Department for
Business, Energy
& Industrial Strategy

Role of Vehicle-to-X energy technologies in a net zero energy system

Summary of responses received to the Call for Evidence

January 2023

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Introduction

Decarbonisation of transport, which contributed 24% of UK domestic greenhouse gas emissions in 2020,[1] is critical to reaching the UK's legally binding target of net zero emissions by 2050.

The phase out of the sale of new petrol and diesel cars and vans by 2030[2] will lead to an estimated 10 million electric vehicles (EVs) by 2030,[3] 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 our electricity supply to increasingly come from variable sources such as wind and solar.

To achieve a cost-effective transition to net zero it will be important to manage these changes in supply and demand through effectively deploying and using flexibility; the ability to shift, in time or location, energy consumption or generation to balance supply and demand. The 2021 Smart Systems and Flexibility Plan set out how we will transition to a smart, flexible, decarbonised energy system.[4] Furthermore, last year's consultation on delivering a smart and secure electricity system set out our proposals for a regulatory framework for energy smart appliances and flexibility service providers.[5] Many EVs are stationary for the vast majority of the day so can offer a potentially significant source of distributed energy flexibility, providing energy system benefits as well as financial benefits to EV owners. The EV Smart Charging Action Plan published alongside this document sets out the actions that are being undertaken by Government and Ofgem to maximise the energy flexibility opportunity from EVs. Currently this flexibility predominantly involves unidirectional smart charging, which enables the timing or rate of vehicle charging to be modified. However, the ability to share electricity from the vehicle battery, which is referred to as Vehicle-to-X (V2X) in this report, offers more energy flexibility potential and will be increasingly important in future.

Vehicle-to-X energy technologies enable bidirectional flexibility to be unlocked from EVs and for them to be deployed as mobile battery storage; electricity can be exported from an EV back to a system, such as to an appliance (Vehicle-to-load, V2L), to a home (V2H) or a building such as a business (V2B) to further manage behind-the-meter energy use, or back to the electricity grid (V2G) to participate in energy markets and services. V2X energy, where "X" stands for everything, is the umbrella term for all forms of this technology and was used in our

[1] **2020 UK greenhouse gas emissions: final figures – statistical release**: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1051408/2020-final-greenhouse-gas-emissions-statistical-release.pdf

[2] **Transitioning to zero emission cars and vans: 2035 delivery plan**: https://www.gov.uk/government/publications/transitioning-to-zero-emission-cars-and-vans-2035-delivery-plan

[3] **UK electric vehicle infrastructure strategy**: https://www.gov.uk/government/publications/uk-electric-vehicle-infrastructure-strategy

[4] **Transitioning to a net zero energy system: smart systems and flexibility plan 2021**: https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021

[5] **Delivering a smart and secure electricity system:** https://www.gov.uk/government/consultations/delivering-a-smart-and-secure-electricity-system-the-interoperability-and-cyber-security-of-energy-smart-appliances-and-remote-load-control

Call for Evidence to show that all applications of the technology and business models are being considered at this early stage.

V2X energy offers potentially significant benefits to the consumer, the energy system and to parties such as EV and charge point manufacturers, energy suppliers, and flexibility service providers. However, though V2X bidirectional charging has been technically feasible for over a decade, the challenge has been to reach widespread commercial deployment, with barriers including high equipment costs and difficulties developing viable business models. There are a small number of bidirectional capable cars, charge points and energy products on the market, and there have been trials worldwide studying up to hundreds of vehicles at a time. The UK is a leader in bidirectional charging innovation; in 2017, BEIS and the Office for Zero Emission Vehicles (OZEV) provided up to £30m of funding to 20 Vehicle-to-Grid projects, which took place between 2018-2022. The advances and experience gained from these competitions, as well as the wider accelerating uptake of EVs, have started to remove some barriers to V2X energy technology.

A Call for Evidence[6] was published last year to better understand the role of V2X energy technologies in a net zero energy system, including when and how business models and consumer tariffs/propositions may deploy, the barriers that exist to this, and the actions that may be required from Government and industry. This document summarises the responses from stakeholders to questions on these topics, and the forthcoming strategic direction of Government to facilitate this emerging source of flexibility, including a new £12.6m V2X innovation programme launched in March 2022.[7]

[6] **Role of Vehicle-to-X energy technologies in a net zero energy system: call for evidence**: https://www.gov.uk/government/consultations/role-of-vehicle-to-x-technologies-in-a-net-zero-energy-system-call-for-evidence

[7] **V2X Innovation Programme**: https://www.gov.uk/government/publications/v2x-innovation-programme

Summaries of responses

This section contains summaries of the responses to each question presented in the Call for Evidence collected in the period 20 July to 21 October 2021; the number of respondents is in brackets, out of 50 total respondents. More detail can be found in the more in-depth summaries provided in Annex 1. Annex 2 provides a Glossary defining some of the key terms used throughout this document.

Understanding the current and future landscape

Role in energy system

Q1: What role do you think V2X energy technologies will play in a future energy system? (44 responses out of 50 total respondents)

The majority of respondents were positive about the potential size of the role V2X will play in a future energy system, though with some uncertainty about the rate of its evolution. Respondents were positive about the potential wider system benefits of V2X, particularly in helping to efficiently integrate renewable energy sources and reduce the need for network reinforcement, as well as about the benefits (primarily financial) for individual consumers. They discussed the potential role of both behind-the-meter (exporting to a home, building or site) and Vehicle-to-Grid (exporting to the wider energy system) modes of operation in providing flexibility. Respondents highlighted various barriers and enabling factors that they thought would impact on take up of V2X.

Q2: How do you think V2X energy technologies will interact with other flexibility technologies in a future energy system? (39 responses out of 50 total respondents)

Respondents discussed several different types of interaction – for example, in energy system markets and services; choices or complementing factors at particular locations; and communication between technologies. Many discussed how interactions would vary according to business models, and the role of aggregators in V2G business models, who may be aggregating different technologies together for export to the grid. The importance of level-playing fields between different technologies competing in energy system markets and services was also emphasised. Some mentioned the importance of integration and effective communication between V2X energy and other flexibility technologies. The interaction of V2X with stationary battery storage was particularly discussed, at potential specific types of deployment locations as well as in the wider energy system, with respondents highlighting similarities and differences between the technologies, and mixed views presented on the likelihood of their simultaneous deployment at a given location. Respondents also considered the interaction between V2X and other forms of flexibility, primarily unidirectional smart charging and electrified heating.

Deployment

Q3: When and how do you think V2X energy technologies will deploy in the future? (41 responses out of 50 total respondents)

Respondents to this question highlighted key barriers determining the deployment timeline of V2X, with a popular view being that progression in areas such as standards, the availability of V2X-compatible EVs, and the suitability of the energy system for V2X, would facilitate more mainstream V2X deployment by 2025. Many considered that behind-the-meter business cases (such as V2H and V2B) would deploy earlier than V2G, given a lesser need for scale of the technology for aggregation; when V2G did deploy, some early use cases were highlighted, such as fleets. Regarding the location of bidirectional conversion, and whether this was likely to occur onboard the vehicle (AC V2X technology) or inside a charge point (DC V2X technology), there were mixed views on how these technologies may differently deploy, with no clear consensus expressed.

Business models

Q4: What are the potential business models for V2X energy technologies in the future energy system? (40 responses out of 50 total respondents)

Respondents agreed with the different possibilities of behind-the-meter and exporting business models set out in the Call for Evidence. Responses suggested precise business models for particular consumers would depend on the characteristics of the consumer – for example, the benefits of a behind-the-meter business model would likely depend on the interplay between a user's electricity consumption and EV plug-in patterns, and whether they have behind-the-meter generation. The opportunities and challenges associated with different business models were discussed, and how different actors would interact in each, including the role of aggregators in V2G business models.

Consumers

Q5: How can Government and industry enable and incentivise consumers to realise the full value of V2X energy technologies? (46 responses out of 50 total respondents)

Many respondents highlighted a need for increased numbers of V2X-capable EVs, and a lower cost of entry for consumers to V2X, including potentially through financial support to buy V2X charge points. Many noted the need for clarity, transparency and certainty in the availability of revenue to provide sufficient financial benefit to incentivise consumers. The benefit of consumer education was a common point, particularly to address potential concerns about the impact of V2X on EV battery health. V2X tariffs and systems that are compelling to consumers, and easy to use, while still leaving them in control and appropriately protected (including regarding interoperability) were also highlighted as important. Several respondents also noted that difficulties in connecting V2X charge points to networks (in terms of time, complexity and cost, and locational variations in these factors) would disincentive consumers. Finally, respondents noted that any measures to incentivise consumers should not disadvantage those without private parking or EVs, or vulnerable consumers.

Understanding the barriers to uptake of V2X

Q6: Do you agree with the barriers identified and are there any barriers missing? (50 responses out of 50 total respondents)

The call for evidence proposed classifying barriers into three categories: 'Technical', 'Information' and 'System'. The majority of respondents agreed with the barriers suggested – 29 respondents explicitly stated their agreement, and only one their disagreement. Respondents did also suggest related and additional barriers, as well as mitigations they considered would reduce the severity of barriers.

Q7: How would you prioritise the need to address the barriers, including any additional barriers that are missing? (41 responses out of 50 total respondents)

In general, respondents considered the technology and system barriers the most important to prioritise. Limited choice of V2X-capable vehicle models, the high cost of charge points, and potential unequal competition in markets were especially highlighted. Some respondents particularly wanted to stress the need for appropriate standards for V2X, wider market design for flexibility, and the connection process required by the Distribution Network Operator (DNO) because of the conditions placed on domestic export assets, as important.

Q8: Which barriers do you believe require intervention from Government and what form should that intervention take? (46 responses out of 50 total respondents)

Regarding technical barriers, there were varying views as to the degree of Government intervention that would be beneficial, in areas such as increasing the number of V2X-capable vehicles, reducing the cost of charge points, and standards and regulation. For example, some stakeholders did propose more significant policy interventions such as mandating bidirectional capability of EVs, or specific subsidies for bidirectional hardware. Concerning information barriers, many stakeholders believed it was appropriate for Government to ensure there is trusted information on V2X. System barriers were particularly highlighted as important for Government to address, to provide networks and markets appropriate for V2X.

