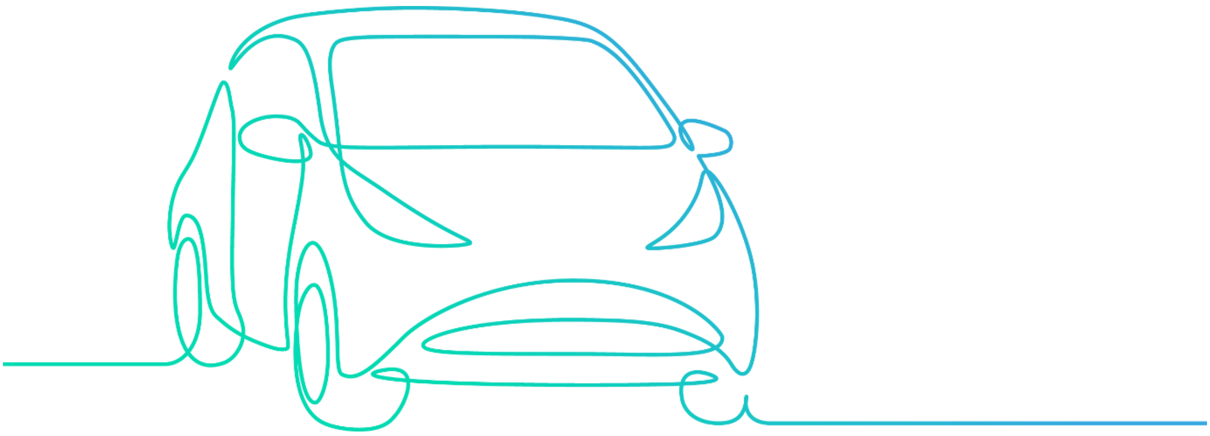

Economic study of the different scenarios

D4.1

August 2022

Deliverable

PROJECT ACRONYM	GRANT AGREEMENT #	PROJECT TITLE
V2Market	101033686	V2Market Valorising energy Efficiency and Flexibility at Demand-side using Vehicles to Grid (V2G) and Vehicle to building (V2B) Technology

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Economic study of the different scenarios, with the assumptions and data sources used

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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This deliverable contains original unpublished work except where clearly indicated otherwise.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.

Abbreviation list

BPS	Basis Points
CPO	Charging Point Operator
DERs	Distributed Energy Resources
DoA	Description of Action
DSO	Distribution System Operators
ECB Statistics	European Central Bank Statistics
EMSP	e-Mobility Service Provider
EOL	End of Life
EV	Electric vehicle
ICV	Internal combustion vehicle
NPV	Net Present Value
PV	Photovoltaics
RD	Royal Decree
SLB	Second Life Battery
SOH	State of Health
TSO	Transmission System Operators
V2B	Vehicle to Building
V2G	Vehicle to Grid
V2M	Vehicle to Market

Executive Summary

The scope of this deliverable which is the output of ***Task 4.1 Economic study of different electricity and battery price scenarios*** *was to carry an economic viability study for the V2G participation in different scenarios of electricity prices and battery prices projections (6 scenarios have been analyzed).*

The assessing of the viability was carried for the EV owners this resulting in a viability for the aggregator as the same time. Indicators like payback time and Net Present Value (NPV) of exchanging the traditional vehicle for an EV with V2G were used to assess the economic viability. Regulatory, market barriers and technological risks have been identified in WP2 and WP3 and have been taken in consideration in this report.

The results and conclusions of this Deliverable will be used in the next tasks throughout WP4 as electricity prices have a significant impact in the total cost of ownership per km and per month these results can help the EV owners assessing whether to choose a service scheme where they do not own the battery and get the electricity as a service, or they prefer ownership of the full vehicle, or include a PV in the model. Whilst at the same time for the aggregator the results provide a complete picture of what other services or schemes can be proposed to the users to make sure that they maximize the results of the V2G capabilities.

Core findings

V2G will have an ever more important place in the various market segments for battery usage in particular bridging the "affordability" issue for the individual car ownership and possibly, although not forming part of our remit under V2G, a further cost reduction in the overall car ownership in combination with a home-based PV production capacity.

This is even more important from a socio-economic standpoint where owners of house, PV and EV are able to store and use the self-generated solar energy. Furthermore, if self-generated could be sold to the grid it would generate:

- *A profit to the EV owner*
- *Possible VAT income to the state*

V2G is a valuable, rapidly implementable grid balancing and energy storage solution which will not cost the government budget and helps to in EU member states to transition to Net Zero.

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1. Introduction

The energy transition as envisaged by the EU to be implemented by various member states is beneficial in the long term not only for the energy security of Europe as an economic bloc, but also for the environment with the aim of keeping global warming to up to 1.5 degrees by 2050.

To be able to achieve the above objectives, it is key to understand that our transmissions and distribution grid have been set up at a time when the needs of the consumers were very different than at the present. In the past the energy generation and consumption have been able to be matched in a more or less efficient way, by matching consumption patterns with production.

These tried and tested base cases have been challenged by an ever-increasing production of new renewable energy sources, which due to its nature (that of relying on the forces of nature) is uneven and predictable, and is occurring at a mismatch with household consumption patterns. Furthermore, the renewable energy sources have underlined a major issue which is a lack of storage capacity. Often when the wind is blowing and sun shining the owners of these assets are not able to dispose of the energy produced either due to a decrease consumption or lack of storage capacity, leading to the potential green energy being wasted or being given away.

Energy transition

The issues related to transition from fossil fuel-based electricity to renewable energy, do not end with putting up a few solar panels and wind powered turbines, but they are just beginning of the issue.

Whilst the developers of PV fields and wind parks are concerned with the reduction in FiT lowering their returns, but only feel the deep impact of the grids inability to take all the energy generated when the TSO needs to decouple the production of PV fields and wind parks as the grid cannot take the excess energy when there is not adequate demand. This in turn has a negative impact on return calculations and affect the willingness of bankers and investors to support the development of further PV fields and wind parks.

Inflationary implications

Energy is a key Inflation driver, as it hides as a secret cost driver beyond and above the two key elements of transport and housing cost as published by the ECB statistics. A hike in the energy costs increases the cost of not only clothing via higher transport costs, but of food and beverages. The effect of volatile energy cost is acerbated by the need to add a safety cushion into the price structures for the baker, brewer, milkman to the airline industry in order to account for the unpredictability of rises in energy cost and these magnify the problem.

The grid is taken for granted

It is easy to think about solar and wind parks as the easy solution in the energy transition, but little attention is paid to the physical grid which somehow takes energy produced in a certain part of a country or Europe to other parts, ultimately powering from household washing machines to industrial production.

Whilst the power cables crisscrossing Europe, look a familiar sturdy piece of technology, very little attention is paid by all of us that it is only the delivery channels of a fine art what the TSO’s and DSO’s perform in matching and anticipating, the ever-changing production and consumption patterns. Even more so, when the patterns of production are shifting ever more to time horizons where there is very little demand, the work for the grid operators becomes ever more complicated, and their only solution before decoupling is to store energy on a short-term basis.

