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Vehicle to everything

ELECTRIC VEHICLES ON THE ROAD TO INCREASING SYSTEM FLEXIBILITY

REFORM INSTITUTE

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REFORM

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Abstract

V2H and V2G, i.e. Vehicle-to-Home and Vehicle-to-Grid, are technologies that allow electric cars to be used as mobile energy storage devices. Both fall under the broader concept of V2X – Vehicle-to-Everything – which involves utilising the possibilities offered by connecting electric vehicles with their surroundings.

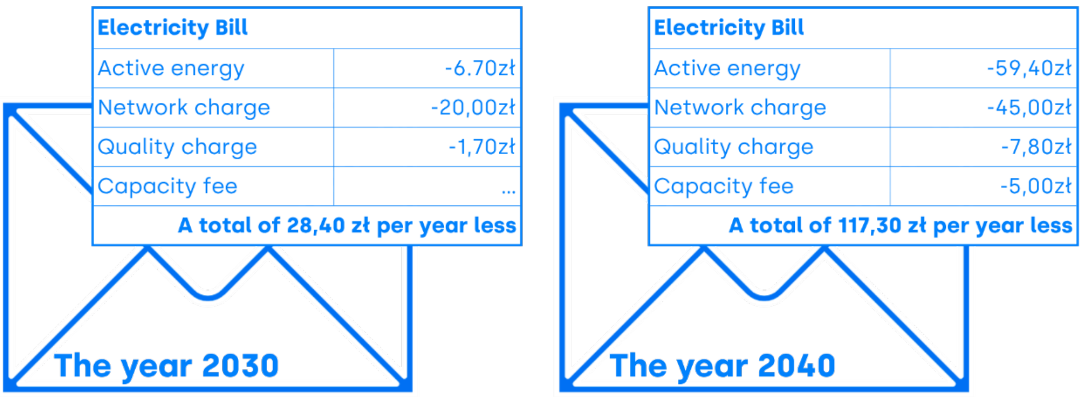
V2H can be used in single-family homes to **increase self-consumption** of energy from domestic photovoltaic (PV) installations and **optimise energy costs** under a dynamic tariff. V2G, on the other hand, is an opportunity for car batteries to work with the power grid as part of **DSR** (Demand Side Response), a mechanism for flexibility on the consumer side.

In the long term, V2X combined with smart charging is an opportunity to achieve **systemic benefits** such as:

- reduced curtailment of renewable energy sources;
- reduced production of expensive electricity from gas;
- lower costs of expanding power grids;
- lower peak power demand in the system.

In the short term, the development of V2X technology – and V2H in particular – has the potential to reduce electric car owners' bills by as much as 15-30%. Households with PV installations and heat pumps will be able to reap particularly large benefits. At the same time, the large-scale implementation of cooperation between electric cars and the power system within the framework of V2X will reduce network and system costs for all energy consumers. In total, these benefits could amount to savings of up to PLN 39/MWh in 2040.

V2X means lower electricity bills for everyone



**the estimates were made for a household with an annual electricity of 3000 kWh*

However, in order to unlock the potential of V2X, an appropriate regulatory environment is needed, including the introduction of V2G and V2H into the legal system, the definition of settlement and tariffing rules, as well as the dynamic development of the necessary infrastructure, i.e. charging points supporting V2G and smart meters.

Glossary

AFIR	(*Alternative Fuels Infrastructure Regulation*) – regulation on the development of alternative fuels infrastructure – its aim is to ensure a coherent and accessible alternative fuels infrastructure within the European Union
DSR	(*Demand Side Response*) – a flexibility mechanism on the part of electricity consumers who voluntarily and temporarily reduce their electricity demand at the request of the transmission system operator, which helps to stabilise the grid during periods of overload and offers consumers additional revenue
EV	*Electric Vehicle*
EPBD	(*Energy Performance of Buildings Directive*) – Directive on the energy performance of buildings
FCR	(*Frequency Control Reserve)* – a service that stabilises the power system by responding to frequency fluctuations
National policy framework for market development in relation to alternative fuels in the transport sector and the development of appropriate infrastructure	a document prepared by the Ministry of Climate and Environment and adopted in the form of Resolution No. 149 of the Council of Ministers of 28 October 2025
Assessment of V2G potential	(Assessment of the potential contribution of bidirectional charging to reducing user and system costs and increasing the share of electricity from renewable sources in the power system) – developed by the Energy Regulatory Office, resulting from AFIR
PSNM	(Polish Association for New Mobility) – an industry organisation creating a market for electromobility and hydrogen technologies in Poland and the CEE region
RTE	(Réseau de Transport d'Électricité) – French transmission system operator

SRI	(Smart Readiness Indicator) – an indicator of the readiness of buildings to support smart grids
Electromobility Act	(Act of 11 January 2018 on electromobility and alternative fuels) – Journal of Laws 2018, item 317) – a legal act providing a framework for the development of electromobility in Poland
V1G	**Vehicle-one-Grid/smart charging** – intelligent management of electric vehicle charging, controlling the time, speed and power of charging to optimise energy use and support the power grid
V2G	**Vehicle-to-Grid** – technology enabling intelligent control of energy consumption and energy transfer to the power grid
V2H	**Vehicle-to-Home** – technology that enables the power supply of household electrical appliances with energy stored in the car battery
V2X	**Vehicle-to-Everything** – a set of technologies that create a communication network between an electric vehicle (EV) and its entire environment in order to increase comfort and efficiency of its use

1. Introduction

Electricity from renewable energy sources (RES) is a cheap and universal energy carrier. Investments in wind and solar sources allow us to become independent of imported fossil fuels, whose prices are uncertain. This is why electrification is the target path to decarbonisation for many sectors – individual and district heating, transport and industry. However, the accelerating pace of electrification of the Polish economy is synonymous with a significant increase in electricity demand. If we want this energy to be cheap and accessible, we must start building a systemic framework for consumer flexibility today. V2X technology should be a crucial pillar of this framework.

1.1 What is V2X?

In broad terms, the concept of V2X, or Vehicle-to-Everything, involves creating a communication network between an electric vehicle (EV) and its entire environment in order to increase comfort and efficiency of its use. In this study, we focus on solutions that enable the use of electricity stored in a car battery for purposes other than driving. These solutions include, among others:

- **V2G** – **Vehicle-to-Grid**: this technology enables intelligent control of energy consumption and energy transfer to the power grid.
- **V2H** – **Vehicle-to-Home** – this technology enables households to power their electrical appliances with energy stored in the car battery.

