

Warsaw 2018

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Dear Readers,

The vision behind the UK Government's new, highly ambitious Industrial Strategy is to help create a high-growth, high productivity, green economy across Great Britain – an economy fit for the 21st century. The strategy will put the UK at the forefront of the design and manufacture of zero emission vehicles: All new cars and vans should be effectively zero emission by 2040. Our aim is for at least 50% of new car sales and up to 40% of new van sales to be ultra-low emission by 2030.

There are more than 150,000 ultra-low emission vehicles and around 14,000 public charge points across the UK. More than 15,000 people are employed in the low emission vehicle sector and one in eight zero emission cars bought in Europe in 2017 was built in the UK. The UK's low emission vehicle industry is a huge success story and a great potential source of strength in our economy. We want to take advantage of the unprecedented economic opportunities now emerging globally, as countries embrace a cleaner future for road transport.

Large scale deployment of electric vehicles will not only change the way we use cars but will also have significant impact on electricity demand and the way the electric grid operates. Integrating electric vehicles with the grid will be a big challenge. One way to achieve this is to implement new technologies such as a Vehicle to Grid (V2G) system. This would enable plug-in electric vehicles to provide bidirectional flows of energy, when connected to the grid, helping to manage peaks and troughs in demand.

The UK is one of the first markets to test V2G technology in a series of pilot projects. We would like to share these experiences with Poland. I wholeheartedly support the Polish Association of Alternative Fuels initiative to write a report on V2G – a great starting point for promoting this technology in Poland. I encourage you to read this report.

***Jonathan Knott***

Her Majesty's Ambassador  
to Republic of Poland

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Warsaw 2018



Dear Readers,

The main motivation to prepare this Report has been to present the benefits of using electric vehicles as distributed electricity storage. Such focus of the analysis has been determined by the possibilities of development and commercialisation of the Vehicle to Grid (V2G) technology, which enables a two-way flow of electricity between the electric vehicle and the power grid.

The analysis of the V2G technology potential deals both with the cognitive and application aspects. The aim of the first part of the Report is to present the essence of the V2G concept. The potential of mobile electricity storage has been shown together with the main elements of the power grid architecture that are necessary for the deployment of the service. The scenario for two-way cooperation between electric vehicles and the grid made it possible to identify the most important mechanisms providing added value for individual stakeholders involved in the development of this technology. The second part of the Report is devoted to the presentation of the current achievements in the development of the V2G technology. Selected stages of the system evolution have been presented and the automotive, utility and telecommunication companies that can be recognised as the world leaders in rolling out V2G have been identified. The pilot and implementation projects currently underway in selected European countries have been described, with emphasis placed on the efforts to encourage open attitudes and strengthen the links between entities from the private and public sectors with the view to extending and expanding the V2G value chains. The commitment of the UK Government has been recognised as a model example of good practices in supporting V2G implementation.

The results of the analysis of the V2G technology potential show that access to distributed power sources may be of great importance for balancing the power system at the time of peak demand. This potential may prove very relevant when it comes to Poland's efforts to meet its obligations under the EU Climate and Energy packages.

The potential of the V2G technology is particularly important for our country because of the necessity to reduce the role of coal in the energy sector. It is also vital from the point of view of security of transport fuel supply for Poland, which is, to a great extent, dependent on imports of petroleum raw materials. In the recommendations prepared for Poland it has been emphasised that tapping on the V2G potential will require elimination of various barriers of systemic, market, legal, infrastructural and technical nature, which will help the development of V2G technology.

I encourage you to study the Report, hoping that it will spark an industry debate about the technology and the possible benefits Poland can draw from V2G.

**Maciej Mazur**

Managing Director  
Polish Alternative Fuels Association

# TABLE OF CONTENTS

## PART 1 | VEHICLE TO GRID (V2G) CONCEPT

<b>1. Electric vehicle as an element of the Smart Grid</b>	<b>8</b>
1.1. Interrelation: smart grid – electric vehicle – renewable energy sources	8
1.1.1. Smart Grid	8
1.1.2. Electric vehicle	10
1.1.3. Renewable energy sources	11
1.2. Electric vehicles – a challenge for electric power systems	11
<b>2. Main elements and objectives of the V2G concept</b>	<b>15</b>
2.1. Vehicle– grid interface	15
2.2. Technical aspects	16
2.3. Economic aspects of the V2G concept in relation to the vehicle user	16
2.4. Economic aspects of the concept in relation to the grid	17
<b>3. Potential of the V2G concept</b>	<b>18</b>
3.1. Electric vehicles as mobile electricity storage for electric power systems	18
3.2. Electric vehicles as an element of the operation of local power grids	21
3.3. Electric vehicles as an element of DSR services	22
<b>4. Elements of V2G services architecture</b>	<b>23</b>
4.1. System participants	23
4.2. Technical and infrastructural solutions	24
4.3. Communication and information exchange structure	25
4.4. System for data monitoring and analysis	25

## PART 2 | IMPLEMENTATION OF THE VEHICLE TO GRID SYSTEM

<b>5. World leaders in the V2G technology development</b>	<b>26</b>
5.1. History of the system development in Europe	26
5.1.1. Nissan / Enel	26
5.1.2. Mitsubishi / NewMotion	28
5.1.3. Honda / EVTEC	29
5.1.4. Audi / Ampard	30
5.1.5. Renault	31
5.2. Technological potential of the system	32
5.2.1. V2G and RES	32
5.2.2. V2G and development of Smart Building	33
5.2.3. V2G and development of Smart City	34
5.3. V2G market development scenario	35
<b>6. Case study: V2G research and pilot projects</b>	<b>37</b>
6.1. Multiscale projects: United Kingdom	37
6.2. Project: GridMotion (France)	40
6.3. Project: Sustainable Porto Santo (Portugal)	42
6.4. Project: TenneT, The Mobility House & Nissan (Germany)	44
<b>7. Case study: implementation of V2G systems</b>	<b>45</b>
7.1. V2G at the Nissan R&D centre in the United Kingdom	45
7.2. Commercial V2G hub in Denmark	46
<b>8. Potential for V2G technology implementation in Poland</b>	<b>49</b>
8.1. Conclusions and recommendations for Poland	52

<b>SUMMARY</b>	<b>54</b>
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# INTRODUCTION

This Report is a voice in the ongoing public debate on the development of electromobility and the problem of integrating electric vehicles with smart grids, which is one of the assumptions underpinning the new mobility concepts. **The study structures the knowledge about the Vehicle to Grid (V2G) concept and compares it with the current solutions implemented in selected European countries.** The technological progress made recently in different industries as well as in information technology, has been supplied us with more and more effective solutions with which the development of electromobility can gain a new dimension.

**Vehicle to Grid (V2G), that is, a technology that enables bidirectional flow of electricity between an electric vehicle and the power grid, is an example of an innovative solution that will play a key role in the process of delivering measurable energy efficiency of the future.**

The symbiosis of electric vehicles and power grids changes the pioneer vision of electromobility development and opens the way to new business models. **Thanks to V2G, apart from being used for transport, vehicles can also play the role of mobile energy storage integrated with the grid. Two-way flow of electricity makes it possible to “purchase” energy during periods of low demand and higher generation from renewable energy sources (RES), and then to “sell” it back to the grid during peak demand, for a higher price.** In practice, by plugging their cars into the grid, electric vehicles owners become active participants of the electricity market and can earn additional income.

**V2G technology thus increases the options for the use of electric vehicles turning them into a platform for continuous optimised management of electricity flows.**

Introducing mobile energy storage into the power grid is particularly important from the point of view of the flexibility of power systems, which means the grid's ability to balance power supply and demand within a relatively short period of time. It has become even more important with the growing share of energy generated from renewable sources, mainly wind and solar, in the energy mix of many countries.

The development of renewable energy sources (RES) is currently one of the main objectives of the energy and climate policy of the European Union as well as outside the Community. However, RES pose a big challenge for the efficient operation of the grid. Their use has positive impact on the environment, it is an important alternative to fossil fuels, but at the same time it changes the way in which the grid functions, forcing its operators to solve problems related to operations security as well as availability and quality of power supply. With the development of RES the issue of maintaining affordable electricity prices becomes ever more important. **Access to electric vehicles, that is, to mobile energy storage, thanks to the V2G technology opens new possibilities for the use of such vehicles. In such a configuration they can become an element that stabilizes the operation of the grid and increases its flexibility. At the same time they help integrate RES with the grid and have generally positive impact on the electricity supply infrastructure.**

**In the automotive and power sectors, investment in the development of V2G technology and its commercialisation are becoming an important element of the strategy of many companies.** Governments and local authorities, particularly in Europe, are also more and more frequently involved in its promotion, supporting subsequent V2G pilot and implementation projects. An increase in the number of electric vehicles and the possibility to use their batteries for energy storage may also contribute to the development of smart grids.

**Today, thanks to V2G technology, the scenario for cooperation between electric vehicles and the grid creates a new approach to energy management and brings us closer to making the concept of a smart city real. The implementation projects that have already been completed show that there are technical possibilities to develop two-way communication between electric vehicles and the grid.** However, it is still necessary to spread the knowledge about the capabilities and potential of V2G technology, which is the main goal of this report.

# PART 1

## VEHICLE TO GRID (V2G) CONCEPT

### 1. Electric vehicle as an element of the Smart Grid

#### 1.1. Interrelation: smart grid – electric vehicle – – renewable energy sources

The transport system and the power system are two diverse sets with electric power as an element shared by both of them.

**Within the structure of modern digital economy connected with the development of mobility, transformation of these two systems leads to a higher level of interoperability, based on Smart Grid technology. The Smart Grid concept has a positive impact on integration of distributed power generation, mainly small wind and solar installations, with the electric power system (EPS). It sets out new directions for the development of electromobility in this respect, enabling efficient management of energy input from these installations into the power grid, thanks to the use of the vehicle – grid technology (Vehicle to Grid, V2G).**

Bidirectional electricity flow makes it possible to take energy off the grid into the vehicle during the periods of low demand or increased RES generation and then to transmit it in the opposite direction during peaks of electricity demand.

#### 1.1.1. Smart Grid

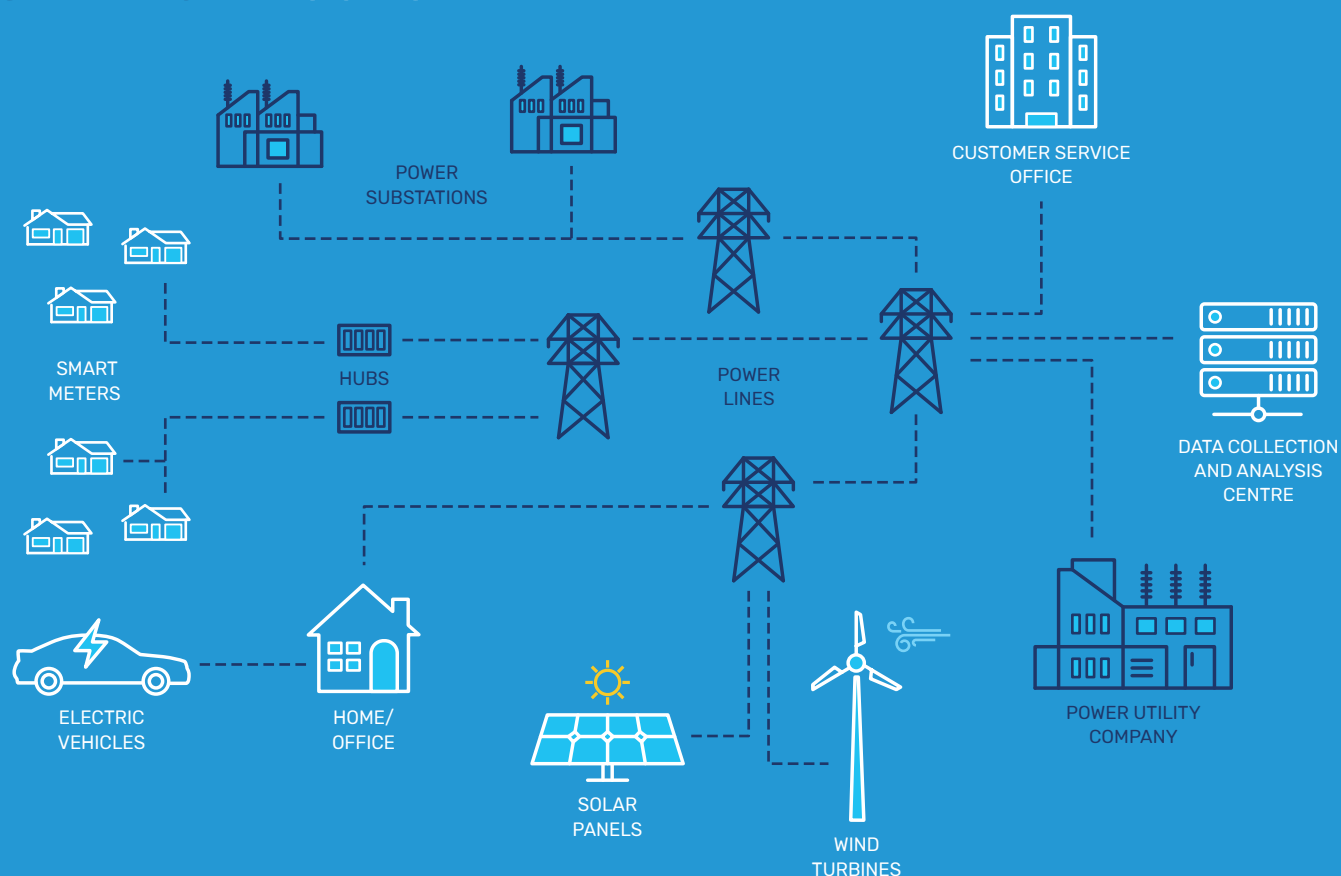
A smart grid is a comprehensive power system enabling connection, two-way communication and best management of the so far dispersed elements of power infrastructure, both for power generators and consumers. It makes it possible to exchange and analyse information and, as a result, to improve the efficiency of electricity use<sup>1</sup>.

**The main objective of implementing the Smart Grid, in accordance with the Directive 2009/72/EU, is to optimise the operation of the electricity system so as to ensure high efficiency, reliability and quality of the electricity supplied.**

<sup>1</sup> *How2guide for smart grids in distribution networks. Roadmap development and implementation*, International Energy Agency, International Low-Carbon Energy Technology Platform, Paris 2015, p. 6.



# SMART GRID CONCEPT



Source: <https://m.elektronikab2b.pl/technika/16187-plc-standardem-przyszlosci>

Effective electricity use and management is a response to the growing environmental protection requirements, such as, e.g. the necessity to reduce CO<sub>2</sub> emissions and the use of primary energy resources.

According to the SMARTer2030 report published by The Global e-Sustainability Initiative, the smart grid technology makes it possible to reduce CO<sub>2</sub> emissions in the power sector by as much as 15% by the end of 2030 and generate USD 0.8 trillion of additional income compared to 2015.<sup>2</sup>

2030 —

15% CO<sub>2</sub> reduction  
Additional income = 0.8 trillion USD

OPTIMISATION  
OF EPS  
OPERATION

High:

- efficiency
- quality
- reliability

2015 —

Base year

SMART GRID DEVELOPMENT

Source: Authors' compilation

<sup>2</sup> SMARTer2030, The Global e-Sustainability Initiative, Brussels 2015.

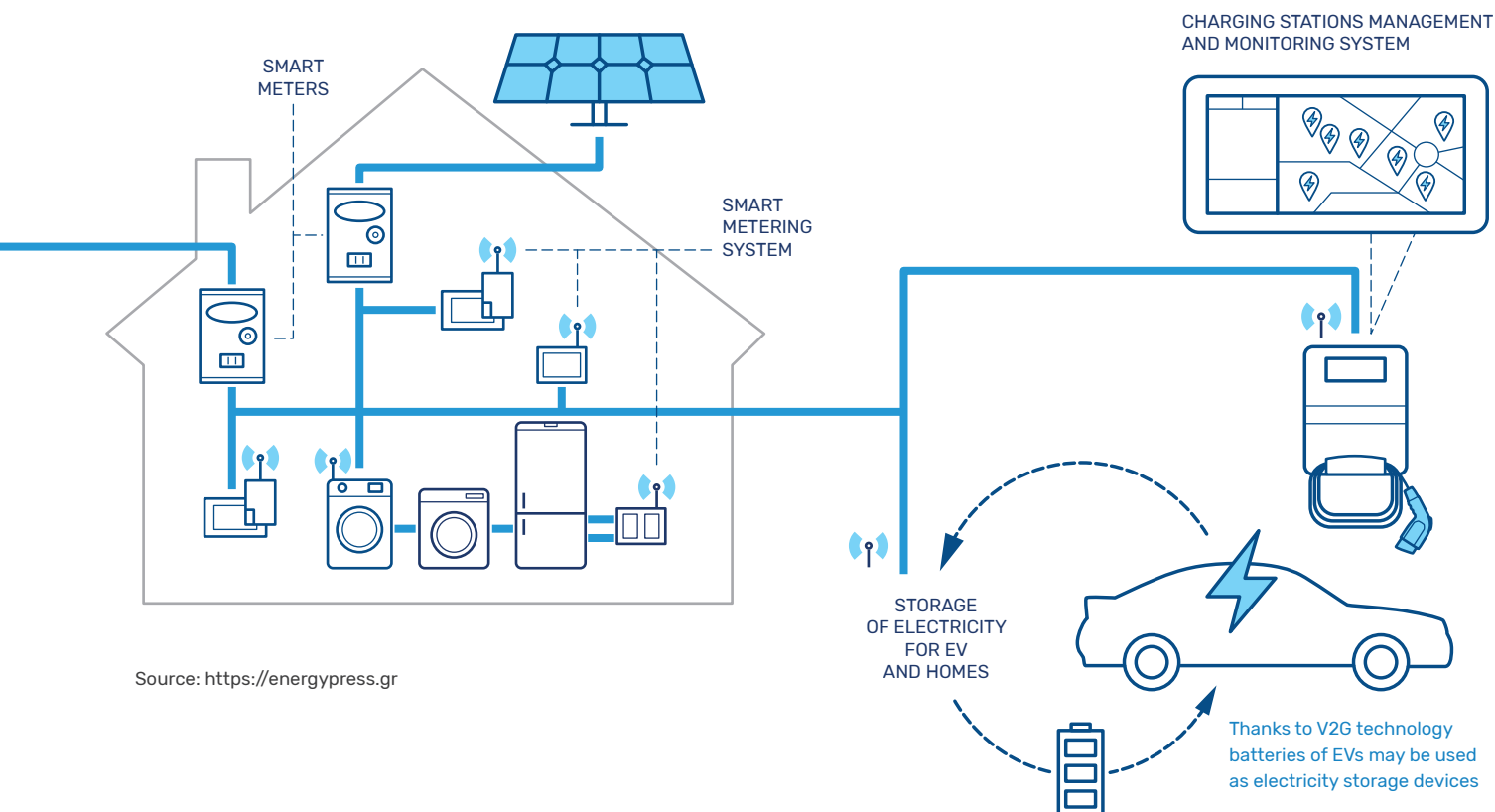
### 1.1.2. Electric vehicle

Electric vehicles (EV) are one of the elements of a balanced electric power system within the Smart Grid structure. From the point of view of integration with power grids, three types of electricity powered vehicles can currently be used: BEV, PHEV and FCV.

The idea behind the all-electric vehicle (Battery Electric Vehicle; **BEV**) is to replace the internal combustion engine with an electric motor and the fuel tank – with a battery. The electric motor propelling the vehicle takes energy from a rechargeable battery. The batteries are charged from an external source, e.g. from power grid or electricity storage. The option of charging the battery from the power grid is also available to hybrid vehicles (Plug-in Hybrid Electric Vehicle; **PHEV**), which are also equipped with conventional propulsion system. Whereas vehicles powered by fuel cells (Fuel Cell Vehicle; **FCV**) use electricity generated from hydrogen.

The development of electromobility and the technological progress in the power industry make it possible to fully integrate electric vehicles with the electric power system thanks to V2G technology. The greatest integration potential lies in BEV and PHEV electric vehicles. By using V2G technology, EVs can both take electricity off the grid and feed it back into the grid. Thus the technology enables management of the surplus electricity generated from renewable sources, which increases the flexibility of the system and its balancing capacity.

## ELECTRIC VEHICLE IN THE SMART GRID



Source: <https://energypress.gr>

### 1.1.3. Renewable energy sources

**As a result of the implementation of the European Union climate and energy policy the share of renewable energy sources (RES) in the energy generation mix has been systematically growing. Environmental values and the broad accessibility of these sources have made them the main factor contributing to the development of electromobility in the EU.**

However, the development of electromobility based on RES is a complex issue. The unstable nature of RES has a negative impact on the stability of electric power systems, which does not help improve the security of power supply. Renewable energy sector, given preferences in the form of systemic support and low variable costs of operation drives out from the market the conventional, that is, stable energy generators<sup>3</sup>, who, in addition, do not have motivations to invest.

The complexity of the electromobility development process is also evidenced by the complexity of efficient and user-friendly conversion of the generated electricity into mechanical energy of the vehicle<sup>4</sup>.

This complexity is a source of significant costs, which is the reason why the use (including the total cost of purchase and possessing) of electric vehicles is still not economically competitive in comparison to vehicles powered by conventional fuels and requires effective mechanisms to control and guide the development of the electromobility market. Whereas delivering V2G services makes it possible to reduce EV operating costs and prove, with an extended cost/benefit analysis, the profitability of their purchase<sup>5</sup>.

