cenex

Lowering your emissions through innovation in transport and energy infrastructure

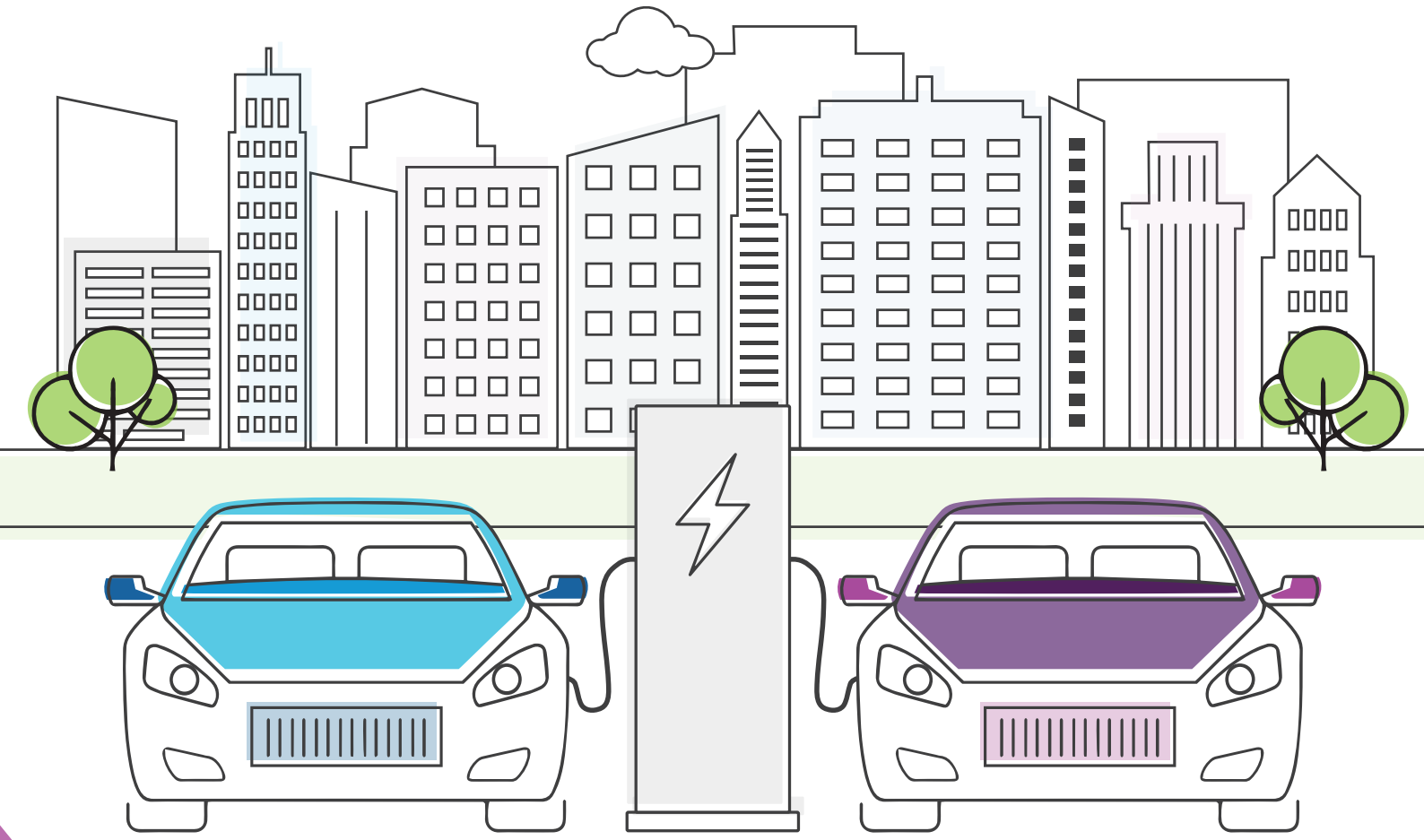
Transport

Energy Infrastructure

Knowledge & Enterprise

A Fresh Look at V2G Value Propositions

June 2020



cenex

UKRI Innovate UK

Contents List

Innovate UK Foreword

Innovate UK, working with our partners in the Office for Low Emission Vehicles and the Department for Business, Energy and Industrial Strategy have supported business-led innovation in Vehicle-to-Grid (V2G) technologies and services since 2017.

Innovate UK and our partners have invested in a £30m programme which is to date the biggest suite of V2G projects in the world, ranging from feasibility studies looking at business model innovation, to R&D for V2G hardware and software technologies, and including 8 flagship real-world demonstrator projects – deploying V2G technologies in actual commercial propositions to customers.

As part of our ongoing support to Vehicle-to-Grid technologies, Innovate UK has been commissioning studies that look at opportunities, market prospects, and challenges for V2G commercialisation and deployment. This report takes a fresh look at the value propositions offered by Vehicle-to-Grid now and in the future, examining the overarching benefits and advantages of V2G beyond the traditional revenue-generation routes associated with the technology. Recognising the evolving landscape for Vehicle-to-Grid, this report will help the eco system in the UK and internationally take stock of the current outlook, the opportunities and the challenges.

Innovate UK is part of UK Research and Innovation, a non-departmental public body funded by the UK government. We drive productivity and economic growth by supporting businesses to develop and realise the potential of new ideas, including those from the UK's world-class research base. With a strong business focus, we drive growth by working with companies to de-risk, enable and support innovation. We fund business and research collaborations to accelerate innovation and drive business investment into research and development. Our support is available to businesses across all economic sectors, value chains and UK regions.

Introduction to Cenex

"Lowering your emissions through innovation in transport and energy infrastructure"

Cenex was established as the UK's first Centre of Excellence for Low-Carbon and Fuel Cell technologies in 2005.

Today, Cenex focuses on low emission transport & associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in the project delivery, innovation support and market development.

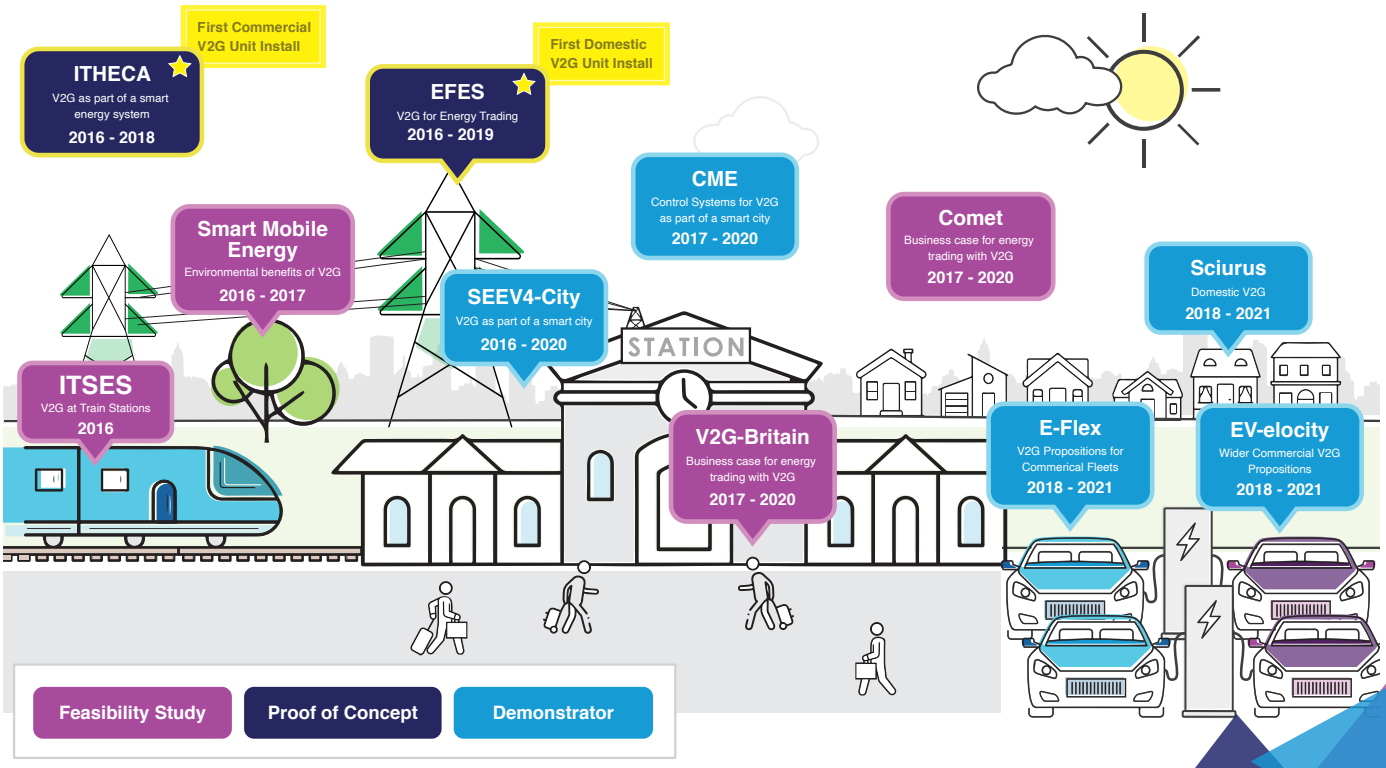
We also organise Cenex-LCV, the UK's premier low-carbon vehicle event, to showcase the latest technology and innovation in the industry.

Our independence ensures impartial, trustworthy advice, and, as a not-for-profit, we are driven by the outcomes that are right for you, your industry and your environment, not by the work which pays the most or favours one technology.

Finally, as trusted advisors with expert knowledge, we are the go-to source of guidance and support for public and private sector organisations along their transition to a zero-carbon future and will always provide you with the insights and solutions that reduce pollution, increase efficiency and lower costs.

Cenex has been an active innovator in the research and development of Vehicle-to-Grid (V2G) technologies and business models since 2016, including being responsible for key milestones such as installing the first domestic V2G unit in Europe and the first commercial V2G unit in the UK. Over this time, we have delivered 11+ public V2G projects, including feasibility studies, proof-of-concepts and real-world demonstrators; as well as providing independent advice and support to numerous organisations.

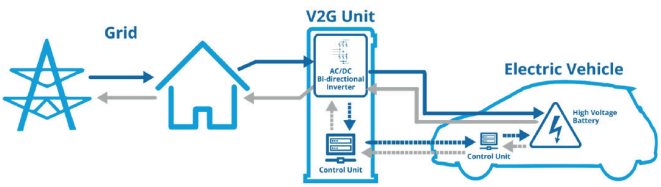
A History of Cenex and V2G



Introduction to V2G

What is V2G?

Vehicle-to-Grid (V2G) is a system whereby plug-in electric vehicles (EVs), when connected to a V2G charger, can provide bi-directional flows of energy and data. This technology enables EV batteries to be used as grid-connected energy storage. They can charge or discharge electrical energy in response to control signals from stakeholders in the V2G system, typically: the end user, owner, energy supplier, service provider/ aggregator, local Distribution Network Operator (DNO), or Transmission System Operator (TSO). By controlling the power and timing of charging and discharging of the vehicle battery, value can be extracted by one or more of the system's stakeholders.



A Brief History of V2G

Notwithstanding initial research going back to 1997 (Kempton & Letendre, 1997), the main stimulus for early Vehicle-to-Grid development took place as a reaction to the Fukushima Daiichi nuclear disaster in 2011 as a method for improving grid resilience and business continuity by enabling homes and businesses to continue to operate when the national or local electricity networks suffered outages (Greentech Media, 2012). Despite this early direction, it was realised that the technology offered other commercial potential and the focus quickly changed to revenue generation through energy trading, and particularly the opportunity presented by frequency regulation and containment services (also called 'Frequency Response').

Early research and demonstration projects across the world went on to prove the technical feasibility of such a service, indicating high initial earnings. At the same time, electricity network operators began a process of modernising their services for balancing electricity supply and demand, including removing many traditional barriers to provision of these services by smaller assets such as V2G. In light of these changes, the prospect of a viable business model seemed promising.

However, more recent studies, such as 'Vehicle-to-Grid Britain', have indicated that the initially high earnings expected from these services were often not reflective of long-term income predictions (Cenex, 2019) and were typically carried out in countries where service income was not always transferrable to other countries, such as the Parker project in Denmark (Peter Bach Andersen, 2019). A previous study by Cenex ('The True Value of V2G' (Cenex, 2019)) set out the variation in revenue opportunity for the UK once specific customer behaviours were considered. This demonstrated further that, while some niche customers could earn significant value through energy trading using V2G, for the vast majority the economic customer proposition was far from convincing.

Purpose of this Study

The purpose of this study is to return to the drawing board to reconsider the value, either financial or non-financial, that V2G can deliver to its stakeholders, taking into account the recent industry changes and the experiences of other V2G projects. The aim is to identify and provide a simple evaluation of alternative value propositions in order to support the ongoing development of the V2G industry in the UK.

The first step in the process was to identify the key lessons learnt by a total of nine recent V2G demonstration projects and comparing these with the issues that were expected to be cited as barriers to V2G, such as:

- **Evolving Energy Markets.**
  There are risks to the financial value of V2G due to changes in trends in the energy market. For example, Ofgem's Targeted Charging Review (TCR) will remove certain revenue opportunities such as arbitrage around use of distribution network costs and peak charge avoidance (The Energyst, 2020). Perhaps more damaging for the financial value of V2G however is the erosion of frequency response service prices in reaction to competition from other fast response assets such as fixed battery systems (The Energyst, 2018). These systems have the advantage of permanent availability and are also simpler to aggregate.