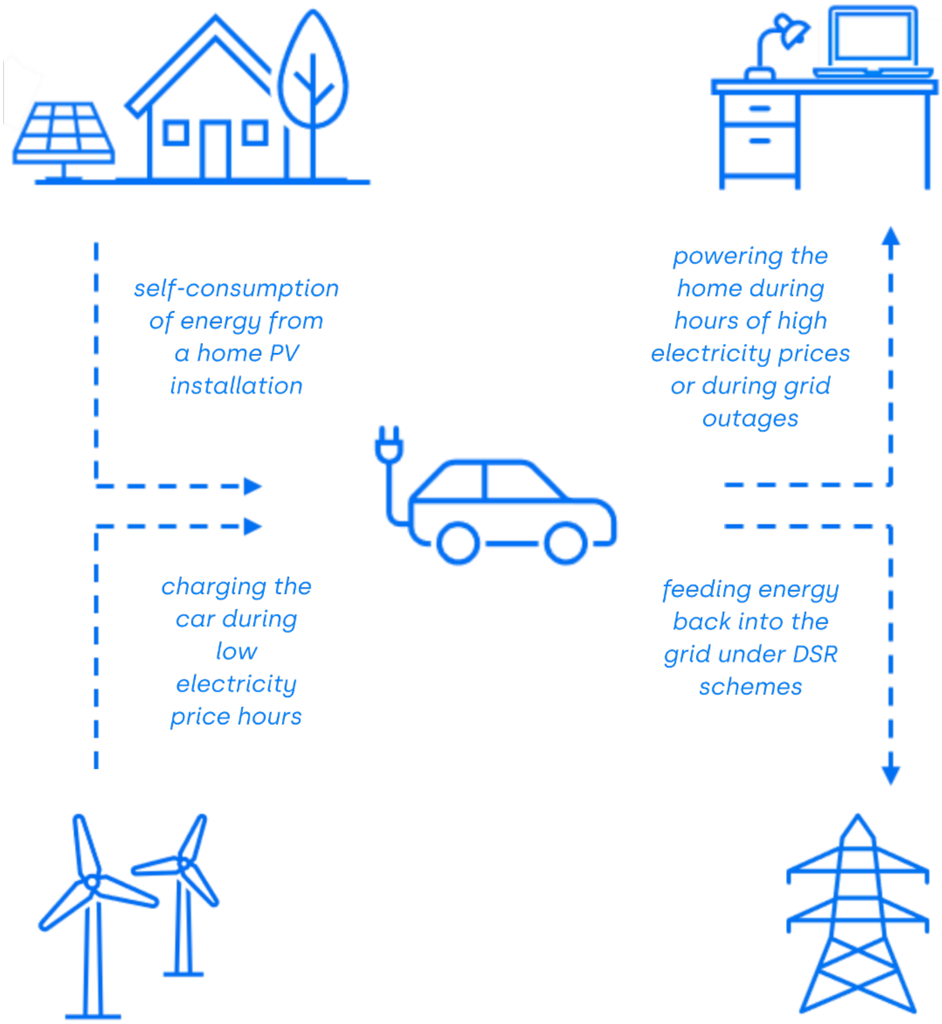
V2X technologies are currently moving from the research and development stage to the implementation stage. Bidirectional chargers are already available for purchase , and their owners can take advantage of V2H capabilities. The first tariffs for V2G are also appearing, for example from Octopus in the United Kingdom. However, the appropriate regulatory and market environment has yet to take shape.

The use of V2X has the potential to contribute to the stabilisation of the power system and increase its flexibility as part of DSR (Demand Side Response), i.e. a mechanism for flexibility on the consumer side. The result will be lower electricity bills for households.

V2G and smart charging

The step preceding the use of V2G is **smart charging**, or **V1G** (**Vehicle-one-Grid**). Smart charging is based on intelligent one-way chargers that adjust the battery charging power in real time. As a result, the charging process can be optimised so that the car is charged, for example, during periods of energy generation from a domestic photovoltaic (PV) installation.

V2G goes one step further. This technology uses special bidirectional chargers. At bidirectional charging points, an electric vehicle can not only receive electricity, but also feed it back into the grid. In this way, the car becomes a kind of "energy storage on wheels".



1.2 EU regulations

AFIR Regulation

One of the most important EU regulations affecting the development of electromobility is the regulation on the development of alternative fuels infrastructure, commonly known as the AFIR. The regulation obliges Member States to expand the charging infrastructure for electric vehicles and defines smart and bidirectional charging. For more information, see **Annex 3.**

Intelligent charging points are designed to enable real-time data exchange between charging point operators, mobility service providers, distribution system operators and consumers. Bidirectional charging points should also enable the flow of electricity from the battery to the charging point (i.e. from the car to the power grid). According to the regulation, all publicly accessible charging points built or modernised after 2024 should enable smart charging. In addition, from 1 January 2027, all newly installed and modernised charging points, both public and private, will have to support the EN ISO 15118-20 standard. Among other things, this standard introduces bidirectional energy flow, integration with the power grid and buildings, and advanced energy management functions. In other words, AFIR is a regulatory step towards V2X.

EPBD Directive

Another important regulation from the point of view of electromobility is the Energy Performance of Buildings Directive (EPBD). One of its requirements is to ensure that buildings have access to electric car charging points, as well as duct infrastructure (for electrical cables) prepared for the installation of chargers at a later date.

One of the key elements of the EPBD is the Smart Readiness Indicator (SRI). It allows buildings to be assessed on the basis of nine categories, including electric vehicle charging, monitoring and control. The indicator is currently in the testing phase, but by mid-2027, the European Commission will publish an act that will provide a framework for the application of the SRI at Union level.

1.3 National regulations

The Electromobility Act still lacks V2X regulations

The main legal act regulating the development of electromobility in Poland is the Act on Electromobility and Alternative Fuels. The Act specifies, among other things, the rules for the development and operation of electric vehicle charging infrastructure and the conditions for creating clean transport zones. Unfortunately, the Act does not introduce provisions directly regulating the issues of V2G (the return of energy from electric vehicles to the grid). In particular, there is a noticeable lack of regulations on billing standards for bidirectional charging and tariff rules. In practice, this prevents the market development of V2G services.

In Poland, there are also no regulations concerning the supply of electricity to homes using energy stored in electric vehicles – V2H. However, if it is technologically possible, electric car owners can power appliances in their homes without the need for grid operator's intervention as part of private installations. Nevertheless, national regulations on testing and certification requirements for V2H devices would be beneficial, as they would ensure greater safety in the use of this technology (e.g. through appropriate cybersecurity and fire safety requirements). What is more, the Polish car market is currently not saturated with electric cars, and dynamic tariffs are not very popular. Polish regulations for V2H could contribute to the growth in popularity of this solution, e.g. by introducing incentives for its use.

Rejected attempts to incorporate V2X into national regulations

In the past, there have been attempts to include V2X in Polish regulations. The 2020 draft amendment to the Electromobility Act introduced a definition of a bidirectional charging point enabling the transfer of electricity from electric or hybrid vehicles to the power grid. Such a point was to be equipped with a metering and billing system, and the energy collection process was to be handled by the charging station operator or the distribution system operator. Ultimately, however, the provision was not included in the adopted amendment.