Q9: What action should industry or other stakeholders take to address the barriers identified? (40 responses out of 50 total respondents)

Respondents particularly highlighted that a) EV manufacturers needed to develop more V2X-capable EVs and consider the impact of V2X on vehicle batteries, and b) that industry generally needed to develop and adopt appropriate standards. Information barriers were considered less important for industry to address, though some highlighted ways in which marketing of V2X goods and services could help overcome these. Many actions were suggested for DNOs in how to overcome markets and networks barriers, and for wider industry in developing business cases for different consumers.

Q10: Where should future innovation funding be focused to most aid the development and deployment of V2X energy technologies? (35 responses out of 50 total respondents)

Generally, respondents considered that future innovation funding should be focussed on:

- cost reduction of V2X hardware
- AC bidirectional charging technology
- CCS (Combined Charging System) DC bidirectional charging technology
- investigating V2X impact on battery health
- interaction with other low carbon technologies, such as heat pumps
- investigating involvement in energy markets and services
- developing new business models
- considering consumer engagement with business models

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Conclusions and next steps

Understanding the current and future landscape

Role in energy system

Q1: The responses confirmed that stakeholders consider that V2X energy can offer a significant source of flexibility, providing benefits to the energy system and consumers. BEIS has subsequently announced £12.6m innovation funding to address barriers to enabling energy flexibility from V2X, which aims to unlock and expand the flexibility potential of V2X technologies and business models, accelerate commercialisation of V2X technologies and services, increase business and consumer interest in V2X, and bring together diverse stakeholders across the energy and transport sector. Government will continue to include V2X in the scope of further EV charge point, battery storage or wider smart systems and flexibility regulation where appropriate, and engage with industry to encourage developments in the area and assess the need for further specific intervention.

Q2: Stakeholders consider V2X energy should be treated holistically and on a level playing field with other sources of aggregated small scale energy flexibility. Government and Ofgem will continue to work towards an enabling regulatory framework in support of V2X flexibility. An enabling regulatory framework for distributed flexibility generally is being considered through consultation on delivering a smart and secure electricity system. Government will continue to monitor the business developments in this area to consider whether specific action is required for barriers that are unique to the V2X energy technology.

Deployment

Q3: Stakeholders consider that several enabling factors over the coming years will help to facilitate V2X energy, enabling more mainstream deployment from 2025. Government will continue to monitor standards, the availability of bidirectional charging-compatible EVs, and the suitability of energy markets for V2X, while seeking to stimulate development in these areas through the V2X innovation programme, and consider the need for further specific intervention to ensure growth of this technology by 2025.

Business models

Q4: There were a variety of views on which business model or models might be the most successful in the future. The innovation programme includes within scope investigation of both behind-the-meter business models, and those involving export to the grid through a variety of different mechanisms. BEIS and Ofgem will continue to monitor the outcomes of these studies and the evolution of these business models in the market.

Consumers

Q5: The responses to this question underlined that consumers need a clear business use case to be incentivised to engage in V2X energy, and to be reassured regarding the impact of V2X on EV batteries, and that V2X should be made easy whilst still leaving consumers in control. These points have been incorporated in the design of the V2X innovation programme, in order to increase consumer interest in V2X energy. Government will continue to monitor consumer attitudes towards V2X energy and consider further interventions to enable and incentivise engagement with this technology.

Understanding the barriers to uptake of V2X energy

Q 6-10: Stakeholders agreed with the list of barriers stated but proposed some barriers that had not been explicitly stated in the Call for Evidence. These were primarily (with the exception of "DNO connection process") more general barriers to flexibility discussed in the Smart Systems and Flexibility Plan, which stakeholders considered were particularly pertinent for V2X energy. There was useful feedback on which priorities should be addressed first, where Government needs to act, where innovation funding is still needed, and which barriers need additional action from industry. These views are summarised in the table below, with additional barriers not included originally highlighted with an asterisk (*).

The list of barriers was presented without prioritisation in the Call for Evidence. Based on stakeholder feedback and further consideration from Government, the below table proposes priorities for addressing the barriers to facilitating increased V2X deployment by 2025. These have been assigned as either Low, Medium, or High, according to how significantly the barriers would be likely to impede V2X becoming more commercially viable by 2025, and this has informed Government action to address these barriers. However, we recognise that while the Government can create a supportive policy environment and address regulatory barriers, the pace of commercialisation will be led by industry. We therefore also highlight where in particular we think industry will need to play a key role.

	Barrier	**Priority**	**Proposals to address**
Technical	Limited choice of vehicle models capable of V2X bidirectional charging	High	We expect industry to continue to develop EVs capable of V2X, including development of AC and CCS technologies, stimulated by demonstration opportunities in the V2X innovation programme.
	High cost of AC-DC converters	High	We expect industry to continue to develop new and innovative V2X charge points and on-board bidirectional control, continuing the cost decreases seen during the last few years, including development of CCS and AC

	Barrier	Priority	Proposals to address
			technologies, stimulated by the V2X innovation programme.
	Complexity between V2X charging protocols	Low	While stakeholders did not consider this a significant issue, the usage of V2X energy with different protocols will continue to be monitored and potential barriers considered.
	*Standards for communication between charge point and flexibility service providers	High	Government is currently consulting on appropriate standards for communicating between Energy Smart Appliances (ESAs) in general and flexibility (or demand side response) service providers, and appropriate cyber security requirements for ESAs and demand side response service providers.[8]
	*Cyber Security	High	
	The impact of V2X activities on battery health	High	We expect industry, with Government support, to undertake research, innovation and dissemination on battery performance in V2X, and use this to inform EV warranties.
Information	Lack of clarity around how V2X will affect vehicle warranties	Medium	
	Low levels of the cars being plugged in and available for V2X when stationary	Low	We expect industry, encouraged by the V2X innovation programme, to develop technologies and business models that are easy to use, incentivise users to plug in, are compatible with their mobility requirements, and which make clear to consumers the benefits of V2X. The EV Smart Charging Action Plan sets out steps to help increase trust and confidence in smart charging so that consumers will be more familiar with the principles of managed charging. While this will primarily concern unidirectional smart charging in the near term, the need for increasing V2X-specific engagement will be monitored as V2X energy becomes more mainstream.
	Consumer concerns around impacts on the availability of their EV	Medium	
	Low consumer awareness of the V2X proposition	Medium	
	User friendliness of V2X systems	Low	

[8] **Delivering a smart and secure electricity system:** https://www.gov.uk/government/consultations/delivering-a-smart-and-secure-electricity-system-the-interoperability-and-cyber-security-of-energy-smart-appliances-and-remote-load-control

	Barrier	Priority	Proposals to address
System	Ensuring V2X energy can compete within markets on an equal basis	High	We expect the Electricity System Operator and Distribution Network Operators, consistent with actions set out in the Smart Systems and Flexibility Plan, to develop markets that reward flexibility. Government will encourage EV participation in energy flexibility, including through the V2X innovation programme, and monitor specific EV/V2X barriers that may arise. Government is undertaking a Review of Electricity Market Arrangements (REMA), which will identify and implement the reforms to electricity market arrangements needed to drive the necessary investment in, and efficient operation of a secure, low carbon electricity system by 2035.[9] The review will consider whether stronger locational and/or temporal signals are needed in the wholesale and balancing markets.
	*Market design for flexibility	High	
	Poor business case for domestic aggregators	High	We expect aggregators, energy suppliers and other industry actors, enabled by the actions in the Smart Systems and Flexibility Plan and EV Smart Charging Action Plan which set out how consumers will be incentivised to offer flexibility, and stimulated by opportunities in the V2X innovation programme, to investigate business models and business cases that will work for different actors and different types of consumers. This is particularly expected to be behind-the-meter applications in the near term.
	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).	High	
	*DNO connection process	High	We expect DNOs to improve the efficiency and consistency of the V2X connection process alongside wider improvements to connections for low carbon technologies; the EV Smart Charging Action Plan commits BEIS

[9] **Review of electricity market arrangements**: https://www.gov.uk/government/consultations/review-of-electricity-market-arrangements

	Barrier	Priority	Proposals to address
			and Ofgem to work with the Energy Networks Association to assist with this.
	Export limits *Networks appropriate for V2X	Medium	We expect Ofgem and DNOs, consistent with actions in the Smart Systems and Flexibility Plan and EV Smart Charging Action Plan, to enable local networks that integrate EVs efficiently, including by effectively utilising the flexibility they can provide.

Government considers that V2X energy offers a very promising opportunity to maximise the flexibility potential offered by EVs. Over the coming years, we expect to see from industry an increase in the number of V2X-capable EVs and charge points, and a reduction in the cost of entry for consumers engaging with this technology. We also expect an increase in the number of services and business propositions that enable consumers to earn revenue from V2X technology, particularly for behind-the-meter applications. Progression on technological and system barriers are likely to be mutually reinforcing, with more choice, and lower cost hardware stimulating business model development and vice versa, and the development of V2X energy goods and services helping to address informational barriers. Overall, this should lead to increasing numbers of domestic and non-domestic consumers engaging in bidirectional charging, with associated benefits for themselves and the energy system.

The actions from Government and Ofgem described above, detailed across the Smart Systems and Flexibility Plan, and EV Smart Charging Action Plan, will assist to progressively remove some of the barriers that have been identified to V2X energy. This will enable a transition to a smart, flexible system effectively integrating and utilising electrified mobility, where the technologies and services that are currently being developed will be able to flourish and gain increasing uptake, and further developments in the market will be incentivised. Government also recognises that this is a nascent, emerging technology. Some interventions suggested by stakeholders through the Call for Evidence are not considered appropriate at this stage, for example mandating bidirectional capability of vehicles, or specific subsidies for bidirectional hardware.

Government will continue to engage with industry to encourage and monitor the V2X market as it develops and consider what further actions may be needed to support and enable this sector to help maximise the opportunity for flexibility from bidirectional EV charging.