A further issue, when it comes to the grid, is the fact that there is a big discrepancy between the approval processes for PV & wind parks which on average is 3 years (and even faster time frames under recent EU laws) and the approval process for new grid infrastructures which is around 12 years. These numbers are exacerbated when one is taking into consideration the build out process which adds a few years to the Grid expansion compared to a few months for a PV installation and years again for wind generation. Furthermore, the cost of upgrading the grid is uncontestably higher than the one of implementing different storage solutions, all of which are calling for rapid solutions such as V2G.

The Value of V2G for electricity system operation

A recently published analysis in “The Drive Towards a Low-Carbon Grid: Unlocking the value of vehicle-to- grid fleets in Great Britain” also suggests that:

- with a lower penetration of 50,000 V2G-enabled EVs, each EV could reduce system operation costs by approximately £12,000 per annum and CO2 emissions by around 60 tonnes per annum.
- Reduced wind curtailment and more efficient frequency response provision through V2G are the main drivers of these cost and emission savings.
- The value offered by V2G EVs for system operation falls with larger fleet sizes. With 150,000 EVs on the system, the marginal value per EV is approximately £600. Competing flexibility sources could also diminish overall operational cost savings from V2G[1].

The human factor and V2G as a possible solution

The conversion from fossil fuel powered vehicles to EVs and the transition to EVs is a major jump for many market participants across the user spectrum, from individuals to fleet operators. Due to the fact that these users have been brought up with the notion that petrol-powered vehicles are easily managed at petrol stations around the clock conveniently and rapidly ensuring a high range, the lack of reliable charging infrastructure and the range anxiety are still the major concerns when it comes to possible EV users.
However, "global EV sales reaching 6,75 million units in 2021, 108 % more than in 2020"[2], a trend which is expected to grow exponentially, and the batteries powering such vehicles are a hidden and spare resource which can overcome the limitations of the grid, by acting as a storage, by possibly taking up energy when it is available in abundance and consequently cheap and feeding it back to the grid when demand is high, and conversely prices are higher.

By harnessing the combined spare capacities in many of these vehicle batteries V2G could support the net in balancing its frequency or power needs.

EV and V2G in local flexibility markets

Today, large quantity of electricity cannot be stored cheaply or at all, "in fact the overall amount of electricity fed into the power grid must always be equal to the total amount of electricity consumed, otherwise there would be a misfunctioning in the power system, potentially leading

[1] The Drive Towards a Low-Carbon Grid: Unlocking the value of vehicle-to- grid fleets in Great Britain, January 2021, pg 4, https://www.researchgate.net/publication/349948445_The_Drive_Towards_a_Low-Carbon_Grid_Unlocking_the_value_of_vehicle-to-_grid_fleets_in_Great_Britain
[2] Global EV Sales for 2021, Roland Irle, EV-volumes.com, https://www.ev-volumes.com

to power cuts."[3] Electricity storage needs are growing rapidly globally, this is driven by the inherent mismatch between renewable generation and consumer needs/demand.

Electricity production and trading are no longer limited to large centralized generators and retailers. With the integration of distributed energy resources, electricity flows in both directions: from the grid to the consumer and vice-versa, from the consumer to the grid. This means that consumers can produce electricity for their consumption "Prosumers" or are able to sell it on the market via bidirectional electricity flows. Consumers can take control of their energy, not only achieving energy savings, but have a financial benefit from participating in the electricity markets[4].

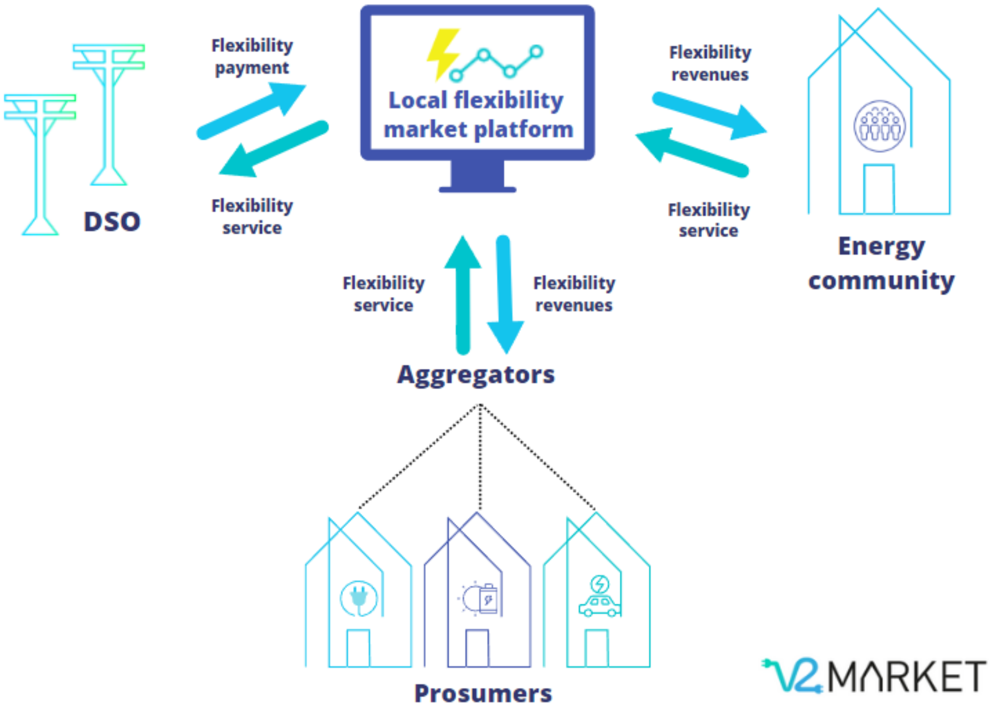

Figure 1 Flexibility service and revenues local flexibility market stakeholders (OMIE and Holaluz)[5]

Prosumers, due to their own energy resources will have the possibility to participate in local flexibility markets by modifying their consumption or generation. With these resources they might be able to participate either directly or through intermediaries such as "aggregators or energy communities to facilitate the integration of these resources into the market"[6].V2G fleets

[3] D3.2 Report on flexibility local market potential, opportunities for V2G in local distributed markets, OMIE and Holaluz, page 58
[4] Ibidem
[5] D3.2 Report on flexibility local market potential, opportunities for V2G in local distributed markets, OMIE and Holaluz, page 59.
[6] Ibidem.

could have "an important role to play in local and flexibility markets due to the capacity of their batteries, when aggregated, can respond to DSO's flexibility requirements in areas where maybe another type of resources cannot"[7] as such solving their grid constrains.

2. Methodology

An economic analysis can be run by using a variety of methods, albite they are similar in approach, such as:

- the payback period method
- the internal rate of return method (IRR)
- the net present value (NPV)

In general, for low investments as the ones being analyzed in this report, with a short duration the widely accepted, and easiest methodology to follow, is the payback period method.