The AFIR is already in force in Poland

Unlike directives, the EU regulations apply directly in all Member States (without the need for transposition into national legislation). Thus, the AFIR has also been in force in Poland since 13 April 2024. In connection with AFIR, Poland had to prepare a national policy framework for market development with regard to alternative fuels in the transport sector and the development of appropriate infrastructure. Such a document was adopted in the form of Council of Ministers Resolution No. 149 of 28 October 2025, almost a year after the deadline.

The document indicates that the first step towards enabling the use of V2G is to accelerate the installation of smart meters. By the end of 2028, at least 80% of end users are to use them. The document confirms that the introduction of V2G technology requires changes to the Energy Law, including the recognition of electric vehicles as part of the power system and the definition of the rules for their operation. Before the implementation of the regulations, a cost-benefit analysis is planned, taking into account the impact of V2G on grid stability and savings for users.

Assessment of the potential of V2G in Poland

In accordance with AFIR, the President of the Energy Regulatory Office prepared an assessment of V2G potential. It showed that by the end of 2023, there were no V2G stations operating in Poland. Two operators were carrying out research and development projects.

At the same time, the document indicates that thanks to V2G and V2H, it will be possible to obtain benefits during periods of high power demand in the power system. This will require:

- economies of scale – a large number of cars and charging stations supporting V2X technologies;
- market mechanisms encouraging car owners to cooperate with the network;
- national regulations governing the V2G process.

V2X pilot project in Poland

The Charging Park in Bolechowo, launched by Solaris in September 2022, is the first bidirectional park in Poland. The charging system consists of two independent 150 kW plug-in chargers, each with a V2G function.

1.4 Polish electromobility, or where are we headed

The status of the EV market in 2025	Underdeveloped market

Total number of registered vehicles:	
▪ **Electric (BEV)**	122,000 (about 0.5% of registered vehicles)
▪ **Hybrid (PHEV)**	116,000 (about 0.5% of registered vehicles)

Liczba nowo zarejestrowanych pojazdów:	
▪ **Electric (BEV)**	43,000 (7.25% of new registrations)
▪ **Hybrid (PHEV)**	34,000 (5.7% of new registrations)

Charging infrastructure:	
▪ **AC stations**	7,000
▪ **DC stations**	4,000

Source: Total number of registered vehicles and charging infrastructure: PSNM. New vehicle registrations: ACEA, PSNM. Note: the share of electric vehicles in the total vehicle stock was estimated based on data from the European Alternative Fuels Observatory.

The first electromobility act, adopted in 2018, assumed that one million electric cars would be driving on the Polish roads by the end of 2025. This target was not met. In light of the observed market trends, the current assumptions for EV development are more conservative. According to the draft National Energy and Climate Plan (KPEiK) of December 2025, the number of passenger electric cars is expected to reach 720 thousand in 2030 and 4.3 million in 2040.

The Polish New Mobility Association (PSNM) forecasts a slightly faster increase in the number of electric vehicles. According to the Association, by the end of 2030, there could be almost 700,000 electric passenger cars and delivery vehicles and almost 41,000 zero-emission trucks on Polish roads. The growth rate of new electric vehicles is expected to accelerate after 2035, if the ban on the sale of new combustion engine cars (passenger and delivery vehicles) by large manufacturers is upheld. PSNM estimates that during this period, the number of newly registered electric vehicles in Poland will exceed 535,000, and the total number of electric passenger cars will reach 2.15 million.

The significant acceleration of electromobility development over the next decade will also substantially ncrease the potential benefits of V2X for the power system. **This means that the possible systemic benefits of V2X should be identified now and an appropriate regulatory and market framework developed to enable them to be delivered.** In order to enable the use V2X technology, it is necessary to first ensure access to bidirectional charging infrastructure and smart meters. The development of electromobility must go hand in hand with the development and adaptation of the power system to changing conditions. These development paths must interact and support each other. Changes in consumer behaviour will also be key: a shift from the combustion engines and vehicles that can be refuelled at any time to conscious planning of charging times and locations.

2. The benefits of V2X

2.1 Greater self-consumption

Between 2019 and 2022, Poland saw an unexpected boom in prosumer photovoltaics. This was influenced by subsidies for the purchase of PV systems under the "My Electricity" programme and a billing system for surplus energy fed into the grid that was favourable to prosumers. The so-called discount system treated the power grid as a virtual electricity storage facility with an efficiency of 80% or 70%. This system had a significant drawback – it did not encourage prosumers to increase self-consumption. The installations were often oversized so that the energy taken from the grid fully covered the prosumer's demand. This was an unfavourable solution for the power system as a whole, causing problems with grid stability. Today, prosumers themselves are also suffering from this. In places where there are many installations and the energy produced is not consumed, the installations shut down. The reason for this is an increase in voltage in the grid.

From April 2022, new owners of PV micro-installations are covered by a different system, known as net billing. Under this system, surplus energy fed into the grid is sold at market prices, and energy taken from the grid is purchased at a standard tariff (covering both the purchase of energy and grid charges).

For prosumers, especially those covered by the net billing system, it is beneficial to increase self-consumption of energy from their own renewable energy installations. Charging a vehicle primarily with electricity from PV installed on the building can help in this regard. Smart charging will also help to reduce PV system shutdowns resulting from voltage surges in the grid. In addition, using EVs as "home batteries on wheels" is a good safeguard in the event of a power outage due to a grid-level failure.

Quick benefits

Lower bills for prosumers

Over the next decade, PV installations, heat pumps and electric cars will become standard features in many single-family homes. Intelligent control systems for heat pumps and EV charging and discharging will increase self-consumption from PV. For prosumers, this means less electricity consumption from the grid – and therefore lower bills. Further energy cost reductions can be achieved by switching to a dynamic tariff. Ultimately, thanks to the use of V2H technology, prosumers have the opportunity **to reduce their bills by 15-30%** (according to analyses by the Fraunhofer Institute).

2.2 Less RES curtailment

Non-market redispatching is a phenomenon where the Transmission System Operator imposes top-down restrictions on electricity production for some RES installations. This action is taken during periods when energy generation from renewable sources would significantly exceed the energy demand in the system. It is necessary to ensure the safe operation of the National Power System and to manage physical constraints in the networks. The RES curtailment is used "as a last resort" – first, among other things, the output of coal and gas power plants is reduced and energy exports are increased.

Redispatching means lost revenue from energy sales for RES producers. Owners of installations are entitled to compensation for non-market redispatching. The cost of this compensation is included in the so-called "quality rate" which is a part of the tariff, and thus ultimately affect the bills of all electricity users.