Annex 1: Full response summaries

50 responses were received to the Call for Evidence. The respondents fell into the following categories:

- Local government or council organisation (2)
- Individual (1)
- Trade association (5)
- Charge point manufacturer (5)
- EV manufacturer (3)
- Consultancy (4)
- Energy supplier (7)
- Distribution Network Operator, DNO (4)
- Transmission system operator (2)
- Academic organisation (3)
- Software solution provider (5)
- Consumer organisation (4)
- Other (5)

This document does not necessarily capture every view each respondent expressed but aims to summarise the more frequently mentioned points. The approximate number of respondents who expressed a particular view is written in brackets within each sentence. This is according to the descriptors of:

- A few – 2-3
- Some – 4-9
- Many – 10 or more

Understanding the current and future landscape

Role in energy system

Q1: What role do you think V2X energy technologies will play in a future energy system? (44)

Of those who expressed either a positive or negative view on the extent of the potential role of V2X in a future system, **the majority were positive** (26) - “significant” (7) being the most widely used adjective. Only a few (2) responses considered there would be a “limited” or “very

limited" role for V2X. Some (5) respondents **expressed uncertainty** regarding the potential role V2X may play, both due to factors related to the early stage of development of V2X, as well as the uncertain future evolution of alternative flexibility technologies and the energy system more generally.

Some (5) respondents pointed to the National Grid ESO Future Energy Scenarios[10] regarding this "significant" role, highlighting the flexibility V2X has been estimated to be able to contribute by 2050. A few (2) stakeholders noted the wide range in V2X flexibility estimated between scenarios as evidencing the uncertainty of the role of V2X. One DNO highlighted the important role of V2X included in their Distribution Future Energy Scenarios.

In terms of the **system benefits of V2X** in a future energy system, the most frequently mentioned by many (15) was the ability of V2X flexibility to facilitate the integration of renewables and enable a more efficient use of such intermittent resources, thus reducing curtailment. Some (8) pointed to the ability of V2X to reduce peak electricity demand, with some (9) noting V2X would enable mitigation of the increased demand associated with the electrification of heat and transport. One DNO noted that V2X would be a source of flexibility deployed simultaneously with EVs, so well aligned to the flexibility needs created by additional demand from EVs. Many (11) noted the reduced need for network reinforcement associated with demand reduction, primarily from a cost perspective but also given the environmental implications of reinforcement. A few (2) also pointed to the benefits of V2X deferring the need for network reinforcement - one DNO noted that this enables improved assessment of future-proofing requirement, improves deliverability and avoids surges in reinforcement work, and allows any reinforcement to be aligned with the natural replacement and upgrading of equipment. However, one trade association cautioned that V2X should not be considered as a panacea for network issues.

Some (8) also highlighted a potential reduced need for capital investment in generation capacity due to V2X energy flexibility, and reduced system costs due to V2X energy helping provide efficient grid services (10). Some (5) also mentioned the benefits of increased utilisation of EV batteries, and the associated reduction in need for standalone battery storage (8), with a few (2) noting the reduced environmental impact of less raw material usage.

Several respondents pointed to studies quantifying these energy system benefits – a few (3) pointed to a study by Ovo Energy and Imperial College London[11] estimating the whole-system benefits of EV flexibility as being worth £3.5bn/year by 2040, with £2.4bn of these savings being associated with bidirectional charging over and above the savings captured by unidirectional smart charging. Others (3) pointed to a study prepared by Nissan, EON and Imperial College London[12] suggesting V2X energy cost-savings of £400-900m/year in the

[10] **National Grid ESO Future Energy Scenarios:** https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021
[11] **A blueprint for a post-carbon society**: https://www.ovobyus.com/m/1d7f8a93e4685f9f/original/blueprintforapostcarbonsocietypdf-compressed.pdf
[12] **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

period 2025-2030. Some (6) respondents noted that these system benefits would translate to lower electricity bills for all consumers.

Many (21) respondents pointed to the additional **consumer benefits of V2X energy** in enabling consumers to generate revenue or reduce their electricity bills. Some (7) suggested that the revenue potential of V2X energy would provide an additional reason to motivate consumers (including businesses) to switch to electrified transport, while some (5) also suggested consumers would appreciate the sustainability perspective and being able to play a role in Net Zero.

In terms of the identity of "X", many stakeholders mentioned a **behind-the-meter/V2H/V2B role**, enabling the optimisation of behind-the-meter renewables (particularly solar) (6), savings on electricity bills to be made using time-of-use tariffs (9), a reduction in connection costs or required reinforcements (1), and providing a source of resilience (7) to reduce exposure to power system disruptions.

Some (4) respondents believed behind-the-meter applications would be the primary/sole use of V2X energy, whereas a few (2) simply believed it would be the first mass usage of V2X, or one of several different roles (10). Many respondents mentioned the potential **role of V2G** in providing grid services such as frequency response services to control energy system frequency (12), in providing local network congestion/constraint avoidance and management (7), and in being compensated for deferment of low voltage network reinforcement (3). However, a few (3) respondents noted the potential difficulties in V2X providing such services, including that they are often location specific, needed for prolonged periods, and need reliability in asset availability. While some (4) noted a potential role in wholesale and balancing markets, one EV manufacturer stressed they believed V2X should be primarily for providing power for a short amount of time, rather than over prolonged periods. A few (3) respondents mentioned the need for stacking/combination of these revenue sources to maximise potential revenue and minimise volatility risk. One respondent mentioned the importance of aggregators in facilitating involvement in markets**. More information regarding business models was provided in response to Q4.**

Regarding the **type of consumers** engaged in V2X energy, one charge point manufacturer believed V2X would only be for "tech-oriented consumers", while a few (2) stressed that it would be particularly significant for fleets. A few (3) respondents suggested V2X would not be available/viable for public charging, while one stressed the need for the benefits of V2X technologies to be accessible to all. Concerning types of V2X technology, one charge point manufacturer stated they believed only AC bidirectional charging had a role to play.

Those who foresaw a more limited role justified this for several different reasons. Those who were more optimistic often caveated that the potential role they envisaged depended on several barriers being overcome, or certain enabling factors progressing**. More detail regarding views on barriers was included in response to Q6 and Q7.**

Some (7) respondents believed V2X energy would be facilitated by smart metering, Market-wide Half-hourly Settlement (MHHS), and an increasing amount of innovative and

tailored/bespoke dynamic tariffs offered to consumers, as well as by the potential development of peer-to-peer trading (3). However, a few (2) respondents noted that the benefits of such tariffs should not be at the expense of exposing vulnerable consumers to higher costs.

Q2: How do you think V2X energy technologies will interact with other flexibility technologies in a future energy system? (39)

There was agreement among respondents that **increasing amounts of flexibility** would be required in a Net Zero energy system, from a range of technologies – one DNO noted the benefit for system resilience in having a diversity of sources of flexibility.

One respondent noted the **uncertainty** in how V2X energy would interact with other flexibility sources, given the lack of real-world trials of different technologies operating together. Another also noted that the uncertainties related to V2X, regarding the size and type of its role in future energy systems, and corresponding uncertainties for alternative flexibility technologies, would lead to a compounded uncertainty in how they would interact.

Some respondents noted that the interaction would **depend on the particular use case**. For a **behind-the-meter use case** leveraging the benefits from dynamic tariffs, a few (3) respondents noted there was potentially no need for direct interaction with other technologies. Some (8) particularly commented on the usage of V2X to optimise behind-the-meter generation (particularly solar).

Several discussed **V2G business models**, involving participation in several revenue streams; national (capacity, balancing, ancillary service) (5) and local (constraint/congestion management) (4) flexibility markets featuring other flexibility technologies participating. There was an explicit mention of the need for stacking and optimisation between different revenue streams highlighted in some replies (3). A few (2) noted the possibility of peer-to-peer trading with neighbours, or the use of V2X to enable a local section of the grid to remain operating in an islanded mode. Some (7) respondents pointed to the need for a **level playing field between V2X energy and other technologies** in such markets, with common rules and markets that are technology neutral/transparent/competitive. A few (3) highlighted the need for different technologies to participate in the same market interfaces, with one industry association noting it was “unrealistic and impractical” to utilise different platforms for different sources of flexibility. An energy supplier noted the benefit of V2X in participating in both local and national markets, compared to large-scale flexibility which may only participate in national markets. One consultancy highlighted the complementarity between short duration V2X and longer term, seasonal storage technologies. One EV manufacturer considered that the type of markets/services participated in, and thus the interaction with other sources of flexibility, would differ between AC and DC technologies.

Several respondents discussed the **role of flexibility aggregators in V2G energy**. A few (2) noted that V2X assets could be aggregated together as a single technology, while another discussed the benefits of aggregating with other flexibility technologies, enabling a diverse portfolio with complementary technologies where synergies can be exploited. A few (3) mentioned that all of the flexibility technologies in a particular home/site could be combined

and packaged for aggregation with other such sites, rather than operating as disparate technologies. A few (2) respondents mentioned aggregation of flexibility in a particular geographic location, though one energy supplier cautioned that requirements regarding the geographical area of aggregation to reach thresholds for provision of system services should only increase granularity (i.e. narrowing the geographical area) where essential for system security. Regarding modes of operation, one respondent mentioned aggregation may allow for more attractive export tariffs and so increase the likelihood of export rather than use behind-the-meter. One academic researcher noted that while V2X was likely to be aggregated in national/wholesale markets, EVs may participate individually in local markets.

Several respondents commented on how technologies would **integrate in homes/businesses**, with a few (2) also mentioning interactions at energy hubs. One noted that an EV may be the trigger for a site offering other forms of flexibility, and another suggested it was better to deploy flexibility as an integrated package rather than sequentially, as this would be more effective and less costly – a few (2) mentioned deployment as part of a DC microgrid. Some (6) noted the need for devices to be able to communicate effectively and to be coordinated efficiently. Some respondents emphasised the need for effective standards to ensure this integration was seamless and interoperable, such as open communication standards – a few (2) mentioned their support for the PAS 1878 and 1879 standards in helping integrate flexibility from demand side response into the energy system. One respondent noted that increased metering and data availability would facilitate integration. A few (3) suggested the need for technologies to provide the most effective and efficient strategies to utilise flexibility from different sources within a single site. There was agreement from some (6) stakeholders that for consumers providing flexibility from different sources, this approach should not multiply the complexity of the system interface to the consumer, but rather that this should be transparent, simple and convenient.

Respondents also highlighted other measures to assist the incorporation of distributed flexible assets into the energy system that would benefit V2X energy alongside other technologies. For example, new approaches from system operators to utilise flexibility most effectively were mentioned. Respondents also noted common approaches to manage potential system operability and stability, and cyber security risks associated with flexibility, while a DNO highlighted connection process improvements benefitting multiple low carbon technologies. A few (3) mentioned how strong, secure, and reliable digital infrastructure would benefit flexibility technologies generally.