  In addition, the results of Ofgem's Significant Code Review of network access and forward-looking charge arrangements (Ofgem, 2018) are not yet known, creating further uncertainty for V2G.

  Finally, it is expected the Distribution System Operator (DSO) services will offer potential for V2G to assist with management of an increasingly stressed distribution network. Despite this, developments of DSO markets and services have been slow.

- **Complex value chains.**
  The numbers of stakeholders required to extract financial value from V2G limits the profitability for each player. A V2G system to provide grid services will typically involve the vehicle user, the vehicle operator and owner (not necessarily the same as the user), an aggregator and an energy supplier. These stakeholders must share any revenue generated.

- **Regulation.**
  Regulatory barriers such as the Distribution Network Operator (DNO) approval process and the associated cost of connection.

- **Technology Maturity.**
  Hardware availability, up-front cost and vehicle compatibility are expected to be cited as significant barriers. At present, the only readily available V2G standard is CHAdeMO, however this is expected to change with the development of AC and Combined Charging System (CCS) based V2G systems. The CharIN V2G roadmap predicts CCS V2G using ISO 15118 to be achieved by 2025 (CharIN, 2018).

This learning was then used to generate and evaluate a shortlist of five potential value propositions – potential promises of value to be delivered to one or more of the V2G stakeholders – for V2G. These five value propositions were also reviewed by focus groups to gauge the current level of consumer interest and create an overall score for each.

While neither aiming to set out a detailed business case or policy recommendations for each value proposition, this report sets out the findings of this study and aims to present high level insights into each of the new value propositions. The intention is to provide fresh insight into the value of V2G to support decision-makers from investors, manufacturers, retailers and policy stakeholders in the V2G industry as they look to understand the future opportunities and direction of the V2G market.

Methodology

The project consisted of two phases:

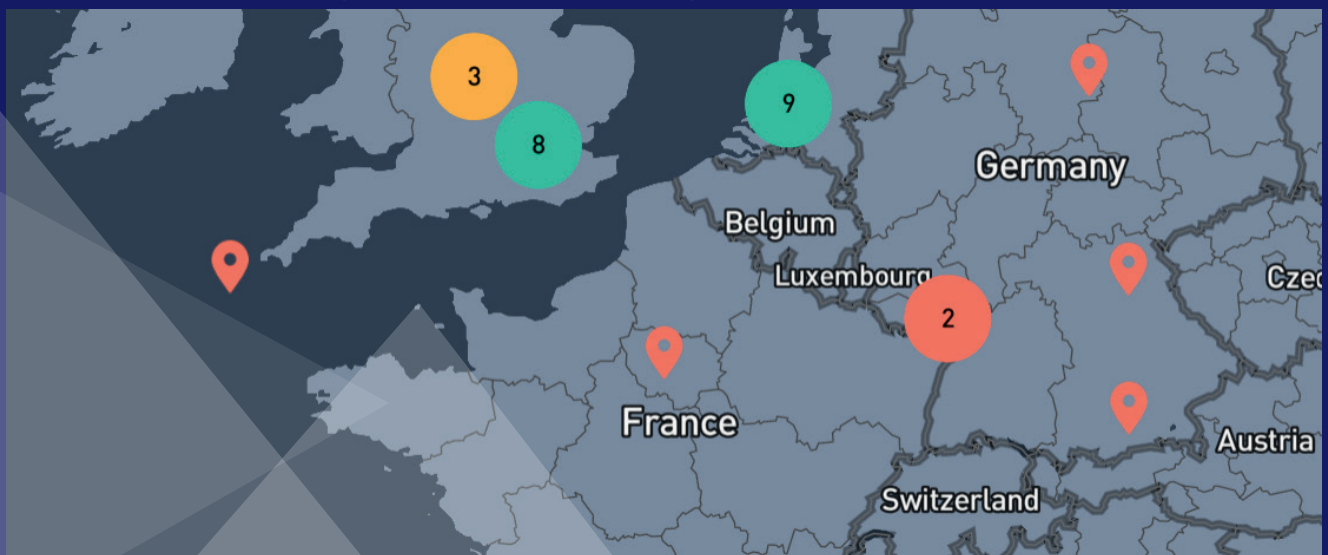
- **Phase 1 – Review of European V2G Projects**
- **Phase 2 – V2G Value Propositions Evaluation**

Phase 1 - Review of European V2G Projects

Information was gathered for V2G projects, both in progress and completed, from around Europe. By means of desktop research and interviews with project partners, the following information was collected:

- Value proposition(s) investigated by the project.
- How value propositions were marketed as value propositions, particularly relevant for domestic demonstration projects, i.e. Sciurus and Powerloop.
- Lessons learnt from the project including the main challenges with demonstrating value propositions and associated business models, and any alternative value propositions considered.

Map of part of Northern Europe showing locations of V2G projects taken from v2ghub.com



Phase 2 - V2G Value Propositions Evaluation

Cenex "Expert Panel"

- V2G value proposition **generation session** with an expert panel consisting of members of the Cenex Energy Systems & Infrastructure Team. This created a longlist of potential value propositions to investigate.
- **Value propositions** grouped into one or more of economic; environmental; social.
- **Shortlisting of top five value propositions** for further investigation.

Customer Focus Groups

- **Members recruited** for domestic and commercial focus groups via industry contacts, social media and other online EV forums. Plug-in Vehicle owners and fleet or energy managers were targeted for the domestic and commercial audiences respectively.
- **Webinar focus group sessions.** 45 minute sessions with a brief introduction to EVs, dumb charging and smart charging and V2G. The applicable value propositions were then introduced, explained and discussed one-by-one. It is important to note when reading the results that the primary purpose of these sessions was not education, but to gather face value opinions of the value propositions, given by potential stakeholders who do not have expert knowledge of the subject.
- **Feedback collection.** Transcripts of the webinar discussions were created and consumer feedback collected. Focus group members were asked to **independently score** the value proposition based on its strength as an incentive to adopt V2G, on a scale of 1-5 from very weak to very strong.

Value Proposition Evaluation

- Cenex **peer review** of value propositions. The value propositions were scored on three further categories: implementation, scalability and stability. Within the discussion for the value propositions, justification is given for the scores allocated.
- For each of the value propositions, **competing solutions to V2G** were identified and discussed.

Results

Phase 1 – Review of European V2G Projects

46 V2G projects were identified, of which 21 were Innovate UK funded. 19 of these were contacted, focussing on larger and more recent projects. Responses were received from a total of nine projects, four of which were funded by a source other than Innovate UK.

For a full list of international V2G projects, refer to the V2G Hub at **https://www.v2g-hub.com/**.

Project Name	Project Partners	Interviewed Partner(s)
Sciurus	**Cenex, Indra Renewable Technologies Limited, Nissan Motor (GB) Ltd, OVO Technology Ltd**	**OVO Technology**

Location:	Description	Value Propositions	Key Lessons
UK **Start:** **2018** **End:** **2021** **Status:** **In Progress**	Domestic V2G demonstration project throughout UK where customers are offered a free DC V2G charger and smart meter if they own a Nissan Leaf, have off-street parking and are willing to switch supply to OVO Energy for the duration of the trial.	• Arbitrage • Wholesale trading • Benefit to Society ('Building a better grid for everyone') • Guaranteed export tariff per kWh • CO_2 optimisation for EV charging and export	Frequency response and constraint management considered but costs to qualify assets are prohibitive for the time being. Cost and time to gain DNO approval proved challenging, particularly since there are many different DNOs throughout UK.

Project Name	Project Partners	Interviewed Partner(s)
Powerloop 	**Octopus Energy, Chargepoint Service Ltd, Energy Saving Trust Enterprises Limited, Navigant Consulting (Europe) Ltd, Octopus Electric Vehicles Ltd, Open Energi Ltd, UK Power Network Holdings Ltd**	**Octopus Energy** octopus electric vehicles

Location:	Description	Value Propositions	Key Lessons
South East England, UK **Start:** **2018** **End:** **2021** **Status:** **In Progress**	Domestic V2G demonstration project based in South East of England where customers are offered a free DC V2G charger and a reduced rate on the lease of a Nissan Leaf in return for carrying out V2G sessions.	• Arbitrage • Save on lease cost by completing 12 V2G cycles per month • Technology Innovation ('Be at cutting edge') • V2H/self-sufficiency ('Your home is being powered entirely by your car') • Benefit to Society ('If system stays as it is then network operators may spend up to £17bn on grid reinforcement' leading to higher costs for customers) ('Just ten Nissan LEAFs could power 1000 homes for an hour')	Frequency response proven difficult to test in real market conditions within current UK energy system. G99 on-boarding process provides administrative barrier.

Project Name	Project Partners	Interviewed Partner(s)
e4Future e4Future	**Nissan Motor (GB) Ltd, E.ON Energy Solutions Ltd, Imperial College London, National Grid ESO, Newcastle University, Northern Powergrid (Yorkshire) plc, UK Power Networks Holdings Ltd**	**E.ON; Nissan Motor (GB) Ltd** e·on NISSAN

Location:	Description	Value Propositions	Key Lessons
UK **Start:** **2018** **End:** **2021** **Status:** **In Progress**	Commercial V2G demonstration project aimed at business fleets with Nissan electric vehicles offering subsidised V2G charger installations and 10,000 free miles per vehicle per year.	• Arbitrage • Support renewable penetration	V2G revenues from commercial fleets dependent on plug-in times. Continuously evolving energy markets and regulations creates challenges around V2G revenue opportunities. Value in spot market optimisation. DNO flexibility products could offer good potential for V2G in the future.

Results

Project Name	Project Partners	Interviewed Partner(s)
V2GO	**EDF Energy, Arrival Ltd, CleanCar.io, EO Charging, Oxfordshire County Council, University of Oxford, Upside Energy Ltd**	**Upside Energy**

Location:	Description	Value Propositions	Key Lessons
Oxford, UK **Start:** **2018** **End:** **2021** **Status:** **In Progress**	Commercial V2G demonstration project based in Oxford. One of a limited range of V2G projects based on AC V2G. Intention to run with 22 kW AC V2G chargers and compatible vehicles.	• Grid constraint management on site • Prioritising van charging to a schedule • Reduced dependence on grid • Earn revenue for idle asset • Sustainability targets • Attract business by showing innovation	Early stage due to project delays relating to AC V2G vehicle availability.

Project Name	Project Partners	Interviewed Partner(s)
V2Street	**Durham County Council, EDF Energy R&D UK Centre Ltd, Honda R&D Europe (UK) Ltd, Imperial College London, Loughborough University, Southend On Sea Borough Council, Upside Energy, e-Car Club, Ubitricity Distributed Energy Systems UK Ltd, UK Power Networks Holdings Ltd**	**Loughborough University School of Design & Creative Arts**

Location:	Description	Value Propositions	Key Lessons
UK **Start:** **2018** **End:** **2020** **Status:** **Near Completion**	Feasibility study into the potential for residential, lamppost V2G charging to encourage the adoption of EVs; assessing the technology, the business case and the consumer response.	• Any financial savings on electricity is seen as a positive • The possibility to adjust personal car use habits to maximise the financial benefits • Benefit to society and the environment	Concerns of customers included access to the lamppost and associated parking near their house, potential battery degradation and needing reassurance that charge would be available at short notice, e.g. caregivers taking emergency trips to hospitals

Project Name	Project Partners	Interviewed Partner(s)
Parker	**Nuvve, Nissan, Groupe PSA, Mitsubishi Motors, Insero, Frederiksberg Forsyning, Enel, Mitsubishi Corp, Technical University of Denmark**	**Technical University of Denmark**

Location:	Description	Value Propositions	Key Lessons
Denmark **Start:** **2016** **End:** **2018** **Status:** **Completed**	Project to test commercial case for V2G in Denmark with main focus on frequency response market. Two test sites with 10 kW Enel V2G chargers: one commercial site with ten vehicles and one research site based on university campus. Further research carried out into Distribution System Operator (DSO) services.	• Frequency response	Frequency response could be lucrative, particularly in Nordic market. Average annual revenue per vehicle on Danish market was 1860 euros. Expected profit dependent on frequency response prices, charger cost and efficiency, energy costs and battery degradation. Requirement for more OEMs to come on board to standardise V2G. Acknowledgement that evolving markets could make DSO services interesting.

Project Name	Project Partners	Interviewed Partner(s)
Smart Solar Charging	**LomboXnet, Utrecht Sustainability Institute, Last Mile Solutions, We Drive Solar, New Solar, Vidyn, Jedlix, Stedin, Utrecht University, University of Applied Sciences Utrecht**	**Utrecht Sustainability Institute**

Location:	Description	Value Propositions	Key Lessons
Utrecht, Netherlands **Start:** **2014** **End:** **2021** **Status:** **In Progress**	Demonstration project to develop AC V2G charging infrastructure for an ecar club in Utrecht, which could be included in future housing developments looking to discourage personal vehicle ownership and to work in sync with heat pumps and solar PV to reduce need for local network upgrades.	• Frequency response • Energy arbitrage • Optimising consumption of solar PV	Frequency response and energy arbitrage are only markets where money can be made at present. Working with local DSO to discover how they can unlock value of congestion services.