## 1.2. Electric vehicles – a challenge for electric power systems

**EVs have an important role to play in the transformation of both the power and the transport sectors.** They are currently believed to be a forward-looking alternative for internal combustion engines. Potential benefits of their use have led to campaigns aimed at electrification of road transport.

**The declaration signed during the Paris Climate Summit in December 2015 provides that by 2030 the share of EVs in the total global fleet will reach at least 20%<sup>6</sup>.** Whereas the International Energy Agency (IEA) forecasts in its annual report "Global EV Outlook 2017" that in 2030 this share will grow to 30%. In the EU the share of PHEVs in the sales of new cars is expected to reach 20%, while BEVs – 30% by 2030.

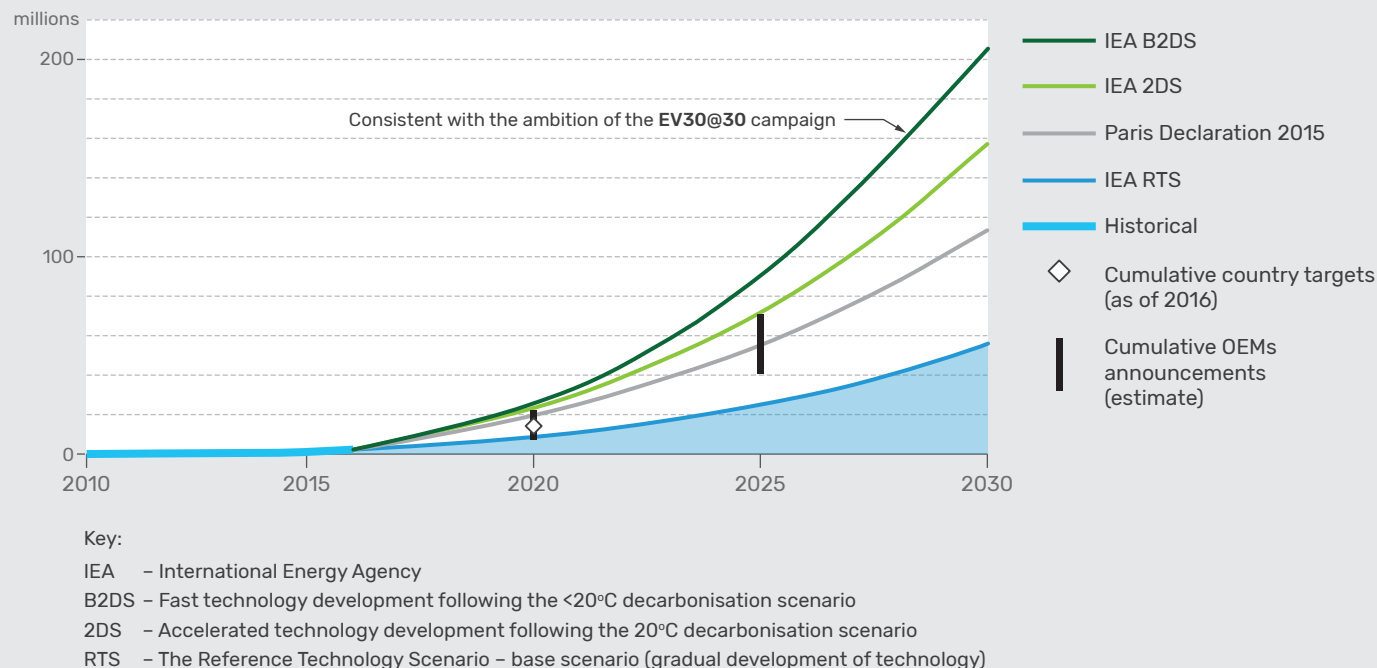
<sup>3</sup>J. Malko, *Rynek konkurencyjny czy gospodarka planowana – dylemat, który zdawał się być rozstrzygnięty*, „Nowa Energia” 2014, No. 5–6.

<sup>4</sup>Al. Moro, E. Helmers, *A new hybrid method for reducing the gap between WTW and LCA in the carbon footprint assessment of electric vehicles*, p. 3–4, <http://download.springer.com/static/pdf>.

<sup>5</sup>S. Bielecki, *Pojazdy elektryczne jako mobilne źródła mocy biernej*, „Przegląd Elektrotechniczny” 2016, No. 11.

<sup>6</sup>United nations conference on climate change COP 21, November 30<sup>th</sup> to December 11<sup>th</sup>, Paris 2015.

## SCENARIOS FOR GLOBAL EV MARKET DEVELOPMENT



Source: Global EV Outlook 2017, OECD/IEA, p. 6.

In order to develop electromobility and achieve the expected goals it is necessary to expand and transform electric power systems so that they could guarantee the supply of power to EVs. The EPS should ensure the ability to quickly connect renewable energy sources and to signal the occurrence of periods when these sources generate huge amounts of electricity. This signalling system will make it possible to charge vehicles when the electricity prices are low, which is important both for economic and environmental reasons as well as for the balancing and stability of the EPS<sup>7</sup>. Smart Grid, equipped with Smart Metering systems<sup>8</sup> can provide such functionalities to power systems. EV batteries can help to balance and stabilise EPS as thanks to the V2G technology they can be used for electricity storage.

It is also worth mentioning that if appropriate methods are used (controlled use of the batteries) the process is not harmful to the vehicle but, to the contrary, it can even improve the functioning of the battery.

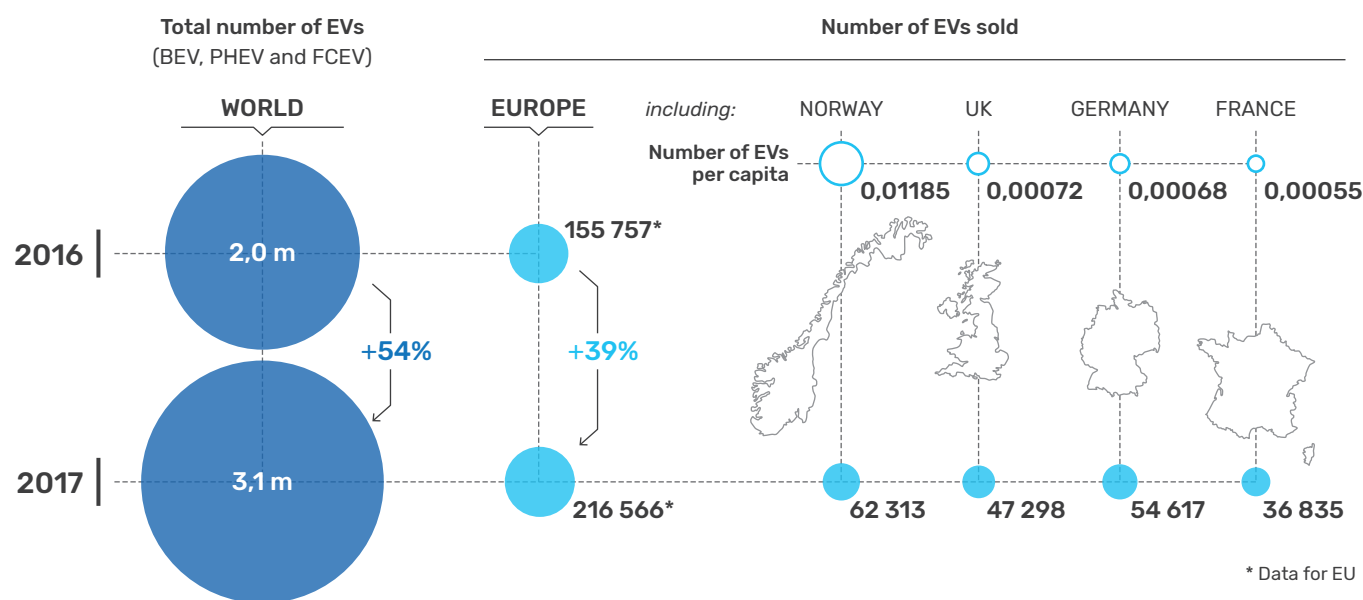
**EVs constitute a solution that is ready for implementation and can help the EU in reaching the 2015 Paris Agreement targets.**

The automotive industry is beginning to invest heavily in electric engines and the number of customers deciding to purchase such vehicles has been systematically growing. According to IEA data, the number of electric vehicles (BEV, PHEV and FCEV) in the world reached 3.1 million in 2017, which means 54% growth compared to 2016. In 2017 customers from the EU purchased 216,566 EVs that is, 39% more than a year earlier (155,757 vehicles). The greatest number of EVs was sold in Germany (54,617), the United Kingdom (47,298) and France (36,835).

<sup>7</sup> Consortium Smart Power Grids Polska, [www.smartgrids.pwr.wroc.pl](http://www.smartgrids.pwr.wroc.pl).

<sup>8</sup> *The role of DSOs in a smart grid environment. Final Report*, European Commission, DG ENER, Amsterdam-Rotterdam, 23<sup>rd</sup> April 2014.

## NUMBER OF ELECTRIC VEHICLES



The number of EV registrations is growing dynamically. In the first half of 2018, 143,017 electric vehicles have been registered in the EU, which means an increase by 46% compared to the same period in 2017.<sup>9</sup> According to the statistics of the European Automobile Manufacturers' Association (ACEA), the number of actively used EVs on the European market will exceed 1 million in 2018.

### EVs IN EUROPE

**1 million** actively used EVs on the European market in 2018 (acc. to ACEA)

In Poland the government plans for the development of electromobility assume that in 2020 there will already be about 70 thousand EVs, and by 2025 their number will have grown to one million<sup>10</sup>. Today these forecasts seem very ambitious. EVs share in the Polish car market is still negligible and amounts to about 0.1%. **However, the interest in electromobility in our country is growing very fast. In 2017, 439 BEVs were registered in Poland, which means more than 300% growth compared to 2016.** At the same time, the number of PHEVs has increased by 585, that is, by almost 45% compared to 2016. **The ACEA report indicates that in 2017 the dynamics of growth in the sales of BEVs in Poland was one of the highest among EU Member States.**

### EVs IN POLAND

#### GOVERNMENT PLANS

**50 thousand** Number of EVs in 2020

**1 million** Number of EVs in 2025

#### 2017

**0,1%** Share of EVs in the Polish automobile market

**439** Number of BEVs registered in Poland  
**+300% y/y**

**585** Number of PHEVs registered in Poland  
**+45% y/y**

#### H1 2018

**279** Number of registered BEVs  
**+123% y/y**

**393** Number of registered PHEVs  
**+58% y/y**

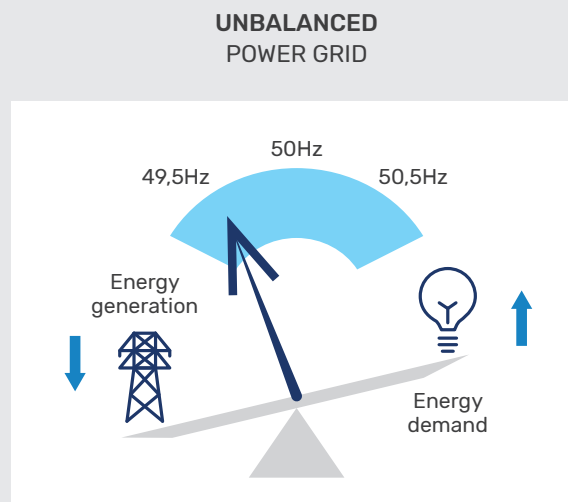
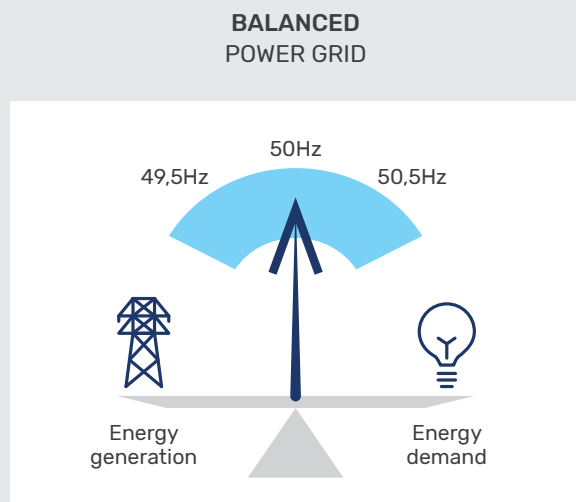
<sup>9</sup> <http://www.acea.be>.

<sup>10</sup> Plan for the Development of Electromobility in Poland, Ministry of Energy, Warsaw 2016.

Further dynamic growth of EV sales in the first half of 2018 indicates the emergence of the electromobility ecosystem in Poland. The number of BEV registrations in this period amounted to 279 vehicles, which means growth by 123% compared to the same period in 2017. At the same time, the demand for PHEV cars in the first half of 2018 has grown by 58% (393 vehicles) compared to the first half of 2017.

**According to forecasts, global development of electromobility will accelerate strongly in the subsequent years, which will pose a serious challenge for power systems.**

The report “Electric Vehicle Outlook 2017” estimates that the global electricity demand from EVs will grow from 6 TWh in 2016 to 1,800 TWh in 2040<sup>11</sup>. **Switching from internal combustion engines to electric propulsion systems will therefore require developing synergies between the power and the transport sectors.** In Poland the implementation of the government plans, according to which by 2025 there will be one million EVs on Polish roads, will entail the growth in electricity demand by approx. 4.3 TWh per year<sup>12</sup>. This raises concerns whether the current electric power system will be able to cope with the increased power demand



Source: Impact of e-mobility on power grids, IMP PAN – CB Jabłonna.

Meanwhile, modern technology expands the functions of electric vehicles. Apart from the transport function, they can also supply electricity needed by distribution systems operators (DSO) and, increasingly, the transmission systems operators (TSO) to provide system services necessary to ensure the proper operation of their systems.

**With the vehicle-grid interface (V2G) and smart charging, the integration of EVs with EPS offers solutions for energy storage and system services.**

<sup>11</sup>Electric Vehicle Outlook 2017, Bloomberg New Energy Finance, July 2017.

<sup>12</sup>Report from consultations of the draft *Plan for the Development of Electromobility in Poland. Energy for the Future*.



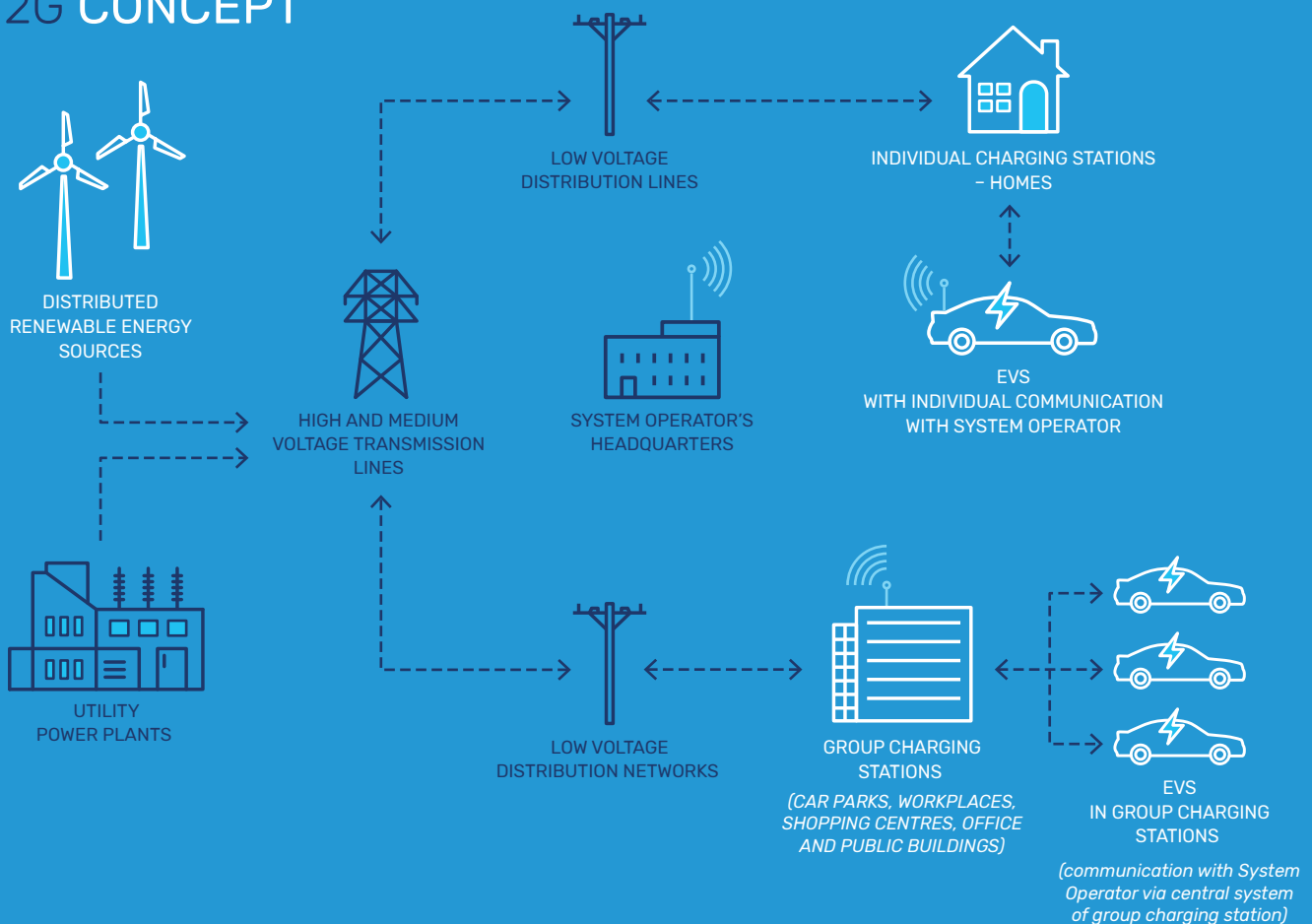
## 2. Main elements and objectives of the V2G concept

### 2.1. Vehicle-grid interface

Vehicle to Grid (V2G) is a system that enables bidirectional flow of electricity between an electric vehicle and the power grid.

The idea to transfer electricity from EV to EPS is based on the storage of electricity in the vehicles' batteries, taken off the grid in the periods of low energy demand and feeding it back into the grid in the periods of peak demand. At the same time, it also assumes that the reverse flow of electricity will take place at the time of peak RES generation. The V2G concept includes the technical aspects as well as economic ones.

## V2G CONCEPT



Source: W. Kempton S.E. Letendre, Electric vehicles as a new power source for electric utilities, „Transportation Research Part D: Transport and Environment“ 2 (3), 1997, pp. 157-175.

## 2.2. Technical aspects

**Equipping the vehicle with a bidirectional converter makes it possible for the electricity stored in its battery to be fed back into the EPS. It is a prerequisite for integrating dispersed vehicle –based electricity storage with the grid that there should be an appropriate charging station which serves both as electric and communication interface between the vehicle and the power grid.**

The device must allow bidirectional electricity flow, must have a smart charging/discharging control system so that the vehicle retains its availability for the driver and at the same time that the energy stored in the battery could be made available to the network operator while the car is parked, depending on the needs<sup>13</sup>.

Controlling the process of charging and discharging the vehicle batteries should be carried out remotely, depending mainly on:

- battery discharging level
- power grid load
- technical condition of the battery and the power grid
- type of the grid (smart or traditional grid)
- provisions of the contract between the vehicle owner and the utility company
- time and distance of the journey planned by the EV user

## 2.3. Economic aspects of the V2G concept in relation to the vehicle user

**The cooperation between EVs users and the power grid leads to the emergence of new business models where the vehicle users play the role of energy suppliers while at the same time being electricity consumers<sup>14</sup>. In practice these models are expected to lower the costs of EV use, mainly thanks to the possibility of earning income on the sale of the electricity stored in the batteries or making the battery available for the purpose of balancing the system**

**The viability of the V2G system is based on the assumption that EVs will be charged at night or during the periods of increased generation from RES. This provides an opportunity to take the surplus electricity off the grid taking advantage of the cheaper tariff.**

**The electricity stored in the EV's battery may be used during the day to meet the needs of the household at the time when a higher tariff is in force or may be sold back to the grid earning profit for the EV owner.**

In addition, in return for the prior declaration of readiness to feed electricity back into the EPS, an EV user could receive higher remuneration for selling it back while earning additional bonus in the form of recommendation points for the reliability of this supply.

<sup>13</sup> Attachment No. 2 to the feasibility study of the sectoral programme which is subject of an application submitted by the the Polish Chamber of Commerce for Electronics and Telecommunications, [www.kigeit.org.pl/FTP/SWPSICT/FP\\_10.pdf](http://www.kigeit.org.pl/FTP/SWPSICT/FP_10.pdf).

<sup>14</sup> An EV user enters the energy market as a prosumer, this solution being easier for him formally than in the case of the typical RES assets – electromobility services are not, in principle, regulated by the Energy Law but by the Act on electromobility. One can imagine that the appearance of V2G services on the market could also, partially, separate electricity trading for the purpose of electromobility from the physical uptake of electricity, by applying the principle of virtualization of the electricity offtake point. As in: [https://www.cire.pl/pliki/2/2017/05\\_\\_\\_\\_rzepka\\_soltysik\\_szablicki\\_fvpolsi.pdf](https://www.cire.pl/pliki/2/2017/05____rzepka_soltysik_szablicki_fvpolsi.pdf).