From the system's perspective, it is beneficial for electric cars to charge when there is a lot of energy from wind and sun. Smart chargers allow the charging time and power of EVs to be adjusted without the need for "manual" control by the car owner. As a result, smart charging allows electric vehicles to be charged primarily during periods of high generation from RES. Wider use of the V2X will translate into a reduction in the scale of non-market redispatching of renewable energy sources, as well as a reduction in the quality rate on the consumer bill.

Medium- and long-term benefits

Reduction in the RES curtailment

Smart charging has the potential to reduce RES curtailment by 0.7 TWh in 2030 and 4.6 TWh in 2040. Savings related to the reduction in RES generation may amount to PLN 0.1 billion in 2030 and **PLN 0.7 billion in 2040**. They will translate directly into lower quality rate, which is a part of energy bill. A description of the methodology used in the calculations can be found in **Appendix 2.**

2.3 Lower energy production costs

As indicated above, V2X has the potential to systematically reduce the curtailment of RES. This will have a positive impact on system costs (quality rate). Another clear benefit will be the reduction in energy production costs, as more cheap energy from RES means less expensive energy from fossil fuels. Lower electricity production costs will be reflected in end users' bills in the active energy charge item.

Medium- and long-term benefits

Less expensive energy from gas

Smart charging and V2X have the potential to reduce electricity production from natural gas by 0.8 TWh in 2030 and 5.5 TWh in 2040. A smaller share of expensive electricity means lower bills for end users. These savings could amount to as much as PLN 0.4 billion in 2030 and **PLN 5.3 billion in 2040**. They will be reflected in the active energy charge rate. A description of the methodology used in the calculations can be found in **Appendix 2.**

2.4 Lower network expansion costs

To deliver electricity from the generating source to the consumer, an electricity grid is needed with adequate capacity. When electricity demand in a given location begins to exceed the grid's transmission capacity, it results in a grid congestion. If this phenomenon occurs continuously, it is necessary to expand the network (i.e. build new power lines and transformers).

The problem of grid congestion is often local and temporary, i.e. it is related to a specific part of the grid and occurs, for example, at a specific time of day. Localised grid congestion can be eliminated by reducing peak power consumption by consumers. At these critical moments, EV owners will be able to reduce consumption by using the electricity stored in their car batteries. Thus, V2X technology can be a systemic tool for managing network capacity issues. Exploiting this flexibility potential will reduce the scale of costly investments in network infrastructure, which affect energy distribution charges.

Long-term benefits

Lower network expansion costs

According to analyses by the Fraunhofer Institute, the implementation of V2X technology is an opportunity for Poland to reduce its financial outlay on power grid expansion by PLN 1.3 billion in 2030 and **PLN 4 billion in 2040**. These savings will translate into lower network charges for all energy consumers.

2.5 Lower peak capacities

As mentioned above, at critical moments, EV owners will be able to reduce their energy consumption from the grid by using the electricity stored in their car batteries. Some of them will even be able to feed energy back into the grid by discharging their cars. Such flexibility on the demand side is extremely important from the perspective of reducing peak power demand in the power system. Reducing peak capacities will translate into lower demand for controllable generation sources (such as gas-fired power plants). Thus, V2X will reduce the system costs of keeping these sources ready for operation. These costs are borne by all end users – currently in the form of a capacity charge.

Long-term benefits

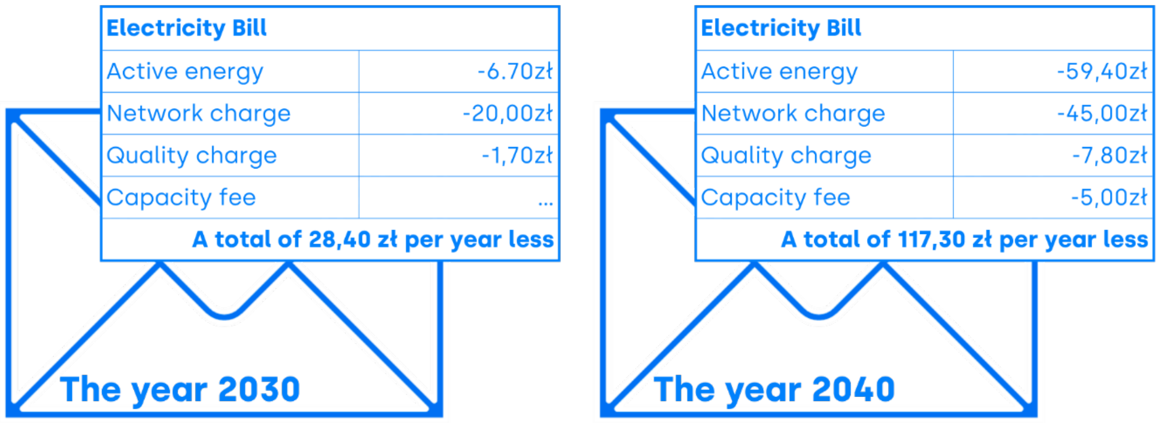
Less peak capacities

V2X has the potential to reduce the demand for controllable peak capacity by more than 1 GW in 2040. This will translate into lower costs of maintaining support for these units within the capacity market, and thus lower capacity charges. This saving could amount to as much as **PLN 0.4 billion in 2040**. A description of the methodology used in the calculations can be found in **Appendix 2.**

2.6 Summary – how will V2X affect our bills?

In the short term, the development of V2X technology – and V2H in particular – has the potential to reduce the bills of electrified car owners by as much as 15-30%. Households with PV installations and heat pumps will be able to reap particularly large benefits. At the same time, the large-scale implementation of V2X cooperation between electric cars and the power system will reduce network and system costs for all energy consumers. In total, these benefits could amount to as much as 39 PLN/MWh in electricity savings in 2040 (compared to a scenario without V2X implementation).

V2X means lower electricity bills for everyone



**the estimates were made for a household with an annual electricity of 3000 kWh*

3. Barriers

3.1 Lack of regulatory framework

As already mentioned, the AFIR regulation has been in force in Poland since April 2024. However, it does not provide a sufficient regulatory framework for the development of V2X, as it does not address issues such as common rules for V2G tariffs. A national legal framework is therefore needed.

It will be particularly important to regulate the method of settling energy fed into the grid from mobile energy storage (V2G):

1. Currently, the sale of energy stored in a home energy storage facility is only permitted if it is charged from a prosumer photovoltaic installation. The V2G service, on the other hand, requires the car owner to be able to purchase energy from the grid during periods of high RES generation and return it to the grid during periods of low generation. Without the appropriate regulations, this activity could be treated as a business activity – requiring a license and subject to tax.
2. Although in practice an electric car can function as an energy storage facility, it does not meet the definition of such a facility under Polish law. This means that it is not covered by regulations exempting storage facilities from part of the grid fees related to the volume of stored electricity. Appropriate regulation of network charges for energy storage facilities (including V2G) is necessary to increase their market viability.