Many respondents commented on the **interaction between storage provided by V2X energy and that from standalone battery storage**.

A few (2) respondents mentioned that these interactions would be complex, and it was important to ensure that no counterproductive events disadvantaged consumers. Some (6) respondents noted that there was no fundamental difference between these technologies and they were **substitutable**, noting for example their response times were similar, they were both short duration, and both would be deployed on the low voltage network. Some (4) noted that due to their similarity they would compete for the same revenue streams, and this may lead to markets becoming saturated. However, others (4) highlighted differences, such as that the

primary purpose of EVs is not for storage, and that they differ in typical capacity and price point. Comparative strengths of V2X energy mentioned included potential widespread availability, intrinsic geographic decentralisation, and the maximised use of an asset that is already present.

Because of EVs' primary usage for transport, some (5) commented their disadvantage in not being constantly connected to the network/potentially not being plugged in when needed, though one noted that availability of EVs for V2X energy would still be high despite use for transport. One energy supplier considered the concern that EVs may not be able to provide flexibility at traditional peak hours, but noted shifting future demand profiles and constraints due to intermittent generation occurring throughout the day in arguing that substantial amounts of EV flexibility would still be available when most useful. One charge point manufacturer suggested that due to potential poor alignment between solar output and home EV plug-in times, a standalone battery may be able to capture more value in solar optimisation. A few (2) respondents commented on the advantage of EVs' mobility – for example, that they could charge in one location, and then discharge in another, including that autonomous vehicles could drive to where grid services are required. One software solution provider noted that the variable location of EV V2X assets could complicate network planning, operation and management. A few (3) respondents noted that, compared to stationary storage, the flexibility contribution from V2X would be harder to forecast and dependent on understanding human behaviour, with a standardised approach to assessing the flexibility contribution, and detailed data (2), being needed to facilitate an appropriate contribution. The use of such forecasting in combination with aggregation to improve diversity and reliability was suggested.

Several respondents commented on the **likelihood of simultaneous deployment** of behind-the-meter battery storage and V2X energy. A few (2) noted that V2X might displace the need for domestic battery storage, avoiding this additional expense and providing an alternative where the cost of batteries was prohibitive (4). One consultancy noted that a combination with a battery was likely to provide minimal additional value, with V2X adding most benefit when the only storage asset at a property. A few (2) however noted they may work alongside and complement and reinforce one another, while others (3) considered it would depend on the circumstances. One EV manufacturer suggested they were more likely to coexist at commercial/office buildings rather than in homes.

Some (8) commented on the possible useful **combination of V2X energy with electrified heating**, with V2X enabling the shifting of heat demand away from periods of peak demand - one local energy organisation suggested that early adopters of EVs were also likely to be early heat pump adopters. One trade association considered V2X substitutable with thermal storage, while an energy supplier suggested V2X was superior to heat pump flexibility that could only shift demand. One DNO considered that V2X may be less disruptive than heat flexibility, if for example this required changing heating schedules during daytime hours.

Several respondents commented on the **interaction between unidirectional smart charging and V2X energy**. Some considered that they are complementary, allowing EVs to charge when energy is cheaper and then discharge when demand is higher. A few (3) noted that smart charging would be the forerunner/precursor to V2X, establishing a landscape of

standards, tariffs, and business models, and letting consumers familiarise themselves with externally managed charging events. One respondent believed smart charging would offer many of the same benefits for a lower cost, while others (2) noted that the additional investment would be justified only for certain use cases and careful consideration would be required to ensure it was worthwhile. One DNO stated it was important that charge point interfaces explicitly differentiate between smart charging and V2X energy operation.

Deployment

Q3: When and how do you think V2X energy technologies will deploy in the future? (41)

Some (5) respondents mentioned that the case for V2X energy would naturally increase with the expected increase in EV deployment, while a few (2) mentioned the likely increased benefits of V2X due to expected increases in EV battery size. One consultancy considered that with the increased demand associated with the electrification of heat and transport, the benefits to the energy system of V2X would become increasingly clear over time.

A few (3) respondents mentioned the uncertainty in when and how V2X energy would deploy because of the various **barriers needing to be overcome** to achieve significant V2X deployment. These barriers determining deployment include the need for: a greater number of V2X-capable vehicles (with V2X-compatible warranties), decreased charge point hardware cost (5), EV-compatible flexibility markets (5), straightforward network connections (2), and a change in consumer attitudes (1). A few (2) mentioned Government incentives could help accelerate deployment. Several mentioned current progress was being made to address these barriers, and one mentioned how the growth of unidirectional smart charging was helping remove barriers.

2025 was frequently mentioned as a point when V2X may deploy at greater scale/become a more mainstream proposition (12). Several reasons were highlighted for this. From a hardware viewpoint, stakeholders mentioned: the likely increased availability of V2X-capable vehicles (10), including increased development of AC bidirectional charging (2); the anticipated incorporation of bidirectional charging into the CCS standard (11); and an increased number/lower cost of bidirectional charge points (4). Many respondents also highlighted an enhanced business case by this point, due to factors including: more variable electricity prices due to an expected increase in variable renewable generation; consumers being increasingly exposed to these prices due to smart meters/MHHS, and dynamic tariffs; increased DSO (Distribution System Operator) services; and ESO (Electricity System Operator) balancing and reserve market design changes. One vehicle services company also noted likely increased consumer awareness and interest by this point.

However, a few (3) respondents were more pessimistic - one noted that the deployment of Market-wide Half-hourly settlement by 2025 would mean widespread V2X deployment delayed beyond this, also commenting that the barriers of charge point cost and vehicle availability, and the smart charging market not yet being well-established, would mean substantial deployment would not occur before 2030. Another considered it optimistic for CCS and AC standards to be sufficiently progressed by 2025.

A few (2) respondents noted the danger of lock-in – that the longer it is before the necessary enabling factors are in place for V2X, the more likely that businesses and consumers will have invested in non-V2X capable infrastructure, presenting a barrier to V2X deployment.

Many respondents mentioned that **behind-the-meter applications would deploy earlier** than other applications – many mentioned **Vehicle-to-Building, V2B** (10) (including businesses), such as fleet and bus applications, allowing businesses to reduce their energy costs and connection requirements, with businesses able to achieve the scale to make V2X beneficial. Many also mentioned **Vehicle-to-Home, V2H** (10) as being an early application. A few (3) noted that behind-the-meter applications would be particularly beneficial to help manage the demand associated with increased EV uptake in certain geographical areas and that it may be beneficial for local authorities to identify these areas, while others (4) mentioned the benefit in helping to optimise behind-the-meter solar generation, with one respondent believing a potential growth in behind-the-meter solar generation in the near future would catalyse V2X growth. Some mentioned that V2H was a likely early deployment as large numbers of EVs would not be needed for aggregation, though supportive tariffs by suppliers were cited as a necessary enabling factor.

Some (4) also mentioned that **Vehicle-to-Load and Vehicle-to-Vehicle applications would deploy early** and indeed mentioned current usages, noting this was the application with a deployment most independent of other factors.

Several respondents mentioned that **V2G would likely deploy later than these behind-the-meter applications**, when market development facilitated this; fleets with predictable patterns were particularly highlighted as early adopters of V2G (4). However, a few (2) respondents highlighted that new patterns of domestic EV and energy usage would help provide a case for V2G for domestic properties over time, with supportive tariffs, and aggregation and software systems, also noted as enabling factors. A few (2) noted that V2G was more likely in locations with longer dwell times, and less so in public settings. Long stay car parks (2) were highlighted as a possible early use case, due to their predictable concentrated capacity and simple propositions for operator and consumer.

A small number of respondents mentioned **who might lead deployment**: for example, a charge point manufacturer, dedicated e-mobility service providers, an energy supplier, or an EV manufacturer. One EV manufacturer considered that suppliers may seek to deploy V2X as a means of attracting and retaining customers, while a charge point manufacturer believed that EV manufacturer ongoing involvement was unlikely due to an aversion to highly regulated and country-specific energy markets. An energy supplier commented that successful V2X deployment required a narrowing of a perceived knowledge and communication gap between EV manufacturers and electricity market actors. Partnership opportunities were mentioned, such as EV manufacturer white label suppliers, or referrals to suppliers, or bundling/leasing opportunities.

A small number of respondents considered how **AC and DC V2X technologies may deploy**, though there was no clear consensus on this issue. One respondent considered that both AC and DC would both deploy, but for different use cases – for example, with DC preferred for

V2G grid services, and enabling efficient systems in combination with domestic solar and battery storage. Regarding cost, one respondent considered the overall cost would be similar, but DC may be cheaper if the charge point was shared between users; however, one charge point manufacturer considered that DC hardware costs would be preventative to adoption, and so AC would be the only widely adopted form of V2X. A few (2) respondents thought that DC would deploy first, while one EV leasing provider thought that AC would deploy first.

Business models

Q4: What are the potential business models for V2X energy technologies in the future energy system? (40)

Most respondents identified the same types of potential business models detailed in the Call for Evidence (behind-the-meter, V2H/V2B, and involving export, V2G), though one charge point manufacturer did note that with the evolution of the V2X ecosystem new business models may emerge over time.

Respondents highlighted that it was important for the **market to decide** which models would predominate. Regarding the precise V2X business model adopted by a particular consumer, some (4) respondents pointed out that there was **no one size fits all solution**, with the most appropriate in a given situation dependent on many factors of a users' environment, such as consumption/plug-in patterns, behind-the-meter generation, local network situation etc., with the difference between domestic and business consumers being particularly highlighted. A need for flexibility in supplier offers to meet the demands of different consumers was thus noted by one trade association. Another trade association suggested consumers may be agnostic about business models provided they allowed for a return on investment in V2X technology in a reasonable timeframe. One charge point manufacturer also noted that DC and AC V2X could have different predominant business models, due to likely different charging rates.

Some (6) respondents stressed the need for Government to ensure that as flexibility technologies and markets evolve there is a level playing field between V2X and other flexibility technologies to facilitate the evolution of business models. Respondents also highlighted the need for appropriate governance and regulation regarding aspects such as interoperability, data privacy, grid stability and cyber security, with appropriate consumer protections and transparent pricing in place. One EV manufacturer highlighted the need for vehicle and charging hardware capable of facilitating different possible revenue streams.