The methodology used for in this report had a starting point the Norma VALERI "Valuation of Energy Related Investments" which provided the team with a description on how to gather, evaluate and document information in order to create solid business cases. The calculations however are based on the own internal know-how of the ESC team and some elements of the VALERI methodology such as: Net Present Value (NPV) had been included. The NPV captures the difference between the discounted value of present and future value of all cash inflows and outflows, and it tells an investor whether the proposed investment opportunity is achieving a target return for at a given initial investment. This indicator can be directly used in the decision-making process.

On top of the NPV the following elements have been included in the financial spreadsheet to assess the economic viability model for an EV user **vs** an internal combustion (IC) vehicle user and an EV user **vs** EV with V2G services in accordance to the payback period method:

- Initial investment: EV cost, charging infrastructure cost
- Operating costs: fuel/electricity and car wash
- Service/maintenance fees- tires, consumables

[7] Ibidem

- Depreciation
- Fixed costs: Insurance, road tax and other mandatory costs
- Residual value after 7 years
- Total cost of car ownership per month
- Savings: cost per km Fuel vs EV
- Total cost of ownership per km
- Net Savings Petrol vs EV
- Net Savings EV vs EV +V2G
- Payback time period
- Net Present Value

Due to the fact that in this phase within the V2M project, the pilot phase has not started, the current analysis is based on information gathered from either the consortium partners, publicly available information and a couple of assumptions and presuppositions that will be disclosed in the next section of this report.

The 6 different scenarios

For the economic viability studies in 6 different scenarios proposed to be assessed are:

a. electricity price stability with stability of EV battery prices (1),
b. electricity price stability and with decrease of battery price (2),
c. electricity price increase with stability of EV battery prices (3),
d. electricity price increase and with decrease of battery price (4)
e. decrease of electricity prices, with stability of EV battery prices (5),
f. decrease of electricity prices and with decrease of battery price (6)

In order to be able to assess the different scenarios the following assumptions have been taken:

1st Assumption

The analysis of the electricity price is limited to the scope and research data for the last 3 years due to relevance and data accessibility. The analysis is only relevant if it takes in consideration the last 3 years (2019- to date), this is in particular due to the energy crises (as a result of the Ukraine situation) whilst simultaneously capturing the Covid-19 pandemic period. The hike in electricity prices that the market has seen since the Ukraine crises impacts the overall expectations on the market evolution. As such the price analysis will only focus on the last 3 years to avoid the dilution of the current hike in price.

In order to assess the different scenarios, the highest electricity price from the last 3 years was used in the increase in electricity price scenario. The lowest electricity price from the last 3 years was taken in consideration for the decrease in electricity price scenario. Finally, an average of the electricity price from last 3 years was used in the electricity price stability scenario.

A caution to the reader is that realistically a substantial decrease in electricity price it is not anticipated in the next coming years as a result from disruptions due to the current energy crises.

2nd Assumption

The electricity price taken in consideration reflect individual households and not the business rates as those are more varied and are mostly a result from tailor made negotiations and agreements.

In Spain in, December 2021 the price of electricity was 0,2816 eurocents per kWh[8], and varied between 0,2390 eurocents in 2019 per kWh and 0.2298 eurocents per kWh in 2020 [9] which includes all components of the electricity bill such as the cost of power, distribution and taxes. The highest price per kWh in 2022 in Spain was registered in March with 0.2830 eurocents[10].

3rd Assumption

Regarding the battery, the same rational was followed as in the case of the electricity prices. The prices used will be the ones from the last 3 years, for the same reasoning as in the electricity prices. Due to the fragility of the supply chain when we are referring to batteries although initially anticipated to decrease (before the Ukraine-Russian conflict and supplier chain issues) BloombergNEF's (BNEF) forecasted that the "average battery price will climb

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[8] Statista, Electricity prices for households in Spain from 2011 to 2021, semi-annually, https://www.statista.com/statistics/418085/electricity-prices-for-households-in-spain/
[9] Statista, Electricity prices for households in Spain from 2011 to 2021, semi-annually, https://www.statista.com/statistics/418085/electricity-prices-for-households-in-spain/
[10] Statista, Average monthly electricity wholesale price in Spain from January 2019 to July 2022, https://www.statista.com/statistics/1267552/spain-monthly-wholesale-electricity-price/

to $135 per kilowatt-hour in 2022, some 2% higher than a year earlier"[11]. In prior years the price for kwh of battery power decreased in a meaningful way from 2019 219 USD to 2020 140 USD and in 2021 reaching a temporal low of USD 132 dollars[12].

4th Assumption

Although a powerful incentive in the increased adoption of EV's and installing charging infrastructure, subsidies were not included in the calculation model. The rationale behind such a decision, is that neither the amount of such subsidies and timelines are predictable and they change depending on political wishes and controlled, and as such are difficult be anticipate.

Furthermore, the viability of a business case should be positive without the inclusion of such subsidies as they are not constant attributes, but occasional ones.

5th Assumption

As mentioned in the findings of WP3 when it comes to individual EV owners to participate directly to capacity market or any other type of services (peak shaving grid balancing, intra-day electricity market) they can only do so as part of an energy community or with the support of an aggregator due to regulation and market conditions. However, for the scope of this project in the current economic study the viability of such a case of an individual EV owner was analyzed as stated in the DoA.
As such the calculation will focus on the financial benefits of an EV with V2G technologies which will in turn represent the minimum of what an aggregator can generate via V2G.

3. Battery price and different scenarios of degradation

The last 5 years registered the most significant increase of EV acquisition. This is due on the one hand to the increased policy push and subsidies offered by governments, and on the other by increased battery performance and price decrease of the batteries resulting in lower EV costs.

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[11] BloombergNEF July 15, 2022, Race to net zero: Pressures of the battery boom in five charts
[12] Ibidem

Furthermore, investments into charging infrastructure (also due to public incentives), the development of fast charging and bidirectional charging, net zero commitments of the different stakeholders and market players, the increased rollout of EVs from automakers combined with the growing comfort of consumers with EV's[13].

Batteries are the EV major highest cost item, is also a key element in terms of performance limitations and user concerns (such as range anxiety) are built in general around the battery limitations.

According to the BloombergNEF's (BNEF) yearly survey regarding battery prices evolution, "the average cost of EV storage systems declined by 13% between 2019 and 2020, and lithium-ion battery packs, the most common in the EV industry, which were above $1.200/kWh in 2010, have fallen by 89% in real terms to $132/kWh in 2021[14]". The cost of an average battery pack is expected to go below $100/kWh on a volume-weighted average basis by 2024"[15], however the price increase of raw material is suggesting that the predicted $100/kWh could be delayed with 2 years. "The threshold for price parity with gasoline engines, according to BNEF, is around $100/kWh "[16].

However, due to the current situation regarding the increase price of raw materials, the average pack price is predicted to increase in 2022 to $135/kWh (in nominal terms) from $132/kWh in 2021. The numbers used in the economic viability as mentioned in the prior section are the ones listed by the BloombergNEF for the last 3 years including the prediction for 2022[17].