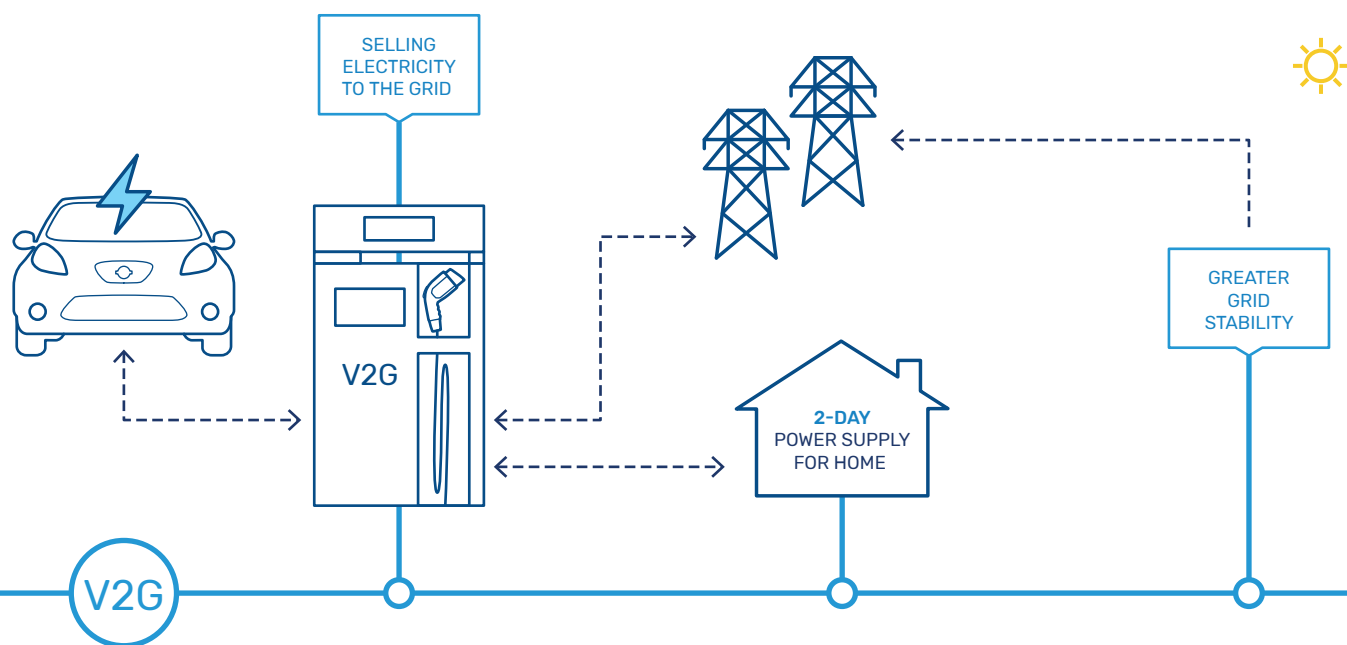
## 2.4. Economic aspects of the concept in relation to the grid

Storing electricity in vehicles is particularly important for the balancing of the power grid.

The electricity accumulated in the EVs' batteries can, thanks to the V2G technology, be used to stabilise the EPS, sustain the supply in the local network and even compensate the reactive power and higher harmonics or control power in the system<sup>15</sup>.

The flattening the power demand curve makes it possible to reduce the need to build new power sources and expand the transmission and distribution networks. Because of the distributed nature and location uncertainty that is characteristic of EVs, their use in the EPS secondary control processes may be limited. It is much easier to use such vehicles for balancing the electricity generated by distributed local RES, particularly from wind or solar farms for which high variability in power generation is typical<sup>16</sup>.

## V2G POTENTIAL



Source: Nissan.

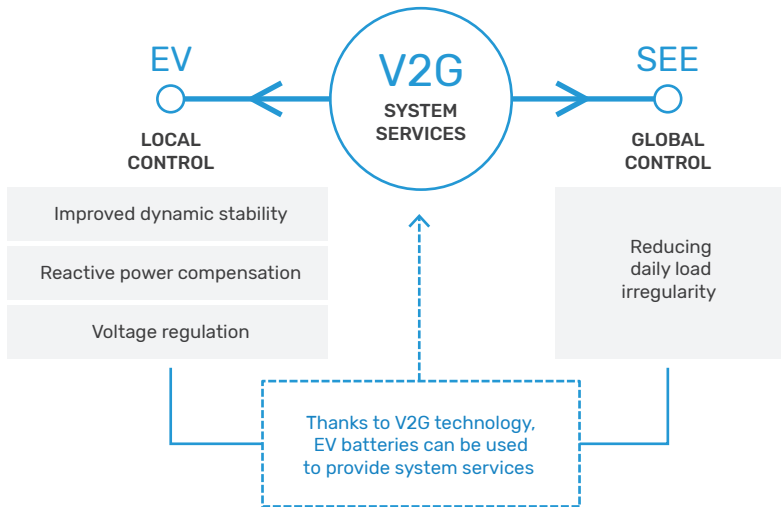
<sup>15</sup> M. Jarnut, G. Benysek, *Zastosowanie układów energoelektronicznych w technologii SmartGrid i V2G (Vehicle To Grid)*, „Przegląd Elektrotechniczny” 2010, No. 6.

<sup>16</sup> J.R. Pillai, B. Bak-Jensen, *Integration of vehicle-to-grid in western Danish Power System*, „IEEE Transactions on Sustainable Energy” 2011, Vol. 2, No. 1, p.p. 12-19.

3. Potential of the V2G concept

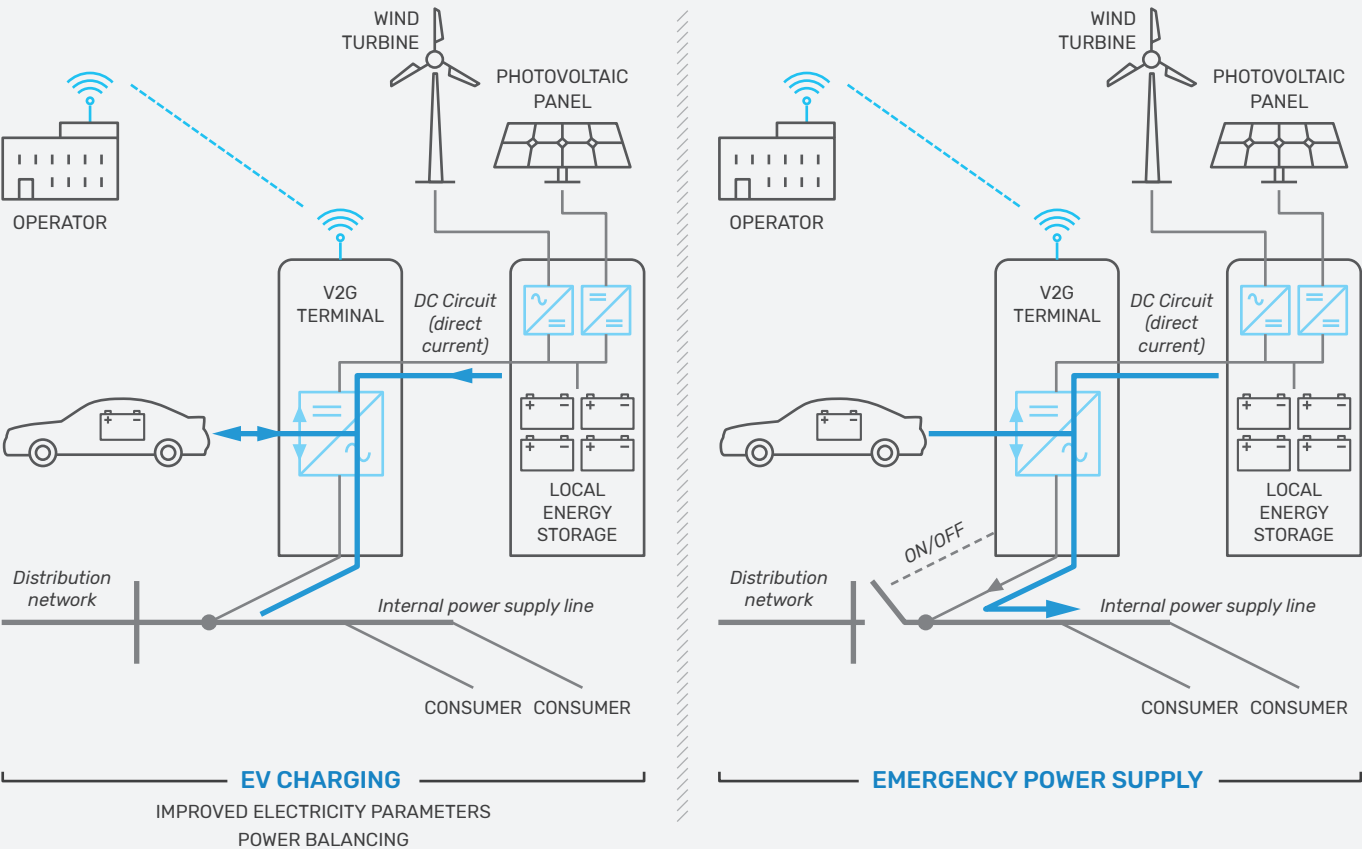
3.1. Electric vehicles as mobile electricity storage for electric power systems

EVs as mobile and controllable power sources, thanks to the V2G technology, can, apart from performing the transport function, supply power, on a large scale, needed by TSOs and DSOs to manage power generation as well as the grid load. They can play the role of distributed power suppliers, thus supporting TSOs and DSOs in providing regulation system services, including transmission services, frequency regulation and reactive power compensation.



Source: Authors' compilation.

One of the challenges for managing electricity distribution is to ensure the stability of the EPS. It is particularly important in the countries generating a large proportion of their electricity from renewable sources with the share of such electricity systematically increasing.

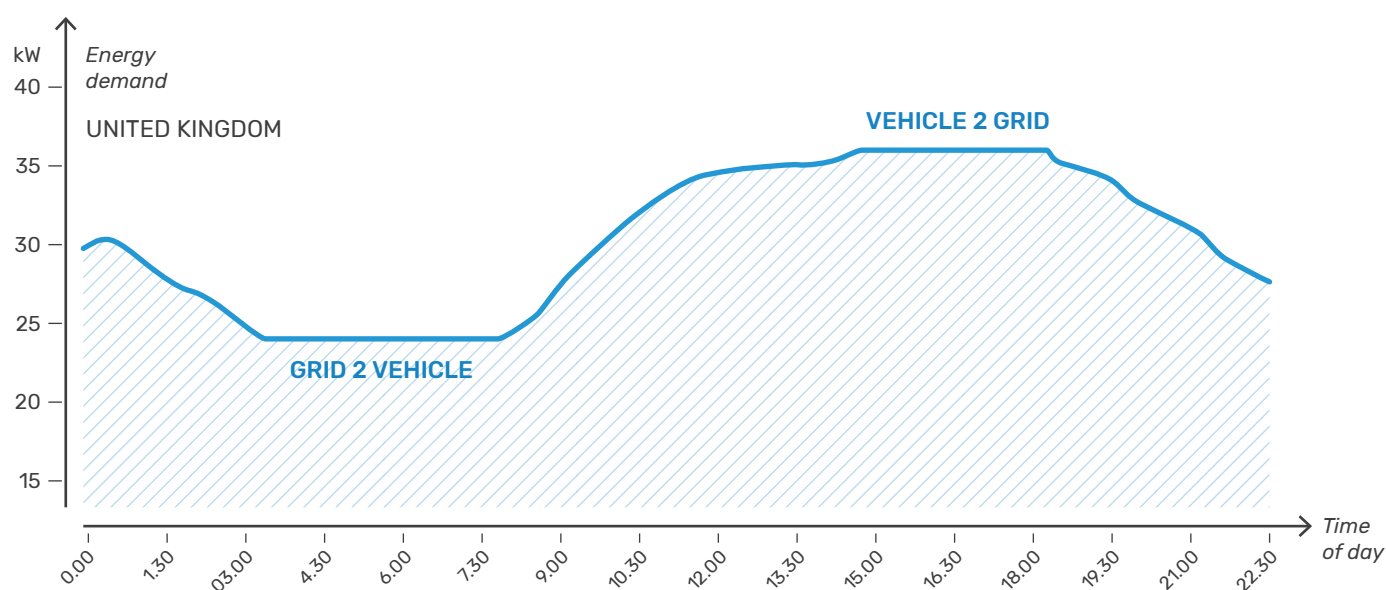


Source: G. Benysek, Institute of Electrical Engineering, [www.iee.uz.zgora.pl](http://www.iee.uz.zgora.pl).

The implementation of systemic vehicle-grid solutions is an important step towards increasing the flexibility of EPS.

**Access to some additional electricity source is vital for network balancing during the periods of peak demand.**

**At the time of peak demand in a certain area, EVs located and connected to the grid in this area, already charged during the “night valley” when there is surplus power in the grid, can be used to meet that demand. For this purpose electricity will be taken off the vehicles and fed back into the grid via the V2G system. Appropriate control of the battery charging and discharging processes makes it possible to shift the grid load as needed.**

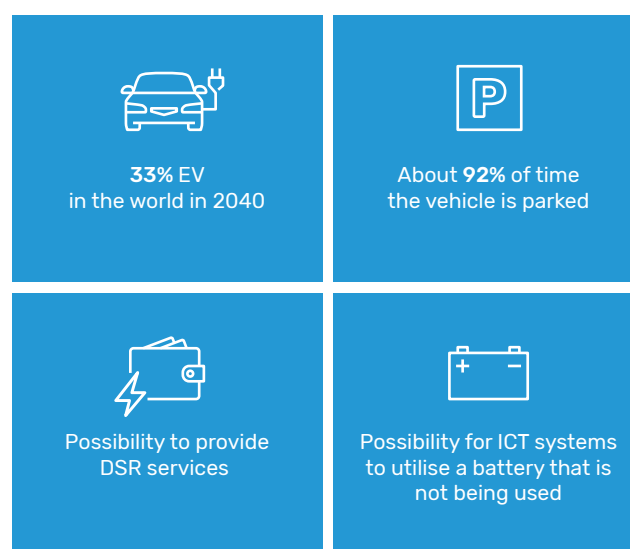


Source: P. Kluś, Nissan CEE.

Power shortage in the system is an important problem to which a conventional solution is to be provided by the currently implemented capacity market mechanism.

**Storage of electricity in EV batteries is a frequently mentioned alternative and a way to provide additional, distributed supply of power to the system<sup>17</sup>. Therefore, the V2G technology is an attractive proposal for DSO to help them maintain network reliability and quality of power supply.** This thanks to the growing number of EVs in use and their high potential as power storage.

#### POTENTIAL OF EVs AS MOBILE ENERGY STORAGE



Source: Authors' compilation.

<sup>17</sup> <https://www.teraz-srodowisko.pl/aktualnosci/magazynowanie-energii-w-samochodach-elektrycznych-4492.html>

Source: Yole Developpement.

The growing importance of EVs as real power storage for EPS is related to the forecasted increase in the number of such vehicles. However, the precise timetable of the changes on the EV market is hard to predict. According to Bloomberg Finance L.P., in the years 2020–2025 the three basic barriers hampering the development of electromobility, i.e. mental, technological and infrastructural barriers, will be broken in a leap forward. According to the first scenario drawn up by IEA experts, the number of EVs in the world will increase to 125 million in 2030. This scenario assumes that the current EU climate policy and related plans will not change.

According to the second IEA scenario, assuming the implementation of more ambitious plans concerning reduction of CO<sub>2</sub> emissions, there will be 228 million electric vehicles on the roads in the world by 2030.

**The forecasted increase in the number of EVs and the availability of the electricity accumulated in their batteries turns them into desirable storage devices. Electric vehicles, providing V2G services while parked, may remain at the disposal of DSO for about 22 hours per day. Thus the otherwise unused capacity of their batteries can be utilised to meet the needs of the electric power system operations.**

PARAMETERS OF POPULAR EVs

	BEV				PHEV		
	Renault ZOE	Nissan Leaf	Hyundai IONIQ Electric	Volkswagen e-Golf	Volkswagen Golf GTE	Mitsubishi Outlander	BMW 740e
BATTERY CAPACITY	41/41/41 kWh	40 kWh	28 kWh	35,8 kWh	8,7 kWh	12 kWh	9,2 kWh
MAX. SPEED	135 km/h	144 km/h	165 km/h	150 km/h	222 km/h	170 km/h	250 km/h
ENERGY CONSUMPTION	133/133/161 Wh/km	194 Wh/km	11,5 kWh/100 km	12,7 kWh/100 km	12–11,4 kWh/100 km	no data	12,5 kWh/100 km
DISTANCE	400/400/370 km	378 km	280 km	300 km	50 km	54 km	40 km

Source: *Elektromobilni.pl. Electric vehicles catalogue 2018*, Polish Alternative Fuels Association.

**An option of bidirectional exchange of power, thanks to the V2G system, may also be used to improve the quality of electricity supplied to end users.** In the era of domination and development of electronic devices, failure to meet the quality parameters of their power supply has a negative, and in some situations even destructive impact on their functioning and service life. In networks with distributed generation, including renewable sources, rapid voltage changes (voltage fluctuations) occur, resulting in deterioration of quality.

High variability of power generation is typical for these sources as it depends on the variability of the primary energy source<sup>18</sup>. **EVs as power storage, cooperating with RES, can help reduce this variability and, in consequence, reduce fluctuations of supply voltage.** Thanks to the V2G technology, electric vehicles can be successfully used to improve the quality of electricity delivered to end users.

<sup>18</sup> I. Wasiak, *Wybrane problemy integracji rozproszonych źródeł energii z siecią dystrybucyjną*, Zeszyty Naukowe Wydziału Elektrotechniki i Automatyki Politechniki Gdańskiej 2015, No. 45.

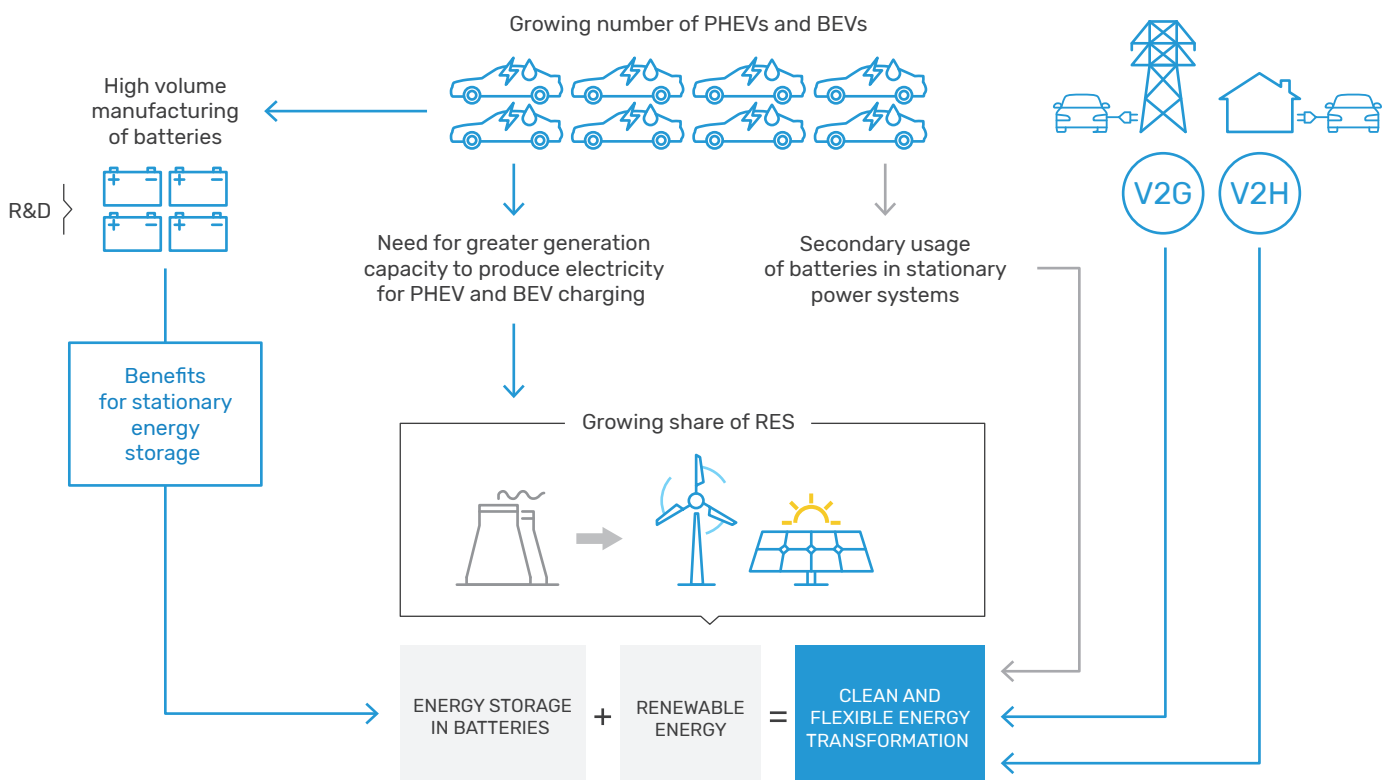


### 3.2. Electric vehicles as an element of the operation of local power grids

EVs, as distributed electricity storage, are taken into consideration in planning, modelling and management of local power systems. V2G technology is considered to be one of the key technologies integrating RES with EPS in this respect. In spite of the significant progress, industrial scale electricity storage is still not possible, which causes serious problems with power systems balancing. The balance between the energy generated and consumed in the power system must absolutely be maintained. Nowadays, in many countries a significant proportion of electricity is generated by wind turbines and photovoltaic installations. **Dependence on the weather and, as a result, the intermittent nature of renewable energy generation are the reasons why its volume is subject to large and frequent fluctuations that upset the equilibrium of power systems.** Restoring this balance poses an increasing challenge for TSOs and DSOs due to the generally low flexibility of these systems.