Results

Project Name	Project Partners	Interviewed Partner(s)
City-Zen Smart City	**Alliander NV, Enervalis, Magnum Cap**	**Alliander NV**

Location:	Description	Value Propositions	Key Lessons
Amsterdam, Netherlands **Start:** **2014** **End:** **2019** **Status:** **Completed**	Small scale V2G demonstration project based in Amsterdam where 4 DC chargers were placed at strategic locations in neighbourhoods close to interested parties with existing compatible EVs.	• Energy arbitrage • Solar optimisation • DSO services	Partners put V2G as public service on hold until more OEMs involved and smoother regulatory process available. Close cooperation required between chargepoint manufacturer, operator and DSO. Finding suitable locations key to use. Battery warranty and accurate, transparent communication is required to gain customer trust.

Project Name	Project Partners	Interviewed Partner(s)
SEEV4-City	**Cenex, City of Oslo, AVERE: Leicester City Council, KU Leuven, Hogeschool van Amsterdam, City of Amsterdam, Johan Cruijff ArenA, POLIS, Northumbria University, Cenex Nederland**	**Cenex; Johan Cruijff ArenA**

Location:	Description	Value Propositions	Key Lessons
Various: Loughborough & Leicester, UK; Amsterdam, Netherlands; Kortrijk, Belgium & Oslo, Norway **Start:** **2014** **End:** **2020** **Status:** **Near Completion**	V2X applied research and demonstration project consisting of six distinct pilot trials located around the North Sea region. Evaluated based on three key performance indictors: CO_2 emissions, energy autonomy and avoided grid investments.	• Optimal PV integration • Site peak shaving • Frequency response • Back-up power • Energy arbitrage • Self-sufficiency	*Amsterdam:* Johan Cruijff ArenA can earn 50 euros per week from frequency response, using one EV but is awaiting maturation of half-hourly market to make arbitrage possible. It has enough back-up power from second-life EV batteries to maintain peak match-day power for almost one hour. *Loughborough:* Keep systems simple and coordinated, commercial frameworks for V2X need to evolve, taxation rules can hinder trials, data quality drives analysis, V2X currently has limited value.

Phase 2 – V2G Value Propositions Evaluation

The top five shortlisted value propositions generated as a result of the Cenex expert panel that were subsequently proposed to the domestic and commercial consumer focus groups for feedback are listed in **Table 1**:

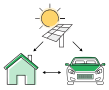
Value Proposition Name	Value Types: Economic	Value Types: Environmental	Value Types: Social	Consumer Focus Groups: Domestic	Consumer Focus Groups: Commercial
 Revenue-Generating Energy Trading	✓			✓	✓
 Resilience	✓	✓	✓		✓
 Personal Net Zero / Self Sufficiency	✓	✓		✓	✓
 Benefit to Society		✓	✓	✓	
 Enhanced Battery Management	✓	✓		✓	✓

Table 1 - Value Proposition Types and Consumer Applicability

Table 2 gives a summary of the existing projects studied in Phase 1 and which of these five value propositions they investigated. Note that two of these projects, Powerloop and V2GO, also included "Technology Innovation" as an additional value proposition. However, as this was not selected as one of the top five value propositions, it has not been included in Table 2.

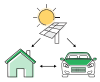
	Value Proposition Name	Existing V2G Project: SCIurus		e4Future	V2Go	V2Street	parker	smart solar charging	CITYnZERO	interreg
Financial	 Revenue-Generating Energy Trading	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-Financial	 Resilience				✓					✓
Non-Financial	 Personal Net Zero / Self Sufficiency	✓	✓		✓			✓	✓	✓
Non-Financial	 Benefit to Society	✓	✓	✓	✓	✓				
Non-Financial	 Enhanced Battery Management									

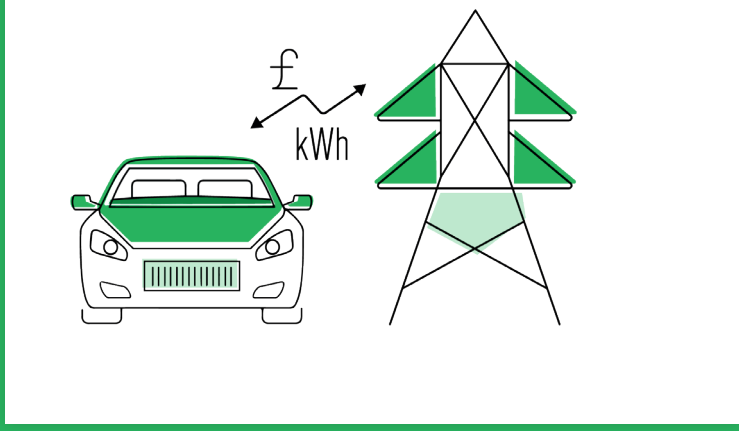
Table 2 - Existing Projects Value Proposition Summary

Phase 2 - V2G Value Propositions Evaluation

Value Proposition:

Revenue-Generating Energy Trading

Revenue-generating energy trading is using the electric vehicle as an energy storage asset for financial reward. The majority of existing V2G projects have tested this value proposition.

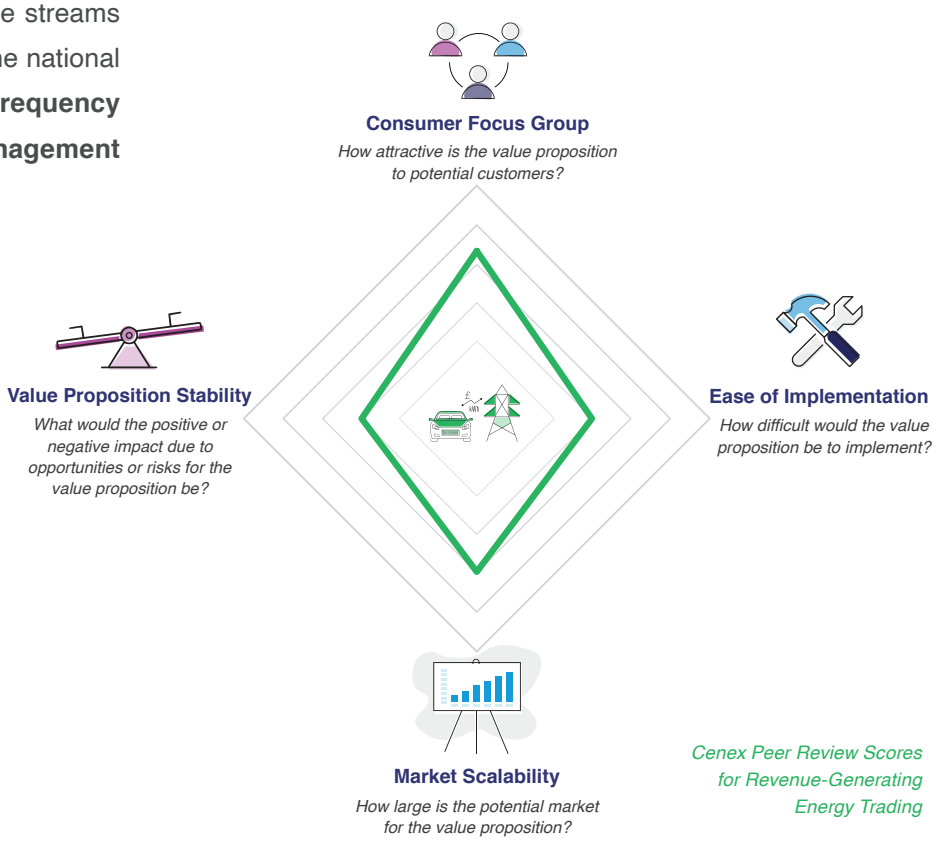


Description

Revenue can be generated by performing energy **arbitrage** – discharging during expensive peak times and charging during cheaper periods. The revenue or saving realised will depend on whether any energy is exported or change occurs behind the meter, as well as the magnitude of round-trip efficiency losses, which must not be ignored.

There are also a variety of potential revenue streams arising from providing services to support the national (TSO) or local grid (DNO), including **frequency response, reserve** and **constraint management services**.

The provision of these services can help the local or national grid to match supply and demand whilst greater flexibility supports the rollout of intermittent renewable generation. Arbitrage requires a variable tariff, which are increasing in number. However, grid services require an aggregator to combine assets in order to bid into markets, adding complexity and a third party with which to share revenue.



Cenex Peer Review Scores for Revenue-Generating Energy Trading

Scoring Discussion

Consumer Focus Groups Both the focus groups were interested in the revenue generation opportunity, scoring it as the highest of the five value propositions, but were anxious over the time for return on investment - ***"people would be more willing [to invest in V2G] with a payback over [a period of] three years"***. Clearly this consumer expectation is incongruous with the typically longer Return on Investment (ROI) timescales of smart energy technologies.

Businesses that are leaseholders are least willing to agree longer ROI due to the risk of stranded assets if leases are terminated. More stable businesses may be more willing to accept a longer payback period of 4-6 years, however any longer would likely be discouraging without additional guarantees in place.

Ease of Implementation From existing V2G projects Cenex has seen that marketing and using V2G for financial rewards is **technically possible, but a combination of factors,** including the number of stakeholders required, a lack of easily accessible markets and concerns of battery degradation for repeated cycling for arbitrage, **have limited success**.

Market Scalability At first glance it seems that this value proposition is open to most electric vehicle operators. However, domestic customers need to be able to charge at home and commercial users will need to have depot-based charging of their fleet. For both, it is unlikely that there are barriers to switching to a flexible tariff.

*Cenex modelling and analysis has shown that using V2G for revenue generation is **mainly advantageous for use cases where vehicles are plugged in for long periods of time whilst not charging**. The average customer with plug-in rates of 30% could capture just a quarter of the annual revenues from TSO services compared to those able to plug in 75% of the time. Based on a mixed portfolio of V2G users, the average revenue generation from V2G is estimated to be in the region of £150-200 per year, with customers with a high plug in rate achieving in the region of £400 per year.*

Value Proposition Stability One of the main financial revenue generation opportunities, **frequency response is at significant risk of falling prices**, as has been the trend due to saturation of the market (Cenex, 2019). It is possible that prices could stabilise and see a resurgence to avoid major grid events, such as that which occurred on 9 August 2019, and to support greater levels of intermittent renewable generation. Falling V2G hardware prices will also positively impact this revenue stream with prices expected to drop from £6000 in 2020 to approximately £1000 by 2030 (Cenex, 2019).

Overall

There are a number of risks surrounding the design of the V2G system for revenue generation and the value that can be achieved, which have been encountered by existing V2G trials. Despite these reservations, and those highlighted by consumers, the consumer focus group score reflects a natural desire for an investment to at least break even, and hence this value proposition achieved the highest score from consumers.

Competing Solutions

Clearly, investment into and deployment of **stationary batteries** designed to earn money from grid services or to access behind the meter savings are a key competitor to this V2G value proposition. This has already been shown by the concurrent fall in frequency response prices. Stationary batteries are easier to aggregate and are always available, but there is a significant up-front investment cost which can make V2G appear an attractive alternative. Smart charging is another competing solution, as some of the revenue generation available from V2G can be captured by a smart charging system, at a lower capital cost and with fewer technical limitations such as vehicle compatibility.

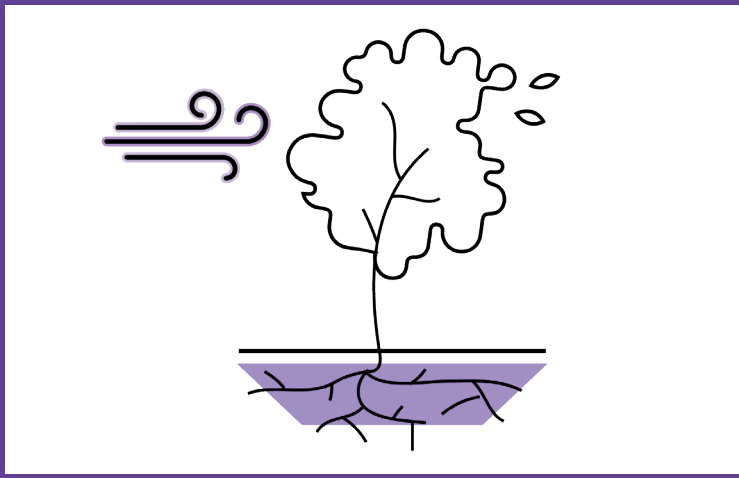
However, work carried out by Cenex as part of the 'Understanding the True Value of V2G' (Cenex 2019) report indicated that, for most customer archetypes, smart charging was able to capture between 40-90% of the value from behind-the-meter optimisation, but only about 10% of the value from grid services, compared to V2G in the same scenario.

Phase 2 - V2G Value Propositions Evaluation

Value Proposition:

Resilience

The concept of V2G expanded rapidly in Japan as a means of ensuring electricity supply following the 2011 earthquake and tsunami and ensuing rolling blackouts.