Appropriate legal changes must be included, among others, in the Energy Law, the Electromobility Act and the RES Act.

Electromobility and the achievement of RES targets

Legislative work is underway to enable energy from RES supplied to road and rail vehicles to be counted towards the National Indicative Target. This will help to increase the share of RES in transport and support the development of charging infrastructure.

3.2 Tariffs and meters

Dynamic tariffs for V2H

Appropriately structured dynamic tariffs are needed to stimulate the potential of V2H. In a dynamic tariff, energy prices change in real time, reflecting current prices on the wholesale energy market. In this way, consumers are encouraged to consume energy during hours when energy prices are low (high availability of green energy) and to reduce consumption during periods of high prices (i.e. limited generation from renewable energy sources).

From 24 August 2024, larger electricity suppliers will be required to offer dynamic tariffs. However, these are not yet popular. There is also no similar billing model for network charges, which would make variable energy distribution rates dependent on the situation in the power grids. As a result, the resulting price signal for flexible consumers may be distorted (e.g. low electricity prices overlap with high distribution rates).

Special tariffs for V2G

Creating a market model for V2G services will require the formulation of special tariff rules. V2G tariffs may be based to a large extent on dynamic tariffs . However, in order for these tariffs to provide sufficient incentive for EV owners to cooperate with the grid, they should also include a partial exemption from grid charges for the volume of electricity drawn from the grid, stored in the battery and fed back into the grid. This mechanism could, for example, be analogous to that existing for stationary electricity storage facilities.

Another solution is to create a market framework for specialised entities that aggregate and manage the V2G on a large scale. They could offer consumers a "monthly subscription" for charging their electric vehicle at a fixed, affordable price in exchange for the ability to manage the bidirectional charging process.

Smart meters – you can't do without them

Smart meters are devices that measure electricity consumption in real time, as well as the volume of energy fed into the grid by the consumer. They allow for remote reading of energy parameters and their automatic analysis. They are an essential element for the use of dynamic tariffs (or future tariffs for V2G). If an electric car owner does not have a smart meter at home, in order to provide the V2G service, they will have to submit a request to the operator for the early installation of such a device (which involves an additional fee) or wait for its installation according to the schedule (which may not happen until 2031).

Smart meters – how many do we have and how many do we need?

The Energy Law requires distribution network operators to install smart energy meters for at least 65% of end users by the end of 2027 and at least 80% by the end of 2028. In turn, by 4 July 2031, every end user should be equipped with a remote reading meter.

According to data from the Energy Regulatory Office, 38% of end users were equipped with smart meters at the end of 2024.

3.3 Charging infrastructure

To unlock the potential of V2G and V2H, an extensive infrastructure of points enabling smart one-way and two-way charging is necessary. Chargers in residential and public buildings, as well as public charging points, e.g. in car parks, will play an important role. Unfortunately, Poland does not currently have a developed charging infrastructure. According to an assessment by the Energy Regulatory Office, in 2024 there were no public or private bidirectional charging points connected to the power grid.

Private individuals living in single-family homes can invest in a bidirectional charger themselves and use V2H. The purchase of a private charger will also enable them to use V2G in the future (when the relevant regulations are introduced). EV owners living in multi-family buildings, who are subject to common property management regulations, are in a worse situation. These regulations are so general and imprecise that they often lead to unfavourable interpretations that prevent the installation of private car chargers in multi-family buildings.

3.4 Concerns about battery life

One of the barriers to the development of V2H or V2G may be the concern of electric car owners about a decrease in battery life – the most expensive component of the vehicle. However, bidirectional charging does not necessarily result in a significant decrease in battery capacity. The key factors limiting the negative impact of bidirectional charging on the car battery will be maintaining the battery charge level in accordance with the manufacturer's recommendations (e.g. between 20-80%) and intelligent management of charging cycles, in particular the use of slow charging (lower charging power).

By maintaining these operating conditions for the electric car battery, the risk of reduced service life as a result of bidirectional charging may be much lower than the potential financial benefits. In some cases, battery life may even increase.

Research on EV battery life – conclusions

A study by the Technical University of Munich has shown that the capacity of EV batteries used for daily commuting within a city will only decrease by 7.5% over 160,000 km. According to these analyses, an electric car can travel 1.5 million km before the battery capacity falls to 70% of its initial value.

What is more, smart charging can have a positive impact on battery life. A study by the Mobility House showed that over a period of 10 years, smart charging reduces battery capacity loss by 3.3-6.8%. The use of V2G, on the other hand, causes a slight increase in battery capacity loss (1.7-5.8%), but the financial benefits for vehicle owners (6-10 thousand euros) outweigh the losses resulting from the decrease in battery capacity (100-300 euros).

4. How are other countries implementing V2X?

V2X is at an early stage of development in most countries. However, some of them are already introducing regulatory, technological and business solutions to enable V2X. We present the most interesting ones. More details and a comparison of markets can be found in **Appendix 1.**

V2G pilot project in the United Kingdom

Between 2018 and 2021, a three-year pilot project was conducted in the UK involving 300 V2G chargers installed in homes. Participants in the study received 30p per 1 kWh fed into the grid, which in some cases translated into an annual profit of £725. Based on the pilot, it was estimated that the potential for systemic benefits in 2030 could reach £3.5 billion if 50% of electric cars in the UK provided V2G services. The project is an example of a successful public-private partnership.

Business solution in Denmark

Denmark has a special platform for managing electric vehicle charging infrastructure – SPIRII. Thanks to the platform, companies (which own charging points) can monitor the entire infrastructure, including consumer behaviour, charging statistics and network performance. This analysis enables companies to optimise their tariff offers and identify the need for new charging points in specific locations. Car owners, on the other hand, have easy access to smart chargers and a convenient payment system thanks to the SPIRII GO app. They can also actively participate in the Danish energy transition by choosing to charge their vehicles at times when renewable share of electricity is highest.

V2G aggregation in France

In 2022, the French transmission system operator (Réseau de Transport d'Électricité – RTE) certified the first V2G aggregator to qualify for frequency control reserve (FCR) services. RTE takes into account the role of electric cars in network development scenarios, assuming that by 2035, 2% of the vehicle fleet will be able to provide V2G services.

Smart meters in the Netherlands

The Netherlands has one of the highest rates of smart meter usage in Europe, with around 90% of the population using them. Smart meters in the Netherlands are equipped with a port that allows both consumers and external home energy management systems to access data. This lays the foundation for the implementation of V2H technology, which enables the smart use of energy from electric vehicles in households.

5. Recommendations

Unlocking the potential of V2X requires the right regulatory environment (V2G billing rules, tariffs), infrastructure (bidirectional chargers, smart meters) and market instruments (tariffs, service providers).