Adding to the points in response to previous questions, many (10) respondents highlighted that **behind-the-meter models** would be likely to be early viable business models, presenting an easy proposition to consumers. Optimising on-site renewables (particularly solar) was seen as a particularly attractive proposition (9), while a few respondents also highlighted business fleets as an early use case, enabling financial benefits, allowing for increased numbers of vehicles to be added without the need for reinforcement, and providing security of supply with lower emissions than diesel generators, and lower cost than standalone batteries. One EV manufacturer highlighted that V2B savings had been achieved in a trial with 5 vehicles, and so

for such a model large fleets are not a prerequisite. Some (7) respondents highlighted the importance of time-of-use tariffs in facilitating behind-the-meter business models, and the benefit for Government in encouraging these to maximise charging with renewables. However, a few (2) respondents did state they believed V2H would be unlikely to be more attractive than smart charging for most consumers.

Many respondents discussed **Vehicle-to-Grid (V2G) business models** involving export from EVs to the wider energy system. Some (6) highlighted wholesale market arbitrage, noting advantages compared to standalone batteries in terms of lower marginal cost and greater geographic diversity. A few (2) also highlighted arbitrage of dynamic network charges. Some (9) highlighted involvement in frequency response markets, noting studies demonstrating the revenue potential. However, some (4) respondents suggested that participation in frequency markets may be prohibitively challenging, due to expensive testing and metering requirements. One energy supplier noted that frequency and reserve services could also be provided without the need to export to the grid. Some (6) also discussed involvement in the balancing mechanism. Use cases such as fleets and long-stay car parks were highlighted as attractive V2G opportunities in the near-term, providing high volume charging locations with predictable schedules that can conveniently package flexibility – studies were highlighted regarding the benefits of utilising fleets in this manner.

Many (11) discussed involvement in local DSO services, such as constraint/congestion management, though a few (2) noted the opportunities from these services may be difficult to predict. A few (3) highlighted that while there was benefit in V2X energy being utilised to enable postponing or removing the need for local network reinforcement, there was however a lack of mechanisms for this to be appropriately compensated at present (though some did mention ongoing trials). Other revenue sources mentioned included capacity markets (3), local peer-to-peer energy markets (3), and carbon trading markets (2).

Some (8) respondents discussed the **role of aggregators in V2G business models**, either associated with the supplier, charge point operator, EV manufacturer, or as independent entities, and highlighted the need to facilitate their role in order to enable V2G business models. As with previous questions, respondents discussed either EV-specific aggregation, or aggregations of different technologies – either physically co-located where local loads could be optimised and then bid into markets, or not co-located. Benefits of aggregation highlighted included consumers otherwise not having the time/awareness/capability to engage in V2G, easier entry to markets in terms of satisfying capacity limits and spreading costs, and mitigation of the risk of individual connections not being available, allowing stability of service to be provided. One DNO did highlight it may be harder to provide reliable EV-specific aggregated services at a local level due to the small number of units involved, while a local council suggested that the need for there to be a share of revenue for an aggregator would mean that export-based models would be less attractive for consumers.

While some pointed to ongoing reforms in local and national flexibility markets that would benefit V2G viability, the uncertainty and immaturity of flexibility opportunities was highlighted by some as a cause for uncertainty in potential business models. Some also highlighted the need to ensure that as local and national markets evolve, market mechanisms and rules are

aligned between local and national markets, to enable optimisation and stacking across multiple markets. Potential market saturation was highlighted as a concern, though one EV manufacturer suggested that this was likely to be negated by reduced V2X costs reducing revenue required to provide a satisfactory return on investment. Given the potential for saturation, one EV manufacturer suggested that the use of V2X energy should be prioritised above standalone battery storage, to ensure the most sustainable use of resources. Other issues highlighted regarding V2G business models were double charging of levies on energy stored and re-exported to the grid, minimum market entry limits for aggregated flexibility, and the recent removal of some revenue sources (e.g. BSUoS embedded benefit, Triad avoidance).

Respondents also provided different views on **how costs and revenues could be distributed** between different actors, such as consumers, charge point operators, aggregators, and EV manufacturers, to ensure viability of business models from these different perspectives. One EV manufacturer suggested that businesses who were purchasing a V2X system would likely require a 3-year return on their investment. Regarding the up-front capital cost, one charge point manufacturer suggested this was unlikely to be absorbed by an energy supplier, as this would necessitate a tie-in period. Respondents suggested that V2X charge points could be bundled into EV finance leasing packages or long-term rental packages to provide digestible options to consumers (3); a few (2) respondents suggested lower cost AC charge points may make these packages more attractive. A few (2) respondents suggested either V2X charge points could be financed similarly to solar, or that V2X could be financed in combination with solar.

Regarding sharing of revenue/savings, to the consumer, the need to cover the potential cost of the charge point, any potential impact on the battery, as well as any behavioural change associated with V2X energy was highlighted. A few (3) considered that V2X could be presented to consumers as a lower cost, all-inclusive EV charging offering or as a reduced lease/loan cost, bundled with an energy tariff, while others suggested (3) instead that consumers could be exposed to more variable pricing with more direct revenue sharing. The benefit of an ongoing contract to avoid the complexity of consumers opting in or out of every transaction was highlighted by one respondent, while another pointed out that different incentives would be required to change behaviour for businesses and domestic consumers.

Some respondents suggested coordination between EV manufacturer and energy supplier, for example in offering batches of customers to suppliers, or in operating energy management systems inside the car, or providing specific grid services to suppliers, or in the marketing of V2X as a point of sale difference for vehicles. Regarding the interaction with the EV manufacturer, a few (2) respondents highlighted the need for business models to consider the impact on battery degradation given the significant capital cost of the battery – as the EV manufacturer bears the battery warranty cost, sharing of this warranty cost was suggested by one academic researcher.

Consumers

Q5: How can Government and industry enable and incentivise consumers to realise the full value of V2X energy technologies? (46)

Firstly, a few (3) respondents highlighted the importance of the continued transition to electrified transport in acting as a precursor to V2X energy, noting that any V2X interventions must complement and not impede EV adoption. A few (2) also noted the importance of ensuring the maximisation of unidirectional smart charging initially, an effective roll-out of which would create the right conditions for V2X. However, the need to ensure V2X was facilitated before consumers were invested in an alternative system that they might be reticent to change from was also highlighted by one respondent.

Many respondents to this question highlighted the current **high cost of V2X-compatible charge points, and the current relative lack of V2X-compatible EVs**, as barriers to consumer involvement in V2X energy. Noting the success of the plug-in vehicle grant, some (7) respondents suggested there should be adapted and enhanced financial incentives specifically for V2X-compliant EVs. One consultancy went further and suggested it should be mandated that all EVs are V2X-compliant. Regarding the barrier of high V2X charger costs, many (14) respondents suggested there should be enhanced Government subsidies/grants specifically for V2X-capable charge points; a few (2) also suggested a Government-backed loan, to be paid back using revenue/savings from V2X services, would help to de-risk investment for consumers. Most suggested such financial support should be time-limited, helping to catalyse early demand and grow the market for V2X products, enabling hardware costs to reduce and revenue potential to increase. Less frequently mentioned suggestions included tax/VAT benefits for V2X charge points (2), and a revenue support scheme such as a Contract for Difference to support end user revenue to attract early users. However, one trade association did note disagreement among their members as to whether a V2X energy subsidy would be appropriate, or whether public funding would be better targeted in the nearer term in the roll-out of unidirectional charge points.

Many (25) also considered the need to ensure **viable business cases and sufficient revenue** potential for consumers to justify the investment in V2X-compatible hardware. These respondents covered similar points as discussed in Q4, regarding the need for facile participation of V2X in local and national markets that appropriately value the bidirectional flexibility EVs can provide, to ensure sufficient revenue to incentivise consumers. The need for clarity, transparency, and certainty (over several years) in these revenue sources was emphasised. One respondent suggested peer-to-peer trading may be able to offer enhanced revenues and so should be particularly facilitated. A few (2) also noted the importance of network charging in ensuring viable business cases. However, one EV manufacturer suggested that even if there was clear future revenue/savings potential to justify higher cost, high up-front cost would still put off consumers, who often have a short horizon when making investment decisions. One EV manufacturer suggested there was a need for Government to ensure a fair sharing of revenues between different stakeholders to ensure incentivisation.

Some (4) respondents highlighted the need for Government-funded **research and development/innovation** into different V2X energy technologies, business cases and their integration into wider networks. A few (2) also suggested there should be regulatory flexibility for innovation projects, to enable emerging solutions with less restrictions than usually applied.

Many (10) pointed to the need for **consumer awareness and education**, to illustrate to consumers the benefits of V2X energy to their finances, the energy system, and decarbonisation. A few (3) highlighted the positive impact of demonstration projects in helping to illustrate the benefits of V2X and raise awareness. One respondent noted that positive consumer outcomes were important in the early stages of deployment in encouraging wider consumer confidence and positive perception of V2X. Some (8) respondents mentioned consumer concerns regarding the **impact of V2X on EV batteries** – while respondents highlighted positive evidence on this topic, the need for further studies/evidence under multiple scenarios and its dissemination to consumers was noted as necessary to reassure consumers and address misconceptions. Some (4) noted the importance of ensuring EV warranties were compatible with V2X energy, helping allay consumer concerns regarding battery impacts.

In terms of how V2X energy propositions are presented to consumers, some (7) noted the **importance of smart metering, MHHS, and time-of-use tariffs in encouraging engagement**. One respondent noted that more dynamic tariffs were likely to be a gateway to wider consumer participation in flexibility, while another noted that while initially they may be simple and reflect wholesale prices, eventually network charges and ancillary service revenue could also be incorporated.

In general, respondents considered that **no single business proposition** for consumers should be mandated, with regulations facilitating innovation. Some (4) emphasised that consumer propositions should incentivise consumers to plug in as much as possible, given that plug-in rate has been shown to be a key driver for the benefits of V2X energy. Some (4) respondents noted the importance of **appropriate consumer protections to give consumers confidence to** engage, given that these offerings may be from unfamiliar companies and more complex than consumers may be used to. Suggestions included protection from misinformation about financial benefits and complex and opaque terms and conditions, appropriate complaints handling standards, the right to exit unsuitable tariffs, and standardised methodologies for the comparison of EV tariffs. Some respondents suggested simple propositions should be prioritised where possible, such as long-stay carparks where V2X participation would translate to lower parking costs, while others noted that behind-the-meter models may be easier to understand. Some suggested bundled arrangements incorporating some combination of EV, charge point and tariff could be easy and compelling to consumers, though one consumer organisation noted many different possibilities would complicate comparison between offerings.