The supply for raw materials, such as manganese from currently known reserves, is predicted to be sufficient to meet demand up to 2050. However, "to assure the balance for the other metals needed such as lithium, nickel and cobalt will require the formulation of a strategy that

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[13] Battery Pack Prices Fall to an Average of $132/kWh, But Rising Commodity Prices Start to Bite, 30 Nov 2021, https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/#_ftn1
[14] BloombergNEF, "Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh," Dec 2020. Available: https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/#:%7E:text=This%20indicates%20that%20on%20average,prices%20will%20be%20%24101%2FkWh
[15] Ibidem
[16] BloombergNEF, "Electric cars are about to be as cheap as gas powered model", https://www.bloomberg.com/news/articles/2020-12-16/electric-cars-are-about-to-be-as-cheap-as-gas-powered-models#xj4y7vzkg
[17] Ibidem

will require all stakeholders i.e., governments, auto producers, cell manufactures and recycling facilities to collaborate. The EV battery recycling process can also help EV owners to obtain revenues back due to the sale to a third party”[18].

The following table shows the comparison of the different types of batteries in terms of their cost, specific power, safety, energy density, performance and life span.

Table 1 Comparison between the different types of batteries[19]

Specifications	**Lead-acid**	**NiCd**	**NiMH**	**LCO**	**LMO**
Specific energy density (Wh/kg)	30–50	45–80	60–120	150–190	100–135
Internal resistance (mΩ)	<100	100–300	200–300	150–300	25–75
Cycle life (80% discharge)	200–300	1000	300–500	500–1000	500–1000
Fast charge time	8–16 h	1 h	2–4 h	2–4 h	1 h or less
Overcharge tolerance	High	Moderate	Low	Low	
Self-discharge/ month (room temp.)	5%	20%	30%	<10%	
Nominal cell voltage (V)	2	1.2		3.6	3.8
Charge cutoff voltage (V/cell)	2.4	Full charge detection		4.2 V	
Discharge cutoff voltage (V/cell)	1.75	1.00		2.5–3.00	
Peak load current	5 C	20 C	5 C	>3 C	>30 C
Best result	0.2 C	1 C	0.5 C	>1 C	<10 C
Charge temperature (°C)	−20 to 50	0–45		0–45	
Discharge temperature (°C)	−20 to 50	−20 to 65		−20 to 60	

[18] BloombergNEF, “Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh,” Dec 2020. Available: https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/#:%7E:text=This%20indicates%20that%20on%20average,prices%20will%20be%20%24101%2FkWh
[19] Mohammed Hussein S. M. H. , Jia Woon Lee, Gobbi Ramasamy, Eng Eng Ngu, Siva Priya Thiagarajah, Yuen How Lee, Feasibility of utilising second life EV batteries: Applications, lifespan, economics, environmental impact, assessment, and challenges, Alexandria Engineering Journal, Volume 60, Issue 5,2021, Pages 4517-4536, Online Source: https://www.sciencedirect.com/science/article/pii/S1110016821001757

Maintenance requirement	3–6 months	30–60 days	60–90 days	Not required		
Safety requirements	Thermally stable	Thermally stable, fuse protection common		Protection circuit mandatory		
Toxicity	Very High	Very High	Low	Low		
In use since	Late 1800s	1950	1990	1991	1996	1999[20]

Source: Feasibility of utilising second life EV batteries: Applications, lifespan, economics, environmental impact, assessment, and challenges, Alexandria Engineering Journal, Volume 60, Issue 5,2021

Based on the various “manufacturers' descriptions and the existing literature, “once EV batteries reached 70–80% of their nominal capacity, their role as EV first life batteries is considered to have reached its end. The main reason behind is that these kind of batteries (that reached 70-80%) will result in lower mileage and speed. The percentage of residual capacity represents the battery SOH (State Of Health). This degradation is estimated to be happening around 5–8 years of usage or the equivalent to 100,000 miles (160,000 km) of travelling. However, the retired EV batteries, even with lower SOH, could still be re-purposed in other applications such as residential households or power variance in grid-scale PV plants [….SOH] are estimated to have another 7–10 years of the lifespan before reaching the End of Life (EOL) as Second Life Batteries (SLB).”[21]

Based on the research on SLB “the cost of re-purposing and the selling price vary from optimistic estimation to reasonable and to relatively high. For example, it was estimated that the selling price of SLB would be around $44/kWh, including the cost of re-purposing set at $20 [….] The study projected that the selling price would drop to $43/kWh in 2030. Casals *et al*. investigated the economics of using SLB in a residential application and concluded that buying SLB becomes profitable for consumers if it is bought at €38.3/kWh.”[22]

Regarding battery degradation some manufacturers, such as Nissan, are claiming that in a real environment via monitoring and smart optimization of the charging cycles (charging/discharging) no major impact will be registered on the batteries’ lifetime (meaning that it will not degrade faster than a normal usage of the EV battery). However, the second

[20] Ibidem
[21] Ibidem
[22] Ibidem

life of the battery is an interesting and vital aspect that was explored briefly in this section as it is also a financial item taking in account in the economic model as part of the residual value of the EV.

4. Regulation, market risks and technologies

Regulation and Legal barriers in relation to EV's presence and V2G in the electricity market in Spain

As presented in D3.1 Analysis of the electricity markets and its potential for integrating V2G to be able to provide generation services and participate in the market, aggregators need to possess a set of technical criteria and comply with regulatory criteria.
In the global market case in order to provide generation services and participate to the market the following criteria need to be fulfilled:

- **"Aggregated capacity**: Minimum bidding of 0,1 MWh enables the participation of aggregated resources. A V2G aggregated fleet could reach the minimum bidding size by aggregating less than 50 electric vehicles."[23] This minimum biding is the same in Spain in the minimum bidding on the Day-ahead and intraday markets.
- **Service duration**: The minimum period is 1 hour and 15 minutes. "Shorter service timers represent an advantage for V2G, since it has the possibility to charge/discharge for short periods if possible.
- **Time to activation**: The operation on the intraday market is as minimum confirmed 1 hour in advance the moment of the energy delivery/consumption, which would be enough time to activate available V2G capacity.

