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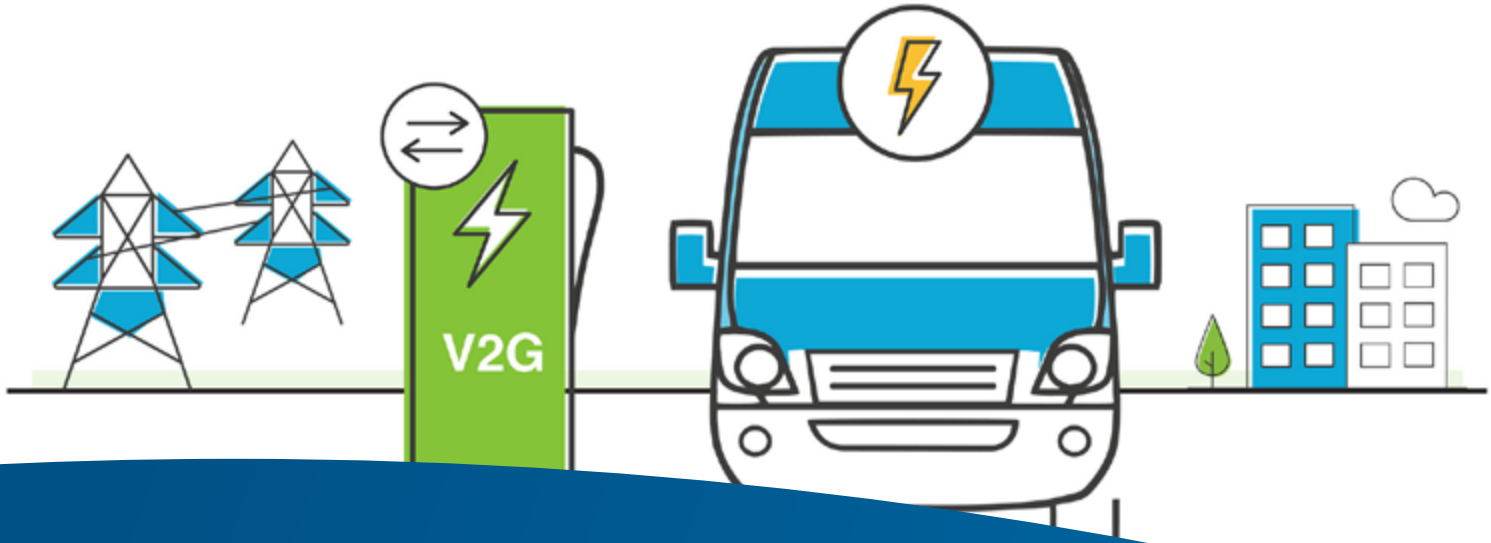


An Introduction to Vehicle-to-Grid Charging for Electric Vehicles

Cenex Insight - August 2022

Commercial vehicle fleets with clear, predictable usage patterns, or where they have low utilisation, are ideal for providing V2G services.

Bi-Directional Charging

Vehicle-to-grid (V2G) is a system whereby plug-in electric vehicles (EV), when connected to a V2G charger, can provide bi-directional flows of energy and data so the battery can charge, store and discharge electricity when necessary.

By controlling the power and timing of charging and discharging of the vehicle battery, customers can optimise the electric resources available.

The term V2G typically refers to any bi-directional charging and discharging of EVs, though there is also a specific use case for grid connections.

Historically, energy systems have relied on supply-side changes to balance supply and demand. However, V2G can act as demand (consuming electricity) and generation (producing electricity), and store electricity in an EV battery for when it is needed most.

It can therefore offer flexibility to manage peaks and troughs in supply and demand as the energy system transitions to distributed renewable sources, and transport transitions to electric.

After conceptualisation as early as 1997, and the first compatible EV (the Nissan LEAF) sold in 2010, V2G found a niche following the 2011 Tõhoku earthquake, tsunami and Fukushima nuclear disaster to provide back-up power to affected buildings.

At this time the EV industry was in its infancy. However research and trials since 2016 have shown the capabilities, benefits and limitations of the technology as more EVs take to the road.

V2G is still in its trial phase, but R&D projects by Cenex suggest it is close to mass market rollout.

This document gives a brief overview of the technology and summarises some of the findings from Cenex's V2G portfolio.

System Architecture

V2G systems have two distinct system architectures, either AC or DC, which determines where the power electronics are located.

In a DC V2G system, the rectification for charging and inversion for discharging is performed in the Electric Vehicle Supply Equipment (EVSE), possible via the CHAdeMO protocol, which is used by a limited number of vehicles, typically from Japanese manufacturers (Nissan Leaf, Mitsubishi Outlander).

The CHAdeMO protocol is largely expected to be superseded by CCS for the European market once bi-directional standards are implemented within the CCS system, planned for 2025.