Some (9) respondents noted the **importance of interoperability** in incentivising users to engage with V2X energy – that a compatible ecosystem for the lifetime of products, with switching between different vehicles, charge points, and tariffs possible without adverse impacts, was needed to give consumers confidence, reduce complexity, and maximise

convenience, while still enabling innovation. **Standards** were particularly highlighted as helping to increase consumer confidence regarding interoperability (5). A few (2) respondents mentioned their support for the PAS 1878 and 1879 standards in having increased consumer confidence. Some (6) noted the importance of support for the ISO15118-20 communication standard, suggesting progress in this standard would encourage additional V2X energy products. The potential benefit of standards regarding safety and batteries were also mentioned by a few (2).

Regarding how consumers would engage with V2X energy systems, some (7) noted that while early adopters may accept complexity, most consumers would require **simple and user-friendly systems that could be automated.** Transparency and the need to explicitly differentiate between unidirectional smart charging and V2X was also emphasised (3). However, respondents also noted the **importance of consumer choice** (6), and that consumers should ultimately be in charge of the charging behaviour of their EV, being able to delegate control to whoever they prefer, but also opt-out of and override default options, and have flexibility in setting charging preferences. Some (7) respondents particularly emphasised that systems should have the flexibility to reassure consumers they will have **sufficient charge** when they need to use their EV for mobility purposes, for example enabling export only when there is a certain level of charge, or ensuring charge will not go below a certain level if there is a need for unexpected journeys.

A few (2) respondents noted the importance to consumers of considering V2X as part of a wider holistic energy transition strategy, consistent and compatible with other forms of domestic flexibility, and with an avoidance of inconvenient and inefficient sequential deployments of technology where possible.

Some (6) respondents also noted that V2X energy systems should be **straightforward to connect to the electricity network**, highlighting the need for a faster and simpler connection process, with greater transparency in timelines and costs, than at present. Positive progress by some DNOs in digitising and automating connection processes was highlighted by some, though others noted a need for greater alignment between DNOs, emphasising this as particularly important for business fleets that operate in different areas.

Some (7) respondents highlighted it as important that incentives and actions to facilitate V2X energy **do not penalise non-EV drivers or those without private charge points**; for example, that consumers should not be disadvantaged if they are unable to shift energy usage to avoid high prices in time-of-use tariffs, if they may not be confident using digital products, if they do not have access to private charging infrastructure, or may find it difficult to modify their residences. However, one DNO did note that V2X energy could also present opportunities for some vulnerable consumers, for example by using an EV as back-up power supply for medical equipment.

Understanding the barriers to uptake of V2X

Q6: Do you agree with the barriers identified and are there any barriers missing? (50)

All 50 respondents answered this question, which concerned a variety of barriers proposed across the categories of Technical, Information and System. Below the views on the barriers are discussed in detail for each category – the original wording and detail of the barriers can be found in the Call for Evidence document.

Technical

The technical barriers put forward in the Call for Evidence were:

- Limited choice of vehicle models capable of V2X
- High cost of AC-DC converters
- Complexity between V2X charging protocols
- The impact of V2X activities on battery health

There was generally good agreement from respondents regarding this set of barriers, though one charge point manufacturer considered the technical barriers were over focussed on DC technologies, and that AC technologies should have been considered in equivalent detail.

Regarding "**Limited choice of vehicle models capable of V2X**", respondents agreed with this and some (4) specifically mentioned they considered this the most significant barrier. Some (6) also highlighted the associated barrier of the development of CCS V2X capability, as this would facilitate a greater availability of V2X-capable vehicles. A few (2) respondents considered that specifically a lack of vehicles capable of AC bidirectional charging was an important barrier. However, a few (2) respondents did mention positive current and expected future developments in terms of the availability of V2X-capable vehicles.

Regarding "**High cost of AC-DC converters**", one academic researcher raised the associated barrier of an immature supply chain and a lack of manufacturing capability for V2X charge points. One respondent noted the connection between these first two barriers – that an increasing availability of V2X-capable vehicles would increase demand for charge points and thus potentially reduce their cost.

As well as these hardware barriers, a DNO highlighted the barrier of V2X software systems being immature and needing further development.

Regarding both hardware and software, one respondent raised the additional barrier about whether existing infrastructure could be upgraded to be V2X compatible, and how this could be planned effectively so it could be done in an efficient way.

Regarding "**Complexity between V2X charging protocols**", a few (2) respondents considered that "lock-in" and complexity between CHAdeMO and CCS protocols would not be a concern due to a perceived anticipated decline in the use of CHAdeMO in EVs in the UK in

the future. One EV manufacturer considered that the risk of lock-in related not just to consumers, but to the whole service provider implementation of V2X energy, which potentially could not be easily ported between the protocols. Regarding the CCS protocol, an academic researcher raised the specific barrier of uncertainty concerning Root Certificate Management for the ISO15118-20 standard.

In this category, several respondents raised additional **barriers concerning standards**, particularly regarding communication between the charge point and flexibility service providers. Some (5) specifically mentioned the need for interoperability standards appropriate for V2X, while one highlighted it was important for standards to consider behind-the-meter applications. A few (3) respondents highlighted barriers regarding potential non-convergence to common standards (and the alternative usage of proprietary standards), while one respondent noted the danger of mandating the charge point to service provider communications, given fast development in the area. A few (2) respondents also highlighted the difficulty of being aligned internationally on standards. A local Government organisation also noted the need for general safety standards.

An additional barrier raised by some (5) respondents was **cyber security**, and the need for robust cyber secure communications to protect consumers and the energy system.

One charge point manufacturer highlighted the additional barrier of a need to maintain reliable communications with V2X charge points, as without this they would not be able to be relied upon for grid services.

Regarding "**The impact of V2X activities on battery health**", an energy supplier noted that in trials in which they were involved no evidence of significant degradation impact had been observed, but considered further trials to investigate this would be beneficial. Furthermore, a DNO considered that as research was underway in this area, and battery technology is evolving fast, they did not consider this to be an enduring barrier. A few (3) respondents considered this was more of an issue of consumer perception of potential battery degradation (with one highlighting a decrease in this issue during trials). A few (2) respondents highlighted the complication of V2X battery impacts in terms of the impact on the financial value of the vehicle, with mileage not providing a good measure of degradation, and that this was of particular concern for leasing companies.

Information

The information barriers put forward in the Call for evidence were:

- Lack of clarity around how V2X will affect vehicle warranties
- Low levels of the cars being plugged in and available for V2X when stationary
- Consumer concerns around impacts on the availability of their EV
- Low consumer awareness of the V2X proposition
- User friendliness of V2X systems

Respondents generally agreed with this list of informational barriers, though frequently suggested mitigations or circumstances that would reduce their severity. Some additional related barriers were also suggested.

A DNO made the general point that consumer acceptance of V2X energy would need to be underpinned by drivers becoming comfortable with the transition to EVs.

Regarding "**Lack of clarity around how V2X will affect vehicle warranties**", respondents considered this was fundamentally linked to the above barrier regarding battery impact.

Regarding "**Low levels of the cars being plugged in and available for V2X when stationary**", a few (3) respondents highlighted in trials that plug-in levels had been sufficient to provide useful services; an energy supplier, as well as an EV manufacturer, also noted that V2X capability at workplaces as well as homes would increase the time during which bidirectional charging could occur. A DNO highlighted that this issue could be addressed with appropriate financial incentives (and shared positive trial evidence to this effect), as well as systems that notified users of the revenue opportunities available if they did plug in. However, the DNO also considered that this barrier was more significant, and any mitigation less effective, for time-constrained users such as buses, as well as for those utilising primarily public charge points planned with charging needs in mind and not flexibility. An EV manufacturer also noted that unidirectional smart charging would familiarise users with a "plug as soon as you can" approach. Another respondent suggested wireless charging may lessen the severity of this barrier.

Regarding "**Consumer concerns around impacts on the availability of their EV**", one respondent highlighted that software to enable a minimum State of Charge to be set would reassure consumers. One EV manufacturer considered unidirectional smart charging would familiarise users with the concept of their charging being externally managed. A DNO highlighted trial evidence that consumers were open to use of their EV for flexibility provided their mobility demands were met, with override functions helping to provide peace of mind (and being limited in use given appropriate incentives).

Regarding "**User friendliness of V2X systems**", a consultancy highlighted positive evidence from trials suggesting participants had found V2X energy user-friendly. A DNO highlighted the importance of universal user-friendly interfaces in increasing EV plug-in time for V2X. An EV manufacturer considered that unidirectional smart charging would familiarise users with the type of platforms used for V2X. Related barriers were that business offers may be too complex or unfamiliar for consumers to understand. A consumer organisation also suggested that it was important for managing V2X to not be too time-consuming from a consumer perspective.

Regarding "**Low consumer awareness of the V2X proposition**", a few (3) considered that this would be addressed by the wider development and proliferation of V2X energy over time, though one noted the issue of raising awareness could be more complicated for non-domestic consumers than domestic ones, due to the need for awareness among different stakeholders in an organisation. One energy supplier further highlighted that it was important to consider V2X awareness from the perspective of fleets, and for the benefits to be explicitly outlined for

such consumers. One respondent suggested that simple propositions such as long-stay car parks would provide easy to understand opportunities. A DNO noted increasing awareness could help address other issues, such as plug-in rates.

System

The system barriers put forward in the Call for Evidence were:

- Ensuring V2X can compete within markets on an equal basis
- Poor business case for domestic aggregators
- Export limits
- The business case currently only works for a few specific user types

While respondents generally agreed with the barriers presented, they additionally highlighted several other barriers related to electricity networks and markets.