Description

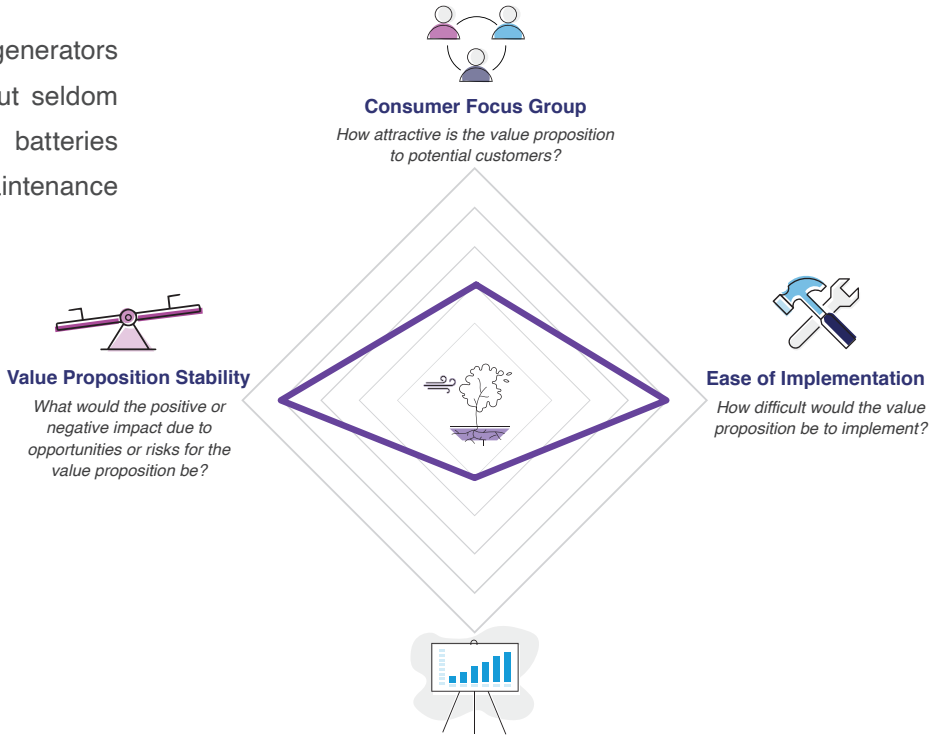
Whilst the UK electricity network is one of the world's most resilient, there are still applications where V2G could be used to provide **resilience**. For example, in a domestic context there remains rural areas which are more susceptible to power outages. However, perhaps the more interesting concept is the use of V2G as an energy source for **back-up power** or **uninterruptible power supply (UPS)** in commercial contexts.

Back-up power systems are typically diesel generators which are costly to install and maintain, but seldom used. UPS systems often use lead-acid batteries which also have an associated cost and maintenance burden.

This value proposition would use EV batteries to augment or even replace the energy of the back-up or UPS systems.

This could result in a cost saving and/or reduced carbon footprint if reliance on diesel generators or system sizes can be reduced.

Whilst an interesting concept, the applicability would be very specific to local requirements and availability of the EVs.



Cenex Peer Review Scores for Resilience

Scoring Discussion

Consumer Focus Group This value proposition was only scored by the commercial group as the value to the domestic customer is limited due to the security of the UK grid. They agreed that the idea was good but had serious reservations about whether it would work operationally, with both capacity - ***"You would need enormous capacity in the system to cope..."*** and vehicle availability cited as barriers.***"...you're better off having static batteries for that purpose"***.

Ease of Implementation Technologies for **islanded energy systems** are well understood and **could be readily extended to V2G** connected systems. Whilst operating V2G for resilience purposes is why the technology was originally developed, this functionality is **yet to be trialled in the UK** and the regulatory environment would need to evolve to allow this. Hitachi has been trialling hardware in Europe that was first designed to run as a V2B/V2H system and therefore the ability to run as a back-up power supply was key (HITACHI, 2018). However island-mode operation is not commonly a function included in the majority of V2G chargepoints and requires certification for use in the UK.

Market Scalability Whilst the technology could technically be deployed in any commercial or domestic setting with a V2G compatible EV, there are some serious risks to the systems' scalability. Firstly, it is very **difficult to guarantee the availability of EVs**, even for fleets with very consistent usage patterns. This could make it very difficult to use V2G in place of UPS. Furthermore, there will be limited applications where the size of the fleet is able to deliver power to meet (potentially very high) building demands for any significant length of time. Therefore, it is most likely that V2G would only be used in addition to other back-up power systems or for critical loads, limiting the environmental and cost benefits.

For comparison, the cost of a small UPS system with a 10-20 minute run time is in the region of £3,000 to £5,000. With V2G hardware prices predicted to fall below this level by 2025 (Cenex, 2019), using the vehicle's battery could soon become a financially viable alternative to traditional UPS systems.

Value Proposition Stability The technical barriers could be removed with low risk and any suitable applications will increase in number as a greater number of fleets electrify.

Overall

Whilst it appears to be easily achievable, the value of using V2G for resilience purposes is **limited** by the **number of applications in which it could replace traditional back-up power systems**.

Competing Solutions

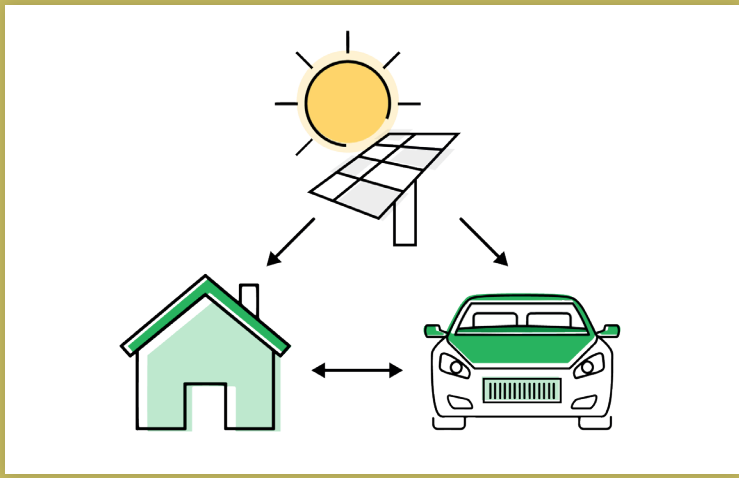
The competing solutions for resilience are the existing solutions for back-up power, namely **diesel generators, or UPS systems using stationary batteries**. For UPS systems, the function of being able to provide power instantaneously during a loss-of-grid event is more important than the size or weight of the stationary system. Therefore, cheaper lead-acid batteries have been used historically. However, the falling prices of lithium-ion batteries (BloombergNEF, 2019) and the emergence of a second-life market for Li-ion will impact the competitiveness of V2G in this area. There are already commercial outfits selling lithium-ion UPS systems, citing the enhanced run times as a key sales point. Again, **how the capital costs of a V2G system compare** with competitor solutions, and how the difference changes over the coming years, will be imperative for the competitiveness of V2G and the Resilience value proposition.

Phase 2 - V2G Value Propositions Evaluation

Value Proposition:

Personal Net Zero / Self Sufficiency

This environmentally focused value proposition helps the user to optimise self-consumption of energy generated by on-site renewable energy technologies such as small-scale wind and solar PV.



Description

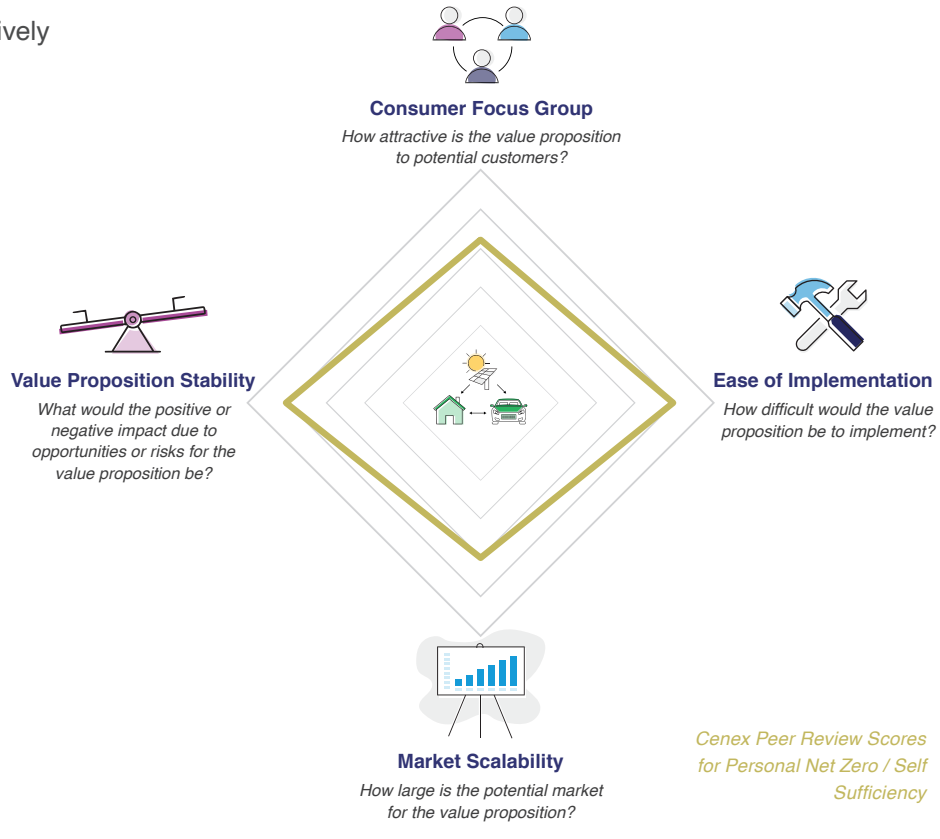
In a domestic setting, this value proposition can appeal to the environmental conscience of the customer, with the slogan of **"driving on sunshine"** prevalent in the industry when electric vehicles are matched with PV generation.

In commercial applications, businesses looking to enhance their **environmental reputation** would be able to demonstrate that their V2G system reduces consumption of decarbonising, but still relatively "dirty", grid electricity.

In both cases however, this depends entirely on whether the site's on-site **generation** profile (or potential profile) exceeds its consumption profile at any point. If not, then the value proposition is redundant. If there are periods when generation exceeds consumption, resulting in exported energy, then including V2G in the system can also have a small financial benefit depending on the local incentives for exported energy.

How great the additional benefit of V2G is above that for smart charging is case dependent.

V2G can also promote investment in increased generation capacity and **low-carbon** consumption technologies such as heat pumps.



Cenex Peer Review Scores for Personal Net Zero / Self Sufficiency

Scoring Discussion

Consumer Focus Groups The commercial group were intrigued but unsure of the applicability for large sites - ***"I'm not sure we ever get to a place where we are storing excess... [but] it's a very good idea for small scale"***. The domestic group scored higher with interest in how costs would compare to a stationary battery – ***"I'd be more tempted to buy PV if I knew I could use my Leaf as a way to store some of the excess rather than just export it back again"***. Both focus groups were aware of the potential impact of increased battery cycling on battery degradation but did not cite this as a key issue, particularly if the vehicle owner has control over the system operation and it is not entirely trusted to a third party.

Ease of Implementation **Optimising the self-consumption of on-site generation** using stationary batteries is already a service provided commercially by multiple providers. Extending this to using vehicle batteries would take some system design changes to consider vehicle availability, but this is a low risk development which is being explored through demonstrators such as SEEV4-CITY.

Market Scalability This value proposition depends on the customer having or being willing to invest in on-site generation. Over the last three years, deployment of PV has stabilised at much lower rates when compared to the early 2010s. Nevertheless, the very strong sales of PV in these earlier years has created a **sizeable customer base** who will be incentivised to self-consume. In addition, the continuing fall in PV prices combined with greater public environmental consciousness and the desire to be self-sufficient in energy, may yet result in steady growth of deployment rates. However, the number of useful applications are limited in a commercial setting as many large consumers will already self-consume all of their own energy generation, and in a domestic setting by 9-5 workers whose vehicles are unavailable on weekdays when the sun is shining and storage is needed. In this case it could be more sensible to install a stationary battery and a smart charger.

*The **exact impact** of using V2G in this way will **vary significantly from customer to customer**. However, taking a simple case it can be calculated* that using an EV battery to store generation from a 4 kWp domestic solar PV system over a weekend with 6 hours of sun per day could save 12 $kgCO_2e$ of emissions per weekend (or over **600 $kgCO_2e$ per year**) relative to having no storage and instead importing from the grid outside times of solar generation. Using a typical energy cost of £0.15/kWh this could also lead to a saving in excess of £300 per year.*

** Based on efficiencies of EV charging/discharging at 78%, solar inverter at 96%; Average daily domestic electricity consumption of 9.25 kWh, 30% of which is during 6-hour window 10am-4pm; average grid carbon intensity of 0.283 $kgCO_2e$/kWh*

Value Proposition Stability The loss of incentives for exporting solar PV energy increases the value and visibility of **self-consumption** to customers. Being environmentally friendly will only increase in importance for domestic customers and as part of a brand image for commercial entities. Potentially, working from home becoming more commonplace following the COVID-19 pandemic could make this proposition more attractive to the domestic market. The changes of the Ofgem TCR will also have an impact as consumers are currently able to reduce their use of transmission and distribution system charges using on-site generation. However, this method of behind the meter saving may be removed which could create extra interest in V2G for optimising use of existing on-site generation.