An important solution ensuring security of power supply and stability of EPS is the use of EV batteries. According to the V2G concept, they help optimise the consumption of renewable energy. **The electricity for EVs is to be supplied from renewable sources and the vehicles are to be charged during the periods of high renewable generation.** This solution should enable absorption (storage) of surplus electricity. It should also help reduce the demand for power during peak load periods. **In these periods EV batteries may become important electricity storage facilities, stabilising the operation of the electric power system.** Renewable energy stored in an EV battery is not included in EPS balance records. However, in many cases it can be sufficient to meet the needs of a household or to power a specific device.

## POSITIVE IMPACT OF ELECTRIC VEHICLES ON THE RENEWABLE ENERGY MARKET



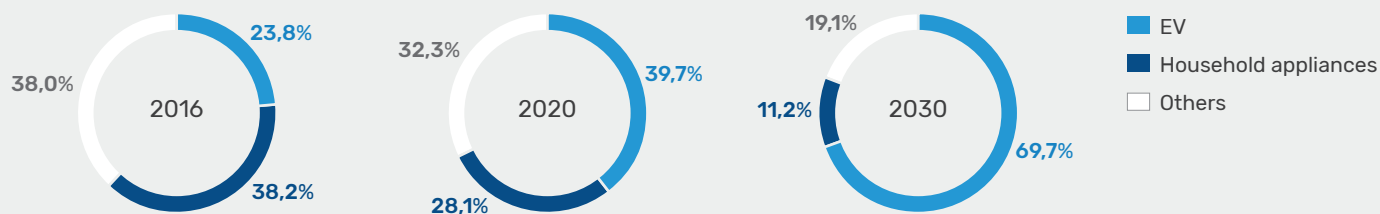
### 3.3. Electric vehicles as an element of DSR services

Together with the growing share of RES in electricity generation mix in a number of EU Member States, including Poland, the importance of demand side management (DSM) services has increased. **In the short term, the objective is to persuade electricity users to reduce their offtake, especially during peak demand periods, that is, to take advantage of their DSR (demand side response) potential<sup>19</sup>.**

DSR services allow electricity end users to play an active role in the capacity market mechanism. It consists of a possibility to reduce power consumption, e.g. at the time when wholesale electricity prices are high or when the stability of the power system is at risk<sup>20</sup>. The main motivation for consumers to make their DSR potential available are appropriate economic benefits.

**A special role in DSR services provision can be played by EV users.** It is related not only to the greatest theoretical DSR potential, compared to other categories of electricity consumers, but also to the highest forecasted dynamics of their growth. **The main factor determining the development of DSR potential by 2030 will be the increase in electricity consumption as a result of the use of electric vehicles.** In the period 2020–2030 alone, it is expected that the electricity demand from EV users will triple in Europe. At the same time, these vehicles, as distributed electricity storage, may be used to provide DSR services needed to ensure reliable operation of the power system<sup>21</sup>. In 2016, the use of electric vehicles accounted for 23.8% of DSR potential of all electricity consumers in the EU. It is anticipated that in 2030 the significance of the EV users' DSR potential will grow to 69.7%

## EVS POTENTIAL FOR DSR SERVICES PROVISION



Source: Authors compilation based on Impact assessment study on downstream flexibility, price, flexibility, demand response & smart metering. Final report, COWI Consortium

The costs of activating DSR services by consumers are generally lower than the costs of activating such services by industrial and commercial clients. In addition to the lower activation costs, there are also longer periods of power consumption shifts.

For instance, a shift in electricity consumption not exceeding 3 hours and delayed use of the electric vehicle generates costs amounting to approx. 10 EUR/MWh.

<sup>19</sup> T. Motowidlak, *Programy DSR instrumentem poprawy bezpieczeństwa dostaw energii elektrycznej*, Przegląd Naukowo-Metodyczny „Edukacja dla bezpieczeństwa”, Year X No. 1/2017 (34).

<sup>20</sup> D. D. Rasolomampionona, S. Robak, P. Chmurski, G. Tomasiak, *Przegląd istniejących mechanizmów DSR stosowanych na rynkach energii elektrycznej*, „Rynek Energii”, 2/2010, p. 140.

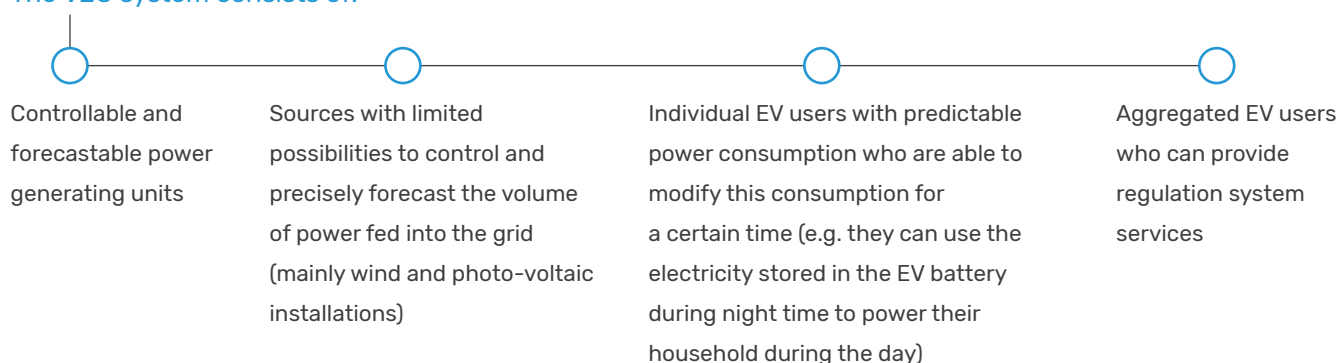
<sup>21</sup> Electric cars which are able to drive the distance of 160 km can store up to 40 kWh of electricity. Assuming that they need 0.25 kWh to travel the distance of one kilometre and that they make 40 km per day, the electricity stored in their batteries will be enough for 4 days of use.

## 4. Elements of V2G services architecture

### 4.1. System participants

V2G is a centrally optimised and controlled set of mobile energy storage devices, i.e. EVs, which are able to regulate the capacity (take electricity off the grid or feed it back to the grid) on request of the aggregator controlling the network operation and, as a result, help the balanced and efficient operation of the EPS.

The V2G system consists of:

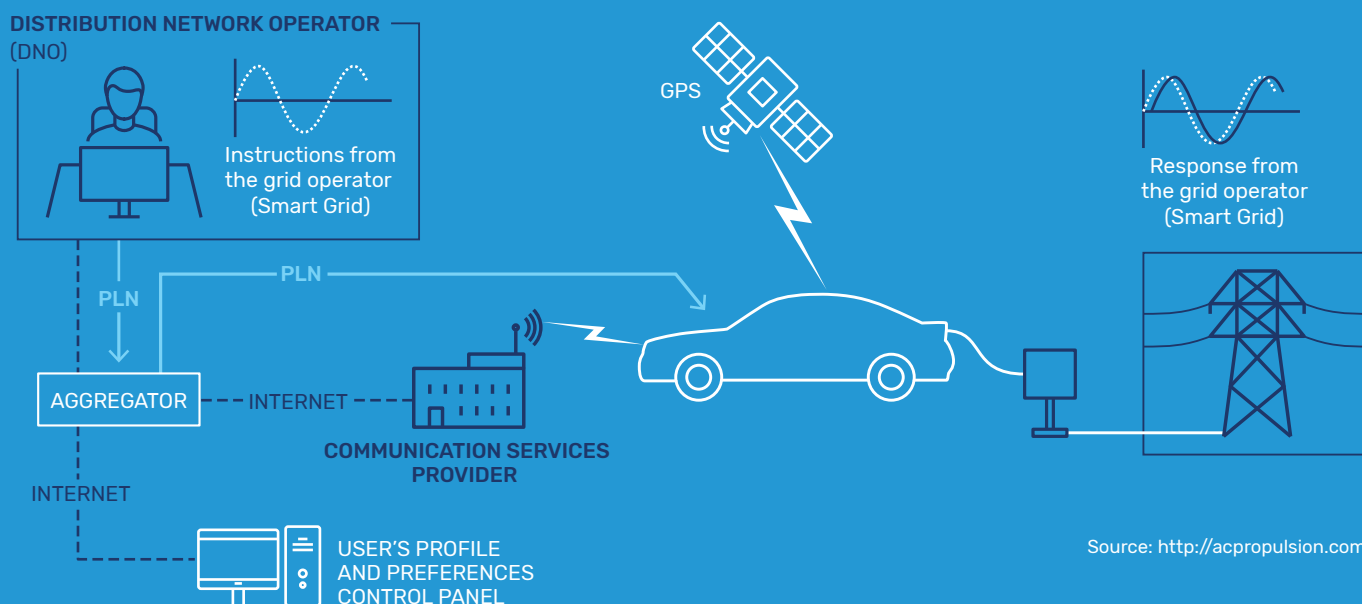


## ELEMENTS OF THE V2G SYSTEM

ELECTRICITY DRIVEN CAR HAS BEEN CONNECTED TO THE GRID VIA A V2G INTERFACE

**VEHICLE CONNECTED TO THE GRID – USED AS AN ENERGY RESOURCE**

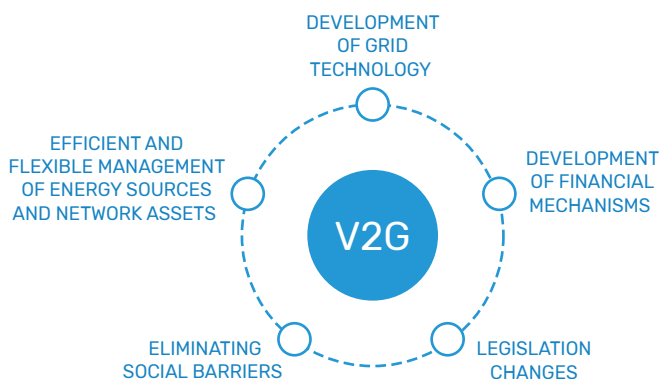
(DER – Distributed Energy Resources)



The implementation of a complete V2G system is a complex process which requires investment related to the construction of appropriate charging infrastructure, IT systems managing communication and data analysis, as well as modernisation of power plant automatic control systems.

The implementation of V2G functionality also requires taking into account technical possibilities and limitations, introduction of appropriate changes in the law and activities that help to gain public acceptance.

## CHALLENGES TO THE DEVELOPMENT OF V2G SYSTEMS



Source: Authors' compilation.

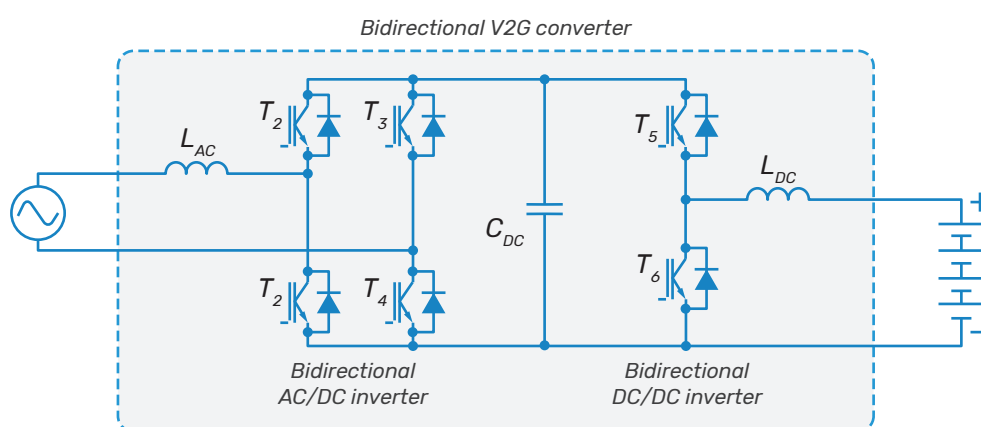
### 4.2. Technical and infrastructural solutions

Thanks to the V2G technology, EV becomes an object of continuous and optimised power management that can work both as a mobile power source (discharge mode) and can be used in the receiving mode (storage device charging mode).

**Bidirectional electricity flow between the electric vehicle and the power system requires special charging converters.**

Equipping the EV with a bidirectional power converter makes it possible to convert the power stored in the batteries into AC power that can be fed into the power grid.

### CONVERTER FOR THE V2G

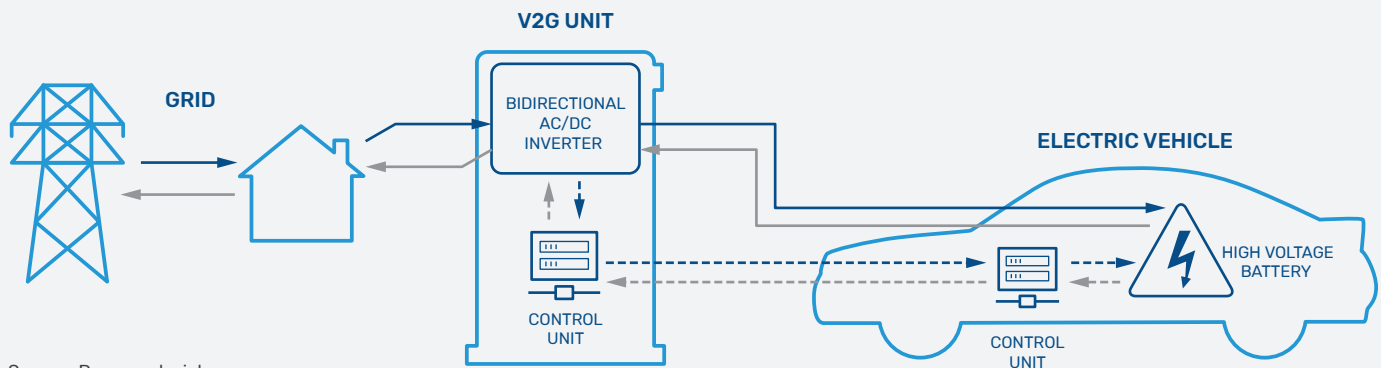


Source: J. Guziński, M. Adamowicz, J. Kamiński, *Infrastruktura ładowania pojazdów elektrycznych*, „Automatyka – Elektryka – Zakłócenia” 2014, No. 1.

**Integration of EV with EPS and the possibility to provide V2G services requires access to charging facilities that enable two-way electricity flow.**

Charging of EV batteries and transmitting electricity back to the system, depending on the level of technology development and the adopted standards, may take place through individual chargers or with the use of module solutions.

## CHARGING/DISCHARGING CONCEPT IN THE V2G SYSTEM



Source: Press materials.

### 4.3. Communication and information exchange structure

The V2G concept requires the implementation of a system aggregating multiple EVs, as the benefit of adapting a single V2G installation to work independently with DSO in the provision of system regulation services is likely to entail a significant increase in operating costs.

**From the perspective of cost-effectiveness of providing V2G services, it is justified to combine as many EVs as possible within one scheduling unit participating in the market.** The work of individual units is controlled by the aggregator who optimizes their work in accordance with the set objectives. This involves the introduction of ICT technology in the form of smart bidirectional meters, software, interfaces or end-user applications. GSM and GPS systems can also be helpful.

### 4.4. System kontroli i analizy danych

**An important element of V2G is a metering system for precise measurement of the amount of electricity taken off and returned to the grid, which is needed for financial settlement between the EPS operator and the EV user.** The financial accounting system for V2G services can be imagined as a model similar to the current mobile phone billing systems. Since a single user of an EV is of relatively minor importance from the point of view of the needs of DSO, the solution most likely to be adopted is the introduction of a number of small companies acting as intermediaries between EV users and TSO and DSO. **The implementation of this solution could take place via the infrastructure of GSM network operators and at the same time provide them with additional scope of business activity and revenue generation.** The main risk associated with the provision of V2G services is that EV users are very likely to be concerned about discharging vehicle batteries and thus limiting the distance their vehicles could cover. **It is therefore necessary to ensure that it is possible to limit the level of battery discharge, depending on the time and range of the planned journey, using an appropriate control panel on the vehicle dashboard.**

## PART 2

# IMPLEMENTATION OF THE VEHICLE TO GRID SYSTEM

### 5. World leaders in the V2G technology development

#### 5.1. History of the system development in Europe

##### 5.1.1. Nissan / Enel

After many years of tests, an energy company Endesa, owned by the Enel Group, developed an optimum low-cost V2G technology, ready for large scale application. The company presented the V2G technology for the first time in 2008, as part of the Smart City Malaga project, on a test site used by the Enel Group for testing smart city solutions. Another presentation of the improved technology was organised by the company in 2012 as part of the ZEM2ALL project. However, the breakthrough moment for the development of V2G system came in 2015. During the 85th Geneva Motor Show, on March 3, Nissan and Endesa signed an agreement that opened the door to large scale implementation of the V2G system. Then, on March 12, in Madrid, both companies presented a plan for introducing a low-cost V2G system that allows integrating EVs with electric power system. The next step in the development of this technology and creating an innovative business model was a partnership agreement signed in December 2015 in Paris during the United Nations Climate Change Conference. The parties to that agreement, that is, Nissan and Enel, confirmed in it their plans to carry out pilots and commercialise the V2G system in Europe.



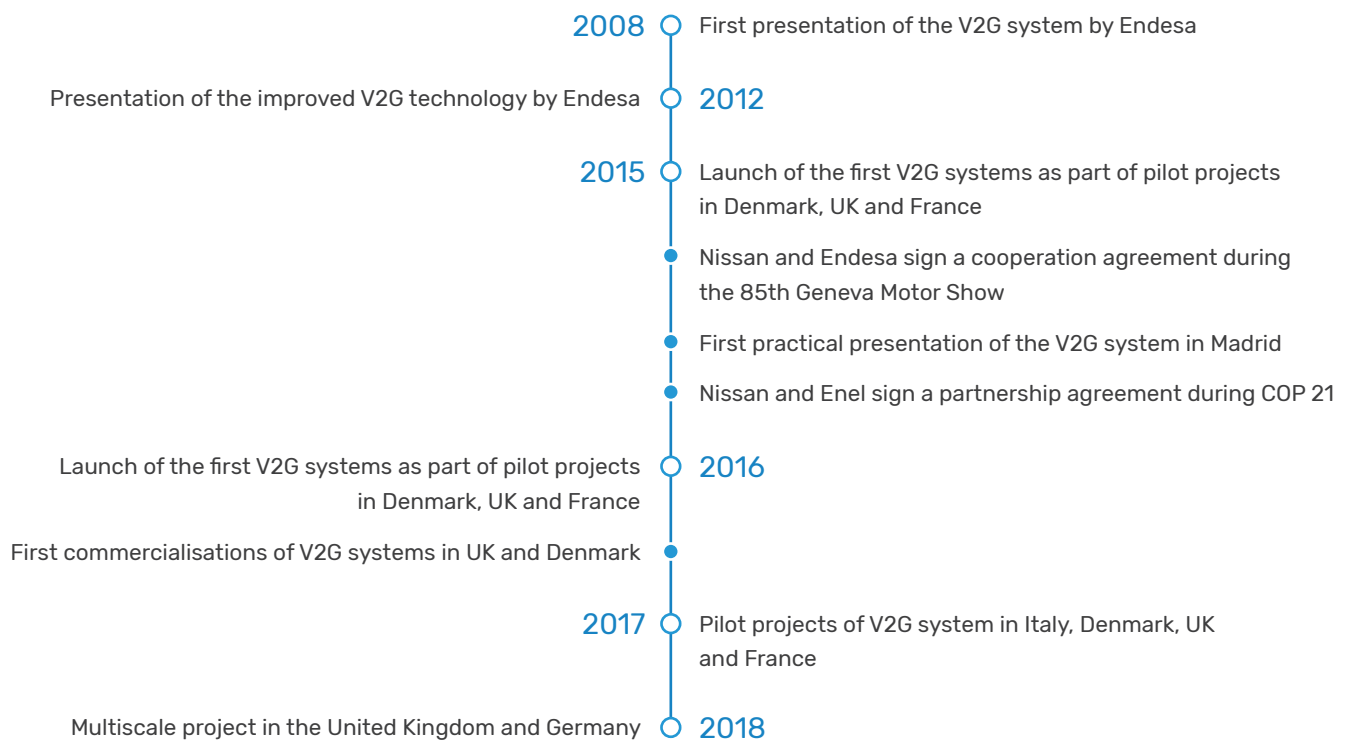
Source: Nissan and Enel press release.

The first effect of the cooperation was the launch of 40 V2G modules in Denmark as part of pilot tests in January 2016. Further modules were installed, among others, in the UK and France. In 2016, the first commercial implementations of the V2G system took place in the UK and Denmark.