Regarding "**Ensuring V2X can compete within markets on an equal basis**", many (10) respondents highlighted the need for wider reform of electricity markets to be suitable for participation of, and adequately reward, distributed flexibility in general, particularly so that certainty in revenue can be provided. A specific issue highlighted by some (4) respondents was the size and geographical extent of aggregation limits; others included a need to facilitate peer-to-peer trading, difficulties participating on a level playing field in the capacity market, and a need for clarity on EV participation in carbon markets. One respondent highlighted a need for mechanisms for compensation for V2X reducing or postponing the need for investment in network capacity.

One respondent noted that stringent requirements for flexibility provision were there for good reason to provide confidence in the flexibility acquired, while also noting that the diversity of a large number of aggregated EVs itself helped with improving confidence in deliverability. Positive progress was highlighted in this area regarding technology-agnostic markets procuring flexibility from EVs.

Regarding "**Export limits**", a few (2) respondents considered that this was less of an issue for behind-the-meter applications.

Some (8) respondents highlighted that they considered the key networks issue regarding V2X to be the "**DNO connection process"**, noting a variety of concerns regarding the length of the connection process, the size and uncertainty of costs and administration processes, requirements for on-site witnessing which add time and expense, as well as general inconsistency in these issues between DNO regions. Installers not notifying the DNO of installation was also highlighted as a barrier by one trade association. However, regarding both the connection and notification barriers, respondents highlighted positive work underway to address these.

A few (3) respondents suggested the capacity of local networks may represent a barrier, and network planning needed to consider V2X. Others suggested potential problems, for example regarding voltage control and harmonic issues, needing to be considered by DNOs, as well as possible mitigations. A few (2) respondents suggested it was important to understand how to utilise V2X to support local networks. A DNO highlighted that the requirements of the Distribution Code were not written with V2X in mind, and it was important to consider how they would be applied to V2X, while another respondent similarly noted that it was important to implement V2X such that the electricity system did not become a significant barrier.

Regarding "**The business case currently only works for a few specific user types**", one respondent considered that over time these would naturally emerge with increasing opportunities due to more volatile demand, while another noted business cases would work for more users by being able to do V2X in different locations. However, a few (2) respondents suggested that for those without an individual charge point, this was likely to be a more significant barrier. A few (2) respondents also highlighted double charging of final consumption levies as a barrier that affected business cases, while further (2) respondents suggested network charging reform would improve business cases. One respondent suggested a limited number of time-of-use tariffs also represented a barrier to viable business cases.

Regarding "**Poor business case for domestic aggregators**", one respondent disagreed with the claim in the Call for Evidence that there was a better business case for non-domestic aggregators, disputing assumptions on revenue and suggesting fleets may not be sufficiently incentivised. However, other respondents were more optimistic, with a DNO suggesting an improving business case with increasing purchasing of low voltage flexibility and with increasing numbers of EVs to be able to be aggregated.

One DNO noted the interplay and potential trade-off between these network and market barriers, and whether unfettered V2X activity with either network reinforcements or local constraints markets to facilitate was optimal, or whether limitations should be imposed.

A few (3) respondents suggested an additional barrier regarding **data**, and that there was a need for protocols regarding data access and sharing. An EV manufacturer also suggested there was a need for greater energy system digitalisation.

A few (3) respondents noted an additional barrier regarding a need for appropriate **metering** to measure and accurately compensate V2X activity.

A few (3) respondents suggested a further barrier was uncertainty regarding the availability of relevant technical **skills** for the development, installation, and maintenance of V2X technology.

Q7: How would you prioritise the need to address the barriers, including any additional barriers that are missing? (41)

Regarding the most important general category of barrier to prioritise, views were mixed though generally the technical (5) and system (4) barriers were highlighted as important. The information (2) barriers were less frequently mentioned, with some respondents considering

these would be facilitated by removal of the other barriers and would fall away with time as a result of increasing uptake. However, a few (3) respondents did also consider that the technology barriers would also be resolved with time.

Technology

Many (13) respondents highlighted "**Limited choice of vehicle models capable of V2X"** as a priority barrier. Respondents particularly noted appropriate vehicle availability as underpinning V2X rollout; they also highlighted the risk of consumers becoming locked in to non-V2X compliant vehicles, as well as long lead times for vehicle development, as reasons why this barrier should be prioritised.

Many (11) respondents also highlighted "**High cost of AC-DC converters"** as a priority. A few (2) did consider this barrier would naturally reduce with vehicle availability and scale. A few (2) noted the related barrier of supply chains for V2X technology currently being too under-developed to be capable of providing the technology at scale, and that supporting supply chains could facilitate cost reduction of V2X charge points.

Some (7) respondents also highlighted prioritisation of appropriate standards for interoperability and cyber security, though with cautioning by some that these should be such as to enable innovation and provide certainty, without excessive regulation.

Some (5) highlighted "**The impact of V2X activities on battery health"** as a key barrier to be resolved, with some suggesting further trialling would help address this barrier.

Information

A few (3) highlighted **"Lack of clarity around how V2X will affect vehicle warranties**" as an important barrier to prioritise, with it being highlighted this could be resolved in tandem with a better understanding of battery impacts.

Some (6) considered "**Low consumer awareness of the V2X proposition**" was an important barrier to prioritise, in terms of raising visibility, educating and informing consumers, and improving consumer understanding.

However, a few (2) considered it too early to address this barrier, and that solutions would become more apparent as V2X became closer to mass deployment.

System

Some (7) respondents considered "**Ensuring V2X can compete within markets on an equal basis**" was an important barrier, as well as some (9) also highlighting **wider energy market design for flexibility.** A DNO considered participation in peer-to-peer markets was particularly important.

Some (5) considered improving the "**DNO connection process"** for V2X charge points should be prioritised, in terms of streamlining and increasing uniformity of this process.

A few (2) mentioned "**Export limits**", with one energy supplier considering this particularly in the context of how connections could be streamlined for those sites with management of export, or where there was minimal export due to high behind-the-meter usage.

A few (2) suggested network management and planning regarding V2X was important to consider.

Some (5) suggested ensuring viable business cases and addressing "**The business case currently only works for a few specific user types"** was to be prioritised, with different focuses suggested, including fleets and homes initially. Relatedly, respondents suggested appropriate tariffs for consumers, and appropriate transmission charging, as important. However, one respondent did consider that poor business cases and low margins for aggregators would improve with time. As well as a viable business case for aggregators, a few (2) also noted a need to regulate and facilitate the role of aggregators. Those without access to off-street parking were particularly highlighted as needing the viability of their business case to be addressed.

A few (2) also highlighted training to enable appropriate **skills for installation and maintenance of V2X charge points**. One EV manufacturer stated clear data disclosure rules should be a priority.

Q8: Which barriers do you believe require intervention from Government and what form should that intervention take? (46)

Regarding general points, some (6) mentioned a role for Government in convening and coordinating across the transport and energy sectors, and the many associated actors in order to facilitate V2X energy, including developing timelines for the technology and supporting trials. Some (5) respondents specifically considered that the Government had a role in addressing the system barriers. A DNO considered Government should prioritise technical barriers to facilitate future-proofing of infrastructure.

A few (2) also mentioned their support for the Government's push for smart charging, in addressing the spectrum of barriers – facilitating technological readiness, incorporating EV flexibility into the energy system (e.g. through participation in flexibility services); and exposing consumers to new price concepts, familiarising them with automated charging, and increasing plug in time.

Technical

Many respondents had views regarding how Government could address the technical barriers.

Regarding "**Limited choice of vehicle models capable of V2X",** there were different views as to how to stimulate an increase in the number of V2X capable vehicles: a few (3) suggested the Government had a role in urging and encouraging EV manufacturers to prioritise V2X; others (3) suggested instead incentives were the best option, such as through specific grants for V2X-capable vehicles; a few (3) went further and suggested the mandating of V2X

capability may be appropriate, though with one cautioning this would require international coordination and strong justification. One EV manufacturer suggested the Government should create demand through utilising V2X with public fleets.

Regarding "**High cost of AC-DC converters**", one standards association cautioned against mandating all charge points to be bidirectional, given V2X may not be appropriate in all situations. Some (9) respondents suggested financial incentives would help reduce the cost of bidirectional charge points, suggesting that these would encourage economies of scale. Some (4) suggested supporting innovation and developing timelines regarding AC V2X may help to facilitate a lower cost solution. Others pointed to encouraging supply chain development (2), and innovation in the area more generally (4), as a means to stimulate business interest. One EV manufacturer suggested tax benefits would be of benefit.

Regarding "Standards for interoperability and other", many (11) suggested a role for Government in generally supporting the development and adoption of appropriate standards, particularly regarding interoperability (5). A few (3) highlighted the importance of ensuring these were consistent internationally. Some (5) particularly highlighted a role in facilitating the development of standards to facilitate charging using the CCS protocol and in ensuring clear timelines, while others (2) specifically highlighted a role in considering governance issues associated with this standard. One energy supplier also noted standards appropriate for AC V2X needed to be considered. One organisation involved in smart metering considered that Government should focus on the overall architecture, leaving implementation to industry. A few (2) respondents noted the Government's support of PAS 1878 and encouraged the continuation of this work and the monitoring of uptake.

While a few (3) respondents suggested possibilities for specific **V2X regulation**, in the vein of the Electric Vehicles (Smart Charge Points) Regulations 2021, regarding aspects such as consumer protection and cyber security, there was caution that regulation should be appropriate so as to facilitate and not stifle innovation. The need for appropriate consumer protection was highlighted more generally by some (4) respondents. One trade association suggested that rather than V2X-specific regulations, current and future regulations should be reviewed to ensure they did not present a barrier. One respondent noted that building regulations should consider potential EV contributions to building energy management.

Regarding "**The impact of V2X activities on battery health**", some (4) respondents suggested Government could encourage research and innovation regarding battery performance under different V2X scenarios.

Information

Regarding the informational barriers, some (9) suggested a role for Government in **marketing and awareness campaigns**, providing accessible, clear and easy to understand information from trusted and independent sources to educate the public on the benefits of V2X, including businesses, to help them make efficient choices, and reassure them that they would be in control and that it would be easy.

One DNO considered trialling of innovative methods could help encourage consumers to plug in more.

One respondent considered that Government-funded demonstration projects could help raise awareness.

A trade association noted a need to ensure appropriate integration with other smart appliances in a user-friendly way.

System

Regarding the "**DNO connection process**", some (7) respondents suggested a role for Government in facilitating a simplified, lower cost and standardised connection process, including when in combination with other low carbon technologies.

