Department for
Business, Energy
& Industrial Strategy

Role of Vehicle-to-X Energy Technologies in a Net Zero Energy System

A call for evidence

Closing date: 12 October 2021

July 2021

Any enquiries regarding this publication should be sent to us at: evsmartenergy@beis.gov.uk

Executive Summary

In 2019, the UK became the first major economy to commit to a legally binding target of net zero emissions by 2050. Transport contributes 28% of UK domestic greenhouse gas emissions[1] and addressing this sector is a critical element of the plan to reach net zero. The government's approach, as laid out in the 2018 Road to Zero Strategy, centres on the decarbonisation of the transport sector and this was accelerated in the Ten Point Plan for a Green Industrial Revolution with the phase out of the sale of new petrol and diesel cars by 2030.

This transport revolution could lead to an estimated 10 million electric vehicles on the road by 2030[2] which, alongside wider electrification (such as increased uptake of heat pumps), will add significantly to electricity demand. This increase in demand will happen simultaneously with the transition of the energy system to a net zero system, with generation increasingly from intermittent sources such as solar and wind. The 2021 Smart Systems and Flexibility Plan and the 2020 Energy White Paper set out how the energy system will transition to a net zero system whilst maintaining security of supply and keeping consumer costs to a minimum.

Flexibility, the ability to shift, in time or location, energy consumption or generation to balance supply and demand, will be important in achieving a cost-effective transition to net zero and electric vehicles could be a major source of flexibility. Smart charging describes the ability to manage EV battery charging flexibly, based on communicated data signals; it offers potential savings for consumers and the system as well as a source of revenue for suppliers and other parties. Recognising the importance, BEIS consulted on smart charging in 2019 and is developing the legislation, using powers under the Automated and Electric Vehicles (AEV) Act 2018, to require new chargepoints to have smart charging functionality.

But the potential for EVs to contribute to a flexible energy system goes beyond shifting when they charge. The next step in development is enabling the EV battery to export electricity back to a system, be that a building such as a home (V2H) or a building (V2B) such as a business or back to the electricity grid (V2G), in response to signals. V2X, where "X" stands for everything, is the umbrella for all forms of this technology and is used in this document as we expand beyond considering only exporting to the grid. This increased utilisation of the EV battery allows it to be used to further manage behind-the-meter energy use or to create an additional revenue source by exporting electricity and offering grid services.

Vehicle-to-x is an emerging technology with trials worldwide involving hundreds of vehicles but is not yet at mass deployment. This call for evidence is to learn more about the role that V2X energy technologies could play in a net zero energy system, how the technology may deploy,

[1] BEIS (2020), '2018 UK greenhouse gas emissions: final figures - data tables', https://www.gov.uk/government/statistics/final-uk-greenhouse-gasemissions-national-statistics-1990-to-2018
[2] National Grid ESO (2020), FES 2020, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

how business models and the consumer proposition could change in the future and what barriers exist.

Contents

General information

Why are we issuing a call for evidence?

BEIS is seeking information to better understand the role that Vehicle-to-X energy technologies could play in the transition to a net zero energy system and the electrification of the transport. We want to understand the potential value of the opportunity, and whether there are barriers that might affect the impact of vehicle-to-x energy technologies.

Call for evidence details.

Issued: 20 July 2021

Respond by: 12 October 2021

Enquiries to:

Net Zero Electricity Networks Team
Department for Business, Energy and Industrial Strategy
3rd Floor, Abbey
1 Victoria Street
London
SW1H 0ET

Tel:
Email: evsmartenergy@beis.gov.uk

Call for evidence reference: Vehicle-to-x call for evidence.

Audiences:

We are keen to hear from all stakeholders with an interest in the transition to a net zero energy system or vehicle-to-x technologies; especially network companies, automotive original equipment manufacturers, energy suppliers, charge point operators and flexibility providers.

Territorial extent:

Great Britain

How to respond

Your response will be most useful if it is framed in direct response to the questions posed, though further comments and evidence are also welcome.