Overall

A very strong value proposition due to a lack of technical and legislative risks, strong consumer interest and the increasing **importance of being environmentally friendly** to both the general public and businesses. Also, importantly, the narrative of increased self consumption is easy to understand for the end user.

Competing Solutions

The main competing solution to enable homeowners and businesses to optimise the consumption of on-site renewable generation is **stationary batteries**. Tesla, Moixa and Powervault are well known examples of companies who already provide increasingly popular solutions in a domestic context whilst at a commercial level the likes of EvoEnergy, EDF and Connected Energy provide larger systems, the latter as part of a charging hub solution in combination with EV charging and solar power (Connected Energy, 2018).

Clearly, the stationary battery is guaranteed to be available when needed, but it is the avoidance of the capital cost of such a system which V2G can exploit for this value proposition.

Smart charging also has the potential to provide a limited version of this service. Based on work carried out by Cenex as part of the 'Understanding the True Value of V2G' report (Cenex, 2019), for most customer archetypes smart charging was able to capture between 40-90% of the value from behind-the-meter optimisation.

Phase 2 - V2G Value Propositions Evaluation

Value Proposition:

Benefit to Society

"Benefit to Society" is about engaging with V2G for altruistic reasons; doing your bit for the greater good of helping to solve wider society's environmental challenges.

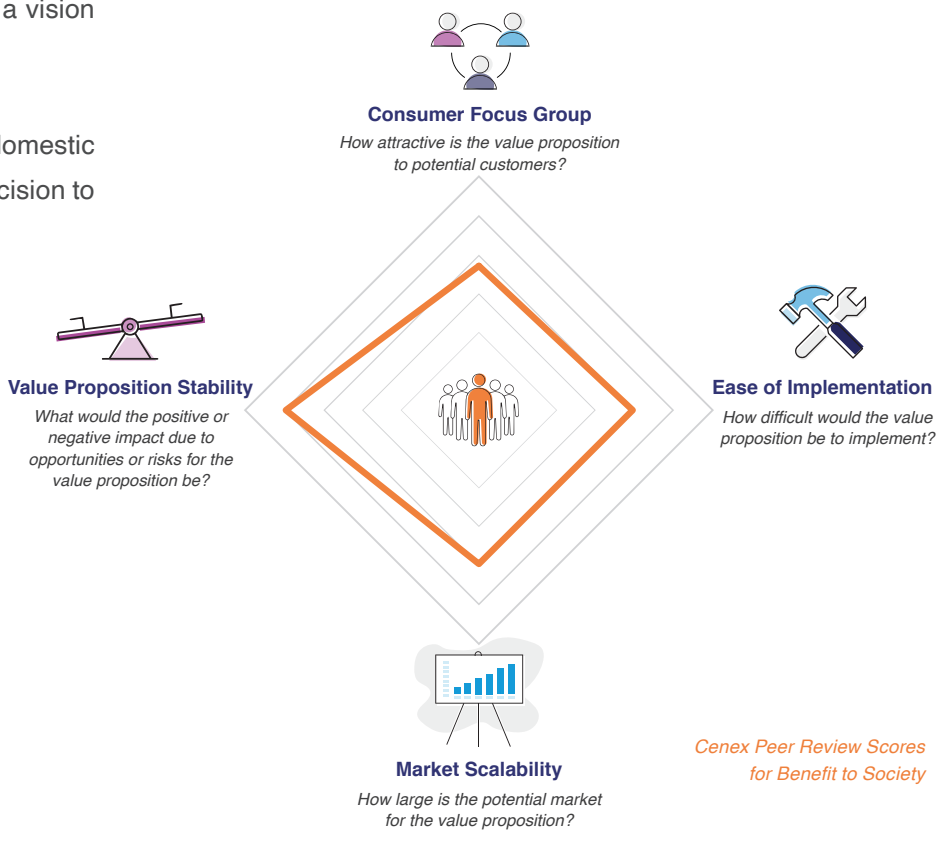
Description

Combating the **climate crisis** is often cited as the greatest challenge currently, or even ever, faced by humanity. EV drivers have already taken a step to reduce their own personal transport carbon footprint and air quality impact. The exact carbon saving of EV versus internal combustion engine (ICE) vehicles is debated, but it is agreed that the benefits of electrified transport can only increase with the **decarbonisation of the energy system** – a vision that V2G can help to make reality.

'Benefit to society' was proposed to the domestic focus group only as it is a very **personal** decision to operate V2G purely for the **societal** benefit.

Nonetheless, there may also be a commercial value proposition here as enterprises use the environmental and community benefits of V2G to contribute to their **brand image** or to contribute to sustainability policies with potential indirect financial advantages. Marketing V2G to target this value may be challenging, however.

Whilst there may be an added benefit of avoiding local distribution network constraints, this value could be even harder to explain to consumers. In any case, as there would be **no direct benefit to the user**, the market engagement for this value proposition is key.



Cenex Peer Review Scores for Benefit to Society

Scoring Discussion

Consumer Focus Group The group was interested by the idea, especially if the benefit could be realised at a community and local energy system (LES) level. **"This would be enough…"** as long as upfront costs were taken care of **"…if it didn't cost me anything and the risk to battery degradation was low"**. **"I'm not going to spend £5,000 out of the goodness of my heart."**

Ease of Implementation There is complexity in how V2G is operated to achieve optimal societal benefits in terms of network upgrade avoidance and grid carbon reduction, whether it is through existing or new grid services or markets. The level of complexity will vary depending on the scale of benefit targeted. For example, operating V2G locally to defer a DNO network upgrade could be relatively simple compared to using V2G for full scale grid decarbonisation. For the latter, although the commercial agreements would likely be simpler, there would be similar **technical and operational challenges** to entering energy markets purely for revenue generation.

In addition, another difficulty here would be the education and subsequent framing of the value proposition such that it can be easily understood by the layman. This risk could be mitigated using evidence from studies designed to understand the environmental benefit achievable – on a local and national basis – and how this compares to a smart charging only scenario.

*A piclo study (piclo, 2020) has found that for the UK to achieve net zero by 2050, implementing greater flexibility in the electricity network from demand side response and smart charging could reduce annual costs to the electricity system by 10% or £4.55bn through avoided network upgrades of 15 GW, avoided generation peaking capacity and reduced curtailment of renewables. Further modelling showed that with additional widespread V2G deployment, network upgrades could be reduced by a further 5 GW and take savings up to £5bn – equivalent to a saving of £180 per household. Utilising **flexibility from V2G on a national scale** could also reduce the curtailment of variable renewable generation by 30 TWh/year – giving a carbon saving of about 6 $MtCO_2e$ per year*.*

**assuming replacing gas power stations at 200gCO_2/kWh*

Market Scalability Whilst there are no firm technical barriers to doing V2G for the greater environmental benefit of society (decarbonisation of the grid), the benefit achievable will be different depending on the use case of the EV owner. For the savings presented in the Piclo study (piclo, 2020), **7 million vehicles** (i.e. 20% of the predicted national fleet in 2050, each providing 20kWh of storage) would be required.

Value Proposition Stability As per the 'Personal Net Zero / Self Sufficiency' value proposition, consumer interest in technologies that have an environmental benefit are likely to increase in parallel with the **greater public consciousness of environmental issues**. In addition, the number of viable customers will increase with compatible EV uptake.

Overall

The challenge in deploying V2G to achieve a wider system benefit – either for environmental reasons or to defer grid upgrades – will be in the marketing of the proposition to the customer. Evidence may be needed to help convince potential customers and to incentivise proper usage of the system once deployed. Nevertheless, this value proposition is very promising.

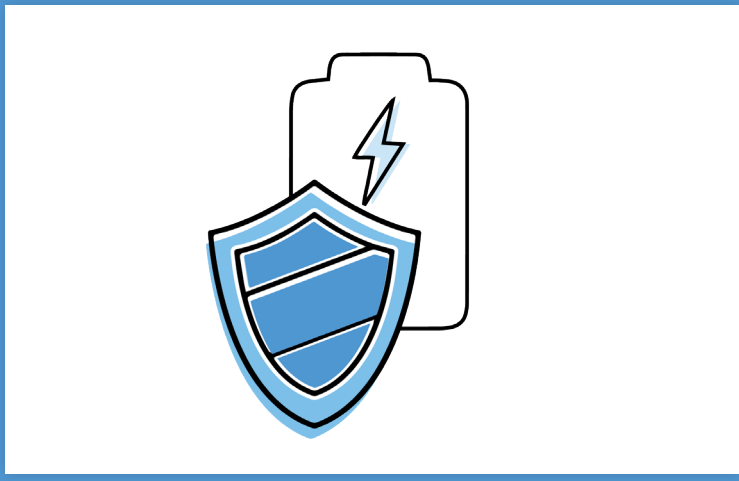
Competing Solutions

Again it is stationary battery systems which are the most likely competing solution for this value proposition. On a national scale, large scale **grid-connected stationary battery storage systems** aid the deployment of renewables either more directly as part of an energy supplier's portfolio or indirectly by providing grid services. The UK **energy storage sector has seen huge growth in recent years** (Energy Live News, 2019), and the indication that Nationally Significant Infrastructure Project (NSIP) planning restrictions for installations of over 50 MW are likely to be removed (tnei group, 2019) will only increase investment in this area. As with the other value propositions where stationary batteries are the key competitor, the benefit of **reduced capital cost** against the added operational complexity will determine V2G's success. This trade-off is also relevant at a local level, where this decision is in the hands of the DNO or the operator of a Smart Local Energy System (SLES).

Phase 2 - V2G Value Propositions Evaluation

Value Proposition:

Enhanced Battery Management



Preserving the health of an EV's lithium-ion battery is vital. Multiple benefits can be realised by maintaining an acceptable capacity and power over its lifetime.

Description

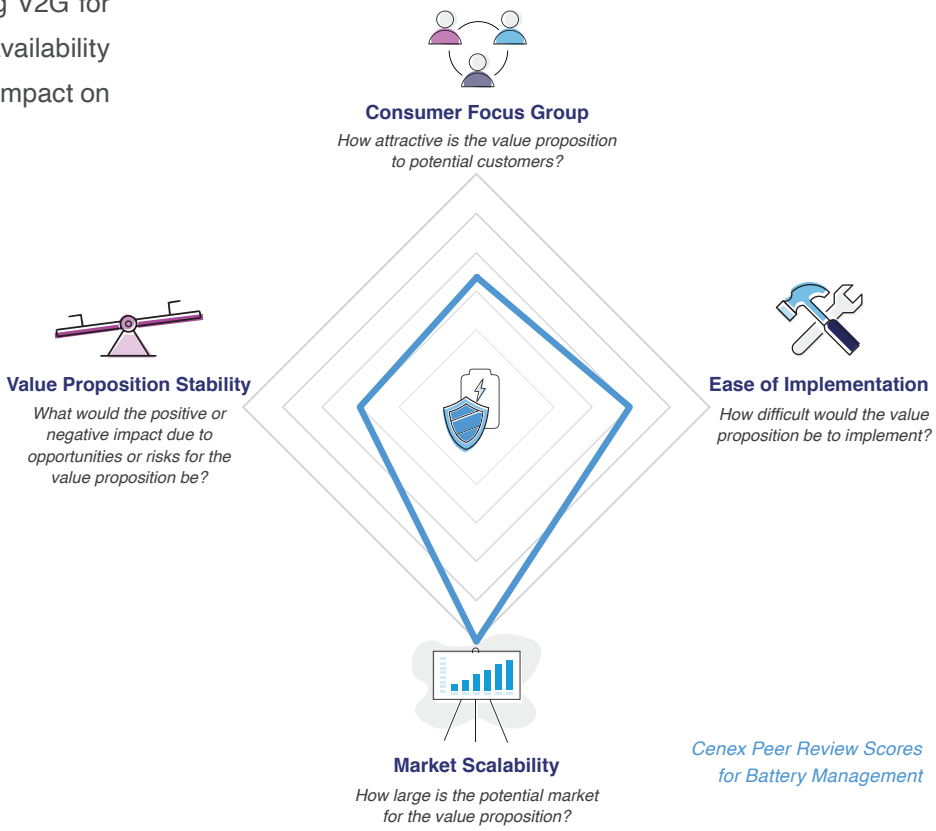
Battery degradation is a complex science, dependent on multiple use and environmental factors such as charge/discharge current, temperature, cycle depth and calendar age. Generally, increased cycling for arbitrage is very likely to increase a battery's degradation. Hence, V2G for revenue generation is typically associated with increased battery degradation as the consumer envisages repeated battery cycling for arbitrage. However, using V2G for grid services which are based on power availability but have low energy usage will have limited impact on battery degradation.

This value proposition considers the opposite – using V2G to maintain state of charge at an optimum level by charging and discharging as necessary. This has been proven to protect the vehicle battery from degradation (Uddin, et al., 2016).

Even with the current trend of falling battery prices, the battery remains a significant proportion of the cost of producing an EV. Therefore, **limiting battery degradation** of this asset has a direct positive impact on the **depreciation** of the vehicle.

In addition to this, if the battery degradation can be limited, its useable lifetime can be prolonged. If demonstrated, this could improve **user confidence in EVs**.

Extending the useable life of a battery has the secondary **environmental** benefit of improving the **life-cycle assessment** of the battery's carbon footprint.



