

# Innovate UK Global Expert Mission Report

Electric V2X Mission to California, US

July 2023







# Contents

01 Exe	ecutive Summa
02 Ac	ronyms
03 Inti	roduction
04 See	ctor Overview
05 Ca	lifornia Innovati
06 Co	llaboration Opp
07 Pot	tential Barriers
08 Co	nclusions



# ary 04 06 08 14 14 tion Landscape 29 portunities 48 to Collaboration 54 57



# **01. Executive Summary**

Bidirectional charging technologies enable EV batteries to act as storage assets so that energy from the battery can power other devices when energy system prices are high, or grid supply constraints exist. Energy can be exported from the EV to a home, building, vehicles or the grid (Vehicleto-Home/-Building/-Vehicle/-Grid) which can be summarised as V2X. The GEM mission to California aimed to understand the current V2X market, identify key barriers and opportunities and potential routes to collaboration to support sector growth.

The mission met an excellent cross section of industry and public sector stakeholders in California which provided invaluable information and insights for future opportunities. Both territories have undertaken previous trials in the field and have identified challenges which have impeded adoption of V2X among consumers and businesses. The UK has strong links to the US on collaborative R&I which offers opportunities for both UK and California to address these challenges together.

There is a clear opportunity and benefit to working closely with California in V2X. Our findings indicate areas where there are shared challenges in equitable V2X rollout such as infrastructure for fleet, freight and domestic consumers, the impact on battery health and equitable rollout of public on-street and shared residential charging stations.



While the mission identified a number of opportunities, there is a need to work on a G2G level on regulations and grid codes to facilitate rollout of technology in both territories. Regulatory areas to explore include interconnection regulation, overcoming barriers to AC V2X in the US, metering and carbon credit concepts.

This report provides an overview of the V2X landscape in California and the UK and captures R&I opportunities and potential challenges to working with California in V2X. There was a clear appetite by Californian organisations to work closely with the UK who are a leader in the V2X arena. The GEM recommends working with California to scale and accelerate market adoption of V2X technologies.

# 02. Acronyms

B2B	Business to Business
B2C	Business to Consumer
BEV	Battery Electric Vehicle
CAGR	Compound Annual Growth Rate
CCA	Community Choice Aggregator
DBT	Department for Business and Trade
DESNZ	Department for Energy Security and Net Zero
DNO	Distribution Network Operator (UK Electricity Grid operator)
DSIT	Department for Science, Innovation and Technology
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment (charging infrastructure)
FCDO	Foreign, Commonwealth and Development Office
G2G	Government to Government
GBIP	Global Business Innovation Programme
GEM	Global Expert Mission
GIP	Global Incubator Programme
IUK	Innovate UK (Part of UK Research & Innovation)
MoU	Memorandum of Understanding
NZIP	Net Zero Innovation Portfolio
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer (EV Manufacturer)
OFGEM	Office of Gas and Electricity Markets (UK energy regulator)
R&I	Research and Innovation
SB	Senate Bill
SIN	Science and Innovation Network
S&I	Science & Innovation

- **UK** United Kingdom **UKRI** UK Research and Innovation V2B Vehicle to building V2G Vehicle to grid V2H Vehicle to home V2V Vehicle to vehicle V2X Vehicle to everything **VGI** Vehicle to Grid Integration **ZEV** Zero emission vehicle



Electric V2X Mission to California, US

**V1G** Smart charging (single-direction managed EV charging)

(an all-encompassing term for V2G/V2H/V2B/V2V)



"Working with California on V2X brings us unparalleled opportunities to tap into the world's leading hub of innovation and technological advancements. From its vibrant ecosystem of startups and tech giants to its progressive regulatory framework, California offers unique insights that can shape the future of connected vehicles and transform the way we navigate our roads and manage the grid."

Indra Renewable Technologies

# **03. Introduction**

## 3.1 Innovate UK and the Global Expert Missions

Innovate UK supports business-led As innovation is increasingly a global innovation and is part of UK Research endeavour and the ambition of UK and Innovation (UKRI).<sup>1</sup> UKRI convenes, businesses to become truly international catalyses, and invests in close collaboration enterprises is at its highest, Innovate UK with others to build a thriving, inclusive, established its Global Expert Mission (GEM)<sup>2</sup> research and innovation system. To this end, programme in 2017. Delivered by Innovate Innovate UK helps businesses to identify the UK, in partnership with the FCDO Science commercial potential in new technologies and Innovation Network (SIN),<sup>3</sup> GEMs help and turn them into new products and further Innovate UK's global strategy by services that will generate economic growth providing the evidence base for where it and increase productivity. With a strong should invest and the opportunities for business focus, Innovate UK drives growth UK businesses to build partnerships and by working with companies to de-risk, enable collaborations with key economies. and support innovation. Innovate UK exists to connect innovators with new partners and new opportunities beyond their existing thinking - accelerating ambitious ideas into real-world solutions.

<sup>1</sup> https://www.ukri.org

<sup>2</sup> https://iuk.ktn-uk.org/programme/global-expert-missions/

<sup>3</sup> https://www.gov.uk/world/organisations/uk-science-and-innovation-network

### 3.2 Mission Overview and Objectives

The UK Government's ambition is for Great Britain's electricity grid to be zero carbon by 2035. With the demand for electricity in the UK forecasted to more than double between 2020 and 2050, the government is investing in energy flexibility services to mitigate generation capacity requirements and minimise grid reinforcement costs. A number of initiatives are underway in the UK including:

- i. Legislation placing smart charging as the default option in domestic and workplace charging locations,
- ii. The government's Electric Vehicle Smart Charging Action Plan (2023)<sup>4</sup> and,
- iii. Government funding for V2X programmes since 2018.