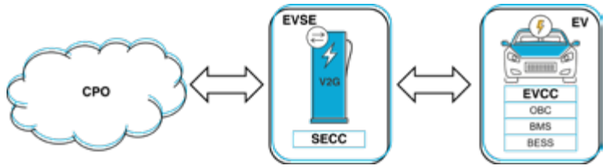
By comparison, AC V2G shifts the power electronics on to the vehicle where the rectification and inversion for charging and discharging happens 'on-board' the EV (Renault Zoe, Hyundai Ioniq 5).

There are three key sub-systems within the V2G eco-system, as follows:

The vehicle: comprising EV Charge Controller (EVCC); On-board Charger (OBC); Battery Management System (BMS); Battery Energy Storage System (BESS)

The chargepoint: known as Electric Vehicle Supply Equipment (EVSE), this includes a Supply Equipment Charge Controller (SECC)

The chargepoint operator (CPO): operates software that communicates with the EVSE to instruct charges and discharges.



Communications

There are two interfaces used for V2G control: the local interface between the chargepoint and the vehicle, and then a remote interface between the chargepoint and the CPO.

EVSE to EV control

For V2G, the communications between the EVSE and EV require information to control discharging, as well as charging.

The ISO 15118-20 standard includes the transfer of messages necessary to control bi-directional power transfer. These include a proposed charging and discharging schedule, sent by the EVSE to the EV, and in return a power profile, calculated by the EV.

Its adoption by EVSE and EV manufacturers facilitates bi-directional charging using existing hardware standards such as Type 2 for AC V2G and CCS for DC V2G, and removes a significant barrier to the widespread use of V2G.

EVSE to CPO control

For many of the use cases for V2G, the EVSE responds to remote instructions from the CPO to charge or discharge.

The key standard for communications between the EVSE and the CPO in conventional EV charging is the Open Chargepoint Protocol (OCPP), which defines the messaging structure to be exchanged between the EVSE and the CPO's software system – known as the chargepoint management system (CPMS).

OCPP Version 2.0.1 implemented a number of added and improved functionalities, including support for the ISO 15118-20 standard.

Other V2G manufacturers may choose to act as the CPO and use their own proprietary CPMS to control charging and discharging.

Use Cases

There are three main applications for using an EV with bi-directional charging capabilities:

Vehicle-to-Grid (V2G)

This is specifically where electricity is discharged from the vehicle and enters the wider electricity network, directly or via a building or site.

As the price of electricity varies from hour to hour and day to day, vehicle-to-grid technology means it is possible to buy electricity for charging when it is cheap (for example overnight) and then sell it back when it is expensive (for example early evening), for a profit.

Vehicle-to-Building (V2B)

This use case discharges electricity from the vehicle into the building, but not the wider network, to manage energy demand.

V2B can offset expensive electricity for the building by discharging the EV at peak times.

Where sites have renewable energy generation installed, such as solar panels, V2B can be used to charge and store excess energy in the EV battery and discharge it to meet demand when generation drops.

This use case also has applications in periods of power outages, when the EV can supply energy stored in the battery to the building.

Vehicle-to-Load (V2L)

In this instance, an EV that is V2L capable will be able to provide power from the vehicle as an auxiliary service and transforms the EV into a mobile power supply.

This can be useful when there is no grid electricity available, such as network failures or in remote locations.

Value Propositions

Cenex has identified five key value propositions which can be used to market V2G following a review of nine European projects:

Revenue generation

V2G allows customers to use an EV as an energy storage asset for financial reward by discharging to the grid or premises during expensive peak times and charging during cheaper periods. Study results vary, but the EV-elocity project reports commercial users could save £400 per vehicle per year.

Personal Net Zero

V2G allows users to optimise self-consumption of energy generated by on-site renewable energy technologies such as solar PV panels. The EV battery can charge at peak generation, and discharge it to the premises in place of grid electricity.

Resilience

V2G could be used to provide resilience in areas susceptible to power outages, or as an alternative to polluting back-up generators. In the US, V2G-enabled school buses were used to provide power following blackouts caused by wildfires.

Enhanced Battery Management

Preserving the health of an EV's lithium-ion battery is vital. Limiting battery degradation can be realised by maintaining an acceptable capacity and power over its lifetime, prolonging its usable lifetime. EV-elocity found that V2G could extend the life of an EV battery by about 10% (around one extra year of use).

Benefit to Society

Mass V2G deployment can deliver widescale environmental and societal benefits. Based on avoiding curtailment of renewable generation alone, this could equate to savings of 6 megatonnes of CO_2e per year, and avoided network upgrade costs could equate to approximately £180 per household, meaning lower bills and improved quality of life.

Barriers

Financial business case

V2G prices have dropped dramatically since 2017, when hardware cost between £10-15k per unit.