At the moment it is not possible for V2G to participate in wholesale electricity markets as it is not an approved storage asset type. It is necessary to amend regulation related to electricity storage to include storage facilities and V2G services in the market scheme. The participation

[23] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Pg 89.

of storage in the electricity markets is reduced to pumped hydro storage and storage associated with solar power"[24]

Deliverable D3.1 Analysis of the electricity markets and its potential for integrating V2G in Chapter 7.5 Legal barriers and considerations for EV to enter the electricity market in Spain had performed a through and complete regulatory framework analysis, of EU and local legislation for the participation of aggregators in the electricity markets in Spain.
The following have been identified as possible barriers that can hinder the V2G implementation of V2G technology in Spain:

1. "Interoperability of the infrastructure: there is a clear need for the development of interoperability standards for communication and control between the different distributed resources (for example, the different brands of electric vehicles, as well as the charging stations and systems).
2. Attributes for EMSP and CPO: also, regarding EV charging regulation, the fact that the figure of the EMSP does not include at all the attributions of a flexibility services aggregator, nor are energy exchanges in the direction from vehicle to grid envisaged or regulated, is a barrier for V2G."[25] For more details please consult D3.1 Analysis of the electricity markets and its potential for integrating V2G.
3. "Representation in TSO markets: regarding rules for participation in the markets, currently, if the market participant is a representative on behalf of another (direct representation), it must act with the programming unit of the owner of the production or storage facility. On the other hand, if the market participant is a representative in its own name (indirect representation) of installations with an installed capacity greater than 1 MW or groups of installations whose sum of installed capacities exceeds 1 MW, it may act with its programming unit or with the programming unit of the owner of the production or storage facility.

   For EV battery aggregation it will be necessary to regulate for the possibility of the aggregator to participate with its own operative unit, regardless of the type of representation.
4. Regulation for storage in wholesale electricity markets: it is necessary to review the regulation and Market Rules.
5. Regulation on flexibility services for DERs: furthermore, there is a need for a definition of the rights and obligations with respect to storage, (for the purposes of this work,

[24] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Pg 89.
[25] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Pg 101-102

distributed storage though EV batteries) of regulated figures, namely, the DSO and TSO, as well as non-regulated figures, such as independent aggregators or energy communities, in relation to their participation in the market.

6. Update of technical codes: from the technical perspective, ITC-BT 52 is the technical instruction that regulates the connection of the infrastructure for the recharge of electric vehicles. This instruction needs to be revised in light of V2G and V2B technological developments in order to define minimum standards for deployment of recharging facilities which are capable of bidirectional energy flows.
7. Promotion of V2G: finally, from a business model perspective from the aggregator's point of view there will be many different issues to consider when dealing with the value proposition for EV users. For example, under the current VAT regulation in Spain, receiving recurrent income, regardless of its amount, entails the obligation of registration with the tax authority and making quarterly VAT declarations. This administrative burden could easily draw away the interest of a residential EV owner to participate in V2M, especially if the returns from such participation are not very high."[26]

V2G infrastructure costs, regulation and technological barriers

Deliverable 3.1 Analysis of the electricity markets and its potential for integrating V2G makes a thorough analysis on the current EU and Spanish regulation regarding the recharging infrastructure, as such the same data will be used in this Deliverable.

"The EU and Spanish regulation related to recharging infrastructure is the following:

Regulation	Description
Directive 94/2014 on the deployment of alternative fuels infrastructure	Sets a common framework of measures for the deployment of an infrastructure of alternative fuels with the aim of achieving long-term oil substitution in transport.
Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for	Sets the guidelines for the creation of a Trans-European transport network with the aim of promoting the growth and cohesion of member states. This transport network is based on the principals of efficiency and sustainability,

[26] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Pg 101-103

the development of the trans-European transport network	aiming to achieve a significant reduction in CO2 emissions.
Royal Decree 639/2016 establishing a framework of measures for the implementation of an infrastructure for alternative fuels	This Royal Decree transposes into Spanish legislation the provisions of Directive 94/2014. However, this regulation falls very short in ambition, providing no specific commitments and only some very general guidelines regarding infrastructure for alternative fuels, including recharging points for electric vehicles and refueling points for natural gas and hydrogen.

Regulation	Description
Royal Decree 1053/2014 passes a new Complementary Technical Instruction, ITC-BT-52 "Facilities for special purposes. Infrastructure for recharging electric vehicles"	This Technical Instruction regulates from the electrical point of view the connection of the infrastructure for the recharge of electric vehicles.
Royal Decree 647/2011 which regulates the load manager activity of the system for the performance of energy recharge services	This Royal Decree has been practically all repealed by Royal Decree-Law 15/2018, which eliminated the load manager figure and thus liberalized the provision of recharge services. Still in force are the additional and final dispositions which regulate tolls.
Royal Decree 15/2018 of urgent measures for the energy transition and the protection of consumers	Repeals most of RD 647/2011 and simplifies the regulation on energy recharge services.
Royal Decree Law 24/2021 for the transposition of EU Directives. Directive 2019/1161, on the promotion of clean and energy-efficient road transport vehicles is transposed	It transposes Directive 2019/1161 into Spanish legislation. This regulation establishes emission thresholds for the public sector when purchasing road transport vehicles which are set at 0 g CO2 /km from January 1st 2026.

Royal Decree-Law 29/2021 by which urgent measures are adopted in the energy field to promote electric mobility, self-consumption and the deployment of renewable energies	This Royal Decree-Law modifies art. 48 of ESL defining the scope of the energy recharging service. Also, it simplifies the requirements and duration for obtaining authorizations for installing recharge infrastructure on roads and in municipalities[27].

Regulation	Description
Royal Decree 184/2022 which regulates the activity of providing energy recharging services for electric vehicles	This regulation develops article 48 of the ESL by setting the requirements for the provision of energy recharging services for electric vehicles. It introduces for the first time in Spanish regulation the figures of Charging Point Operators and eMobility Service Provider.[28]

In the economic viability model the data used when it came to the cost of V2G infrastructure were the one provided by the consortium partners and also based on the Market study and data provided in D3.1 Analysis of the electricity markets and its potential for integrating V2G in the Figure 2 "prices are dropping faster than projected but still vary depending on power ratings for example for V2G from 7 kW to 150 kW."[29]

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[27] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Table 4 - Regulation in Europe and Spain regarding recharging infrastructure, April 2022, Pg 37-39)
[28] Ibidem, Table 5 Regulation in Europe and Spain regarding recharging infrastructure, April 2022, Pg 39.
[29] Ibidem, Pg 27-28

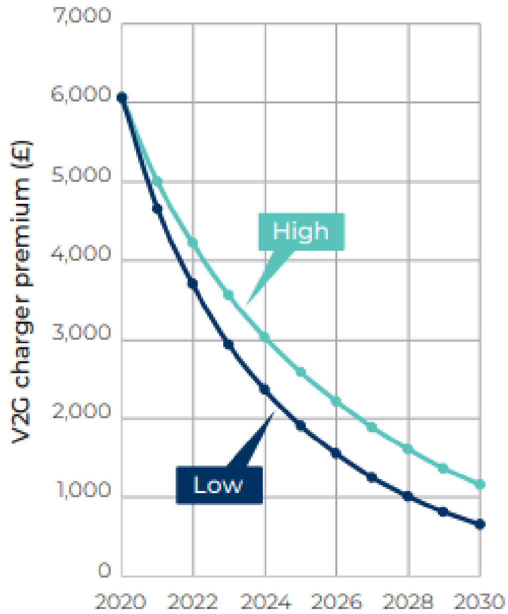

Figure 2 Projected V2G charger premium price[30]

Regarding the EV deployment the ICCT (International Council of Clean Transportation) in a published study predicts that by 2030 approximately 69% of EV owners will charge their EV at home, this translates into approximately 3.45 M residential charging points in Spain. The forecast made by the Spanish Association of vehicle manufacturers regarding the public charging infrastructure is that of 360.000 public charging points by 2030.[31]

Due to the high number of electric vehicles a shift in "the residential demand curve may generate potential risks to grid congestion caused by peak hours due to EV charging. "[32] "Uncoordinated charging demands of EVs increase the load during peak hours, which in turn has a negative impact on the stability of power grids due to its sizable rating. Typically, an EV draws approximately 7 kW power from the grid, which is significantly higher than the peak demand of most of the residential households. Moreover, EV owners tend to charge their EVs after returning from work, which is also usually the time of peak demand in the grid, thereby coinciding with the power drawn from EV and household peaks. This scenario leads to a significant increase in system peak demand and threatens the stability of the power grid."[33] This is why the V2G concept is crucial in supporting of the grid and increased energy demand.