1 Recognition of the potential of V2X

Estimation of the potential systemic benefits of implementing V2H and V2G in the long term at the national level, including as part of work on strategic documents. Assessment of the scale of systemic benefits of using V2X in relation to the costs and benefits of implementing "classic" electricity storage facilities (large-scale and home-based).

Addressee: Ministry of Energy, Ministry of Infrastructure
Perspective: 2026

2 Support for institutional capacities

Increased funding for ministries and administrative institutions responsible for strategic, regulatory and reporting work in areas related to V2X in order to increase the number of positions and basic salaries for relevant employees working on the topic (including the Energy Regulatory Office and the Ministry of Energy).

Addressee: Ministry of Finance, Council of Ministers
Perspective: 2026

3 Legal regulation of V2H and V2G

Introduction of definitions of V2H and V2G into the Polish legal system. Establishment of rules for settling energy consumed and fed into the grid from mobile energy storage without double taxation. Abolition of part of the grid fees for the volume of energy stored and fed into the grid under V2G.

Addressee: Ministry of Energy
Outlook: 2026-2027

4 V2G as a standard for charging points

Introduction of an obligation for all new and modernised charging points to support V2G from 2027.

Addressee: Ministry of Energy
Outlook: 2026-2027

5 Inclusion of the V2G standard in the implementation of the Energy Performance of Buildings Directive (EPBD)

Ensuring that charging points and duct infrastructure (electrical cables) covered by the requirements of Article 14 of the EPBD are ultimately adapted to support V2G technology.

Addressee: Ministry of Development and Technology, Ministry of Energy
Timeframe: 2026-2027

6 Regulation of V2G chargers in multi-family buildings

Removal of regulatory barriers to the installation of private V2G charging points in common areas in multi-family buildings.

Addressee: Ministry of Development and Technology, Ministry of Energy
Outlook: 2026-2027

7 Faster implementation of smart meters

Introduction of an obligation for DSOs to install smart meters as a priority (e.g. within two weeks) of an application being submitted by an end user who owns a V2G charger.

Addressee: Ministry of Energy, DSOs
Outlook: 2026-2027

8 Development of dynamic network charges

Regulation of the obligation to offer dynamic distribution tariffs to complement dynamic energy tariffs by DSOs.

Addressee: Ministry of Energy, Energy Regulatory Office
Outlook: 2026-2027

9 Financial support for electromobility conditional on V2G readiness

Introduction of an obligation that financial support for the purchase of electric vehicles and chargers under national and regional programmes may only be granted for solutions supporting V2G. Introduction of an obligation for beneficiaries to have a dynamic tariff for charging electric cars (other electricity consumption may remain covered by a single-zone tariff).

Addressee: National Fund for Environmental Protection and Water Management, Ministry of Energy
Outlook: 2027-2028

10 Research and development

Design and implementation of pilot projects for V2G and V2H technologies, including the collection of data on vehicle charging and discharging parameters, routes travelled, charging locations and owner behaviour.

Addressee: National Centre for Research and Development, Ministry of Energy
Outlook: 2027-2028

11 Friendly dynamic tariff programme

Conducting a pilot programme on the use of dynamic tariffs for a group of willing consumers. If participants obtain financial benefits compared to a single-zone tariff, the programme achieves an educational and promotional effect. If the bill under the dynamic tariff turns out to be higher, the difference in costs is reimbursed to the participants from the programme funds.

Addressee: National Fund for Environmental Protection and Water Management, Ministry of Energy
Perspective: 2027-2030

12 Educational campaigns

Conducting an educational campaign aimed at end users covering the topics of V2H, V2G, energy consumption flexibility and self-consumption of energy from prosumer installations.

Addressee: Ministry of Energy, Ministry of Climate and Environment
Outlook: 2027-2030 ■

Appendix 1. V2G in other European countries

V2X is at an early stage of development in most countries. The success of V2X largely depends on a country's starting point – the state of its power grids and their flexibility, the regulatory environment, access to support mechanisms, public attitudes and other financial and technical factors that can stimulate innovation. Below is an overview of the state of EV market development in four countries: the United Kingdom, Denmark, France and the Netherlands, along with the most interesting examples of solutions being implemented.

State of EV market development (2025)	**United Kingdom**	**Denmark**	**France**	**Netherlands**
	average	good	average	good
Total number of vehicles:				
▪ Electric (BEV)	1,738,000	505 thousand	1,663,000	681,000
▪ Hybrid (PHEV)	868,000	131,000	853,000	483,000
Share of vehicles:				
▪ Electric (BEV)	4.4	15.7	3.5	6.7
▪ Hybrid (PHEV)	2.2%	4.1	1.8	4.7
Total new vehicles:				
▪ Electric (BEV)	473,000	127,000	327,000	156,000
▪ Hybrid (PHEV)	225,000	5 thousand	109,000	73,000
Share of new vehicles:				
▪ Electric (BEV)	23,4%	68,5%	20%	40,2%
▪ Hybrid (PHEV)	11,1%	2,5%	6,7%	18,9%
Charging infrastructure:				
▪ AC stations	82,000	42,000	147,000	196,000
▪ DC stations	21,000	8,000	40,000	7,000
Share of smart meters	61	100	92	90
Access to subsidies:				

▪ electric vehicles	Subsidy #1, Subsidy #2	Tax relief	Subsidy	Tax relief
▪ charging infrastructure	Subsidy	Subsidy	Grants	Consulting
E-mobility applications	Zapmap	Spirii Go	Elton	Smoov
V2G regulatory framework	under development	not	under development	no
V2G aggregation as DSR	theoretically	theoretically	yes	theoretically
V2G pilot projects	SCIURUS	Commercial hub	EVVE	Utrecht energised

Source: Based on, among others, the smartEn report and the European Alternative Fuels Observatory database. . Data on the total number of vehicles in the United Kingdom (Q3 2025), Denmark (Q3 2025), France (end of 2025) and the Netherlands (Q3 2025); data on charging infrastructure (as of December 2025) in the United Kingdom, Denmark, France, and the Netherlands; ; data on new vehicle registrations: ACEA; NOTE: the share of electric vehicles in the total vehicle stock was estimated based on data from the European Alternative Fuels Observatory.

Case study #1 – United Kingdom

SCIURUS V2G pilot project – an example of public-private partnership

The SCIURUS project is one of the world's largest pilot projects investigating energy consumption when charging electric vehicles. The pilot began in 2018 and lasted three years, involving representatives from the public and private sectors and owners of Nissan electric cars. Seven partners played key roles in the SCIURUS project:

- distribution system operator: OVO Energy;
- interactive charging management platform developer: Kaluza;
- electric car manufacturer: Nissan Motor Company;
- consulting company: Cenex;
- charging infrastructure provider: Indra Renewable Technologies;
- institutions financing the project: Office for Low Emission Vehicles (OLEV) and Department for Business Energy and Industrial Strategy (BEIS).