Cenex Peer Review Scores for Battery Management

Scoring Discussion

Consumer Focus Groups The domestic group were unsure whether V2G could maintain battery health but most thought that it was important to protect a serious investment **"[the vehicle] is a large financial commitment… [so protecting battery state of health] would be really favourable"**. The commercial group saw the benefit but wanted to understand the model for leased vehicles.

Ease of Implementation Technically using a V2G charger to ensure that the vehicle battery is stored when not in use at a mid-range state of charge is simple. However, implementation challenges exist such as designing the business model to incentivise battery care for leased EVs and **compatibility with optimising charging behaviour for lowest carbon or cost**. In addition, more study is required to understand how much of the benefit could be achieved with smart charging.

Capacity fade *is a key parameter in battery ageing and a combined study (Uddin, et al., 2016) by Warwick Manufacturing Group and Jaguar Land Rover has shown that this can be* ***reduced by 9.1% over the course of a year through careful battery management****. For a V2G-ready 2017 Nissan Leaf which loses 2% of its state of health per year, this could extend the usable life (considered 80% of its state of health) of the vehicle battery for an extra year, from 10 to 11 years. A typical Nissan Leaf with an initial price of £25,000 and simplifying to use a linear depreciation model (note that in reality depreciation is more complex), a 10% extension of the life of the vehicle would equate to an* ***annual saving from reduced depreciation of approximately £230****.*

Market Scalability Like others, this value proposition requires the vehicle to have choice over when it charges, which means **off-street home charging or low utilisation workplace or fleet charging**. However there seem to be few other barriers and therefore scalability appears to be very good, especially if the value proposition could be incentivised to both private owners (improved resale value) or leasing customers (reduced leasing cost).

Value Proposition Stability There is some uncertainty surrounding **who will be accountable** for maintaining health and as a result how this will be done. On one hand there is a risk that manufacturers rely on advanced battery management systems to preserve health, without the need for enhanced charging management through V2G. Conversely, the manufacturer could choose to employ V2G to preserve battery health which would be a great opportunity for this value proposition. Who takes ownership of the vehcile battery may influence this decision. Meanwhile, battery trends and technology innovation have the potential to affect the importance of systems to manage battery health. For example, due to greater capacity at low cost or the use of chemistries which are inherently more resistant to ageing or cycling degradation mechanisms compared to current commercially available lithium ion chemistries.

Overall

This value proposition has **good consumer engagement** as concerns over battery health is a known barrier to EV adoption. Whilst technically feasible, there is **uncertainty over the achievable benefit** and the business models to support this value proposition.

Competing Solutions

There are a number of competing solutions for this value proposition.

Firstly, **battery management functionality** included within the vehicle is a competitor. Simple functionality is already very common; factory preset useable battery state of charge constraints and user programmable maximum state of charge limits or charging timers. More sophisticated battery management techniques developed by OEMs would be an increasingly strong competitor.

Smart charging is also a competitor that would capture some of the value. However, the key stakeholder is most likely to be the **vehicle manufacturer**, who can influence the value attainable from this proposition through battery ownership models and battery management techniques. Depending on the models and methods selected, this is both a risk and an opportunity; if V2G were to be endorsed by **OEMs** as a means of maintaining battery health, this would instantly create a large and well understood market for the technology. Future vehicle ownership models could even include a V2G charger as part of the sales package.

Combining this value proposition with others to optimise the value extracted from each would be the next challenge.

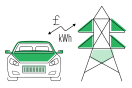
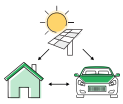
Stakeholder Analysis

The graphic below gives a map of the stakeholders for each value proposition.

✓ **Direct stakeholder.** These are the key stakeholders which are required to be directly involved in the value proposition in order for it to work, or those who are judged to have a strong influence.

✓ **Indirect stakeholder.** These are either:

- secondary stakeholders which may take an interest in becoming a stakeholder in the value proposition, but are not necessarily required for its operation, or
- actors that have a weaker influence in the result of the system.

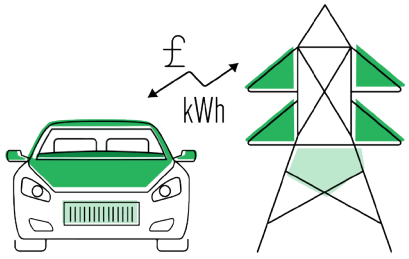
		Value Propositions				
		 Revenue-Generating Energy Trading	 Resillience	 Personal Net Zero / Self Sufficiency	 Benefit to Society	 Enhanced Battery Management
Drivers (Fleet & Domestic)	Drivers of personal, company and fleet electric vehicles	✓	✓	✓	✓	✓
Vehicle Owners / Operators	The owner or operator (if leased) of the vehicles	✓	✓	✓	✓	✓
Energy & Facilities Manager	The person(s) responsible for facilities and energy management at the site(s) where the vehicles are charged / discharged	✓	✓	✓	✓	✓
Distribution Network Operators (DNOs)	The seven UK DNOs, their licensees and independent DNOs.	✓	✓	✓	✓	
Transmission System Operators (TSOs)	National Grid ESO in the UK	✓	✓	✓	✓	
Energy System Regulator	Ofgem in the UK	✓			✓	
Energy Suppliers	Companies buying energy in the wholesale market and selling to customers	✓			✓	
Aggregators	Aggregators group agents from the energy system to act as a single entity in markets	✓		✓	✓	
Vehicle Manufacturers	Original Equipment Manufacturers (OEMs) of electric vehicles	✓	✓	✓	✓	✓
Chargepoint Manufacturers	Original Equipment Manufacturers (OEMs) of electric vehicle chargepoints	✓	✓	✓	✓	✓
eMobility Service Providers (eMSPs)	Provider of EC charging related services (including chargepoint access and locating, route planning and potentially, energy-related services) to the end user.	✓	✓	✓	✓	✓
Chargepoint Network Operators (CPOs)	Technical operators of networks of electric vehicle chargepoints (eg back offive provision). Does not interface with end user.	✓	✓	✓	✓	✓
Government	National and local government	✓	✓	✓	✓	✓
General Public	Local communities and wider UK general public. Not just those interacting with vehicles directly.				✓	

General Points

There are some stakeholders which are involved in the V2G system irrespective of the value proposition. The vehicle operator (the fleet manager in a commercial context and simply the owner/leaser in a domestic setting) will always be a key stakeholder as they will determine how the vehicles are used and therefore their plug-in availability for V2G.

Clearly, the vehicle OEMs and chargepoint manufactures are key stakeholders in all V2G value propositions as the vehicle and chargepoint must both be V2G compatible. However, for the purpose of this study, this is ignored and other influences for these stakeholders are considered.

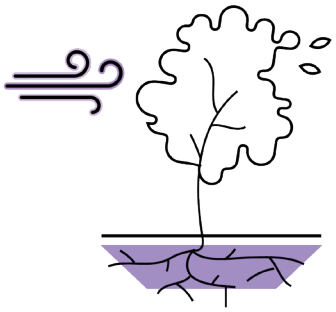
Other stakeholders are more likely to be involved indirectly. Government can directly impact value propositions through policy decisions but otherwise are more likely to indirectly affect value propositions through the likes of central decarbonisation targets, and battery recycling and disposal regulations. CPNOs and e-Mobility service providers are indirect stakeholders as they could provide and operate networks and services to facilitate the use of V2G for any of the value propositions. Likewise, drivers are always indirect stakeholders as the use of the vehicle – for example, an individual's driving style will change the vehicle's driving efficiency and indirectly impact on the useable charge available for discharging following use.



Revenue Generating Energy Trading

As previously mentioned, this is the most complicated value proposition in terms of the number of key stakeholders required. For revenue generation through arbitrage, the energy supplier is a key stakeholder as a variable tariff is required. To access revenue from grid services, the TSO, the Energy System Regulator and "to an increasing extent" the DNO all become key stakeholders as they are responsible for creating, managing and regulating energy markets. An example of this is the technical requirements set by National Grid for the frequency response market, which include a minimum power provision of 1 MW. This introduces the need for aggregators, another key stakeholder, for this value proposition.

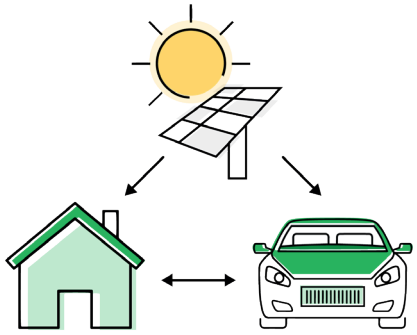
Stakeholder Analysis



Resilience

For this value proposition there are fewer direct stakeholders. An important stakeholder is the site energy system and infrastructure (and its operator), either in a domestic or commercial context, which the EVs are to provide energy resilience for by the means of V2G. The criticality of the operations of commercial sites are important. If the site has critical energy demands, a hospital is an obvious example, then ensuring back-up power availability through V2G may be difficult, especially in the shorter term where it is likely that there will only be small numbers of EVs interfacing with the energy system at any one site.

The chargepoint manufacturer is included as a direct stakeholder here as it is possible to design and manufacturer the V2G unit with functionality specifically designed to operate in island mode – that is, isolated from the grid during power outages.



Personal Net Zero / Self Sufficiency

The site energy system & infrastructure is an obvious key player as the value attainable is dependent on the site energy consumption and generation profiles, and how these align with vehicle energy and usage profiles. The future generation potential should also be considered, yet there will still be cases where heavy consumers will never be able to deploy on-site generation that exceeds the local demand, in which case V2G will have little effect. In addition to these technical and operational considerations, the person in charge of making these decisions – an energy manager in a commercial context – is also a key stakeholder.

Benefit to Society

For this value proposition, DNOs, TSOs and Energy System Regulators are once again key stakeholders as they can have a direct impact on how V2G is used for the greater good of the energy system. This can be at a local level (DNOs) where V2G could be used to defer network upgrades, a cost saving that should then be socialised to network users. On a national level, how V2G is used in order to decarbonise the grid is a complicated and difficult question that for which ultimately the TSO and its regulator are accountable.

The general public is included as an indirect stakeholder as there is greater opportunity to influence the value proposition than with the other four propositions. This could perhaps be at a local level via the creation of local energy systems which would require significant community engagement and consultation. A good example of such projects is the Western Isles V2G feasibility study (Cenex, 2019) and the Isles of Scilly Smart Islands project (Council of the Isles of Scilly, 2019).

Enhanced Battery Management

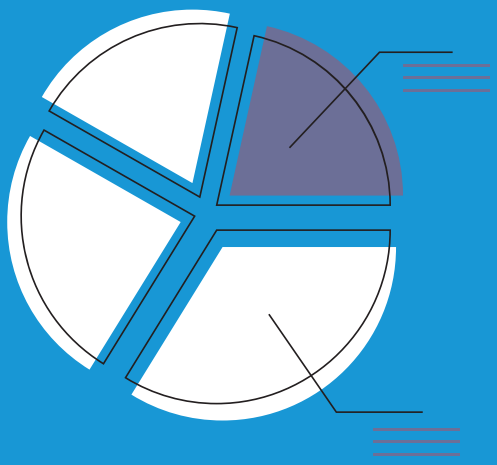
In this value proposition the vehicle manufacturer becomes a key stakeholder as it is they who will not only follow innovation in battery technology and design battery management systems to preserve battery life in use, but also define battery ownership models. All of these are important factors for the potential value of using V2G to maintain battery health to the user and operator.

There is also a long list of stakeholders who can have an indirect effect on this value proposition. For example, national battery recycling and disposal directives indirectly impact the importance of extending battery life. In addition, the site energy system and its operator will be an important stakeholder – is discharging the vehicle battery to preserve its health worthwhile if it means exporting the energy for no financial reward? This relationship is more complicated if the vehicle operator and the site energy system operator are not the same person (in the case of a workplace V2G and a privately owned vehicle, for instance).

Finally, depending on the battery and vehicle ownership model, 3rd party financiers and insurers of electric vehicles could have a strong influence on how battery health is managed and consequently, this V2G value proposition.