In 2017, Nissan, together with energy companies from Italy and Denmark, conducted a one-year-long study which confirmed the positive impact of the V2G system on the stabilisation of the local grid and the reduction of EV charging costs. In 2018, Nissan announced plans to launch further projects. **As part of the cooperation with Enel, a multi-scale V2G system will be implemented in the UK, which is in line with plans to develop and commercialise this technology in the UK.**

As a result of establishing a strategic partnership with the energy company E.ON, Nissan is planning projects to explore the possibility of introducing commercial offers for the provision of V2G services as well as solutions for the generation and storage of energy from renewable sources.



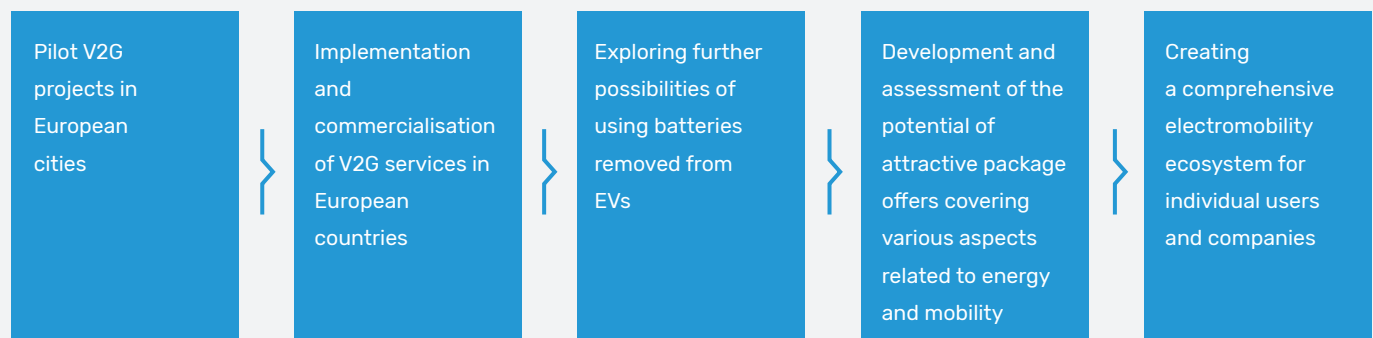
Source: Authors' own compilation.

## COOPERATION BETWEEN NISSAN AND ENEL

**Nissan:** leader among Asian brands in Europe; manufacturer of Europe's most popular EV (Leaf\* model - more than 150,000 vehicles sold)

**Enel:** multinational energy company; supplier of V2G charging stations; supplier of an aggregation platform for distributed energy storage devices

\* Nissan Leaf is almost entirely manufactured in the UK.



Source: Authors' compilation based on press materials.

5.1.2. Mitsubishi / NewMotion

Mitsubishi Motors Corporation (MMC) together with NewMotion, one of the largest EV charge network operators in Europe, in November 2017 launched a pilot vehicle-grid interface in the Netherlands.

As part of the pilot tests, NewMotion has installed public EV charging stations in Amsterdam, using V2G technology. TSO TenneT from the Netherlands is also involved in the project as well as the company Nuvve, which has supplied the Nuvve’s Grid Integrated Vehicle platform, which enables charging of Mitsubishi Outlander PHEVs.

With the use of the NewMotion charging infrastructure for Mitsubishi Outlander PHEV model, parked at home or at workplace, Mitsubishi can provide sustainable energy storage and consumption services.



Source: NewMotion press materials.

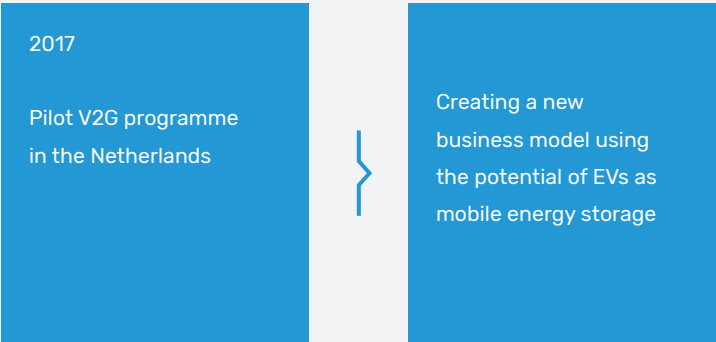
For the users of Mitsubishi Outlander PHEV this means potential financial benefits from the sale of surplus energy back to the grid.

COOPERATION BETWEEN MITSUBISHI AND NEWMOTION

**Mitsubishi Motors:** one of the world pioneers of BEV and PHEV technology; manufacturer of the Outlander PHEV model (the bestselling model in the PHEV category in Europe and Japan)

**NewMotion:** has a network of more than 50 thousand charge points in Europe; in October 2017 it was taken over by Shell

**Nuvve:** world leader in the implementation of V2G technology; supplies GIVE platform, controlling the flow of electricity between the grid and EVs



Source: Authors’ compilation based on press materials.

### 5.1.3. Honda / EVTEC

In December 2017, Honda R&D Europe in cooperation with EVTEC and The Mobility House launched a new bidirectional system for EV charging.



Source: Honda press materials.

It was installed at Honda's European R&D centre in Offenbach, Germany.

The fully integrated bidirectional transfer is intended to optimise the process of energy management in the city, mainly by improving the efficiency of photovoltaic energy use.

The system tested in Offenbach for integrating EV vehicles into the smart grid was presented for the first time at the Frankfurt Motor Show. **The Honda Power Manager Concept system allows the storage and distribution of electricity between grid, solar-panelled houses and companies and electric vehicles.** In the future, the system will also be available for households.

## COOPERATION BETWEEN HONDA AND EVTEC

**Honda:** global automotive brand; author of the bidirectional charging system – Honda Power Manager Concept

**EVTEC:** Swiss supplier of mobile and stationary chargers for EVs

**The Mobility House:** Austrian supplier of services and technical solutions for EV users

2017

V2G project implemented at an R&D centre in Offenbach, Germany

- Testing the possibilities of integrating EVs with RES
- Optimising the management of electricity flows
- Improving efficiency of solar energy use
- Building zero-emission society
- Element of the Smart Company programme

Source: Authors' compilation based on press materials.

5.1.4. Audi / Ampard

In January 2018, Audi announced the Smart Energy Network project, thus joining the group of companies carrying out projects in the field of smart grids and V2G technology.

According to the project assumptions, the vehicle, house and power sources cooperate with each other and interact with the national power grid.

The Smart Energy Network project is implemented in households in the German city of Ingolstadt and in the Zurich region of Switzerland, where photovoltaic systems connected to stationary batteries are installed.

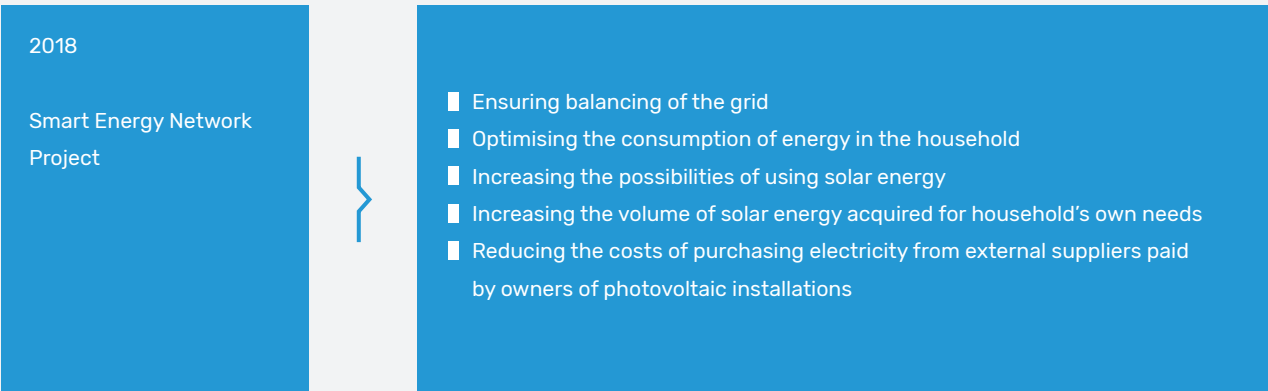
The control software, provided by Ampard (a technology start-up based in Zurich), includes a smart function that anticipates the demand for electricity from home and EVs and automatically sends electricity where it is needed.

Depending on the current or planned demand, it directs the photovoltaic energy to the electric vehicle, household appliances or the building heating system. Thanks to the built-in communication interface, these systems are connected to each other, creating a virtual power plant, which manages the consumption of the generated power.

COOPERATION BETWEEN AUDI AND AMPARD

**Audi:** global automotive brand investing in electromobility and systematically increasing its portfolio of electrified vehicles; implements the Smart Energy Network project

**Ampard:** technology start-up based in Zurich; offers solutions for energy storage in order to make it available on the market



Source: Authors' compilation based on press materials.

### 5.1.5. Renault

The development of the electromobility ecosystem and modern energy solutions is at the heart of Renault's strategy. **The company has set up Renault Energy Services as an entity responsible for projects involving smart grids and charging systems, V2G and the reuse of EV batteries.**

Renault, together with Utrecht City Council, ElaadNL and LomboXnet companies, signed a letter of intent in Paris in March 2016. **The aim of the project is to create a smart charging system for EVs using photovoltaic energy, with the view to applying V2G technology.** According to the letter, in 2017 Renault supplied the city of Utrecht with a fleet of 150 Zoe electric vehicles. In the first phase of the project, 1,000 charging stations, powered by 10,000 photovoltaic panels, will be placed in the Utrecht region. The construction of the infrastructure will be carried out simultaneously with the launch of car-sharing services. **In the second phase of the project, the partners will develop a system based on V2G technology, allowing the accumulation of surplus photovoltaic energy in EV batteries to be later used by the vehicles or the grid.** As early as in June 2015, LomboXnet installed a V2G smart charging station in Utrecht, setting the standard for a new local energy system based on local energy sources. Under the leadership of LomboXnet, the project is being developed by a consortium of GE, Stedin, Vidyn, Last Mile Solutions and Utrecht Municipality.

The next step in the strategy to ensure the Renault Group's key position in the electromobility ecosystem was the acquisition of a 25% stake in Jedlix<sup>22</sup>, a company controlled by the Eneco Group. The Z.E. Smart Charge Renault application, which Renault included in its offer in 2017, enables smart charging of traction batteries. Currently, Renault and Jedlix are working on the development of an application enabling the management of the V2G system. Ultimately, it will be possible not only to manage the charging of vehicles, but also to store electricity from renewable sources in them, and then transfer it to the grid during peak load periods.

Renault's commitment to the development of the V2G system, which is part of the smart energy ecosystem, is confirmed by an innovative project – Sustainable Porto Santo, implemented with Renault's partners, described further in the report.

#### PROJECT INFORMATION SHEET

Location	Utrecht (The Netherlands)
Main stakeholders	Utrecht residents and the City Council
Other Project partners	<b>Renault</b> Providing the Zoe vehicle model  <b>ElaadNL</b> Management of infrastructure and smart charging  <b>LomboXnet</b> Installation of publicly available charging stations with 44 kW connection  <b>Stein</b> Balancing energy supply and demand in the city's power grid
Starting date	2017
Thematic group	RES, V2G
Goal	Integration of RES with EPS
Objectives	Development of smart power system based on local energy sources; reduction of CO <sub>2</sub> emissions
Phase 1	Installation of 1,000 charging stations powered by 10,000 photo-voltaic panels for 150 ZOE vehicles
Phase 2	Implementation of V2G system – testing the possibility of cooperation between EVs, RES and EPS
Expected scope of project application	Implementation of V2G projects in order to improve the efficiency of energy management and the condition of the environment

Source: Authors' compilation based on materials from [media.group.renault.com](https://media.group.renault.com).

<sup>22</sup> Jedlix is a Dutch start-up, specialising in smart charging of electric vehicles.

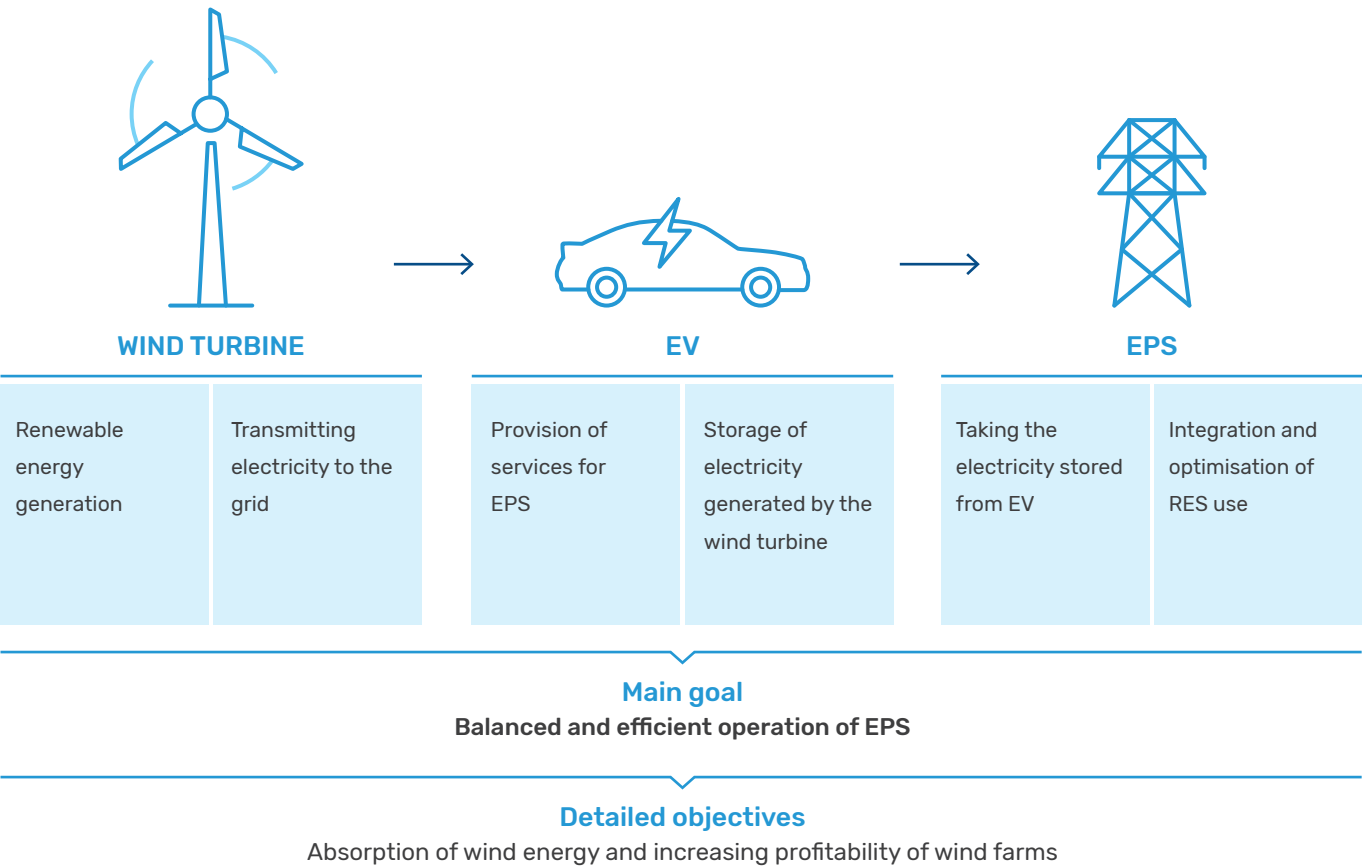
5.2. Technological potential of the system

5.2.1. V2G and RES

In March 2018, the German wind power company Enercon implemented an innovative solution based on the V2G concept with the aim of optimising the use of renewable energy produced from wind to charge EVs and integrating RES with EPS.

The system consists of a wind turbine, EV as an energy storage device, transformers and fast EV chargers. These elements have been coupled via a single network, and the EVs’ energy storage is compatible with V2G technology.

The V2G technology, based on a combination of wind turbines and EV chargers, is a solution with high potential that can be used to support the development of the e-mobility sector<sup>23</sup>. In the installation launched by Enercon, 350 kW chargers are used, which allow the EV to be recharged in 10 minutes. A small wind farm with several turbines could effectively cooperate with a charging station and deliver renewable energy to five ultra-fast 350 kW chargers, thus guaranteeing the stabilisation and optimisation of EPS.



Source: Authors’ compilation.

<sup>23</sup>The average efficiency of wind turbines reaches 25% is about 8 p.p. higher than the same parameter for photovoltaic cells.



## 5.2.2. V2G and development of Smart Building

In April 2018, in the Netherlands, Hitachi Europe Ltd., Mitsubishi Motors and ENGIE, presented a pioneering project aimed at exploring the possibilities of using EV to develop smart and efficient energy management systems in buildings<sup>24</sup>.

As part of a demonstration exercise, the consortium connected EV to the "energy smart" ENGIE office building in Zaandam with the use of an innovative V2X charging station. **This charging station has been connected to the power source of the building, whose energy management system directs the surplus energy to the batteries of EV vehicles. In certain situations, the system transfers this surplus power back to the building or to the grid.**

Thus EV batteries act as both a power source and an emergency power supply. Hitachi's V2X charging station is the first such device that can not only charge an EV but also discharge energy back into the building or power grid, taking into account the different power values.

<sup>24</sup> Charging electric cars at buildings is the optimum supplement to the infrastructure of EV fast charging points. Modern commercial buildings have a high connection capacity which allows integration of charging infrastructure - all the more so as a V2G function - while protecting the stability of the local power grid. Buildings act as a large energy storage facility to protect the grid from sudden power demand caused by EV charging needs. When power reduction is required, the "smart building- charging infrastructure" system acts as a generator, offering a high degree of flexibility to the grid. In Poland, Virtual Power Plant Sp. z o. o., which is currently working on the integration of energy management systems in commercial facilities with charging stations, offers dynamic control of smart buildings' power demand.

### KARTA INFORMACYJNA PROJEKTU

Location	Zaandam (The Netherlands)
Main stakeholders	Facility manager and tenants of the ENGIE office building
Project partners (consortium)	<p><b>Hitachi Europe Ltd</b> Supplier of V2X charging station, which enables bidirectional energy transfer between electric vehicle's battery and the building or power grid; supplier of technology that enables integration of energy between EV and the building and also between EV and the power grid</p> <p><b>ENGIE</b> Connects the EV battery via V2X charger with the building's power supply system and integrates it with photovoltaic cells or other RES thus creating a smart building</p> <p><b>Mitsubishi Motors</b> Supplier of the PHEV model Outlander, which becomes the energy storage centre and the source of renewable power supply for the building</p>
Starting date	April 2018
Thematic group	V2G
Goal	Development of smart and efficient energy management systems
Objectives	Reducing the costs of energy consumption; reduction of CO <sub>2</sub> emissions
Phase 1	Exploring the possibilities of using EVs for energy storage in buildings
Phase 2	Testing the possibilities of cooperation between EVs, RES and building energy management systems
Expected level and scope of project application	Development of smart and more efficient microsystems which can interact with building energy management systems

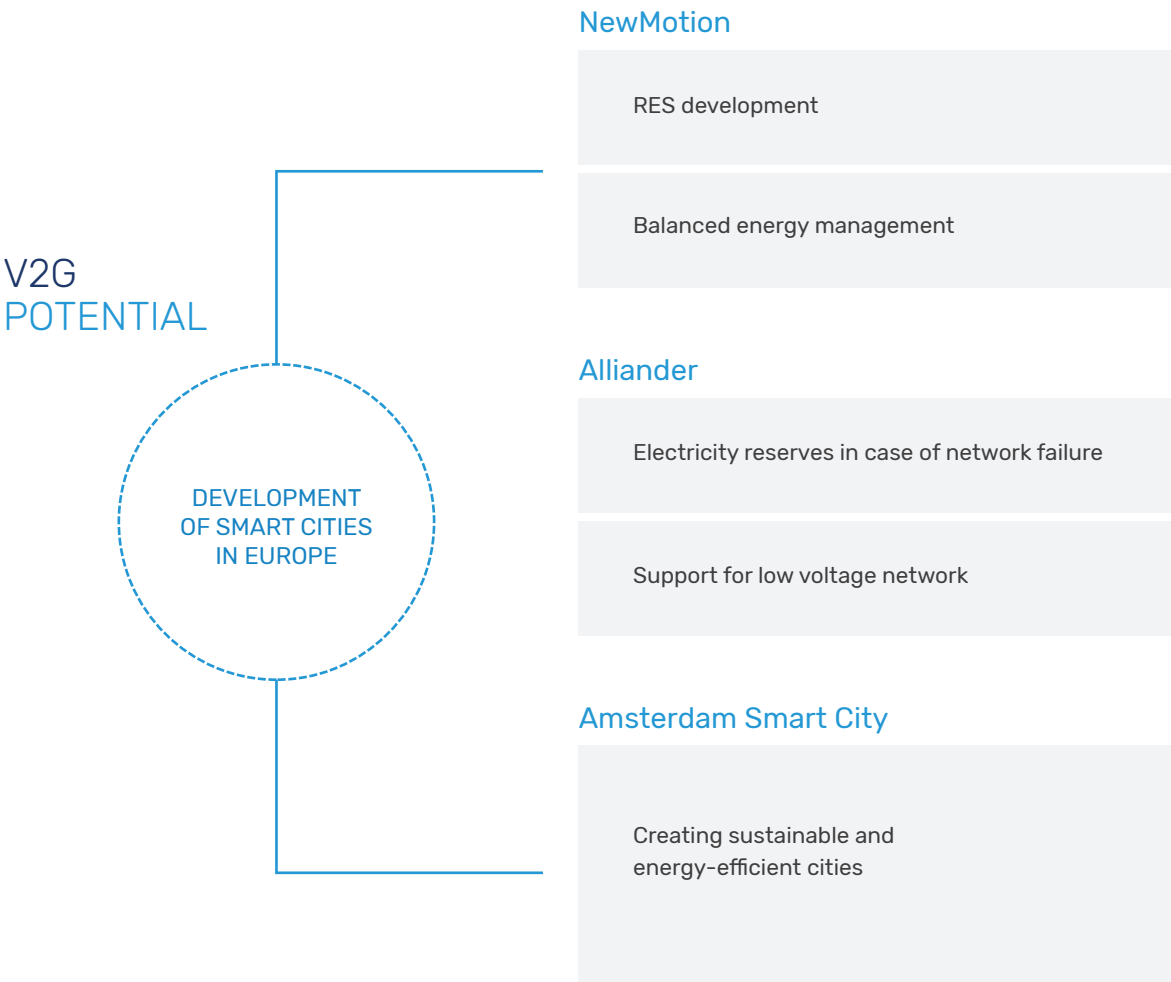
Source: Authors' compilation based on Mitsubishi press materials.