Where possible, responses should be submitted electronically via the e-consultation available at https://beisgovuk.citizenspace.com/energy-security/call-for-evidence-v2x

Responses emailed to evsmartenergy@beis.gov.uk and hardcopy responses sent to BEIS will also be accepted.

Respond online at: https://beisgovuk.citizenspace.com/energy-security/call-for-evidence-v2x

or

Email to: evsmartenergy@beis.gov.uk

Write to:

Net Zero Electricity Networks Team
Department for Business, Energy and Industrial Strategy
3rd Floor, Abbey
1 Victoria Street
London
SW1H 0ET

When responding, please state whether you are responding as an individual or representing the views of an organisation.

Confidentiality and data protection

Information you provide in response to this call for evidence, including personal information, may be disclosed in accordance with UK legislation (the Freedom of Information Act 2000, the Data Protection Act 2018 and the Environmental Information Regulations 2004).

If you want the information that you provide to be treated as confidential please tell us but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws. See our privacy policy.

We will summarise all responses and publish this summary on GOV.UK. The summary will include a list of names or organisations that responded, but not people's personal names, addresses or other contact details.

Quality assurance

This consultation has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this call for evidence has been conducted, please email: beis.bru@beis.gov.uk.

1. Background

This call for evidence seeks information to help government create a strategy, in collaboration with industry and Ofgem, to enable to the deployment of vehicle-to-x energy (V2X) technologies.

The ability to use the energy within an electric vehicle (EV) battery for functions other than mobility has been available for over a decade, with electric vehicles offering frequency services first demonstrated in 2008[3]. The EV can export electricity back to a system, such as a home (V2H) or a building such as a business (V2B) or back to the electricity grid (V2G), in response to signals. V2X, where "X" stands for everything, is the umbrella term for all forms of this technology and is used in this document to show that all applications of the technology and business models are being considered at this early stage.

V2X energy technologies offer potentially huge benefits to the consumer, the energy system and to parties such as energy suppliers or flexibility service providers. Increased utilisation of the EV battery allows it to be used to manage behind-the-meter energy use, for example by adding to the benefits of smart charging EVs by further lowering consumption during peak times, or to create an additional revenue source to the behind-the-meter benefits by exporting electricity and offering grid services. This then provides additional savings or a source of revenue from the EV for consumers and additional flexibility assets to be used by other parties. Our modelling of the expected deployment of other smart and flexible technologies such as short-duration storage, smart heating systems, smart electric vehicle charging and interconnection with other countries, shows potential savings of up to £10 billion per year by 2050[4].This then suggests the huge potential value from millions of V2X capable EVs providing flexibility.

Though V2X energy technologies have been technically feasible for over a decade, the challenge has been to realise a viable commercial model, with barriers including high equipment costs and the difficulty in entering the highly regulated energy system. The huge potential benefits to both system and consumer have resulted in innovation competitions involving V2X energy technologies across the globe. In 2017, BEIS and the Office of Low Emission Vehicles (OZEV[5]) provided up to £30m of funding, through an InnovateUK (IUK) competition, to 20 vehicle-to-grid competitions. The projects are wide-ranging, including feasibility studies, collaborative R&D and real-world demonstrators covering commercial and domestic users, and are expected to finish in 2022.

[3] V2G hub 2018 roadmap https://dl.airtable.com/.attachments/dd74c4cff4b4ec55878e4ede1e583fcb/c88b5a4a/Final-Report-UKPN001-S-01-I-V2G-global-review.pdf

[4] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

[5] Formally known as the Office for Low Emission Vehicles (OLEV).

The advances and experience gained from these competitions, combined with falling costs (due to the mass production of EVs) have started to remove some barriers. This call for evidence looks to understand the role of V2X energy technologies in a future energy system, the barriers preventing this and where government intervention is required.

2. Understanding the current and future landscape

In order to develop a strategy to maximise the opportunities for a flexible energy system from electric vehicle charging, the government needs to have a full understanding of the current landscape and the expected future role of V2X energy technologies. This section presents the information gained from both innovation competitions and available literature, and asks stakeholders to feedback their own evidence and views.