300 electric vehicle owners took part in the project. They gained free access to bidirectional charging infrastructure and the interactive "Kaluza Flex" platform for managing electricity consumption (depending on wholesale and balancing market energy prices). Participants were remunerated for feeding energy back into the grid during periods of high energy prices (high energy demand in the system). Participants also received advance information about times when electricity prices were low, allowing them to charge their vehicles with cheaper energy

from renewable sources. Thanks to these measures, **pilot participants were able to save up to £725 per year.**

The evaluation of the SCIURUS pilot project indicated the potential of V2G technology to reduce costs related to network infrastructure expansion and energy generation and storage. **Based on the pilot, it was estimated that the potential for systemic benefits in 2030 could reach £3.5 billion if 50% of electric cars in the UK provided V2G services.**

The COVID-19 pandemic, which broke out during the pilot, had a significant impact on the project's results. The restrictions introduced led to a significant increase in the number of programme participants working exclusively from home. During the pandemic, the flexible power in Kaluza's V2G portfolio increased by up to 30% compared to pre-lockdown levels. Thus, **the project demonstrated that behavioural aspects play a key role in the potential of V2G.**

Other V2G pilot projects

- Commercial hub in Denmark – the first commercial V2G project in Denmark from 2016. A collaboration between Nissan, Enel and Nuvve. The project involved 10 Nissan e-NV200 electric vans and 10 Enel V2G bidirectional chargers with a total capacity of 100 kW.
- Utrecht energised – an electric vehicle car-sharing service supporting V2G in the city of Utrecht in the Netherlands, operating since November 2024. The project is a collaboration between the Renault Group, We Drive Solar, MyWheels and the city of Utrecht. The project started with 50 vehicles and will eventually include 500 electric cars supplied by the Renault Group.
- The EVVE project – **a project by French energy company EDF supported by the European Innovation Fund. It aims to create a virtual electricity storage facility with a capacity of 8.36 MW by installing and aggregating 800 bidirectional V2G charging stations.**

Case study #2 – Denmark

Spirii Go – Interactive e-mobility management platform

Spirii is a Danish company founded in 2019 that operates electric vehicle charging infrastructure. Spirii is responsible for the installation and supervision of charging stations (maintenance, diagnostics), as well as for the software and infrastructure of the Spirii Go interactive platform.

The Spirii Go platform provides consumers with a convenient payment system for charging electric cars – both at public charging stations and at home. The solution is available in more than 22 markets (including Germany, Belgium and Luxembourg). Spirii Go provides users with access to current data on selected charging stations, such as available charger capacity, current electricity prices and carbon footprint. With this information, users can optimise the charging process for their cars by managing the location and time of charging.

Thanks to the platform, companies (which own charging points) can monitor the entire infrastructure, including consumer behaviour, charging statistics and network performance. This analysis allows companies to optimise their tariff offers and identify the need for new charging points in specific locations.

The solution allows both businesses and end users to reap the benefits of smart charging. It thus contributes to the development and availability of e-mobility services.

Other solutions for managing charging point infrastructure

- Smoov (Allego App) – an application offering users access to a map of charging stations and a payment system. It covers 269,000 charging stations in 16 European countries. The application is provided by the Dutch company Allego, founded in 2013.
- Zapmap – an application offering users access to a map of charging stations and a payment system in the United Kingdom. It covers over 80,000 charging stations.
- GreenFlux – **a Dutch company founded in 2011, offering a platform for managing a network of chargers and billing for operators and providers of electric vehicle charging services. It covers approximately one million charging points.**
- Driivz – **an Israeli company founded in 2012, creating a platform for EV charging infrastructure, billing and energy consumption optimisation for operators and fleets.**
- AMPECO – **a Bulgarian company founded in 2018, providing a white-label solution for EV charging management, enabling full customisation and integration with various business models.**
- EcoG – a German company providing charging point infrastructure management solutions aimed at better integration with the grid. It has received support from the European Investment Fund.

Case study #3 – France

V2G aggregation as a flexibility service

In France, flexibility services such as storage and DSR (Demand Side Response), i.e. flexibility mechanisms on the consumer side, can be provided on the day-ahead market, the balancing market and the frequency services market . Since 2019, flexible capacities can also apply for long-term contracts within the capacity market. Flexibility services can be provided both to the transmission system operator (TSO) and to distribution system operators (the framework for local flexibility markets is being developed by ENEDIS, among others). The first two contracts for the provision of local flexibility services to ENEDIS were signed in 2020.

At the same time, it should be emphasised that the provision of flexibility services by V2G requires an appropriate aggregation framework. Individual charging points will have too little power to provide services on wholesale markets on their own. It is necessary to create a "virtual power plant" consisting of multiple charging stations and to manage its operation by a specialised aggregator.

In 2022, the French transmission system operator (RTE) awarded certification for the first time to an aggregator using V2G to provide frequency control reserve (FCR) services. The entity that obtained the certification is the DREEV consortium, composed of the French energy company EDF and the American aggregation service provider NUVVE. The DREEV consortium used CHAdeMO bidirectional charger technology for aggregation, mainly for charging corporate fleet vehicles.

V2G flexibility is included in RTE's strategies

The French transmission system operator sees a need to further develop the potential for V2G to provide flexibility services. RTE takes into account the role of electric cars in its network development scenarios, assuming that 2% of the vehicle fleet will be able to provide V2G services by 2035. The role of infrastructure development for flexible electric vehicle charging is also one of the priorities in the French energy regulator's strategy for 2025-2030.

Case study #4 – The Netherlands

Smart meters equipped with a "data portal" as a catalyst for VtG and VtH technologies

The Netherlands has one of the highest rates of smart meter usage in Europe. The implementation of smart metering in the Netherlands began with a pilot programme in 2012. The first 600,000 smart electricity meters were installed at that time. They were installed during scheduled meter replacements, in newly built homes, during renovations or at the request of customers. In 2015, a long-term, large-scale project was launched to equip at least 80% of households with smart meters by 2020. By 2022, approximately two-thirds of the population had smart meters, and by 2025, this figure had risen to 90%. Initially, meter data was used solely for billing purposes. Since 2022, under a privacy agreement approved by all distribution system operators (DSOs), the data can be used for network management under The Smart Management Code of Conduct.

Smart meters equipped with a portal that provides 24/7 access to energy consumption data for both homeowners and network operators can be a key factor in enabling the widespread use of V2G and V2H technologies. A portal directly connected to the management system allows network operators to process data on an ongoing basis and provide advice on how to improve energy efficiency in households.

Appendix 2. Methodology for estimating benefits

In order to estimate the potential benefits of V2X, the operation of the power system in 2030 and 2040 was modelled. Most of the assumptions regarding the parameters of the power system (including the capacity of generation sources and electricity consumption) were based on the WAM scenario from the Polish NECP draft presented in December 2025. Where the necessary assumptions could not be made on the basis of NECP data, own assumptions were made.