5.2.3. V2G and development of Smart City

In February 2018, in the Netherlands, NewMotion, a company working on new solutions on the borderline between electromobility and energy, launched a pilot programme to test the potential of V2G technology.

In Amsterdam, NewMotion installed the world's first public EV charging stations using V2G technology. The programme is being implemented in cooperation with the energy company Alliander, the technology company Enervalis and the Amsterdam Smart City platform.

The V2G technology pilot tests carried out in Amsterdam are part of the "The City-Zen" programme, which aims to create smart, energy-efficient cities in Europe (so called Smart Cities) with power grids that are not overloaded. V2G and energy storage will develop simultaneously with the progress of electromobility, paving the way for a broad application of the technology.



Source: Authors' compilation.

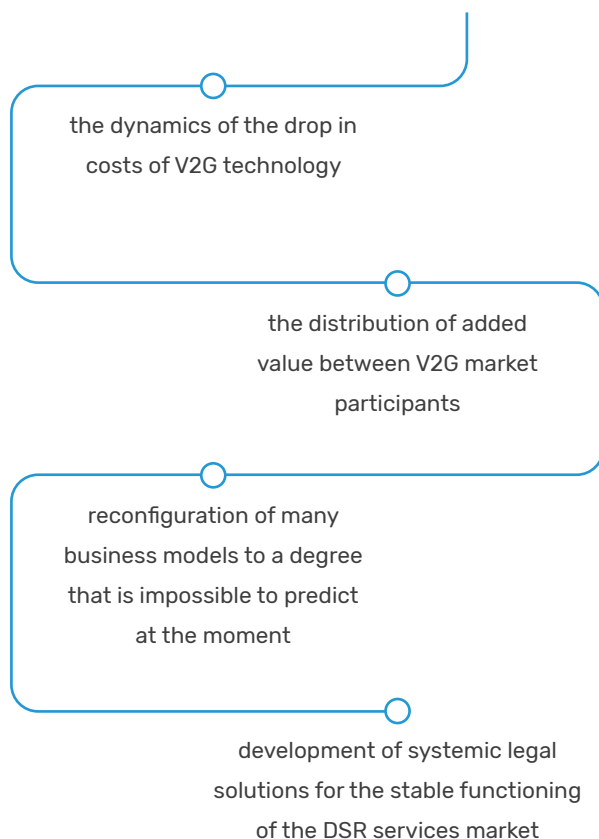
### 5.3. V2G market development scenario

The implementation of V2G services is one of the important trends that may in future change the way we use energy.

Most of the technological solutions necessary for the development of bidirectional electricity transmission (vehicle-grid) are already known and some of them are even available. However, it may not be possible in the coming years to develop solutions that could significantly transform the functioning of the energy market.

Given the wide variety of factors shaping the development of the V2G market, it is possible to anticipate different scenarios for the future of this market. In the report "V2G. Market Study", published in July 2018, Cenex experts stressed that the development of the V2G market is possible, but still burdened with a high degree of uncertainty.

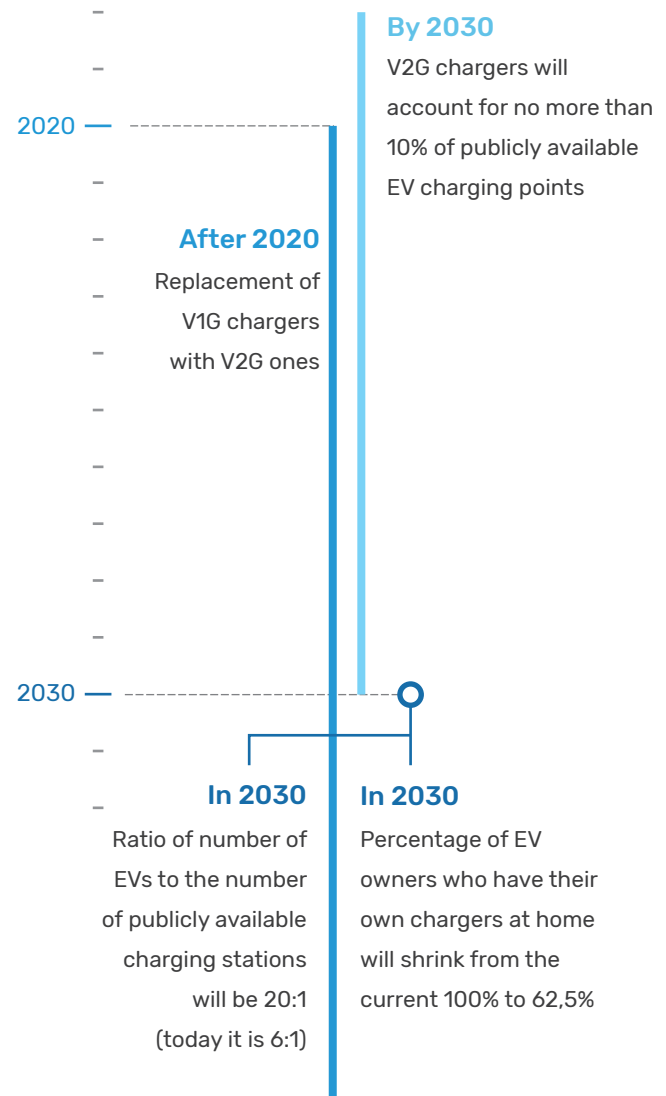
Its shape will depend, among other things, on:



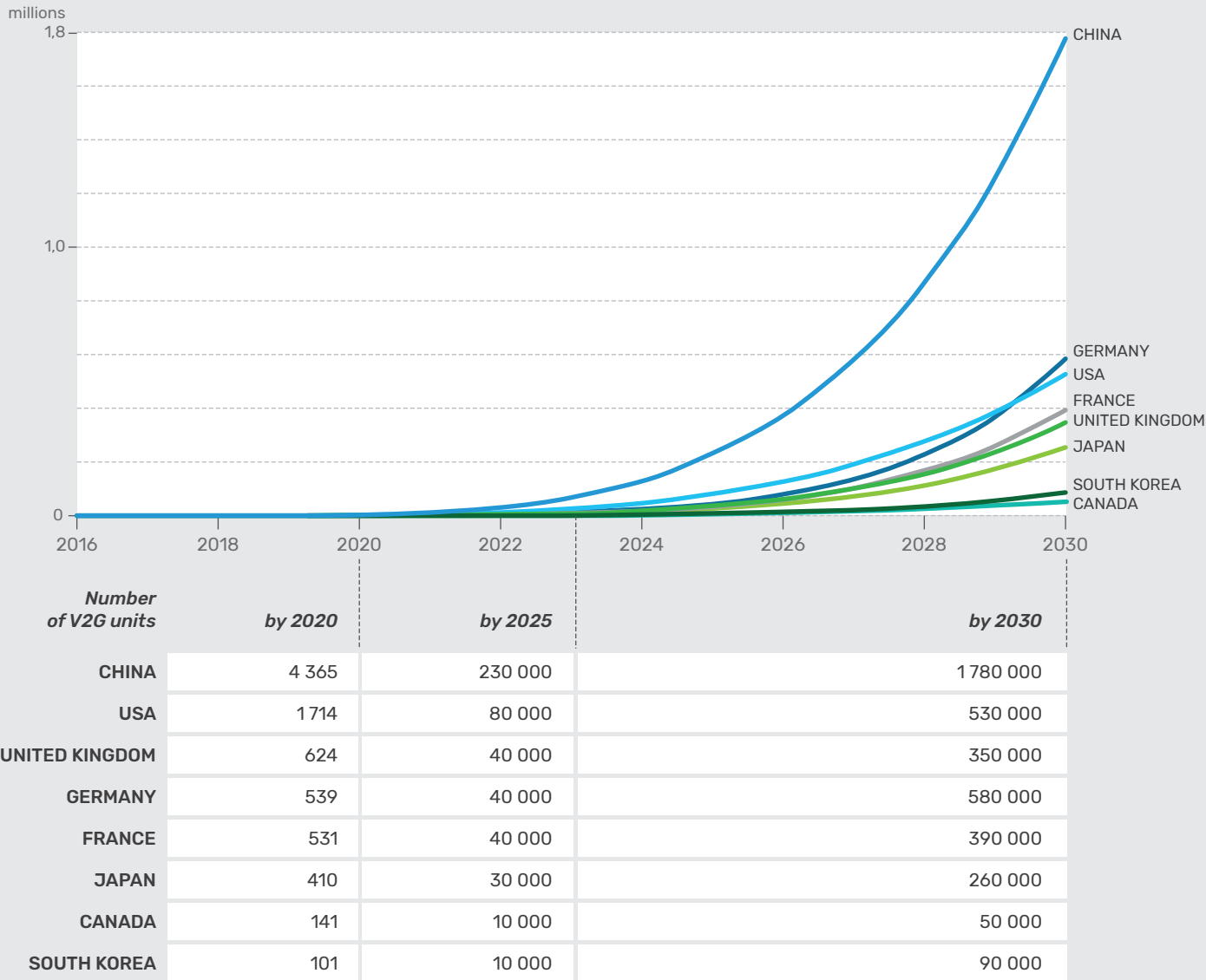
According to the authors of the Cenex report, excessive optimism as to the rapid development of the V2G services market should be confronted with realistic restrictions to their deployment. **Therefore, further research is necessary in order to make more precise predictions of possible scenarios for the development of this market.**

Taking into account the current dynamics of dissemination of technological solutions that are vitally important for the development of the economy, Cenex experts estimated the expected pace of implementation of V2G technology.

In order to demonstrate the **potential scale of the V2G market**, the authors of the report adopted the following assumptions:



## FORECAST OF V2G MARKET DEVELOPMENT IN THE LEADING COUNTRIES OF THE WORLD



Source: V2G. Market Study. Answering the preliminary questions for V2G: What, where and how much?, CENEX, 2018.

The prepared scenario shows that the development of the V2G market will be possible, but its pace in individual countries of the world will not be the same.

Considering the economies of scale and still high costs of V2G technology, the dynamics of its commercialisation will be relatively low until 2025. It is only around 2030 that proper assimilation of V2G technologies is forecasted, especially in China and Germany. The described scenario predicts that China, Western and Central Europe (mainly United Kingdom, Germany and France) will, in the long term, be the strategic markets for the application of V2G technologies.

## 6. Case study: V2G research and pilot projects

### 6.1. Multiscale projects: United Kingdom

In early 2018, the UK Government confirmed financial support of up to 70% of the costs for 21 V2G deployment projects. Following the applications evaluation procedure, almost £30 million of funding was allocated to research, development and testing of the V2G technology and exploration of its potential commercial applications.

The government funding will benefit, among others, Oxford University, University of Warwick, SSE Services, Nissan, Arrival, OVO Energy, Octopus Energy, Cisco, Flexisolar and AT Kearney

**For the UK Government, the development of V2G technology provides an opportunity to improve air quality and the operation of the power grid.** According to RAC studies conducted in the UK and published in the "RAC Report on Motoring 2017", there has been a significant change in drivers' attitudes towards the effects of harmful emissions from diesel-powered cars. Nearly one third of the drivers surveyed were concerned about local air quality and more than two thirds of them supported measures to improve air quality by introducing emission limits and a planned ban on the sale of gasoline and diesel vehicles in the UK by 2040.

**With a change in attitude and the systematic moving away from diesel technology, EV registrations number in the UK is gradually increasing.** By the end of 2018, it is expected to reach 200,000 vehicles.

According to the UK TSO National Grid, this increase will result in the growth in electricity demand of 5 GW by 2040.

**In the UK, Nissan is currently supporting two large-scale V2G projects targeting individual customers and fleets.** They are co-financed by the Office for Low Emission Vehicles (OLEV) and the Department for Business, Energy & Industrial Strategy (BEIS), in cooperation with Innovate UK. **Only under the project designed to build a more environmentally friendly and efficient national grid, 2,000 V2G modules will be installed.**

**In the Oxford region, EDF Energy carries out tests of V2G technology. For this purpose, the company uses a fleet of 100 EVs, both passenger cars and vans that belong to logistics and taxi companies.** The use of EVs in densely populated areas, such as Oxford, helps to significantly reduce local CO<sub>2</sub> emissions and improve air quality, while at the same time raising the standard of living of residents and bringing financial benefits to EV owners.

**The aim of the project is to test and evaluate the potential of V2G for fleet operators using EVs.** The consortium consists of 8 entities, i.e. EDF Energy R&D UK, Oxford University, Oxfordshire County Council, Arrival, EO Charging, Upside Energy and Fleet Innovation.

**The potential of V2G systems for smart management of local grids has been confirmed by pilot simulations carried out in 2016 and 2017 by a team of scientists from the University of Warwick in the UK.**

One of the most surprising conclusions of these tests is that smart management of V2G systems does not have an adverse effect on the EV battery life and can even increase it by around 10%.

Changes in parameters such as charging and discharging cycles, depth of discharge for each cycle (DoD) and temperature are crucial when considering the impact of V2G technology on battery life. Simplified V2G systems, which are currently being tested, show the financial benefits for electric vehicle owners, but do not take into account the potential additional costs associated with increased battery degradation. Nevertheless, the use of smart control algorithms aimed at minimizing the negative effects of additional charging and discharging of batteries may prevent the degradation. In this case, the control algorithm allows the use of the vehicle battery as part of the V2G system only if the additional use of the battery pack does not increase the level of degradation compared to standard use. However, this approach requires the development of more detailed models predicting battery degradation and the adaptation of complex control algorithms allowing, among other things, to predict how the vehicle will be used by the user<sup>25</sup>.

**In 2018, researchers from the University of Warwick launched another project using V2G technology. This project received government funding of £5.6 million.** For three years, the EV-elocity consortium will be implementing a project aimed at developing and commercialising V2G technology in various locations in the UK, including airports and business centres. The project is expected to confirm the profitability of these technologies for business and the public, and to contribute to the increase in EV sales.

Vehicle to Grid EV charging platform from Drive Electric is another project that has been implemented in the UK since mid-2018<sup>26</sup>. The CrowdCharge Platform, which uses advanced machine learning technology and artificial intelligence to provide optimised charging sessions, enables V2G chargers to provide electric vehicle owners with cheaper, greener energy and ensures they get electricity when they need it.

CrowdCharge is already being used in the Electric Nation project<sup>27</sup> to provide unidirectional smart charging of electric vehicles (V1G), which helps increase the scale of energy demand management in local electricity grids.

**The British company OVO Energy has provided further evidence of interest in the development of V2G technology. In the first quarter of 2018, it presented VCharge, the world's first home wall charger for EVs that is compatible with V2G technology.** The OVO Energy device has a power output of 6 kW. According to the manufacturer's assurance, the new Wallbox will reduce EV users' electricity bills, stabilise grid operation during peak hours, and increase the share of energy from renewable sources in the energy mix.

**Thanks to the smart management system, the device will also enable the resale of electricity back to the grid and the charging of electric cars during low tariff periods or increased availability of RES energy.**



Source: Ovoenergy.com.

**The UK highly values the potential of V2G technology and provides financial support for its development. Investment in electromobility is a priority as it enables smart energy management. It is a part of an overall strategy announced by the UK Government in July 2018. The aim of the "Road to Zero Strategy" is to promote electric cars and develop EV charging infrastructure.**

<sup>25</sup> K. Uddin, M. Dudarry, Mark B. Glick, *The viability of vehicle-to-grid operations from a battery technology and policy perspective*.

<sup>26</sup> [www.drive-electric.co.uk/v2g/](http://www.drive-electric.co.uk/v2g/) (Accessed: 02.09.2018).

<sup>27</sup> [www.electricnation.org](http://www.electricnation.org) (Accessed: 02.09.2018).

The Road to Zero Strategy assumes that by 2030 at least 50% of new cars and 40% of vans sold in the UK will be "ultra-low emission vehicles". By 2050, almost every car on UK roads is expected to be zero-emission.

#### EV IN THE UNITED KINGDOM

**14 000**

Number of **public charge points** in the UK

**160 000**

Total number of **electric vehicles** registered so far in the United Kingdom

**NUMBER OF BATTERY ELECTRIC VEHICLES AND PLUG-IN HYBRID ELECTRIC VEHICLES SOLD IN THE UK IN THE FIRST HALF OF 2018**

**28 054**

**25%** growth compared to 1<sup>st</sup> half of 2017

#### SELECTED ASSUMPTIONS OF THE "ROAD TO ZERO STRATEGY"



All newly built homes and lampposts should include charging points for electric vehicles compatible with the vehicles' installations



The launch of a £400 million Charging Infrastructure Investment Fund providing funding to new and existing companies that produce and install electric vehicles charge points



Maintaining the current subsidy rates for electric vehicle purchase until at least October 2018 and in some form until at least 2020



Providing up to £500 for electric vehicle owners to put in an EV charge point in their home and increase the value of grants available to workplaces to install EV charge points at workplace



Creating a new £40 million programme to develop and test innovative, low cost wireless and on-street EV charging technology



The highest in history growth in public investment in research and development – the target level of total capital expenditure on R&D will reach 2.4% GDP by 2027



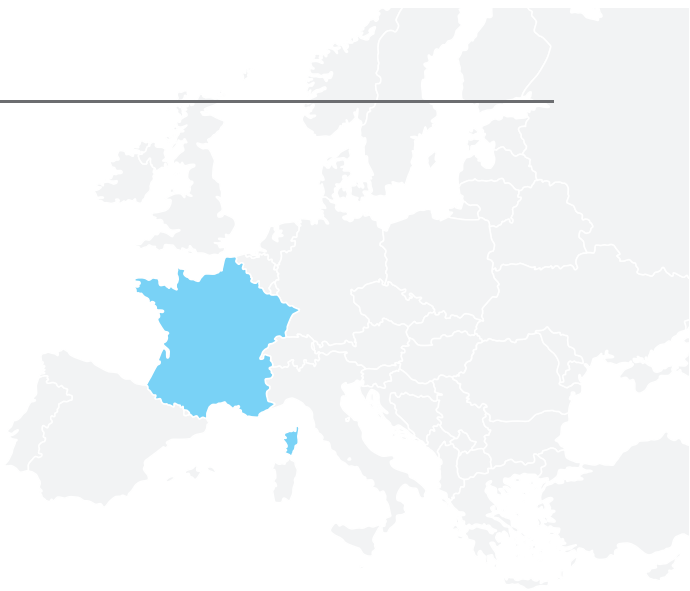
Allocating 246 million GBP for the development of innovative battery technology



Ensuring that by 2022, 25% of the government fleet will be ultra-low-emission vehicles and by 2030 -- it will be 100%

Regardless of the assumptions of the "Road to Zero Strategy" the United Kingdom intends to end the sale of conventional gasoline or diesel powered cars and vans by 2040.





6.2. Project: GridMotion (France)

The two-year GridMotion research project was launched in 2017 by a consortium of companies: The PSA Group, Direct Energie, Enel, Nuvve, Proxiserve and the Danish University of Technology.

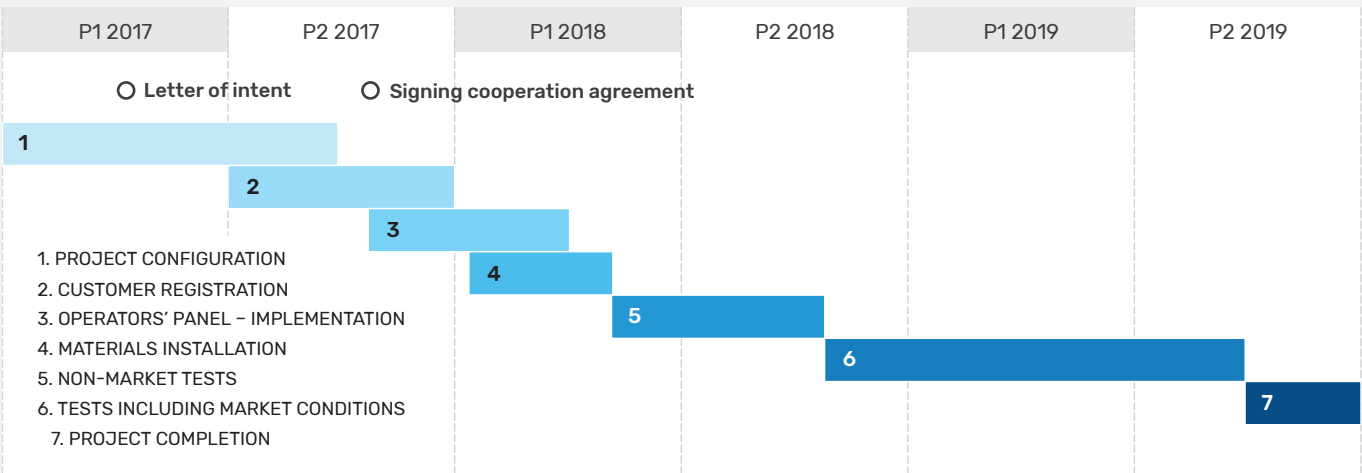
The entities have combined their experience in the development of V2G systems. The project responds to the climate and energy challenges faced by communities around the world. Meeting these challenges requires the development of new models for energy management and distribution.