2.1 Role in energy system

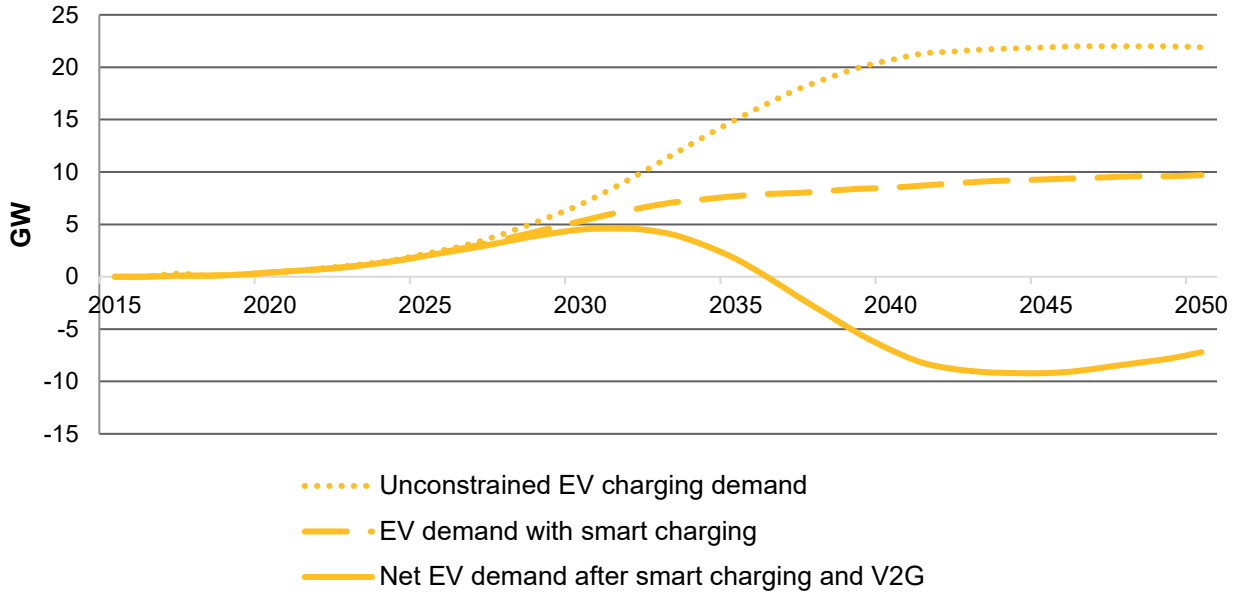
The mass uptake of electric vehicles will create significant new demand for electricity but will also provide opportunities for enhanced system flexibility. The demand for electric vehicles is expected to grow dramatically over the next decade, with estimates of approximately 15 million electric vehicles on the road by 2030. The Climate Change Committee's Sixth Carbon Budget suggests that, by 2030, electricity demand for electric cars and vans could exceed 30TWh (compared to a total UK electricity demand of over 300 TWh). By 2050, the UK car and van fleet could increase electricity demand by approximately 65 to 90 TWh, compared to an overall electricity demand of approximately 590 to 890 TWh. We need to be able to enable these changes with the transition to a net zero energy system, in the most cost-effective way for consumers.

This analysis was completed prior to announcements on the UK's sixth Carbon Budget[6], so does not consider the impact of those decisions. We would expect faster or deeper decarbonisation to bring forward the need for flexibility, though we do not anticipate the level of flexibility required by 2030 to be dramatically higher than the level set out here.

V2X energy technologies could be one of the main sources of flexibility available for the energy system, helping to reduce peak demand and reducing system costs by offering grid services. Figure 1 shows modelling of the potential impact of V2X energy technologies on demand from National Grids Future Energy Scenarios 2020, in which net demand falls below current levels.