[30] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Figure 8 - projected V2G charger premium price, Pg 27-28
[31] Ibidem, Pg 84.
[32] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Figure 8 - projected V2G charger premium price, Pg 84-85
[33] Ibidem Pg 84-85.

The integration of renewables is increasing exponentially in Spain, according to the Spanish Energy and Climate Plan 2021-203, by the year 2030- 42% of the energy must be renewable, in order to reach the abatement targets of the greenhouse gas emissions.[34]

“The largest increase in installed power technology corresponds to solar PV generation […] Solar generation begins to decline in the afternoon when electricity demand begins to increase. This means that the necessary increase or ramp of conventional production in the afternoon and evening hours will be much more accentuated. This leads to the fact that, if there is no flexibility available such as storage, demand-response or bidirectional EV the rest of conventional technologies, must quickly enter in the mix generating electricity during those hours, causing prices to rise at those periods of the day and generating a large price difference between the central hours of the day and peak price hours. However, this scenario can be avoided thanks to the change in consumers behavior, the introduction of the bidirectional electric vehicle, the adoption of demand response strategies and the incorporation of storage systems.”[35]

5. Economic Viability

The scenarios

The calculations to assess economic viability model were made on a 10 000 km/ year of driving range for an EV owner of a Nissan Leaf (40 kWh) **vs** a diesel vehicle owner of comparable model- Volkswagen Golf VI and EV owner of a Nissan Leaf (40 kWh) **vs** and EV owner of a Nissan Leaf (40 kWh) with V2G services integrated.

The items taken in calculation were:

- Initial investment: EV cost, charging infrastructure cost with installation
- Operating costs: fuel/electricity
- Service/maintenance fees- tires, consumables
- Depreciation
- Fixed costs: Insurance, road tax and other mandatory costs
- Residual value after 7 years (70000 km)

[34] D3.1 Analysis of the electricity markets and its potential for integrating V2G, OMIE and Holaluz, Figure 8 - projected V2G charger premium price, Pg 84-85
[35] Ibidem.

- Total cost of car ownership per month
- Savings: cost per km Fuel vs EV
- Total cost of ownership per km
- Net Savings Petrol vs EV
- Net Savings EV vs EV +V2G
- Payback time period
- Net Present Value

The above mentioned items are present in the base case scenario calculations, however in the rest of the 5 scenarios the following 2 items have been introduced in order to include the Electricity price variation (high, low, stable**) New energy cost for 10 000 km range p.a**. and **Back out energy cost** and 2 items have been included to enable the battery price variations **Back out battery constant at average cost** and **Insert battery cost according to scenario** (high and low, base case).

Electricity price stability with stability of EV battery prices (1)

When comparing 2 cars of a similar power and volume class, we decided to compare the base Golf VI with the Nissan Leaf both being a hatchback for up to 5 passengers, with 110 kWh power and both being able to exceed the legal speed limit in Europe.

Whilst the operating cost could be considered similar, but not only is the purchase price app. 5 000 Euro cheaper than the Golf, but the resale value of the Nissan is much lower, pushing up the amortization rate which is very much in the disfavor of the Nissan Leaf. However, this is a trend general to the EV market at present, as at present, the battery represents something of an unknown factor in the second-hand EV market, hence pushing down on values, which generally will prevail until more date is available of life expectancy batteries. As such there is no possibility to calculate a payback or NPV for this case.

The second case is the comparison of the Nissan Leaf in a V2G environment and one without. We based on the data received for our consortium partners we have assumed the cost of 2305 euro with installation included for the unidirectional chargers and 4584 Euro with installation for the V2G compatibility[36]. This is an important cost item, as such with the price of

[36] https://wallbox.com/en_catalog/quasar-dc-charger

infrastructure decreasing, the total cost of ownership of the EV's without V2G should be a lot lower than the one of the fuel vehicles.

Here the finding is that the V2G participating car, assuming a discount rate 5,5% which is assumed based on the Spanish risk-free rate of return of presently 2,5% majorated by 300 BPS to reflect the private borrowing premium, would generate over a 7-year period an NPV of 1553,76. This then equates to a payback of 3,379 years.

This in turn would mean, assuming 10 000 km driven p.a. that the pure operating cost of the EV (with V2G capability) would be app. 19 Euros per month vs. 40 euro in the case of the EV without such capabilities[37], which is not a negligible amount when compared to a median household income of 28 365 Euro p.a. in Spain in 2021.

Whilst our calculation ends after 7 years and considers that the vehicle is disposed and charger are disposed as well, this is a highly unrealistic scenario, as any EV owner will purchase a new EV, which in-turn will be using the already written off charging infrastructures, which in-turn will greatly improve the return numbers going forward.

As a general comment which is valid for all the different scenarios is that the NPV and the payback time do not change in value to do the relationship between the EV and EV with V2G capability which is more or less constant if the income from the V2G does not increase significantly. Regarding the total cost of ownership per month as it is presented in Table 2, the closest total cost of ownership to the VW Golf VI is the low battery price and low energy price. The next scenario that is close to the total cost of ownership to the VW Golf VI is the 'low battery/stable electricity price', which underlines that the more the battery price will drop the more attractive the business proposition will be. This analysis is limited to the case of the EV owner, as such these calculations underline the EV owners' benefit, and not the possible gains of the other stakeholders such as aggregators. By entering into an agreement with an aggregator the EV owner will possibly lock in an energy price and not really take advantage directly of any of the energy price fluctuations.

[37] The difference between the two numbers is given by the V2G "income"generated.