But it is not the actual cost of a V2G unit that is important, so much as the relative cost difference between a V2G unit and a smart charger. This is called the 'V2G premium' which represents the 'added value' of V2G technology.

Based on analysis from V2G trials, the V2G premium would need to be less than £2,000 for the technology to be acceptable to the mass market. The V2G Britain report suggests that the premium over an equivalent smart charger is expected to reduce to between £656 and £1,164 by 2030

Policy

Historically, policy has shied away from being technology specific but is often developed based on existing technologies, and therefore can create barriers as new technologies develop.

As the electrification of transport takes off, policies need to adapt to keep pace with innovation so that they do not create unintended barriers.

Compatibility

The first generation of V2G units have used a DC CHAdeMO connector, while Europe developed CCS DC charging, which has only just started public V2G trials. There may also be a case for AC V2G systems with additional hardware installed on the vehicle.

Additionally, there are still a limited number of compatible vehicles. For the industry to really thrive, it is essential that vehicle manufactureres get on board.

Market Readiness

V2G technology is still in its early phases of development and is only likely to achieve commercial readiness for CHAdeMo around 2025, and for CCS and AC chargers around 2030.

For V2G there are four main measures to assess for market readiness. These are:

- Total size of the automotive market
- Current EV uptake rate
- Existing deployment level of EVSE
- Availability of flexibility services

In 2019 Cenex published an analysis of V2G market readiness, considering markets at a country level.

It shows that the UK and France are currently the lead markets for V2G, with strong emerging opportunities in Germany, Japan, Canada, USA and China.

There is a particularly strong opportunity in China, due to the number of vehicles and rate of EV uptake, and if changes are made to enable trading of flexibility, then this would quickly become the main market opportunity for V2G.

Due to the use of CHAdeMO across Asia, it is likely that Japan, then China, will become the first countries to reach commercial-scale around 2025–2030.

Other lead/emerging markets such as UK, France, Germany, Canada and the USA are expected to follow once V2G is established within the CCS charging protocol – leading to commercial-scale V2G activities around 2030–2035.

V2G in the Real World - EV-elocity

EV-elocity was an R&D project that demonstrated V2G across different applications within the UK. It deployed 15 V2G chargepoints across nine sites.

The University of Nottingham Hallward Library was one such site. It operates from 8am to 2am most of the time, maintaining a high energy demand for at least 18 hours every day. The headquarters of the fleet participating in the V2G trial are located in this building and a Nichicon V2G charger was installed on the 5th of May 2021.

The vehicle connecting to this charger was a Nissan e-nv200 from the University fleet, mainly used between 7am and 7pm. This vehicle was also used from time to time during night time depending on the fleet demand.

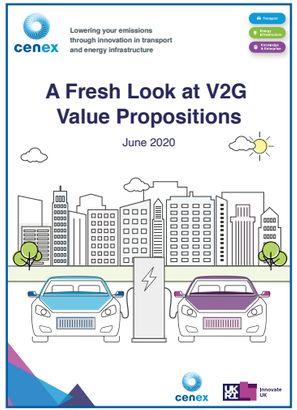
The chargepoint was optimised for carbon as part of the trial, and was able to save 305kg of carbon over one year, with cost savings of £81.

A second site, the Nottingham City Council's Eastcroft Depot, which was cost optimised, saved over £2,000 across the fleet of 20 EVs.

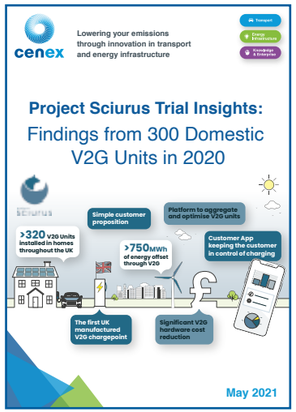
This site had a simple two rate tariff applied (16p/kWh weekdays 6am-10pm, 12p/kWh at other times), so savings were made by charging during the off-peak periods, then discharging and offsetting some of the site demand during peak periods.

Further Reading

EV-elocity Project Final Report
www.cenex.co.uk/app/uploads/2022/06/EV-elocity-Final-Report_published.pdf



A Fresh Look at V2G Value Propositions
www.cenex.co.uk/app/uploads/2020/06/Fresh-Look-at-V2G-Value-Propositions.pdf



Project Sciurus Trial Insights
www.cenex.co.uk/app/uploads/2021/05/Sciurus-Trial-Insights.pdf

Vehicle-to-Grid Charging for Electric Cars - FutureLearn Course
www.futurelearn.com/courses/everything-you-need-to-know-about-vehicle-to-grid-charging

V2G Hub
www.v2g-hub.com/

See more of Cenex's reports and projects on V2G at www.cenex.co.uk

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