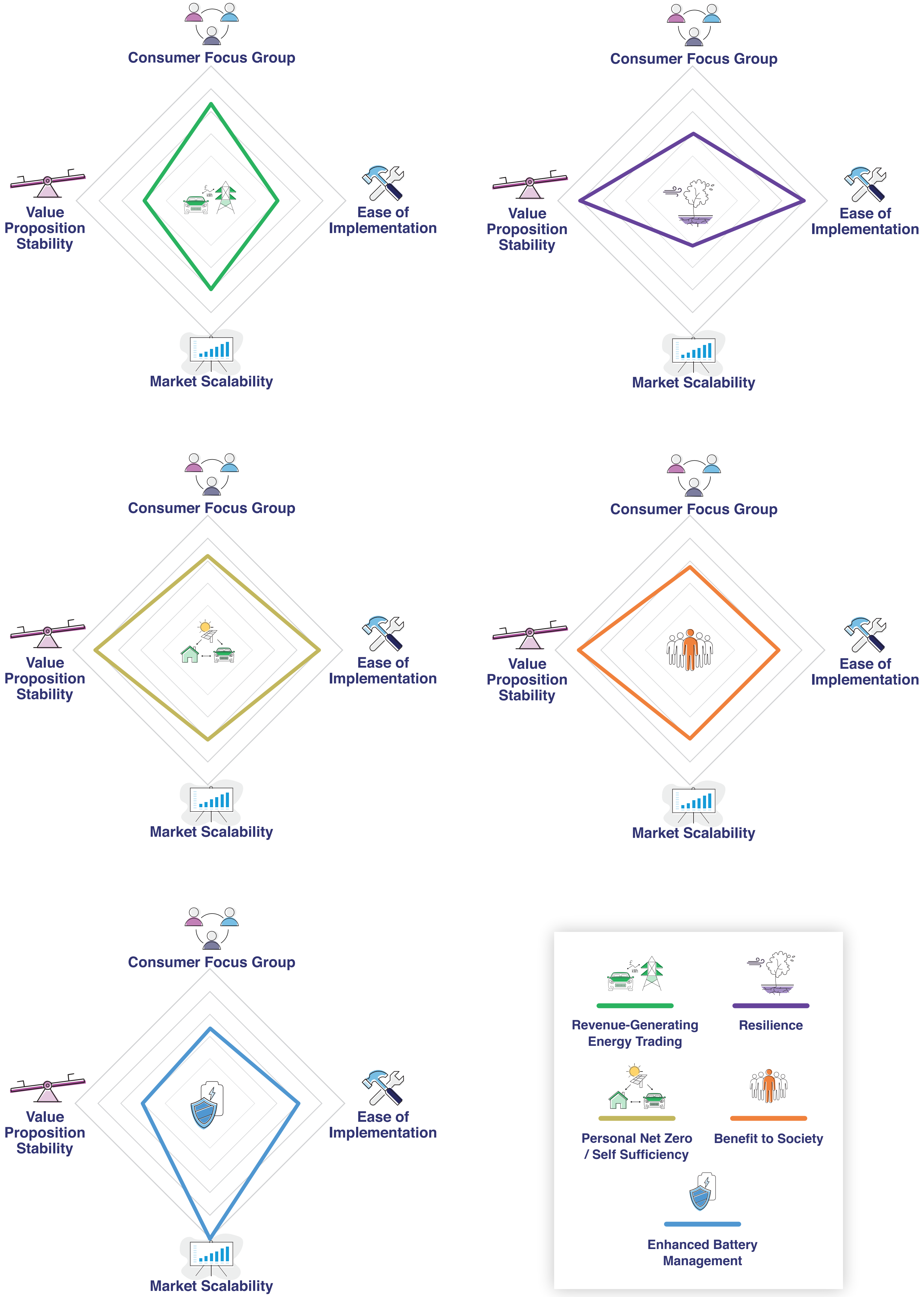
Conclusions

Existing studies have demonstrated the value of revenue generation for V2G through energy trading, along with the scale and direction of the markets and the core customers to whom this approach adds most value. However, these projects have largely failed to investigate alternative markets and opportunities for the technology.



The purpose of this study was to return to the drawing board for V2G in order to identify alternative value propositions and evaluate the benefit they deliver to the stakeholders involved, either financial or non-financial, as well as the scale of these opportunities. As a result, this document also aims to provide recommendations to key industry stakeholders on how to move forwards in investigating these opportunities

Through this study, five key value propositions were identified, including the traditional approach of 'Revenue-Generating Energy Trading' which was used for comparison and benchmarking. These were tested individually with customer focus groups and then later reviewed by an expert panel taking into account challenges around implementation, scalability of the market and the stability of the value proposition. This demonstrated the strengths, weaknesses and risks inherent in each proposition (as shown in Figure 1). However, this also demonstrates that the traditional model of V2G for revenue generation from energy trading is just one of a range of opportunities, and that targeting these different value propositions individually may enable the technology to access a much wider market.


Consumer Focus Group
Value Proposition Stability
Ease of Implementation
Market Scalability
Consumer Focus Group
Value Proposition Stability
Ease of Implementation
Market Scalability
Consumer Focus Group
Value Proposition Stability
Ease of Implementation
Market Scalability
Consumer Focus Group
Value Proposition Stability
Ease of Implementation
Market Scalability
Consumer Focus Group
Value Proposition Stability
Ease of Implementation
Market Scalability
Revenue-Generating Energy Trading
Resilience
Personal Net Zero / Self Sufficiency
Benefit to Society
Enhanced Battery Management

Conclusions

One of the key challenges facing V2G however, is how it competes, compares or compliments with other low-carbon technologies – in particular stationary battery storage and smart charging. Insight is given for each value proposition in the previous section and a summary included below:

> **Stationary Battery Storage:** V2G has the opportunity to provide many of the same services as a stationary battery, both small- and large-scale systems, but potentially at lower capital cost. Current V2G chargers are relatively similar in cost to battery systems, but the predicted trend for V2G costs indicates that DC V2G will become competitive with standard 'smart' charging solutions over the next 5-10 years (Cenex, 2019). The cost-down scenario of V2G could be improved further by the development of cheaper AC V2G systems. In addition, in many domestic scenarios and in some commercial settings, vehicle plug-in times align well with timings for these value propositions, making V2G highly competitive with stationary battery storage systems, with lower capital costs.

> **Smart Charging:** While smart charging is able to deliver many of the same services, the uni-directional nature of smart charging means that the benefit which can be achieved through this approach is limited. By comparison, the bi-directional nature of V2G creates significantly more flexibility. For example, services such as enhanced battery management are limited for smart charging as the battery state of charge can only be increased; when the state of charge is high, smart charging, unlike V2G, is unable to discharge the battery to 'ideal' levels, minimising its ability to deliver the full value of this value proposition. For comparison, work carried out by Cenex as part of the 'Understanding the True Value of V2G' report (Cenex, 2019) indicated that, for a variety of customer archetypes, smart charging was able to capture between 40-90% of the value from behind-the-meter optimisation, but only about 10% of the value from grid services, compared to V2G in the same scenario. This is true for each of the value propositions, to different degrees, with smart charging being capable of delivering some, but not all of the value which can be achieved by V2G.

To date, many of the trials and business cases for V2G have been developed by energy suppliers, vehicle manufacturers or V2G chargepoint manufacturers, with marketing of the products often being focused on traditional financial business models such as return on investment. Over the past decade the approach to sales and marketing as an industry has changed significantly, from the sale of products and services to the marketing of dreams, emotions and lifestyles. Customers are no longer sold trainers, but a vision of health and fitness; cars aren't sold as a means to travel from A-to-B but as a way to escape from the busyness and noise of life and find a place of comfort. The value propositions set out in this report demonstrate the opportunity to follow this trend, moving away from V2G sales as a financial exercise and instead offering products which enable customers to become more self-sufficient or do their part in fighting climate change.

As V2G shifts gear to travel down this new path, it is important to learn from those who have travelled it before:

1. Know your customer

As demonstrated in 'The True Value of V2G' (Cenex 2019) report, there is not just one type of customer for V2G, but rather a wide range of customer archetypes, and each one comes with a different set of value, behaviours and needs. By starting with the product and looking at how to market it, it is possible to miss the real opportunities. Industry has developed a range of processes and approaches to support organisations tackling this problem. These include 'Human Centred Design', 'Customer-Centric Design' and 'Design Thinking', to name just a few. Each one has in common "however" the view that the customer's need is put at the centre of the design process.

This study took the first step in engaging with customers to understand their needs and views; however, much more work is needed in this area to truly identify not just the customer needs, but the value proposition (how you convey the service/product to the customer) and the business models (the approach to developing and selling the product to meet the customer's need) which are needed to turn this from a technical product into a valuable service.

2. Focus on the niche (then grow)

Once the core customer archetypes for a proposition have been identified, it is possible to ascertain the overlapping values, ambitions and pain-points in order to create products and marketing to meet their needs. Historically, V2G trials have attempted a 'one-size fits all' style approach, with minimal customer segmentation and targeting - all of the projects interviewed for this study looked at financial value propositions. Some also looked at the "Benefit to Society" or "Personal Net Zero / Self Sufficiency" but this was typically as a secondary value proposition (V2Street, Powerloop, Sciurus). As a result, those projects which focused heavily on value from energy trading (for example e4Futures) have struggled to demonstrate 'success', while projects such as SEEV4-City which considered a broader range of value propositions have been able to demonstrate success regardless of the economic value of trading in local energy markets.

Each of the five value propositions set out in this report specifically target smaller, niche markets and offer different value depending on the customer – meaning that the proposition may be highly valuable for some, while being totally irrelevant for others. However, taking the example of organisations such as Google or Amazon, focusing on a niche enables the business to develop a high-quality service or product which customers can get excited about.

From there, the organisation has a strong base to expand into new areas and explore new opportunities. For V2G this means tailoring the service to meet a specific market, opportunity or customer and developing a strong business around this, before attempting to grow propositions for the masses.

A key tool in development of niche business models is the "business model canvas" (Strategyzer, 2020). This methodology enables quick and simple adjustments to be made to the business model in response to improved knowledge about the customer and/or value proposition being offered to them.

3. Communicate at the customer's level

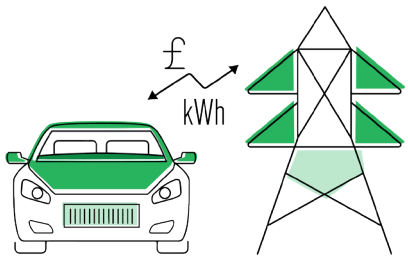
Many of the propositions tested in the current Innovate UK demonstrators identified customer education and overly technical terminology as key reasons for failure to achieve the uptake rates expected for the trials. Vehicle-to-Grid as a term, while commonly understood within technical gatherings in the energy and transport industries, is generally meaningless to the average man or woman on the street. This immediately puts marketing of solutions using this terminology at a disadvantage. A two-pronged approach is required to tackle this, combining a shift to plain-English terminology, along with greater education around the technology and its benefits. The success of the 'Fully Charged' YouTube show and particularly the recent "Maddie Goes Electric" (Fully Charged Show, 2020) series demonstrate the significant interest which arises when appropriately worded and well targeted engagement methods are used for otherwise 'technical' topics.

A key approach taken during the customer focus groups was to avoid, as much as possible, the term 'Vehicle-to-Grid' and instead focus on the role the device was performing for each proposition. This was not fully successful, as the same focus groups were used to review multiple propositions; however, the idea of treating V2G purely as a component in a product, like a resistor or motor, rather than as the product itself could certainly be a valuable approach for the industry. This is anecdotally supported by the current trend for '…-as-a-service' propositions (for example 'Mobility-as-a-Service') which define the ultimate customer value rather than the specific technical approach to delivering this value.

The True Value of V2G

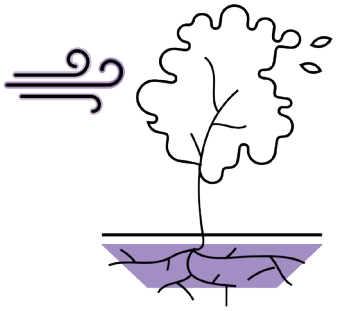
V2G has often promised to be a 'golden egg', providing both economic value to the customer and environmental benefits to the energy system.

The shift to more focussed value propositions may therefore feel like a step away from this lofty ambition, reducing the impact and therefore the value of the technology. However, there are links between each of these propositions which cannot be ignored:



Revenue-Generating Energy Trading:

The economic savings at a per-customer level may, in some cases, be insubstantial (average revenue generation from V2G is estimated to be in the region of £150-200 per year, with customers with a high plug in rate achieving in the region of £400 per year); the savings at a national level would be significant and would result in lower energy bills for all customers. In addition, the impact of replacing traditional power stations with flexibility services from V2G could offset hundreds of thousands of tonnes of CO_2 each year (National Grid, 2019).



Resilience:

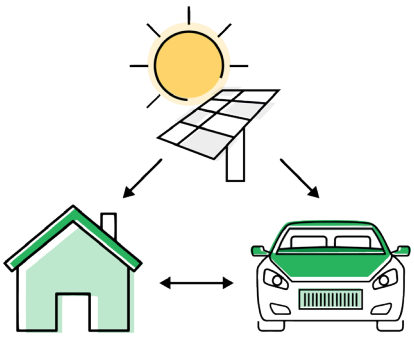
With V2G prices dropping, the provision of this service by V2G could replace a number of existing traditionally diesel back-up power systems or battery UPS systems, or reduce their usage. This would reduce or eliminate the costs associated with maintaining and operating these systems – producing economic benefits for the customer. In addition, there would be an environmental benefit (both nationally in terms of lifecycle carbon footprints and to local air quality for fossil-fuelled powered back-up power systems). While no figures are available for the UK, in the US there are 32 sites with backup power systems for every million households (Julia A Phillips, 2016). Taking a similar ratio, this would give just under 900 backup power systems in the UK.

Benefit to Society:

This proposition focuses entirely on delivering environmental and societal benefits, which in turn should be returned to the customer by way of lower taxes and improved quality of life - for themselves and for future generations. Based on avoiding curtailment of renewable generation alone, this could equate to savings of 6 MtCO2e per year and avoided network costs could equate to approximately £180 per household or an overall saving of £3.5bn per year by 2040 (Ovo Energy, 2018).