The GridMotion project aims to demonstrate the positive impact of EVs on grid stability and to estimate the potential savings for the users of these vehicles that can be achieved if smart charging and discharging is introduced via the V2G system.

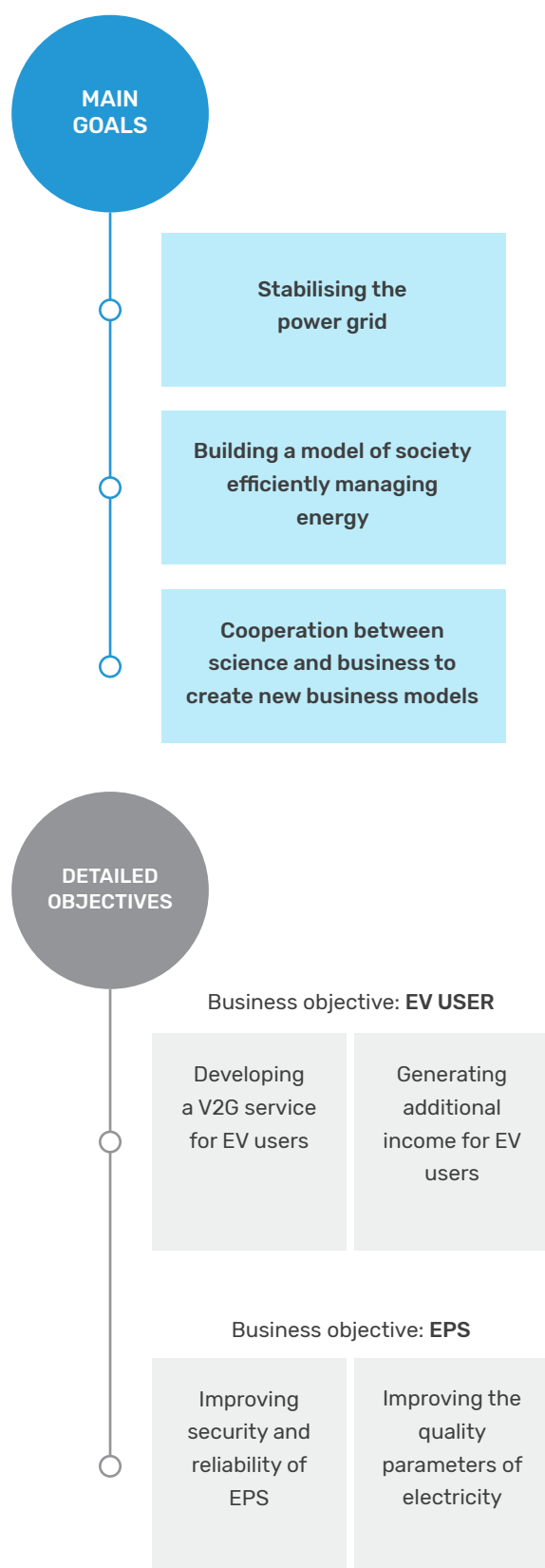
Two groups of EV users are taking part in the project:

- 50 car owners OF Peugeot iOn, Partner Electric, Citroën C-Zero or Berlingo Electric, who are testing “smart” unidirectional charging according to their mobility needs when electricity prices are generally lower (at night).
- Fleet of 15 EV Peugeot iOn or Citroën C-Zero with Enel electric charging stations testing “smart” charging and discharging using the V2G system. It is assumed that EVs will be charged when there is surplus electricity in the grid, and that this electricity will be fed back into the grid during periods of peak demand.

Results of the GridMotion project will be published at the end of 2019



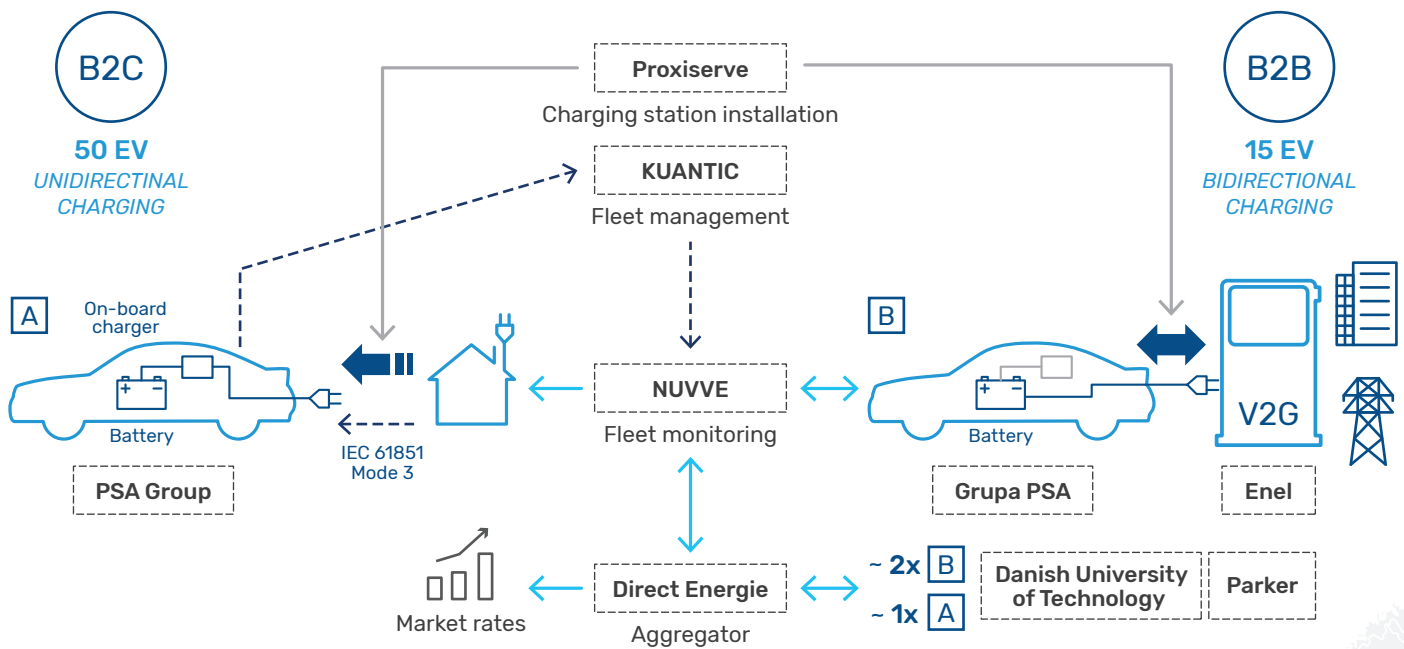
Source: Armand Peugeot Chaire Conference.



## PROJECT INFORMATION SHEET

<b>Location</b>	France
<b>Main stakeholders</b>	<p><b>PSA Group</b> Customers recruitment and project management</p> <p><b>Direct Energie</b> Playing the role of aggregator and submitting bids on electricity and reserve markets, which is made possible by the flexibility of electric vehicle batteries</p> <p><b>Nuvve</b> Monitoring of EV charging/discharging patterns</p> <p><b>Enel</b> Supplying bidirectional V2G charging stations and expertise on smart transmission networks</p> <p><b>Proxiserve</b> Installation of B2C and B2B charging stations</p> <p><b>Danish University of Technology</b> Providing scientific support and testing systems</p>
<b>Concept</b>	<p>Charing EVs when electricity prices are low and discharging them when the prices are high</p> <p>Provision of grid balancing services through short charging and discharging cycles, run according to the mobility needs</p>
<b>Thematic areas</b>	Technical aspects, legal aspects, customers' acceptance, business models
<b>Conditions</b>	<p>Significant growth in the number of EV users</p> <p>Deteriorating air quality</p> <p>RES development</p> <p>Technological progress</p> <p>DSM development</p>
<b>Challenges</b>	<p>EVs as additional burden for the grid</p> <p>Integration of Smart Grid and EVs</p>

Source: Authors' compilation.



Source: Armand Peugeot Chaire Conference.

### 6.3. Project: Sustainable Porto Santo (Portugal)

French car manufacturer Renault and Portuguese power supplier Empresa de Electricidade da Madeira (EEM) are planning to create an innovative power system on the island of Porto Santo. In February 2018, they launched the project "Sustainable Porto Santo - Smart Fossil Free Island".

The duration of the project is 18 months. **The idea is to accelerate the energy system transformation and reduce CO<sub>2</sub> emissions on the island as much as possible.** In addition to EEM and Renault, the project also involves other partners: the French electrical and telecommunications contractor Bouygues Energies et Services, the German charging solution provider The Mobility House and the Swedish-Swiss ABB, which plays a leading role in the development of automatic control and power systems.

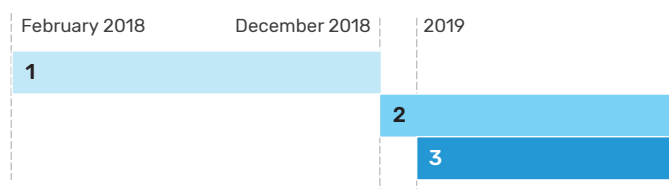
The main components of the project are: electric cars, energy storage, smart charging network and V2G technology. These components will work together to create a smart electrical ecosystem.



Source: Press materials from Renault Group and EEM.

The project consists of three phases whose implementation is expected to facilitate growth of the share of renewable energy in the energy mix of Porto Santo and increase the island's energy independence.

#### PROJECT IMPLEMENTATION – 18 months



##### PHASE 1

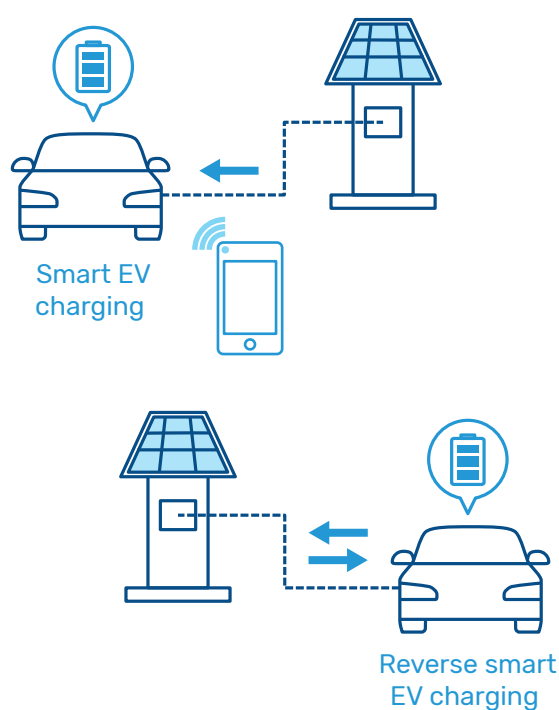
20 volunteers – residents of Porto Santo, will drive Renault ZOE and Kangoo Z.E. cars in everyday traffic. The EVs will use 40 charge points installed all over the island by Renault and EEM.

##### PHASE 2

The EVs will serve as mobile electricity storage. With V2G technology they will return electricity to the grid at the time of peak demand.

##### PHASE 3

Partly used lithium-ion batteries from the Renault cars will be used to store electricity generated by wind farms and photovoltaic cells located in Porto Santo. As in the case of V2G technology, stationary storage will provide additional electricity source at the time when it is most needed.



Source: Press materials from Renault Group and EEM.

#### PROJECT INFORMATION SHEET

<b>Location and population</b>	Port Santo Island (Portugal); Area 42.5 thousand km <sup>2</sup> ; 5.5 thousand residents
<b>Main stakeholders</b>	<b>Empresa de Electricidade da Madeira (EEM)</b> <b>Madeira authorities</b>
<b>Other partners</b>	Renault Bouygues Energies et Services The Mobility House ABB
<b>Project CAPEX</b>	2 500 000 EUR
<b>Starting date</b>	February 2018
<b>Thematic group</b>	EVs, energy storage, Smart Grid, V2G, RES (wind farms and photovoltaic cells)
<b>Goal</b>	Increased share of renewable energy, from z 15% to 30%, in electricity generation, mainly as a result of using wind and photovoltaic energy
<b>Objectives</b>	<p><b>ENVIRONMENTAL</b> Element of the EU 20-20-20 strategy. The aim – to replace fossil fuels with renewable energy</p> <p><b>SOCIAL AND ECONOMIC</b> To improve competitiveness of the local economy by increasing local employment and providing better development opportunities for local businesses</p>
<b>Expected level and scope of project application</b>	Building a model of smart power ecosystem to be used on other islands and in environment-friendly city districts

Source: Authors' compilation.

6.4. Project: TenneT, The Mobility House & Nissan (Germany)

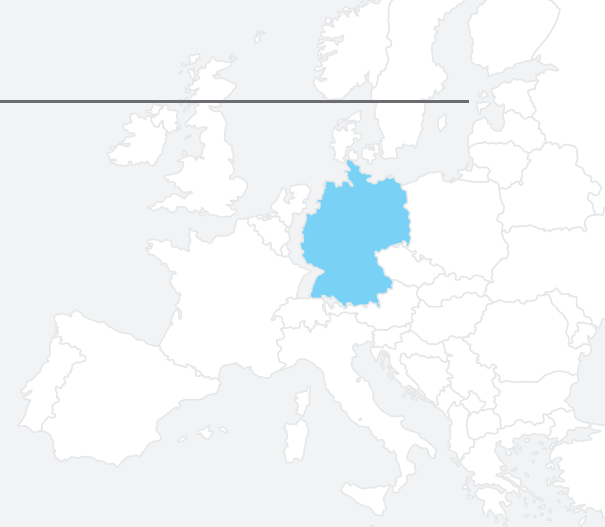
The German TSO TenneT, energy services provider The Mobility House and Nissan launched a pilot project based on V2G technology in March 2018. The aim of this project is to investigate the impact of the use of EV batteries potential on the stability of power grid operation.

In the design phase, Nissan electric vehicles are used as mobile electricity storage systems in the TenneT control area, i.e. in the north and south of Germany, in order to directly balance power demand. Thanks to V2G technology, EV batteries can store electricity and also supply it back to the grid if necessary. The load management software used in the project has been developed by The Mobility House.

The pilot project is one of the blockchain projects aimed at unblocking transmission bottlenecks in the network. The vehicle-grid interface is an efficient instrument to control renewable energy production, which is highly dependent on weather conditions.

In Germany, due to the growing share of renewable energy and the location of its sources in the north of the country, bottlenecks in the transmission grid make it more and more difficult to transmit it to the industrialised southern regions. According to TenneT, in 2017 alone, the costs of preventing the bottleneck consequences amounted to about one billion euros and were ultimately borne by electricity consumers as part of the grid charge. Preliminary pilot results will be available in the first quarter of 2019.

Following the successful implementation of the project, EVs could be used, on a larger scale than so far, as energy sources to stabilise the operation of the grid in Germany.



PROJECT INFORMATION SHEET

Location	Germany
Partners	TenneT The Mobility House Nissan
Starting date	March 2018
Conditions	Unstable electricity generation by wind farms  V2G technology potential
Goal	Stabilisation of EPS operation
Objectives	Maintaining and restoring balance of local EPSs  Reduction of costs of transmission network bottlenecks
Preliminary results	Q1 of 2019
Expected level and scope of project application	Using EVs as energy sources stabilising the grid operation in Germany

Source: Authors' compilation.



Source: Nissan.

## 7. Case study: implementation of V2G systems

### 7.1. V2G at the Nissan R&D centre in the United Kingdom

Nissan and the energy company Enel worked together to implement smart mobility in Europe. In November 2016, eight chargers were installed at the Nissan Technical Centre Europe (NTCE) research and development centre in the UK, enabling both the recharging of car batteries and the return of surplus energy to the grid.

The NTCE Centre was the first Nissan Europe site to start using the V2G system in an enterprise environment.

The V2G chargers, developed jointly by Nissan and Enel, were made available for use by all employees of the centre. They are compatible with Nissan's EV brand as part of the smart energy management system.



Source: Nissan and Enel press materials.

The installation and operation of the V2G system at NTCE was an important step in Nissan and Enel's strategy. According to this strategy, the Nissan LEAF\* and e-NV200 models as well as energy management technologies can play a key role in building a balanced and efficient EPS.

\* Nissan Leaf is almost entirely manufactured in the UK.

**The first commercial contract for the implementation and operation of the V2G system was signed with the Danish municipal utility company Frederiksberg Forsyning.**



## 7.2. Commercial V2G hub in Denmark

The world's first fully commercial V2G installation was commissioned in Denmark in August 2016.

The installation was another effect of cooperation between Nissan, a global car manufacturer, a multinational energy company and a pioneer in smart grid technologies, Enel, and Nuvve, a leading service provider in the V2G segment in California.



Source: Nissan and Enel press materials.

### FULLY COMMERCIAL V2G HUB Installation enabling connection of EV to the EPS

"Fully commercial", i.e. based exclusively on components and technologies that can be purchased by the consumer, from electric vehicles, through charging stations, to the platform managing the V2G system.

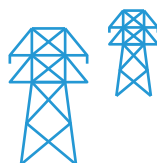
The launch of a fully functional V2G hub was announced by a partnership agreement signed by Nissan and Enel in December 2015 in Paris at the 21st United Nations Climate Change Conference.

**As expected by both project partners, the V2G Hub is one of the areas of innovation in sustainable development that can reduce greenhouse gas emissions for the benefit of present and future generations.**

## FUNCTIONALITY LEVEL OF V2G HUB EXPECTED BY PROJECT PARTNERS



EVs will be an integral element of future energy management systems



Improved grid stability and integration of RES with the generation structure



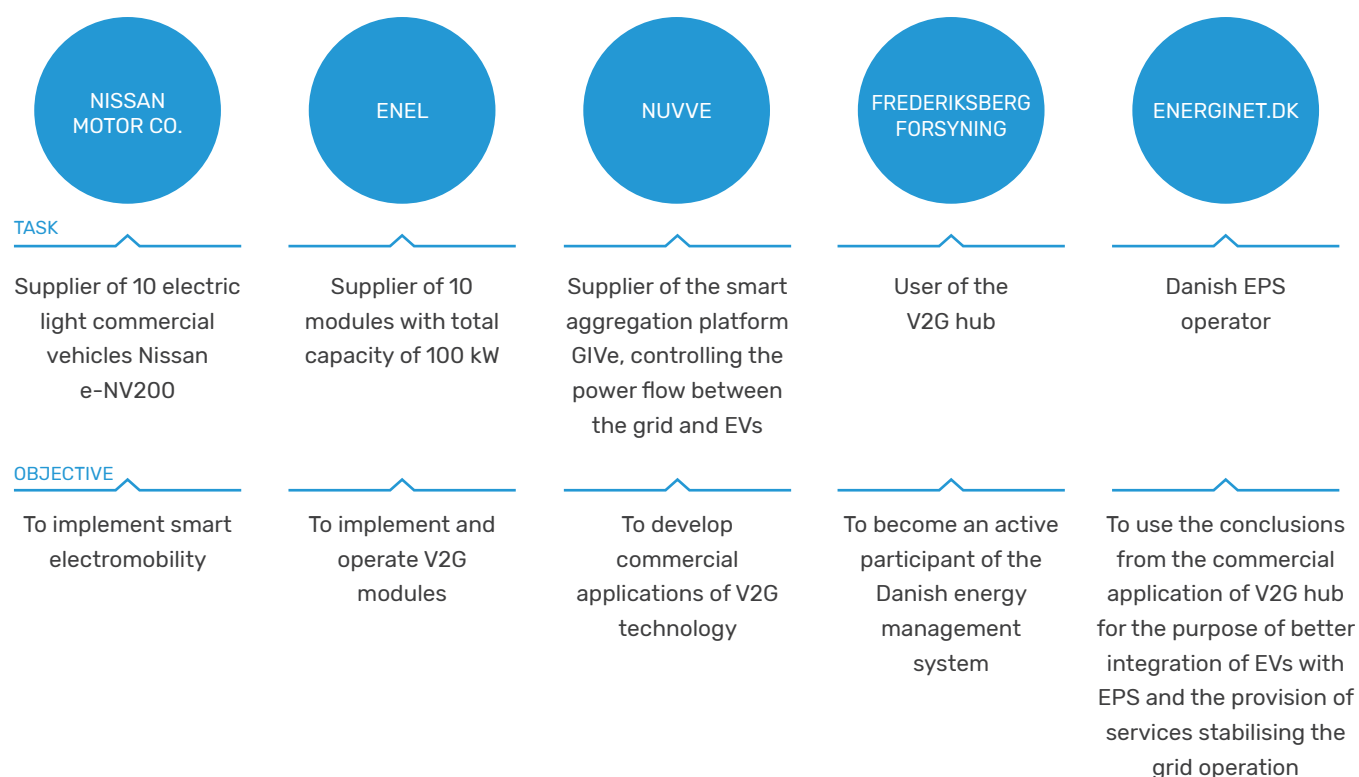
Fully commercialised integration of V2G technology as a turning point for its broader deployment on a commercial scale all over Europe

Source: Authors' compilation.