[6] Climate Change Committee (2020), The Sixth Carbon Budget – The UK's path to net zero, https://www.theccc.org.uk/publication/sixth-carbon-budget/

Figure 1: Electric Vehicle Charging Behaviour at ACS winter peak system demand (Consumer Transformation Model) - National Grid FES2020



The potential benefits of V2X energy technologies to the energy system look very promising, but what is less clear is the interaction between V2X and other flexibility technologies (for example domestic batteries). Literature and the evidence from innovation competitions have shown a number of possible options; for example the different flexibility technologies could carve out revenue niches based on their strengths, or the different technologies could compete for the same markets, or solutions could be hybrids of different technologies. An example of a hybrid solution is the Oxford Energy Superhub which combines electric vehicle charging, stationary lithium-ion batteries, redox flow batteries and ground source heat pumps all to provide energy solutions for the EV charging network[7].

Questions

1. What role do you think V2X energy technologies will play in a future energy system?
2. How do you think V2X energy technologies will interact with other flexibility technologies in a future energy system?

2.2 Deployment

It is essential for government to understand how V2X energy technologies will come to mass market, including the timeframes, barriers and possible opportunities to bring these timetables forward.

Currently EVs only represent a small percentage of vehicles in the UK but with the 2030 phase out of the sale of internal combustion engine (ICE) cars and vans, this is expected to rapidly

[7] https://energysuperhuboxford.org/about-the-project/

increase and in 2020 zero emission capable cars comprised 17.5% of total new car registrations according to trade associations[8]. Deployment of V2X energy technologies is currently mostly limited to demonstration trials and only a small number of vehicles available have V2X capability, but National Grid estimates that by 2050 up to 45% of vehicles could be providing V2X services, offering up to 38GW of flexibility[9].

There are differing views of when the mass deployment of V2X energy technologies will occur, with both National Grid and the Advanced Propulsion Centre Roadmap[10] estimating mass deployment of V2X energy technologies after 2025. When mass deployment begins and the speed of which V2X energy technologies enter the market, rely on the removal of several barriers as shown in section 3. For example, the development and commercial application of international charging standards, and the consumer uptake.

The UK is a world-leader in V2X energy technologies, with the most innovation projects and the largest domestic demonstration[11], but there is a global interest in V2X energy technologies. As part of the InnovateUK funded competitions, the V2G Hub (https://www.v2g-hub.com) was developed to track V2X demonstration projects around the world and at the time of writing lists 83 projects in 22 countries; this highlights the international interest in V2X.

Questions

3. When and how do you think V2X energy technologies will deploy in the future?

2.3 Business Models

Though V2X energy technologies have been technically feasible for over a decade, the challenge has been in developing viable commercial models which will deliver the potential savings and revenues.

V2X energy technologies have broadly two types of value streams available – behind-the-meter or exporting, which also might operate in a hybrid approach.

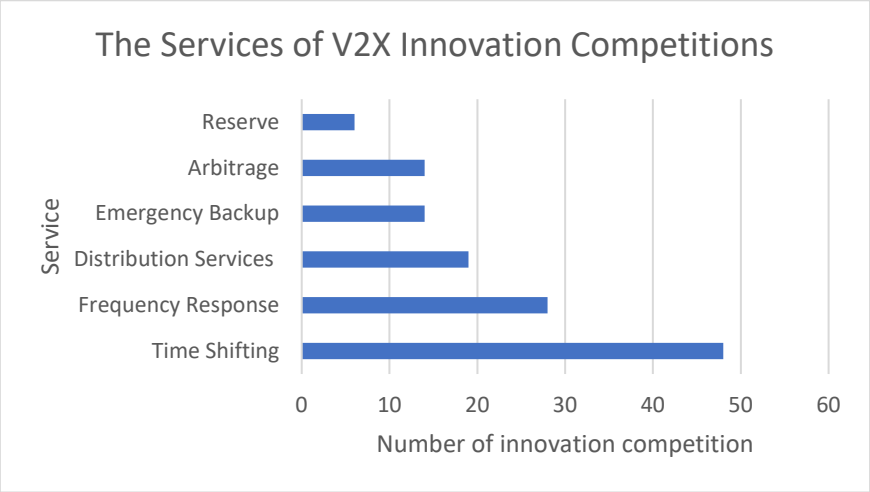
1. For behind-the-meter business models the V2X technology is used as part of the building's energy management; helping to avoid periods of high electricity prices, provide additional resilience and maximise use of intermittent generation. V2X energy technologies can also be used to increase resilience and security of supply but this has been a larger focus in East Asia, especially following the Fukushima Daiichi nuclear disaster in 2011, than in the UK.