Enhanced Battery Management:

Based on current evidence, V2G could extend the life of an EV battery by about 10%. By extending the life of the battery, V2G would help to reduce end-of-life waste and demand for mining of new materials, along with the emissions associated with these activities. Prolonging the life of an asset also allows customers to utilise vehicles over a longer period, reducing the total cost of ownership for the customer. For a commercial fleet of 100 EV's, where vehicles are bought new and replaced on a 3-year cycle, the savings from reduced depreciation could equate to almost £70,000.



Personal Net-Zero/Self Sufficiency:

Optimisation of self-consumption can be combined with arbitrage to create an economically and environmentally attractive proposition for customers. This works to increase the use of renewable energy local to the point of generation and avoid transmission losses and network operation/re-enforcement costs which would otherwise be passed on to the end customer through their energy bills. Taking a typical household with solar PV, this could equate to annual emissions savings of 0.6 tCO2e and energy savings in the region of £300, plus any benefits associated with avoided network investment.

This summary shows that whilst this report separated the benefits of V2G into five individual value propositions, each will have indirect impacts and "in reality" the propositions are inextricably linked. Positive impacts are given here, however it is imperative to consider any negative emergent behaviour when considering value propositions. For example: what is the impact of optimising the revenue generation for arbitrage on the vehicle battery health; would optimising the use of V2G for wider societal benefit come at the financial expense of the operator?

Recommendations

The following recommendations are made, targeted towards the relevant audiences:

Existing V2G Projects and Partners:

The existing V2G trials continue to explore potential value propositions and how the customer interacts with the technology. This is essential to developing new propositions and business models. Where trials are struggling to recruit participants, a particular emphasis should be put on identifying niche customer segments and refining the language with which the proposition is presented in order to appeal to those segments.

V2G Chargepoint Manufacturers / Retailers:

Despite the focused nature of this study, it has demonstrated that there are a broad variety of propositions whereby V2G can still provide a desirable and valuable service. However, propositions need to be designed and targeted around the customer needs, not the product. Further trials and customer testing are required to investigate novel V2G propositions, focusing on customer-centric design principles. Any research in this area should be clear about the niche target customer archetypes and size of the market, and should utilise clear methodologies, such as the 'Business Model Canvas' (Strategyzer, 2020), to explore the full proposition and route to market. Lessons should also be learnt from parallel industries and 'start-up' culture around trends in proposition development and marketing.

Vehicle Manufactures / Operators:

Extending the life of electric vehicles through V2G is likely to result in higher residual values for the vehicles, therefore enabling vehicles to be provided with lower lease prices. Effective battery management may also lower the risk relating to the battery warranty. It may therefore be commercially valuable to provide a V2G unit optimising for enhanced battery management to purchasers of new vehicles or as part of a lease agreement. To be effective this will require vehicle manufactures to develop V2G compatible vehicles and allow V2G operation (at least through approved hardware or optimisation methodologies) in the vehicle warranties.

Investors / Funders:

While V2G has not achieved the commercialisation rates which some expected, the existing trials continue to achieve significant insight into a technology which could still have a crucial role in decarbonising the national energy system. While much of the funding to date has been focused on investigating the business case for revenue generation from energy trading, resulting in identification of the customer archetypes for whom this approach is attractive, this document demonstrates that the market for V2G extends beyond this single business model. As a result, the focus of further innovation funding amd private investment should be targeted towards novel value propositions such as those set out in this document. As these propositions relate to more qualitative value, it is difficult to quantify this quite so clearly as with energy trading. Therefore, customer-centric design principles should be an absolute requirement for all future replication-trials and demonstrators. This will not only ensure that the technology and supporting systems are tested at scale, but that a wide range of propositions are also tested.

Transmission / Distribution System Operators:

Further reform is required to enable provision of energy trading services by small scale and domestic sources of flexibility, including V2G. V2G offers particular value at a local/distribution network level, yet one of the key challenges identified by existing V2G projects related to the DNO connection process. Therefore, distribution network flexibility services and connection standards in particular should be developed and implemented in such a way as to encourage the uptake of V2G.

Policy Makers / Advisors:

While this study does not aim to provide direct policy inputs, policy is a key enabler of new technologies and markets and therefore some high-level recommendations are given with a view to supporting the development of the V2G market:

- **Enforcement of V2G:** The 'Benefit to Society' value stream demonstrates the environmental and economic potential of V2G on the UK energy system. In 2019 the UK government took the approach of setting a requirement for new domestic and public EV chargers to be 'smart' and it would therefore be possible, and even tempting, to take a similar approach with V2G. While this may be advantageous in the long term, the high costs associated with V2G, combined with the immaturity of the technology and uncertainty around the standards which will be required for the future market (in particular whether CHAdeMO, CCS or AC systems will be adopted by suppliers of vehicles to the UK) means that it would be inappropriate and potentially damaging to the industry to enforce the adoption of V2G at this time. Rather, these factors should be monitored and at such a time when these questions have been satisfactorily answered, the idea of enforcing V2G for wider societal benefit should be revisited. It is imperative to review and incorporate lessons learnt from the smart charging policy decisions to ensure any legislation to mandate V2G would not stifle innovation.

- **Further investment in V2G:** While the market for energy trading V2G has proved not to be as significant as initially believed, the technology has been proved to work effectively and appetite for the technology is growing as understanding of the benefits improves. At a time where the UK is becoming increasingly independent from neighbouring countries, investing in and developing UK based technologies and businesses which focus on improving energy independence and self-consumption of energy from local generation sources feels like a natural synergy. Further recommendations on where and how this investment should be focused are set out in the 'Investors / Funders' section of the recommendations.

- **Education:** A key learning from the existing V2G projects was that education around the benefits and value of V2G makes a significant difference to uptake rates of the technology. This is particularly true in commercial settings, where V2G sits in the 'gap' between fleet and energy managers. Targeted campaigns for fleet and energy managers as well as EV owners based on the value propositions set out in this study would significantly improve adoption rates for future V2G trials and commercialisation of the technology. It is recommended that the UK Government appoints an independent organisation to develop and deliver targeted engagement and education services for V2G over a 12-month period, with clear KPIs set out to monitor impact.

- **V2G Standards Working Group:** As set out above, the lack of clarity around the direction which vehicle manufacturers will take with V2G and the standards which they will adopt for the UK is a key barrier to commercialisation of V2G. It is recommended that a UK working group is set up, bringing together both vehicle and V2G chargepoint manufacturers, along with other key stakeholders, in order to create a dialogue on the topic and work together to create a unified view for the UK. Due to the complexity of the topic and relationships between stakeholders, it is recommended that an independent expert organisation is employed to chair this group.

References

BloombergNEF, 2019. A Behind the Scenes Take on Lithium-ion Battery Prices. [Online]
Available at: https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/
[Accessed 22 05 2020].

Cenex, 2019. Understanding the True Value of V2G. [Online]
Available at: https://www.cenex.co.uk/app/uploads/2019/10/True-Value-of-V2G-Report.pdf
[Accessed 22 05 2020].

Cenex, 2019. Vehicle-to-Grid Britain V2GB. [Online]
Available at: https://www.cenex.co.uk/app/uploads/2019/10/V2GB-Public-Report.pdf
[Accessed 22 05 2020].

Cenex, 2019. Western Isles Project Comet. [Online]
Available at: https://www.cenex.co.uk/case-studies/western-isles-project-comet/
[Accessed 22 05 2020].

CharIN, 2018. Grid Integration Levels. [Online]
Available at: https://www.charinev.org/fileadmin/Downloads/Papers_and_Regulations/CharIN_Levels_Grid_Integration.pdf
[Accessed 22 05 2020].

Connected Energy, 2018. Connected Energy to supply innovative energy storage solution to landmark Evolt and Dundee City Council EV project. [Online]
Available at: https://www.c-e-int.com/resources/news-events/connected-energy-to-supply-innovative-energy-storage-solution-to-landmark-evolt-and-dundee-city-council-ev-project/
[Accessed 22 05 2020].

Council of the Isles of Scilly, 2019. Council launches electric vehicle project on Scilly as part of the Smart Islands programme. [Online]
Available at: https://www.scilly.gov.uk/news/council-launches-electric-vehicle-project-scilly-part-smart-islands-programme
[Accessed 22 05 2020].

Energy Live News, 2019. UK energy storage sector sees ‘massive growth’. [Online]
Available at: https://www.energylivenews.com/2019/12/02/uk-energy-storage-sector-sees-massive-growth/
[Accessed 22 05 2020].

Fully Charged Show, 2020. Maddie Goes Electric, SuperCut. [Online]
Available at: https://fullycharged.show/episodes/maddie-goes-electric-supercut/
[Accessed 22 05 2020].

Greentech Media, 2012. Japan, Land of the PV- and EV-Connected Smart Grid. [Online]
Available at: https://www.greentechmedia.com/articles/read/japan-land-of-the-pv-and-ev-connected-smart-grid
[Accessed 22 05 2020].

HITACHI, 2018. Hitachi, Mitsubishi Motors and ENGIE explore using electric car batteries as renewable energy storage for office buildings. [Online]
Available at: https://www.hitachi.eu/en/press/hitachi-mitsubishi-motors-and-engie-explore-using-electric-car-batteries-renewable-energy
[Accessed 22 05 2020].

Julia A Phillips, K. E. W. T. Y. K. J. H. E., 2016. Onsite and Electric Power Backup Capabilities at Critical Infrastructure Facilities in the United States, s.l.: Argonne National Laboratory.

Kempton, M. & Letendre, S., 1997. Electric vehicles as a new power source for electric vehicles. Transportation Research Part D: Transport and Environment, 2(3), pp. 157-175.

National Grid, 2019. Short Term Operating Reserve, Carbon Intensity Report. [Online]
Available at: https://www.nationalgrideso.com/industry-information/balancing-services/reserve-services/short-term-operating-reserve-stor
[Accessed 22 05 2020].

Ofgem, 2018. Reform of network access and forward-looking charges. [Online]
Available at: https://www.ofgem.gov.uk/electricity/transmission-networks/charging/reform-network-access-and-forward-looking-charges
[Accessed 22 05 2020].

Ovo Energy, 2018. Blueprint for a post-carbon society. [Online]
Available at: https://www.ovoenergy.com/binaries/content/assets/documents/pdfs/newsroom/blueprint-for-a-post-carbon-society-how-residential-flexibility-is-key-to-decarbonising-power-heat-and-transport/blueprintforapostcarbonsocietypdf-compressed.pdf
[Accessed 22 05 2020].

Peter Bach Andersen, S. H. T. T. M. S. B. E. C. J. C. M. L. H. A. Z., 2019. Downloads. [Online]
Available at: https://parker-project.com/wp-content/uploads/2019/03/Parker_Final-report_v1.1_2019.pdf
[Accessed 22 05 2020].

piclo, 2020. Modelling the GB Flexibility Market. [Online]
Available at: https://piclo.energy/publications/Value+of+Flexibility.pdf
[Accessed 22 05 2020].

Strategyzer, 2020. The Business Model Canvas. [Online]
Available at: https://www.strategyzer.com/canvas/business-model-canvas
[Accessed 22 05 2020].

The Energyst, 2018. Can the Balancing Mechanism offset FFR price erosion. [Online]
Available at: https://theenergyst.com/can-balancing-mechanism-replace-ffr-price-erosion/
[Accessed 22 05 2020].

The Energyst, 2020. TCR: Triads and tribulations for large energy users. [Online]
Available at: https://theenergyst.com/ofgem-tcr-triads-energy-bill-impacts/
[Accessed 22 05 2020].

tnei group, 2019. Consultation on the energy storage planning process. [Online]
Available at: https://www.tneigroup.com/news/consultation-energy-storage-planning-process
[Accessed 02 06 2020].

Uddin, K. et al., 2016. On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smart-grid system, s.l.: Elsevier.

Glossary

Term	Description
AC	Alternating Current
Aggregator	This is the term used to describe an organisation which acts as a middle-man between the demand source and the service operator
Arbitrage	The practice of taking advantage of energy price differentials
Balancing Mechanism	Tool used by National Grid to balance electricity supply and demand close to real time
Battery Degradation	Decline in battery health over time due to age and/or usage
Bi-directional	Two-way flow of energy - charging and discharging in the context of V2G
Capacity Market	Tool used by National Grid to ensure future security of electricity supply
CCS	Combined Charging System – DC EV charging system
CHAdeMO	“Charge de Move” – DC EV charging system
CPO	Chargepoint Network Operator
DC	Direct Current
DNO/DSO	Distribution Network Operator/Distribution System Operator
DTU	Demand Turn Up
eMSP	E-mobility Service Provider
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FFR	Firm Frequency Response
ICE	Internal Combustion Engine
STOR	Short Term Operating Reserve
TSO	Transmission System Operator
UPS	Uninterrupted Power Supply
V1G	Smart EV Charging
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid. A system which allows an electricity system whereby plug-in electric vehicles (EVs), when connected to a V2G charger, can provide bi-directional flows of energy and data.
V2H	Vehicle-to-Home
Value Proposition	Top level description of how stakeholders can extract financial or non-financial “value” from a system.

cenex

Innovate UK

You can find out more about our work on V2G, along with downloading a range of free, public reports, from our website:

www.cenex.co.uk

Cenex
Holywell Building
Holywell Park
Ashby Road
Loughborough
Leicestershire
LE11 3UZ

Tel: 01509 642 500
Email: info@cenex.co.uk
Website: www.cenex.co.uk