The first customer to implement the V2G installation on commercial terms is the Danish municipal utility provider **Frederiksberg Forsyning**, who purchased 10 Nissan **e-NV200** battery electric commercial vehicles. At the company's own car park at the company's Copenhagen headquarters, vehicles will be connected to ten newly installed Enel V2G modules.

Through these modules, **e-NV200** will both take electricity off and return it back to the national grid according to demand, acting as mobile energy storage. The total nominal capacity available from Enel's 10 kW V2G charger is approximately 100 kW. The control of the V2G installation is provided by the GIVe smart aggregation platform, developed by Nuvve.

## OBJECTIVES AND TASKS OF INDIVIDUAL STAKEHOLDERS







Frederiksberg, Denmark

Source: Nuvve press materials.

The preliminary conclusions from the commercial implementation of the V2G installation, after one year of its operation, were published at the end of 2017. They show, for instance, that the EV user earned additional income for the provision of V2G services amounting, on average, to 1400 EUR/year/EV.

EVs

10

electric light commercial vehicles  
Nissan e-NV200

BATTERY CAPACITY

24 kWh

V2G CHARGERS

10

Enel modules V2G CHAdeMO

CHARGER NOMINAL POWER

10 kW

CHARGER OUTPUT POWER

9,25 kW

EV AVAILABILITY

16:00–06:00

(Monday–Friday)

00:00–24:00

(Saturday–Sunday)

NUMBER OF HOURS

6150

hour/year/EV  
/MWh

AVERAGE PRICE OF ELECTRICITY FED INTO EPS

26,55 EUR

/MWh

(08.2016–08.2017)

INCOME FROM ELECTRICITY SALES

1400 EUR/year/EV

Source: Compilation based on Nuvve press materials.

## 8. Potential for V2G technology implementation in Poland

The development of electromobility, intensified on a global scale, driven by progress in new technologies and communication systems, environmental protection policy and efforts to reduce dependence on oil imports, leads to a shift in the position of the electromobility sector within the structure of the Polish economy. From the perspective of the Polish government it is perceived as a business model with enormous potential. The Electromobility Development Plan drawn by the Ministry of Energy identifies the benefits associated with the widespread use of EV in Poland and points to the economic and industrial potential that can be used to achieve these benefits. It draws attention to the possibility to improve air quality, enhance the national energy security and to the need to develop new technologies as a result of electrification of the automotive sector.

**V2G technology is a natural part of electricity demand side management services (DSM).** Polskie Sieci Elektroenergetyczne (PSE Operator) is developing a range of voluntary power demand reduction services in line with the principle of technological neutrality. This means that there will be no dedicated service for V2G operators on the market - but such operators offer the potential for aggregators of energy assets participating in DSR programmes, which is growing at the same pace as the EV up-take in Poland. The aggregator is obliged to guarantee reduction in power demand upon request from PSE - but for this purpose he utilises the costing analysis within his asset portfolio. The provision of such a service through an EV fleet using V2G technology may be one of the most cost-effective ways of responding to the demand of the National Power System.

**The structure of the electromobility business model in Poland will depend on several important factors. At present, technological progress is considered to be the most important driving force behind its development. Particularly large potential for this development lies in the use of V2G technology.**

The bidirectional flow of energy between EV and EPS provides an opportunity to develop the value chain of the electromobility ecosystem.

**Pilot projects and the commercialisation of V2G technology indicate that this technology is a ready-to-implement solution that can provide support for the development of a safe, clean and innovative economy in Poland.**

Obviously, the number of EVs on Polish roads is still small, but in the foreseeable future it will grow steadily, which is confirmed by forecasts. **Exploiting the potential of the large dispersion of charging stations and the energy stored in EVs can bring many economic, environmental and social benefits for Poland.**

The changes taking place on the electricity market in Poland lead to a shift in the focus of investment strategies from large-scale to distributed energy. The growing number of technological systems using renewable energy sources, the production of which is subject to high variability, creates problems for distribution system operators related to the balancing of the power system. A promising solution to these problems is the use of EVs as distributed electricity storage to store surplus electricity generated in photovoltaic and wind power installations. **With V2G technology, EV's cooperation with the grid can generate a number of positive effects and economic benefits.**

EV batteries enable the release of electricity in periods of higher demand, which are accompanied by high prices. This offers an opportunity to generate revenue from the sale of stored energy, reducing operating costs and increasing the interest of Poles in purchasing electric vehicles.

**Access to additional, i.e. mobile energy sources enables better use of the technical infrastructure of the grid and conventional power plants. This is of particular importance for solving the problem of power shortage in the national power system.** The energy accumulated in EV batteries can therefore be used by distribution network operators to provide services ensuring security of electricity supply and maintaining its desired quality parameters.

In particular, this energy may facilitate power balancing activities in an area where network overload often occurs and provide local back-up power supply in emergency situations.

**An important argument in favour of dissemination of V2G technology on the Polish market is the need to improve environmental safety.**

Increasing the share of energy from renewable sources thanks to mobile energy storage may mean lower amounts of electricity produced from fossil fuels. As a result, CO<sub>2</sub> emissions in Polish cities will be lower and the air quality – better.

**The commercialisation of the V2G technology is also supported by Poland's desire to reduce the consumption of crude oil, which is used, among other things, for powering vehicles.**

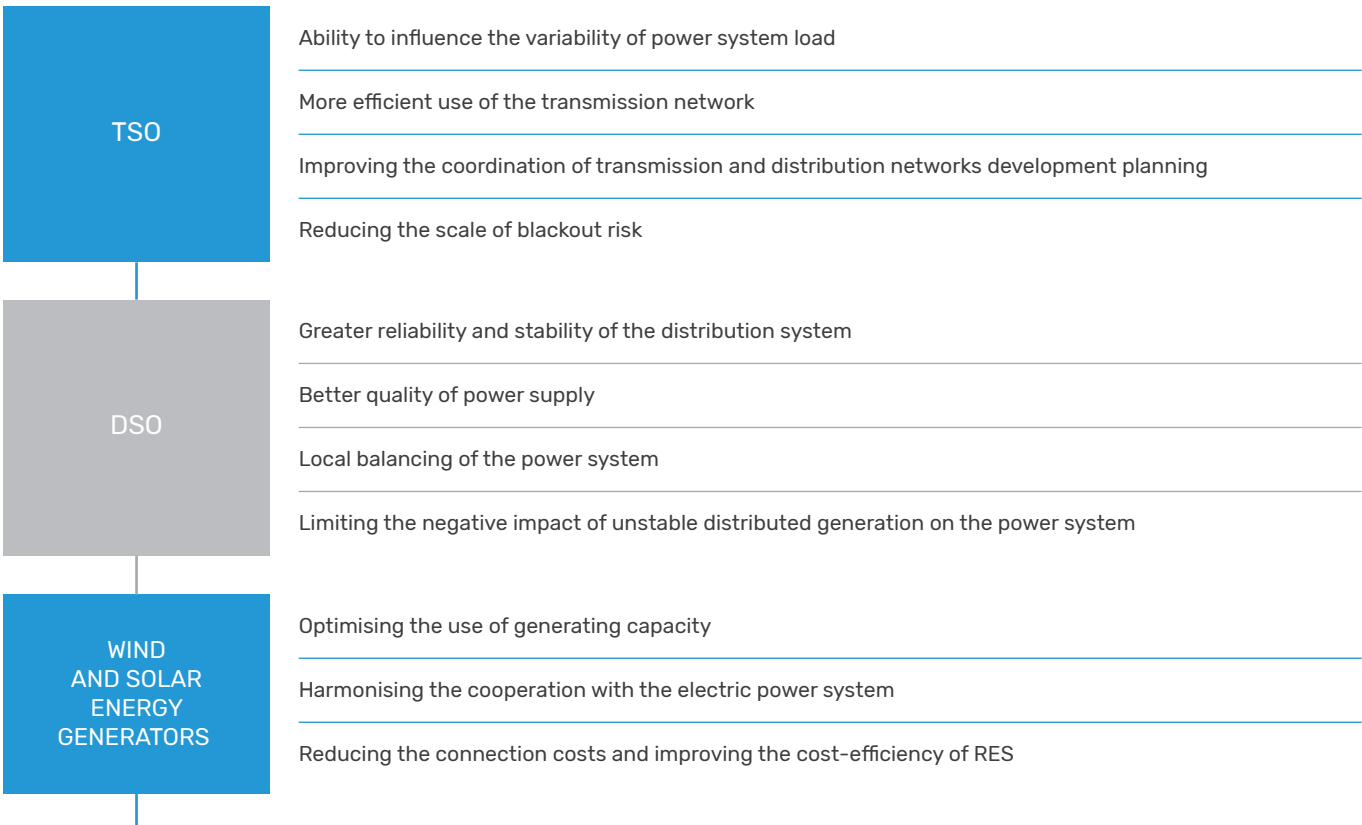
Currently, Poland imports about 96% of raw materials and petroleum products, which generates expenditure of USD 10-20 billion annually and puts a significant burden on the international trade balance.

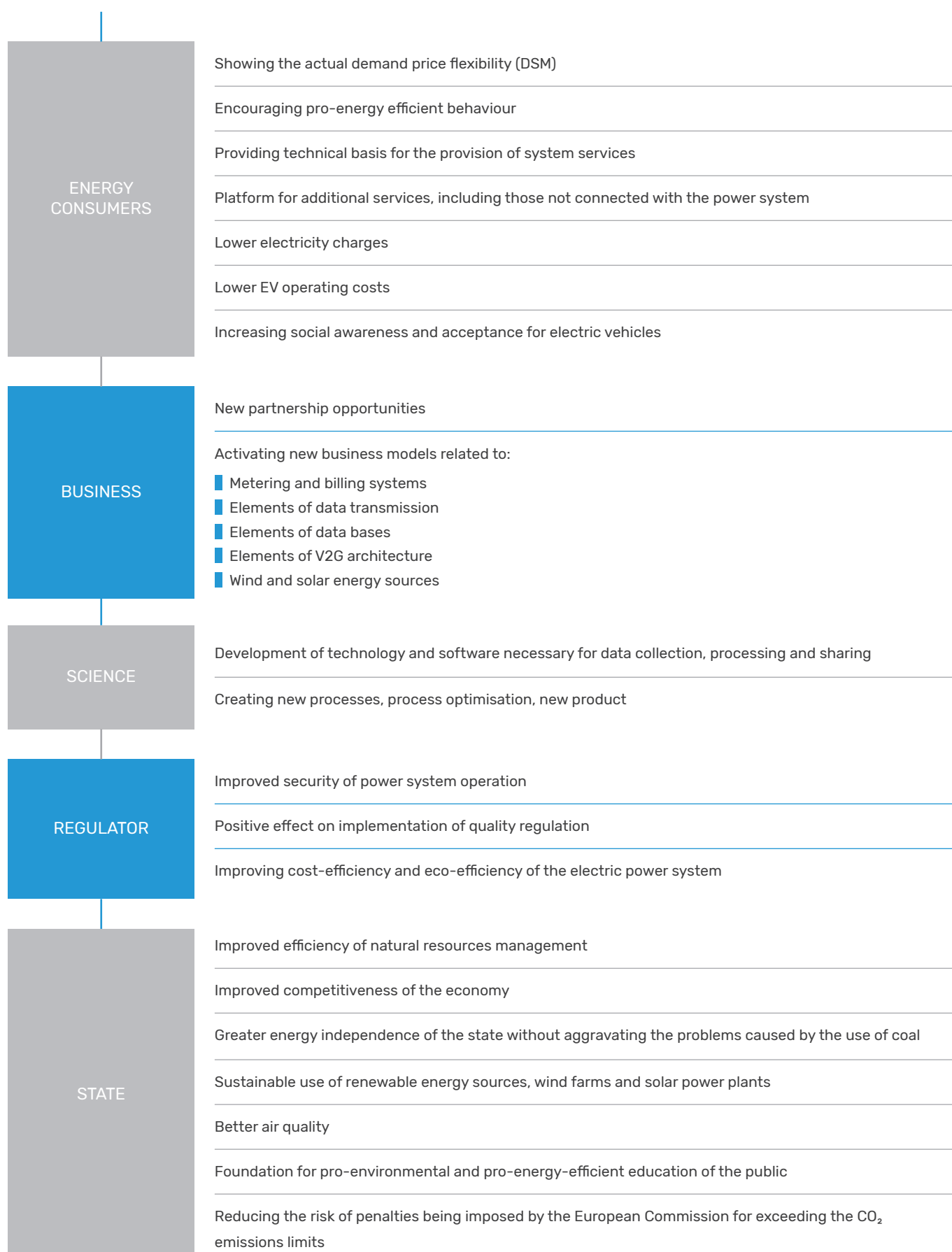
At the same time, the growing demand and costs of oil extraction have a significant impact on the increase in oil prices on world markets, which results in an increase in the costs of production activity and transport.

**Despite negative trends in recent years, Poland is self-sufficient in the supply of electricity. The possibility of using renewable energy sources, thanks to the use of V2G technology, may contribute to the decrease in social sensitivity to changes in crude oil prices, while respecting the main elements of the EU climate and energy policy in the area of electricity generation.**

V2G technology may also significantly influence the development of electricity demand side management services (DSM), which means active participation of electricity consumers in the electricity market and their involvement in the efforts to improve energy efficiency and flexibility and to reduce energy consumption.

## VALUE CHAIN OF THE IMPLEMENTATION OF V2G TECHNOLOGY IN POLAND





Source: Compiled on the basis of T. Dec, Eastern Field Branch of Energy Regulatory Office with the seat in Lublin, analyses, articles and press materials.

## 8.1. Conclusions and recommendations for Poland

# CONCLUSIONS

The value chain of V2G technology has a very high potential, but is still at the initial stage of development.

By accelerating the universalisation of renewable energy generation technologies and innovative electricity demand and supply management services, V2G technology could be one of the important elements of Poland's energy transformation.

According to the experience of European countries, the development of the V2G technology value chain requires the elimination of systemic, market, legal, infrastructural, technological and economic barriers, which in consequence will contribute to the removal of social obstacles.

If Poland is to use the potential of V2G technology value chain development multidimensional action must be undertaken.

## RECOMMENDATIONS

### 01

Aiming to create sustainable forms and platforms for business cooperation between the public and private sector, while the actions taken are consistent both vertically (central government – regional authorities – local authorities) and horizontally (government – research centres – business).

### 02

Openness to cooperation within the V2G value chain which should be stimulated, for instance, through participation in study visits; establishing relations with partner regions or cities involved in V2G technology pilot and implementation projects; networking activities; active creation and participation in international V2G research projects.

### 03

Defining a long-term policy vision as a basis for predictability and certainty of the planned pilot and implementation projects designed to extend and widen the V2G value chain.

### 04

Statutory regulation of issues related to the opportunities for EV users to provide services and receive remuneration for the provision of services improving the stability of the EPS, especially during periods of increased electricity demand.

### 05

Establishment of a pre-commercial procurement system by the government and local authorities.

### 06

Using the potential of the system requires the introduction of appropriate statutory provisions concerning the development of V2G technology infrastructure and the possibility of using EVs as mobile energy storage facilities. Creation of a regulatory framework for the development of V2G technology should be consistent with the Public Procurement Law.

### 07

Encouraging investment in V2G technology, which requires the implementation of targeted financial instruments to reduce the risk for private investors. At the same time, focus on finding and creating additional financing other than EU funds, including earmarked funds and public-private partnership mechanisms.

### 08

Implementation and dissemination of socially-oriented economic instruments in order to achieve the necessary critical mass. At the same time, it is important to stress the need for appropriate synchronisation and time coordination of the measures taken in this area. This will make it possible to respond to the needs of consumers, while maintaining the market-creating role of state institutions.

### 09

Securing trust and acceptance of the public through the preparation of a compendium of best practices concerning the relatively unknown V2G technology. Information campaigns and other communication tools that can be used to identify the economic, social and environmental benefits of V2G technology can also be helpful.

## SUMMARY

New mobility concepts using electric vehicles are attracting more and more attention around the world. Technological progress and examples of further pilot projects point to more and more possibilities of using two-way electricity transfer between the electric vehicle and the power grid.

V2G technology has been known for several years, but now, thanks to the cooperation between business, science and policy makers, discussions have been initiated on how to use its potential in the process of building smart grids and smart cities.

The bidirectional flow of electricity between the electric vehicle and the grid offers technical possibilities for deep convergence of the transport and electric power systems. The idea behind this solution is to optimise the use of renewable energy, which is in line with the energy and climate policy of the European Union. The use of electric vehicles as mobile energy storage may prove to be effective in balancing power systems.

In electric power systems with distributed generation, mainly from wind farms and photovoltaic installations, the role of electric vehicles as energy storage facilities is growing significantly. The new functionality of electric vehicles can be successfully used by the participants of the processes of generation, transmission, distribution and consumption of energy, and in particular by distribution and transmission system operators and their owners. Appropriate control of mobile energy sources can contribute to the elimination of technical barriers to the development of RES, balanced and efficient operation of the grid and the achievement of measurable economic effects.

Implemented projects using V2G technology together with plans to support further projects, including by the UK government, open another stage in the development of the electromobility ecosystem.



# OPINION

## Automotive Industry Institute

**The implementation of the technology that allows smart bidirectional energy flow between the vehicle and the power grid - V2G (Vehicle-to-Grid), aims, first of all, to balance the consumption of electricity at the scale of the entire country or a specific area, in order to level out the peaks and valleys in electricity usage.** The whole process is to be implemented by releasing energy from electrochemical batteries of electric vehicles during the peak demand for power and by mass charging of these vehicles at night, when the demand decreases. For this, it is necessary to introduce legislation that would regulate the settlements between the network operator and potential users willing to make their vehicles available to serve as mobile energy storage. In the first stages of V2G technology development, the involvement of consumers may be inefficient and uneconomic, so it is worth considering the possibility of conducting research and development projects to develop such a system and test it on a microscale. A benefit that cooperation at such projects may bring could be the consortia of research institutions with organisations that have a fleet of electric vehicles (e.g. car sharing companies).

**The implementation of such a system on a wider scale requires a properly prepared infrastructure related mainly to the monitoring and control of the quality and flow of transmitted electricity, especially in low-voltage grids, which is currently not monitored on a continuous basis in Poland.** Thus, the main task would be to modernise Polish electricity grid, because in the case of an uncontrolled, large scale process of bidirectional power transmission from a number of dispersed power storage devices, the impact on the grid and the generated network fluctuations could lead to profound consequences.

From the point of view of the grid operator, in order for such a system to be justified and worth implementing, it is necessary to run a pilot programme and then to try to implement the solution on a large scale.

However, the current number of electric vehicles in Poland is small and would not make it possible to notice changes in the daily electricity consumption even for a single region of the country. In order to enable potential prosumers – electric vehicles owners, to use the V2G system, it is necessary to equip their domestic installations with bidirectional electricity meters, to adapt stationary charging points so that they allow reverse electricity flow to the grid during the peak load and to design and implement an appropriate system of benefits and incentives for potential users to encourage electric vehicle owners to use the system on a voluntary basis. On the side of the owner of the electric vehicle to be used as part of the V2G system, a barrier may be the process of degradation of the power storage. Electrochemical cells have a limited number of charge/discharge cycles, after which their nominal voltage drops below the limit required for the efficient operation of the electric vehicle, so if the users are to agree to multiple charge and discharge cycles, the financial benefits of using the system must also cover the depreciation costs of the electricity storage.

There is no doubt that this area is worth exploring and developing in more detail, but with the current state of electromobility and the power sector in our country, the initial focus should be on infrastructure expansion, research and development and designing the solutions necessary for the application of such a system first in vehicles and prototype systems and then in fleet vehicles. **Once the technology is mature, the number of electric cars users increases, the legislation is in place to regulate this process and the grid infrastructure is adapted to the implementation of such systems, only then the implementation of the system on a wider scale should begin.**

*inż. Karol Żebrowski*

Electromobility Institute  
Automotive Industry Institute  
(Przemysłowy Instytut Motoryzacji, PIMOT)



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# SELECTED ABBREVIATIONS

<b>ACEA</b>	European Automobile Manufacturers Association
<b>BEV</b>	Battery electric vehicle
<b>DSM</b>	Demand Side Management
<b>DSO</b>	Distribution System Operator
<b>DSR</b>	Demand Side Response
<b>EV</b>	Electric vehicle
<b>EPS</b>	Electric Power System
<b>FCEV</b>	Fuel cell electric vehicle
<b>ICT</b>	Information and communication technology
<b>IEA</b>	International Energy Agency
<b>PHEV</b>	Plug-in hybrid electric vehicles
<b>RES</b>	Renewable Energy Sources
<b>TSO</b>	Transmission System Operator
<b>V2G</b>	Vehicle to Grid system, where electric vehicles connected to chargers serve as electricity storage



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