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Table 2 Comparison on the Total Cost of Ownership based on the 6 scenarios

Total cost of car ownership per month		**Standard**	**V2G capable**
	VW Golf VI	**Nissan Leaf 40kw**	**Nissan Leaf 40kw**
Base case (Stable battery price /Stable energy price)	€ 482,04	€ 554,50	€ 498,30
Low battery price/ Low energy costs	€ 482,04	€ 541,25	€ 485,05
Low battery price / High energy cost	€ 482,04	€ 549,89	€ 493,68
High battery. price / Highy energy cost	€ 482,04	€ 561,44	€ 505,24
Base case battery price / Low energy cost	€ 482,04	€ 552,80	€ 496,60
Low battery price/ Base case energy cost	€ 482,04	€ 542,95	€ 486,75
Base case battery price / High electricity cost	€ 482,04	€ 561,44	€ 505,24

Table 3 TOC of different scenarios on EV with V2G

EV with V2G						
Total Cost of Ownership €	€ 498,30	€ 486,75	€ 505,24	€ 493,68	€ 496,60	**€ 485,05**
NPV	€ 1.553,76					
Payback time	3,38					

In Table 3 the data presented is a summary of the numbers of the monthly Total cost of ownership of the EV with V2G capabilities. The numbers are clearly underlining that the best-case scenario for the EV owner is the low electricity price combined with a low battery price, followed closely by the stable electricity price with a low battery cost.

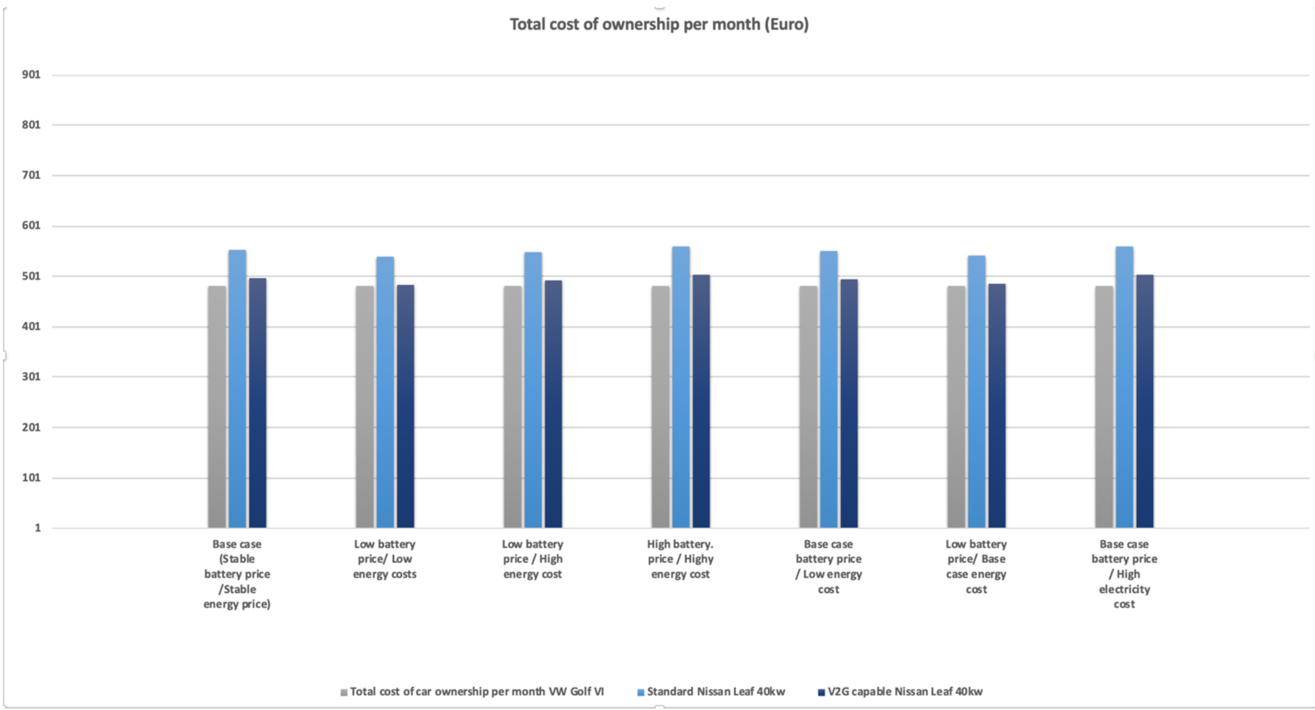

Figure 3 Total cost of ownership per month comparison between VW Golf vs Nissan Leaf vs Nissan leaf with V2G

As Figure 3 shows the difference between the TCO per month between EV with V2G capabilities and an ICV in 2 of the scenarios analyzed is insignificant. Which in turn means that if the infrastructure cost would decrease then the TOC per month for the EV with V2G capabilities would be a far more attractive financial proposition in the future compared to an ICV.

Electricity price stability and with decrease of battery price (2),

This scenario is the second best due to the substantial decrease in the battery price between 2019 from 216 euro per kWh to 130,69 euro per kWh in 2021. As such the lowest price in battery combined with an electricity price is an interesting scenario for the EV owner.

Electricity price increase with stability of EV battery prices (3),

The electricity element is the one that affects the total cost of ownership (per month and per km) significantly, as such if the cost of battery is constant, and the electricity price goes up then there is an increase of the total cost of ownership. This scenario is the one that has the highest cost of ownership which underlines how important the increase in the electricity price is for an EV owner even if the battery price remains stable.

Electricity price increase and with decrease of battery price (4)

The electricity element is affecting the total cost of ownership of the EV owner (per month and per km) significantly, as such if the cost of battery is lower, and the electricity price goes up then there is an increase of the total cost of ownership, even if the battery cost is lower. From a total cost of ownership perspective this scenario is the 3rd most favorable, which means it is more advantageous than the stability one (stable price for both items – battery and electricity) and it is a better scenario compared to the electricity price increase with stable battery price evidently. For the aggregator an increase in electricity price could mean an increase in their income from V2G, however this might not spill directly in the financial benefit of the EV owner, because the agreement that they will enter with an aggregator would mean a locked energy price.

Decrease of electricity prices, with stability of EV battery prices (5),

From a total cost of ownership (per month and per km) this scenario is still more advantageous than the stability one (stable price for both items – battery and electricity). The interesting reflections that come out of this scenario is that compared to the one in which the electricity price is stable and battery price decreases this scenario is 10 euro more expensive per month in the total cost of ownership than the scenario 2.

Decrease of electricity prices and with decrease of battery price (6)

This is the best-case scenario in terms of cost of ownership of the EV vs ICV and also between EV vs EV with V2G capabilities. Which makes the case for the addition of PVs in the proposal to continue to decrease the cost of energy on the EV owners side and be able at the same time to be a more attractive "partner" for an aggregator due to the energy generated from the PV. This aspect will be explored in the next tasks that are part of WP4 including a servitization scheme related to the ownership of the battery.

6. Conclusions

The energy transition is a complicated “problem” to solve, having to do as much with affordability as this report has shown, but at the same time it has to do with social and humanitarian factors which are very often underestimated.

In the context of climate change, humanity is standing at a grave impasse as the tools that are at our disposal are not enough:

- Nuclear power, although was declared a transitional energy source by the EU Parliament in the EU Taxonomy, during summer month when the rivers are either to warm or run too low to cool reactors or when there is a drought (which is currently the situation worldwide) it is not optimal to use– which in “ultima ratio” means, that such generation capability will need to go off grid.
- The same is true for the most sustainable “hydropower”. When a river or a reservoir runs low, then the energy generation capability is substantially reduced.

