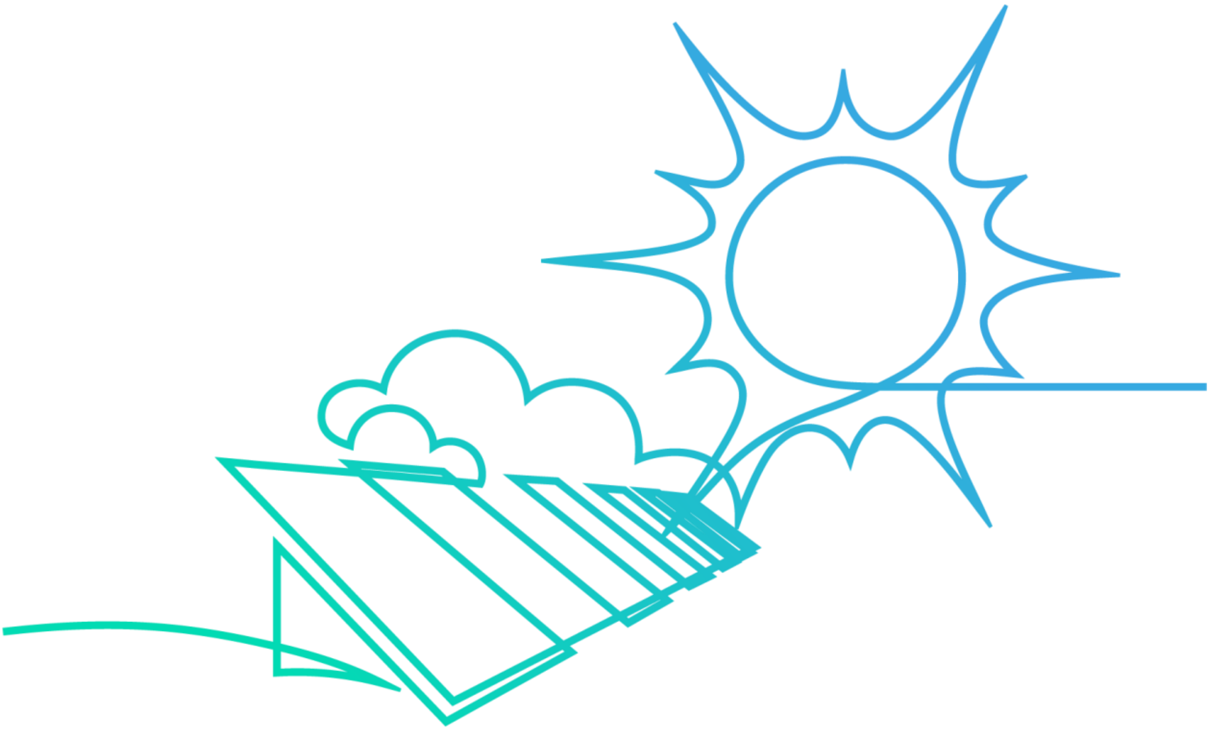
[7] Iberdrola, DSO: https://www.iberdrola.com/innovation/distribution-system-operation

[8] Dixon, J., & Bell, K. (2020). Electric vehicles: Battery capacity, charger power, access to charging and the impacts on distribution networks. *ETransportation*, *4*, 100059.

[9] van der Ven, M. T. (2020). *Vehicle to Grid in Utrecht: Integrating Electric Vehicles into the Energy System of Utrecht* (Master's thesis).

Annex

The following section contains the slides used for the trainings in the framework of V2M project.



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