[8] Data of registrations from the Society of Motor Manufacturers and Traders https://www.smmt.co.uk/vehicle-data/car-registrations/
[9] National Grid (2020), FES2020 Leading the Way Scenario: https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents
[10] Advanced Propulsion Centre UK, Technology Roadmaps, https://www.apcuk.co.uk/technology-roadmaps/
[11] The UK has 17 V2X projects as shown by the https://www.v2g-hub.com.

2. Business models that export to the electrical grid add additional revenue streams to the behind-the-meter models through providing grid services and price arbitrage which is commonly through an aggregator.

Figure 2 shows the services offered by the V2X projects listed on the V2G Hub site at the time of writing this document[12].

Figure 2: Services offered by V2X projects listed on the V2G Hub.



Research has suggested that without providing grid services, the majority of behind-the-meter value from V2X energy technologies could be provided through smart charging alone without the need for the significant cost of the V2X equipment[13]. That said, the V2X business case may still stack up for fleets with the larger energy consumption, more onsite intermittent generation and greater number of vehicles resulting in a focus on behind-the-meter.

The transition to a net zero energy system is expected to result in electricity trading markets in the second half of this decade that will be very different than those of today. This could offer new business models but also reduce sources of revenue currently available. For example, the transition of Distributed Network Operators to Distributed Systems Operators (DNO-DSO transition) could provide a number of new markets, such as those to address localised congestion of the network, and Ofgem's network charge reforms could offer opportunities through more price signalling. Changing markets may also remove revenue opportunities though with the predicted saturation of Electricity Systems Operator frequency services, which currently provide the bulk of revenue from V2X grid services, and the removal of embedded benefits, which provide behind-the-meter revenue, from Ofgem's Targeted Charging Review.

Questions

4. What are the potential business models for V2X energy technologies in the future energy system?

[12] V2G Hub, https://www.v2g-hub.com/insights
[13] Cenex (2019), Understanding the True Value of V2G, https://esc-non-prod.s3.eu-west-2.amazonaws.com/2019/06/Cenex-WP-2-True-Value-of-V2G-Report.pdf

2.4 Consumers

Realising the potential value of V2X to consumers, whether individuals or businesses, is key to enabling the mass deployment of the technology.

According to the RAC, the average domestic car is in use for only 4% of its time[14] and V2X energy technologies enable a use for the EV battery, with the savings and revenues mentioned above, whilst it is parked. Research from Cenex suggests that V2X energy technologies could offer up to £436 of revenue annually to a domestic consumer, on top of savings from smart charging, under current market conditions[15]. This maximum value applied to only a select consumer type (75% plug-in rates, and with solar PV installed) and for other consumer types the value was lower. Mass-deployment of V2X energy technologies will require business cases that work for the majority of consumers.

Consumer behaviour is an important element in realising the benefits of V2X, with the above example showing that plug-in rates are key and although most domestic cars are parked at the home for the majority of their time, the average EV is plugged in only 30% of the time[16]. Innovation competitions and the roll-out of smart charging should help induce needed beneficial behavioural changes (for example increasing plug-in rates) but as shown in section 3 there are still barriers around range-anxiety.

Access to charging infrastructure is an essential component in the transition to EVs, helping to reduce range anxiety and increase EV penetration into rural areas. There are a number of different charging systems for an EV, of which the CHAdeMO system (and CCS in the near future) is capable of providing V2X. Different vehicle manufacturers favour a different charging system and the current lack of interoperability can restrict consumer choice, though there are efforts to address this from vehicle manufacturers.