Assumption	Year 2030	Year 2040	Source
PV capacity [GW]	32.4	43.0	NECP draft from December 2025
Onshore wind capacity [GW]	16.5	28.8	
Offshore wind capacity [GW]	5.9	16.0	
Capacity of utility-scale and residential energy storage and pumped storage hydropower (GW)	7.4	23.1	
Electricity production from biomass, biogas, nuclear and run-of-river hydro sources [TWh]	12.6	59.8	
Electricity demand [TWh]	194.7	266.7	
Electricity demand in road transport [TWh]	2.7	13.1	
Heat storage [GWh]	124	576	
Natural gas price for energy sector [EUR/GJ]	8.02	7.94	
Price of EUA allowances (EUR/tCO2)	120	300	
Number of passenger electric cars	0.7 mln	4.3 mln	
Heat storage charging capacity [GW]	0.6	3.5	

Capacity of large-scale and household energy storage facilities and ESP [GWh]	29.7	92.4	Own assumptions based on the NECP draft
Average energy consumption by EV [kWh/100km]	22	20	Own assumptions
Average battery capacity [kWh]	50	80	
Average charging point power [kW]	5	7	
Share of V2H and V2G vehicles	10%	30%	
Share of smart charging cars	30%	40%	
Cost of reallocating renewable energy sources (quality rate) [PLN/MWh]	150	150	
Cost of maintaining additional peak capacity (capacity charge) [PLN/kW/year]	400	400	
Cost of electricity from peak gas turbines (fuel cost + CO_2 emissions) [PLN/MWh]	569.5	954.7	

A simplified "copper plate" model was used to assess the operation of the Polish power system.

1. Weather-dependent RES

Energy production from weather-dependent RES sources, including PV installations and onshore wind farms (based on historical production data from domestic sources according to PSE data), as well as offshore wind farms (based on literature profiles), was simulated on an hourly basis. The projected energy production profiles for 2030 and 2040 were obtained by scaling the initial generation profiles of individual RES sources according to their installed capacity assumptions.

2. Electricity demand

The hourly breakdown also simulated the electricity demand profile, excluding electricity demand for road transport (i.e. electric cars). This profile was obtained by scaling the historical profile of national energy demand in the National Power System (KSE) according to assumptions regarding total electricity consumption (excluding electromobility).

3. Energy balance

It was assumed that the minimum capacity of controllable synchronous sources operating "at base load" (nuclear, biomass, biogas) is 5 GW. Based on the energy balance for each hour of the year, the difference between the energy production from weather-dependent RES combined with baseload sources and the electricity demand in the system was determined.

4. Energy storage and heat storage

If there was an oversupply of electricity from RES sources at a given hour, it was assumed that electricity storage facilities were being charged at that time. If the electricity storage facilities could not accept more energy from RES (due to limitations in available power and/or capacity), it was assumed that this energy would be partially used to charge large-scale heat storage facilities during the heating season.

During hours when electricity production from weather-dependent RES was insufficient to meet the energy demand in the system, it was assumed that electricity storage facilities would feed energy into the grid to the extent permitted by the available capacity and state of charge of the storage facilities.

5. Electromobility scenarios

To assess the impact of smart charging and V2G on the system, two scenarios were compared.

In the reference scenario (no smart electromobility), the demand resulting from charging electric cars was independent of the situation in the power system. For each day of the year, an identical hourly charging profile was assumed for vehicles. The profile was modelled in such a way as to cover the entire average daily electricity consumption resulting from the movement of electric cars on the roads and to reflect the fact that cars are mainly connected to charging points after users return home.

In the second scenario, it was assumed that only some of the cars are charged according to a "behavioural" (non-intelligent) profile.

In this scenario, it was assumed that cars with smart charging capabilities (V1G, V2H) would be charged as a priority during hours of excess electricity supply from RES sources. If green energy is not available, these cars do not charge. The exception is periods when not charging the cars would mean their charge level falling below 20% (i.e. during periods of prolonged lack of energy from RES). In this case, the cars are charged to ensure the required minimum battery charge level representing the ability to drive the car.

This scenario also assumes that some cars will use V2G technology. The charging of these cars is modelled analogously to V1G and V2H charging – the charging process takes place primarily during hours with high availability of energy from renewable sources. In addition, it is assumed that V2G cars return electricity to the grid during hours of insufficient electricity generation from RES. The exception is situations where this action would cause the battery charge level to fall below the assumed minimum level.

The total available charging and discharging power of electric cars in a given hour was estimated based on the average power of charging stations and the number of cars "parked" (not moving on the road at a given hour).

6. RES surplus and operation of other generation sources

After taking into account car charging and V2G in the hourly resolution of the power system balance, the final results were obtained for the oversupply of generation from RES sources (redispatching), the demand for energy production from other generation sources (including gas) and the peak power in the system for both scenarios. The benefits of V2X were estimated as the difference between the results of the two scenarios.

7. System costs

The total financial benefits for the system were obtained by multiplying the results of the energy balance (volume of RES redistribution; volume of electricity consumption from gas; additional peak power demand) and the assumed unit cost indicators passed on to end users (redistribution cost, higher energy price, cost of maintaining peak power in the system). The average financial benefits per MWh of electricity were obtained by dividing the benefits for the entire system by the total electricity consumption in the system.

Appendix 3. Regulations for charging infrastructure

AFIR Regulation (Alternative Fuels Infrastructure Regulation)

Definitions:

- 'smart charging' means a charging operation in which the intensity of electricity delivery to the battery is adjusted in real time based on information received through electronic communication;
- 'bidirectional charging' means a smart charging operation in which the direction of electricity flow can be reversed, allowing electricity to flow from the battery to the charging point to which it is connected.
- 'digitally connected charging point' means a charging point that can send and receive information in real time and communicate bidirectionally with the electricity grid and the electric vehicle, and which can be remotely monitored and controlled, including, but not limited to, remote start and end of charging sessions and measurement of electricity flows.

According to AFIR, access to public charging stations must be proportional to the number of registered vehicles. At least 1.3 kW should be available for each electric car and 0.8 kW for each plug-in hybrid. The regulation also sets out a schedule for the deployment of charging stations along the Trans-European Transport Network (TEN-T). By the end of 2025, charging zones should be available every 60 km, each with a capacity of at least 400 kW, with one 150 kW charger. By the end of 2035, each such zone must offer 600 kW and at least two 150 kW chargers.

EPBD (Energy Performance of Buildings Directive)

According to the EPBD, by 2027, all non-residential buildings with more than 20 parking spaces should have at least one charger per 10 parking spaces, and ducting infrastructure should be provided for at least 50% of parking spaces. For new and modernised residential buildings with more than 3 parking spaces, the directive requires at least 1 charging point and ducting infrastructure for 50% of parking spaces.

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