The various economic models analyzed in this report have shown that;

- The key in the total ownership cost picture is the **presently much higher depreciation of EV’s vs. fossil fuel vehicles**.
- Whilst the battery cost is a key element in the electric vs. fossil fuel powered vehicles calculation, however by running the different scenarios is evident **that the cost of the energy we are using to power our vehicles is a far more important cost item making the case for home generated PV electricity**.
- Furthermore, whilst not forming part of this report, it becomes implicitly clear that **for V2G purposes, the EV model which will ultimately store the energy is irrelevant**.
    - a kWh of storage capacity i.e, battery in a Tesla or in a Nissan Leaf is having similar production costs and coming out of the same factory.
    - Key is the ability to provide for the aggregator a predefined timeframe of around 14 hours to maximize the V2G services and still be able to manage the own consumption of households.
- Even more, whilst not being in the scope of this particular report (it will be explored and expanded upon in the last deliverable of WP4) one conclusion is that **V2G needs to**

be linked with PVs in order to be able to maximize the entire process of storage capacity and grid balancing and become a reasonable proposition for the users.

The truth is however, that the grid providers even if they would have all the fund in the world (which they don't have) they are still looking at capital allocations as every commercial enterprise and might prefer solutions which are less capital intensive than a grid upgrade, and V2G is a fast and relatively cheap solution. Even if it would go for a grid expansion, the timing mismatch between today's available sustainable production capacity and those capabilities which are coming online shortly and the grid capability will aggravate further, calling for rapid solutions. It takes considerable amount of time to upgrade the net, all having to do with the various approval processes followed by lengthy construction timelines[38].

This will further be aggravated by the EU's recently approved shortened approval timeframe for new PV installations and even more, the new regulation to mandatorily equip buildings with solar generation capability[39], which will in turn worsen for the next 10 to 15 years the mismatch between generation and consumption, which in turn will push the net even further to its limits, and calling for rapid storage solutions. The easiest solution would be using EV's batteries particularly as cars are parked for 95% of their time.

Simply put, the net will not be able to balance the mismatch between sustainable energy generation and the time when this energy will be consumed. V2G is one of the immediately available solutions, and one which can be implemented relatively fast subject to connection capabilities, which in turn will help in smoothing the bumps between generation and consumption going forward.

Whilst clever management and balancing between hydro and solar & wind has a lot of merit, solar and wind will not be able to function properly if the storage issue is not resolved, and here V2G has a significant role to play.

V2G as the various scenarios have shown, is able to mitigate the affordability gap for the average consumer, even match or beat the petrol driven cars which is a key element.

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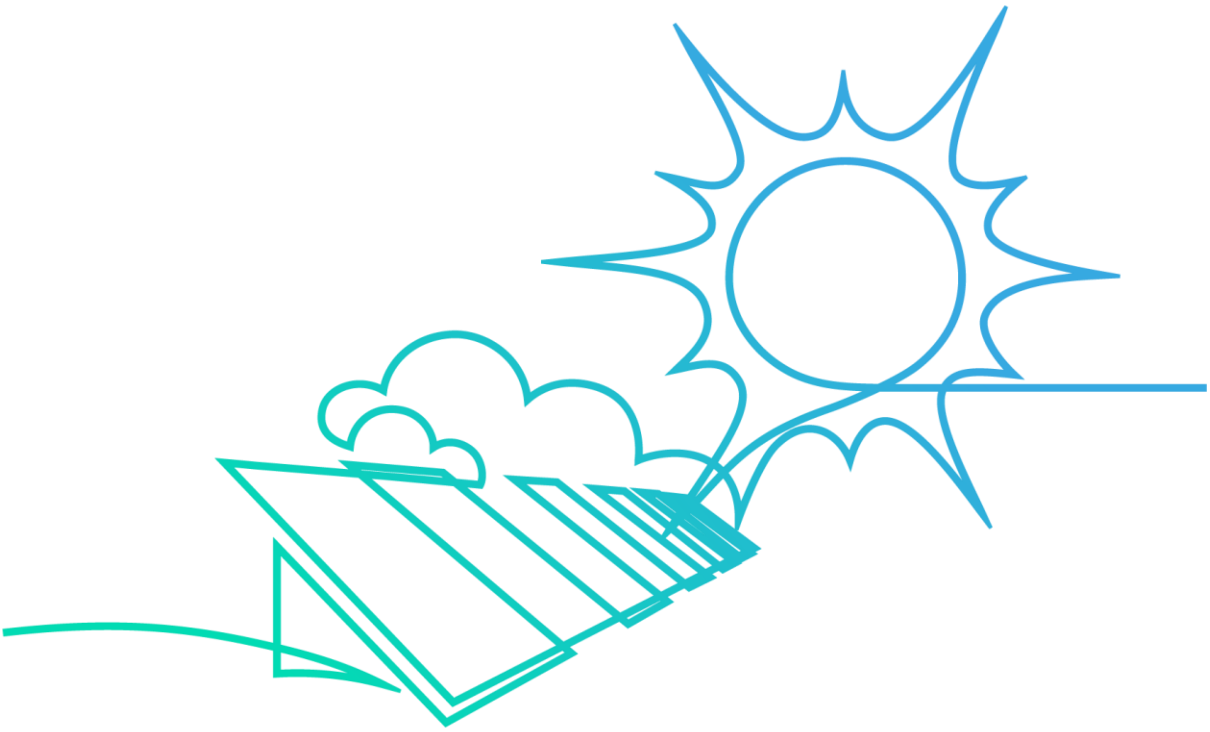
[38] Cleantechnica, https://cleantechnica.com/2022/08/04/the-u-s-power-grid-added-15-gw-of-capacity-in-1st-half-of-2022/#:~:text=Clean%20Power-,The%20U.S.%20Power%20Grid%20Added%2015%20GW,in%201st%20Half%20of%202022&text=The%20US%20power%20grid%20is,the%20first%20half%20of%202022.
[39] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A221%3AFIN&qid=1653034500503

Not only the wealthy population segment, able to afford a Tesla, mind about the world they might leave behind for posterity, but medium to low income population, able to afford a Nissan Leaf or even a second hand EV, have the same concerns for their offspring's. What world are we leaving behind? To use the phrase out of "in Search of Excellence" written in the early 80's "the human being is not afraid of extinction but of extinction without meaning".

V2M with all participants acting together for a better world has the ability to rapidly bridge the gap between sustainable energy generation and the consumption thereof, which in turn, by smoothing out the peaks and troughs is able to reduce the overall energy costs for everyone, whilst rewarding the storage owners for their willingness to do so. What easier than allowing access to the battery of an EV in a risk fenced business model with a fair reward. It however means that the various actors need to be transparent, and create a fair business model.
All participants in the energy market will fundamentally need to understand that we are all in the same boat, and that we need to support each other to successfully master the energy transition.



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Tables and Figures