The high upfront hardware costs and today's limited choice of V2X capable vehicle models available in the UK further restrict the number of consumers able to currently benefit from V2X energy technologies. New consumer propositions, such as the packages that include the car and bidirectional charger, as well as falling hardware costs, (though these are predicted to still be approximately £1,000 in 2030[17]), will help reduce the impact of these barriers. Another option would be for the AC-DC converter to be onboard the vehicle, which will reduce the need for the consumer to purchase and installation of an additional converter but would then have to conform to the vehicle design envelope constraints and could increase the cost of the vehicle.

[14] RAC Foundation Motoring FAQs, https://www.racfoundation.org/motoring-faqs/mobility#a5
[15] Cenex (2019), Understanding the True Value of V2G, https://www.cenex.co.uk/app/uploads/2019/10/True-Value-of-V2G-Report.pdf
[16] Cenex (2019), Understanding the True Value of V2G, https://www.cenex.co.uk/app/uploads/2019/10/True-Value-of-V2G-Report.pdf
[17] Element Energy (2019), Requirements for Market Scale-up, https://esc-non-prod.s3.eu-west-2.amazonaws.com/2019/06/V2GB_WP-4-report-Requirements-for-market-scale-up.pdf

Questions

5. How can government and industry enable and incentivise consumers to realise the full value of V2X energy technologies?

Summary of questions in chapter 2

1. What role do you think V2X energy technologies will play in a future energy system?
2. How do you think V2X energy technologies will interact with other flexibility technologies in a future energy system?
3. When and how do you think V2X energy technologies will deploy in the future?
4. What are the potential business models for V2X energy technologies in the future energy system?
5. How can government and industry enable and incentivise consumers to realise the full value of V2X energy technologies?

3. Understanding the barriers to uptake of V2X

To create a strategy to maximise the opportunities for a flexible energy system from electric vehicle charging, government needs to identify and understand the current (and potential) barriers and to recognise if intervention is required. There are a number of barriers which may slow or prevent the mass deployment of V2X energy technologies, these include V2X specific barriers and those shared with other flexibility technologies.

In the below tables we have listed the barriers identified from the InnovateUK competitions and from our literature review. The barriers have been grouped into 3 classes: Technology, Information, System. The 2021 Smart Systems and Flexibility Plan[18] details the approach of government and Ofgem in addressing the barriers to flexibility technologies in general, for example including the access to markets.

3.1 Technical Barriers

Potential Barrier Identified	**Impact**
Limited choice of vehicle models capable of V2X	As of March 2021, the UK had less than 5 vehicle models capable of V2X. Lack of option will prevent mass adoption due to consumer preference (e.g. loyalty to manufacturers) and consumer needs.
High cost of AC-DC converters.	V2X energy technologies require AC to DC electrical conversion in both directions; into and from the vehicle battery (e.g. DC to AC conversion for discharging). The two options are to have external converters or converters built into the car that care V2X capable. Currently the majority of V2X energy technologies use external chargepoints which can cost up to £6,000. High upfront cost prevents mass adoption and weakens the business case compared to smart charging alone.
Complexity between V2X charging protocols.	There are two charging systems capable of V2X – CHAdeMO and CCS (though CCS is

[18] BEIS and Ofgem (2021), Smart Systems and Flexibility Plan, https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

	not yet available). Currently a vehicle or charger are designed to one standard or the other. This can lock consumers into a manufacturer if the purchase an expensive home charger and limits the available public chargepoints.
The impact of V2X activities on battery health.	The EV battery constitutes the main cost of the vehicle and so V2X activities must balance revenue potential with protecting the battery health. There is uncertainty across the literature as to the impact of different charging systems with research from Warwick University indicating that controlled charging could reduce battery degradation[19]. The battery performance for energy storage over its lifetime will determine the actual achievable revenues.