Regarding "**Ensuring V2X can compete within markets on an equal basis**", many (11) respondents suggested a role for Government in facilitating market participation, with frequency response, capacity markets, the balancing mechanism, local DSO markets, and reward for postponing network reinforcement, specifically highlighted, as well as possibilities in combining revenue streams. A consultancy suggested innovation/research in the area could be of benefit. A few (3) suggested specifically altering minimum bidding and aggregation thresholds in markets.

Some (4) also highlighted "**general market design for flexibility**" as a barrier to be addressed by Government.

Regarding **"The business case currently only works for a few specific user types"**, one charge point manufacturer highlighted regulatory sandboxes may facilitate development of appropriate business models. A DNO highlighted that coordinated public charge point provision could help facilitate V2X in public locations, while one consumer organisation suggested long stay car parks should be specifically encouraged to develop V2X capability. A few (2) respondents highlighted that design of network charging needed to consider implications for V2X business cases.

Regarding **data**, a few (2) respondents suggested there needed to be appropriate rules and responsibilities concerning data sharing, while still enabling data protection and privacy.

One trade association noted it was important to enable appropriate **skills** development for the installation, maintenance, and operation of V2X hardware.

Q9: What action should industry or other stakeholders take to address the barriers identified? (40)

Some (8) respondents made the cross-cutting point that it was important for industry to work across the energy and transport sectors, and closely with Government, to identify and address barriers on a long-term, on-going basis. Some specific points were made about sharing of data, cost, risk, and roles and responsibilities, between different actors. A few (2) considered

that it was important for industry to follow a coordinated direction from Government, while others (2) considered industry should reach a consensus regarding the types of technologies deployed. One energy supplier considered that further trials would help in identifying risks and opportunities for V2X.

Technology

Regarding "**Limited choice of vehicle models capable of V2X**", some (7) respondents suggested EV manufacturers could act to increase the number of EVs compatible with V2Xenergy , as well as taking part in trials and innovation projects. Some (4) respondents suggested that improving market signals and business case for V2X over time would help to encourage this technological development. One EV manufacturer also suggested the ongoing role of EV manufacturers, not just in providing hardware but in terms of battery and vehicle management systems.

Regarding "**High cost of AC-DC converters**", a few (2) respondents suggested industry should consider the potential of AC onboard bidirectional charging as a potentially lower cost overall solution. One consultancy also suggested that industry investment in the technology supply chain, and in research and innovation, would help address this barrier.

Regarding "barriers concerning standards", many (11) respondents mentioned a role for industry in developing standards and in adopting appropriate and harmonised standards. One trade association noted the need for balance between being overly prescriptive and stifling innovation, and a proliferation of standards and systems.

Regarding "**The impact of V2X activities on battery health**", some (6) respondents noted a need for EV manufacturers to determine the battery impacts and associated warranty implications of V2X energy (as well as on the financial value of the vehicle), and to disseminate information from past and future studies in order to reassure consumers.

Information

A few (3) respondents noted a role for industry in providing clear and transparent information for consumers, clearly communicating the benefits and opportunities, to address informational barriers such as "**User friendliness of V2X systems**", "**Low consumer awareness of the V2X proposition**", "**Consumer concerns around impacts on the availability of their EV**", which could be appropriate to deliver through marketing campaigns of V2X technologies and services.

One trade association noted that those who would be ultimately buying the technology needed to be involved in discussions about new developments, to avoid unintended consumer consequences.

System

Regarding "**Ensuring V2X can compete within markets on an equal basis**", some (4) respondents suggested a role for National Grid ESO and DNOs in facilitating markets suitable

for V2X, including by enabling opportunities for smaller and aggregated assets. One respondent noted the benefit of trials regarding V2X participation in flexibility markets, and the sharing of data from these.

Regarding "**DNO connection process**", a few (3) respondents suggested a need for DNOs to improve and streamline the V2X connection process. One charge point manufacturer also suggested that a coordinated way of installing and connecting V2X alongside other low carbon technologies should also be developed.

Regarding local networks suitability for V2X, some (4) respondents suggested DNOs needed to plan and develop, as well as monitor, local networks with appropriate consideration of the potential role of V2X. One charge point manufacturer particularly highlighted a need for DNOs to consider the role of AC bidirectional charging, and the local network implications when the AC-DC conversion occurs onboard a vehicle that then could be connected to different charge points.

Regarding "**The business case currently only works for a few specific user types"**, some (9) respondents suggested a role for industry in developing business models and tariffs appropriate for different consumers, including identifying types of consumer usage and locations most appropriate for early adoption, as well as trialling innovative business models and bringing the learnings from trials to market. One energy supplier specifically highlighted propositions which have a lower associated upfront cost of the V2X equipment for the consumer (i.e. this is provided by a party who subsequently recoups their costs through V2X revenue), which may be attractive to businesses.

One trade association considered industry could ensure appropriate skills training for V2X technologies.

Q10: Where should future innovation funding be focused to most aid the development and deployment of V2X energy technologies? (35)

A few (3) respondents suggested that data collection and trialling of existing demonstration projects should be extended, to maximise the value and learning.

A few (2) respondents made the general point that it was important for Government, network operators, and the wider energy and transport industries to work together as part of future innovation projects.

Generally, respondents focussed on the technical and system barriers, though there were diverging views on which should be prioritised. For example, one charge point manufacturer particularly expressed the opinion that innovation funding should not support the development of proprietary technology, and that instead the focus should be on analysing and opening up the revenue opportunities that will incentivise businesses to develop suitable products. However, another charge point manufacturer did not support more funding for business case studies, which they argued did not necessarily translate to the real-world environment, and that funding should focus on technological barriers to entry.

Technical

Many respondents highlighted how future innovation funding could address the technical barriers of V2X. Many (11) highlighted how they considered general technological development and **cost reduction** should be prioritised. Some (6) respondents considered that **CCS DC bidirectional technology** should be prioritised for innovation. Some (6) also considered that **AC bidirectional technology** should be the focus of innovation, due to potentially offering a lower cost V2X solution.

Some (8) also highlighted that the **impacts of bidirectional charging on battery health** should be a focus of innovation, and how current and future technologies perform under different V2X scenarios.

A few (3) respondents also noted the importance of **standards development and testing**, such as the ISO15118-20 standard for bidirectional charging using CCS DC technology, as well as appropriate protocols for communication and data sharing (2).

Some (8) respondents also considered that how V2X interacted and operated **alongside other low carbon technologies**, such as heat pumps, as part of wider smart building energy management systems, and should be a focus of future innovation.

A few (2) also suggested that development of appropriate software platforms, including payment and transaction systems, should be a focus.

Information and system

Some (6) suggested that innovation should explore aggregated **V2X participation in the markets and services of the energy system**, to explore opportunities and develop a better understanding of barriers regarding local and national flexibility markets.

Some (7) respondents noted how innovation could help in **developing new business models**, with resilience and Vehicle-to-Home being particularly highlighted.

Some (9) respondents highlighted that how such **business models interact with and engage with consumers should be a focus**, for example trialling of time-of-use tariffs appropriate for V2X, and understanding consumer engagement with different propositions, which may help with assessing the impact of some of the informational barriers such as low plug-in rates. One respondent highlighted this may help with ensuring that signals to consumers are aligned with wider system requirements.

Regarding the barrier of low plug-in time, a few (2) suggested that innovation in wireless charging may help address this barrier, as well as other innovation, such as automated connection, to help increase the convenience of V2X.

Some respondents highlighted specific use cases where V2X innovation may be beneficial, such as airport/long-stay car parks (2), or just in general that innovation should span across

home, workplace, urban and rural locations; a few (3) also suggested that commercial vehicles and fleets should be a specific focus.

A few (2) suggested demonstration projects in general would be beneficial, to highlight best practice, and provide publicity to consumers to help dispel information barriers and increase cooperation between different sectors, as well as other methods to automate connection and increase convenience

Some (4) respondents considered how innovation could assess the impact and integration of V2X with local networks, included how they are designed and planned with V2X in mind, with one charge point manufacturer specifically highlighting how DNOs manage AC bidirectional charging as a potential area of focus (as previous DNO pilot demonstrations have primarily utilised DC bidirectional charging). One respondent also highlighted how innovation could help understand risks to wider system stability.

Annex 2: Glossary

AC bidirectional charging	Where an EV has an onboard bidirectional converter, which can convert AC electricity supplied by a charge point to DC onboard the EV to charge the battery, and also convert DC electricity from the battery to AC for export to the charge point.
Aggregator	An organisation that aggregates the controllable load of electricity consumers to provide a consolidated DSR service.
CCS	Combined Charging System (an EV charging protocol).
CHAdeMO	An EV charging protocol.
DC bidirectional charging	Where bidirectional conversion occurs in the charge point – converting AC electricity to DC to be supplied to an EV, and also converting DC electricity from the EV to AC.
Distribution Network / Distribution Network Operator (DNO) / Distribution System Operation (DSO)	A network or the operator of a network that is authorised to be operated by the holder of an electricity distribution licence. They bring electricity to homes and businesses at lower voltages from the transmission network. Distribution System Operation refers to the building by DNOs of capabilities in the areas of planning and network development, network operation, and market development; to enable the efficient and effective development and use of the distribution system in a context of increasing technology, digitalisation and flexibility, with due regard for system and cyber security and resilience.
Demand Side Response (DSR)	Configuring or controlling the consumption, discharge or production of electricity of devices, to help meet the needs of the energy system.

Electricity System Operator (ESO)	National Grid Electricity System Operator performs several important functions, including second-by-second balancing of electricity supply and demand, developing markets, and advising on network investments.
Energy Smart Appliance (ESA)	A device which is communications-enabled and capable of responding automatically to price and/or other signals by shifting or modulating its electricity consumption and/or production.
Grid Services	Services to balance demand and supply and to ensure the security and quality of electricity supply, including e.g. frequency response services.
Smart Charging	Charging an electric vehicle (EV) in response to communication signals, at times when demand for electricity is lower, for example at night, or when there is lots of renewable energy on the grid. V2X is an advanced form of smart charging.
Vehicle-to-Everything (V2X) energy	V2X, where “X” stands for everything, is the umbrella term for all forms of technology whereby the EV battery can export electricity back to a system, be that a home (V2H), a building (V2B) such as a business or back to the electricity grid (V2G).

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