3.2 Information Barriers

Potential Barrier Identified	**Potential Impact of Barrier**
Lack of clarity around how V2X will affect vehicle warranties.	Uncertainty in the literature as to how bidirectional charging will impact battery health has led to uncertainty as to the impact on vehicle warranties. For InnovateUK competitions, the manufacturer stated that V2X activities would not void the warranty. Further clarifications on the impact will reassure consumers.
Low levels of the cars being plugged in and available for V2X when stationary.	V2X energy technologies respond to price signals, in order to capitalise on these signals the EV needs to be available for the maximum amount of time. Change of behaviour is needed to ensure V2X benefits are realised.
Consumer concerns around impacts on the availability of their EV.	Range-anxiety can be compounded by the idea of the EV battery reexporting its

[19] https://warwick.ac.uk/newsandevents/pressreleases/56m_vehicle-2-grid_project/

	electricity. It is essential that the consumers fully understand the proposition and how they can control when the EV is available. A lack of information may reduce take up by not addressing these concerns.
Low consumer awareness of the V2X proposition.	Lack of information, misunderstanding or a perception that the process is complicated may reduce take up. It is then essential that the consumers fully understand the proposition
User friendliness of V2X systems.	Designing V2X systems that are easy to use and consumer friendly is essential to achieve high levels of deployment. Innovation competitions and smart charging will help with this but there needs to be a focus on all consumer types (not just the early movers) including those with a physical or mental impairment. Additional complication may deter some consumers.

3.3 System Barriers

Potential Barrier Identified	**Potential Impact of Barrier**
Ensuring V2X can compete within markets on an equal basis.	V2X energy technologies have their own specific requirements and strengths when compared to other technologies (such as domestic storage or demand-side response) and so it is important that there are no unintended barriers in the design of markets e.g. could V2X support the capacity market if V2X energy technologies are allowed to enter?
Poor business case for domestic aggregators.	Research suggests that there are currently low profits for aggregators in using domestic V2X energy technologies due to low margins. This business case is improved for

	aggregators for commercial fleets[20]. As shown above the additional value for V2G when compared to smart charging comes from providing grid services. Domestic consumers need an aggregator to provide these services and so it is essential to have business models that work.
Export Limits	When adding generation or storage to a site, such as V2X energy technologies, consumers may have to restrict their net export to avoid paying for network reinforcement upstream. This process can be costly and time consuming, creating barriers to mass deployment.
The business case currently only works for a few specific user types (e.g. domestic users with high plug-in rates and home solar PV).	For mass deployment the benefits would have to make economic sense for a wider range of use cases

Summary of questions in chapter 3

6. Do you agree with the barriers identified and are there any barriers missing?
7. How would you prioritise the need to address the barriers, including any additional barriers that are missing?
8. Which barriers do you believe require intervention from government and what form should that intervention take?
9. What action should industry or other stakeholders take to address the barriers identified?
10. Where should future innovation funding be focused to most aid the development and deployment of V2X energy technologies?

[20] Nissan Motor GB, Imperial College, E.ON Drive (2021), The drive towards a low-carbon grid, https://www.eonenergy.com/content/dam/eon-energy-com/Files/vehicle-to-grid/The%20Drive%20Towards%20A%20Low-Carbon%20Grid%20Whitepaper.pdf. For a commercial fleet, an aggregator could earn up to £1250 per EV.

4. Summary of questions

Questions

1. What role do you think V2X energy technologies will play in a future energy system?
2. How do you think V2X energy technologies will interact with other flexibility technologies in a future energy system?
3. When and how do you think V2X energy technologies will deploy in the future?
4. What are the potential business models for V2X energy technologies in the future energy system?
5. How can government and industry enable and incentivise consumers to realise the full value of V2X energy technologies?
6. Do you agree with the barriers identified and are there any barriers missing?
7. How would you prioritise the need to address the barriers, including any additional barriers that are missing?
8. Which barriers do you believe require intervention from government and what form should that intervention take?
9. What action should industry or other stakeholders take to address the barriers identified?
10. Where should future innovation funding be focused to most aid the development and deployment of V2X energy technologies?

This Call for Evidence is available from:

https://www.gov.uk/government/consultations/role-of-vehicle-to-x-technologies-in-a-net-zero-energy-system-call-for-evidence

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