This GEM supports the current V2X Innovation Programme,<sup>5</sup> which runs from 2022 to 2025, funded by the Department for Energy Security and Net Zero (DESNZ) and delivered by Innovate UK. The programme aims to mitigate barriers to enabling energy flexibility from bi-directional EV charging in many use cases (V2building/home/vehicle/ grid etc) and is part of a £1bn Net Zero Innovation Portfolio (NZIP).<sup>6</sup> California is the most mature EV market in the US, with an established ecosystem that coordinates with government, innovators, research, and industry supported by policy and targeted funding for EVs and infrastructure. V2X technologies can play an essential role in achieving California's 100% zero-carbon electricity target by 2045. With a shared market entry and technical barriers, the UK and California can work together to develop solutions and solve those challenges.

The technology for V2X bi-directional charging, business models, consumer propositions and the regulations surrounding it has yet to mature and is currently being developed in both countries. This presents an opportunity for the UK to assess the California research and innovation (R&I) ecosystem in V2X to help inform UK R&I strategy and build relationships with key stakeholders. The GEM programme is pivotal in identifying and shaping bilateral collaboration opportunities between the UK and California in EV smart bi-directional charging. Built around UK business, policy and research representation, the intended outcomes of the V2X GEM are to:

#### Inform UK businesses and government

The findings and opinions of V2X experts will be used to inform UK businesses and government about potential opportunities for collaborative V2X innovation between UK and California..

#### Build International Collaborations

These expert insights will help inform how Innovate UK can best help UK businesses find and exploit the opportunities for V2X innovation partnerships. The GEM creates connections with key organisations and people that will deepen and widen the collaboration with California to benefit UK business.

#### • Share UK Capabilities

During the mission, the delegation of UK V2X experts promoted and shared the UK's V2X innovation strengths to ensure the UK is the partner of choice for future innovation activities.



<sup>4</sup> https://www.gov.uk/government/publications/electric-vehicle-smart-charging-action-plan

<sup>5</sup> https://www.gov.uk/government/publications/v2x-innovation-programme

<sup>6</sup> https://www.gov.uk/government/collections/net-zero-innovation-portfolio

### 3.3 Mission Scope

Bidirectional charging technologies enable EV batteries to act as storage assets so that energy from the battery can power other devices when energy system prices are high, or grid supply constraints exist. Energy can be exported from the EV to a home, building, vehicles or the grid (Vehicle-to-Home/-Building/-Vehicle/-Grid). The term "Vehicleto-X energy" (V2X energy) describes all these propositions.

V2X involves many stakeholders from across the transport, energy and built environment sectors, including EV manufacturers, energy suppliers, aggregators, grid operators, charge point providers and operators, fleet operators and individual EV drivers, in addition to planners and regulators. The V2X landscape presents diverse opportunities for innovation in hardware, software, business models, flexibility services behind and in front of the meter, EV ownership models, electricity tariffs, grid connection processes and the regulations needed to enable energy flexibility using EVs. The UK has worldleading experience in V2X development and real-world demonstration, which it can share with California to accelerate its journey.

Our goals for this mission were:

- To gain an understanding of California's EV charging policy and regulation landscape, including California's transport & energy policies, ambitions, and challenges.
- To investigate California's progress in V2X development and deployment.
- To identify California's V2X challenges and therefore potential areas for cooperation between the UK and California.
- To explore joint-funding opportunities for UK-California R&D activities and interested partner organisations – funders & businesses.





## **Potential of** electric vehicles for energy flexibility

EVs have the potential to provide significant demand side response (changing the timing of energy demand), and energy storage in response to electricity system needs.

For example, EVs can charge when energy demand is low (typically overnight) or when there is plentiful renewable electricity generation.

# 04. Sector Overview

The UK government has funded the development of smart charging and V2X technology and services for many years through programmes focusing on public, workplace, and home charging solutions. This support has resulted in a growing ecosystem of highly experienced and innovative UK businesses developing the relevant hardware and software with an understanding of the business model and consumer needs.

### 4.1 V2X potential

Forecasting V2X capacity is challenging as it depends on several factors including consumer EV uptake, behaviour, technology and energy system development. However, there is a significant technical potential from using EV batteries which could provide an estimated 1500GWh of storage capacity by 2035.<sup>7</sup>

If every BEV with domestic off-street parking across Great Britain could export power, it could provide a potential capacity of 60GW in 2035; for context, peak demand in 2035 is expected to rise to approximately 90-105GW. In reality, it is unlikely that the entire technical potential will be realised as not all vehicles will likely be discharging simultaneously. Great Britain's transmission system, National Grid Electricity System Operator, estimates V2G services could provide as much as 39.3GW of flexible capacity under its most ambitious scenario.8

7 UK Government (2023), https://www.gov.uk/government/publications/electric-vehiclesmart-charging-action-plan, accessed on 13/03/2023 8 National Grid ESO (2022), https://www.nationalgrideso.com/future-energy/future-energyscenarios, accessed on 13/03/2023



UK forecasts and V2X development to date focus mainly on car and van use cases, since 92% of all miles travelled on UK roads each year are covered in these modes.9 However, heavy-duty vehicles such as buses, coaches, freight and construction vehicles, which have predictable usage patterns and downtime with high-capacity EV batteries, also provide good V2X potential, which has yet to be explored. The US is trialling this strategy with public school buses.

<sup>9</sup> UK Government statistics, 2020 https://www.gov.uk/government/statistics/transportand-environment-statistics-2022/transport-and-environment-statistics-2022, Last accessed 03/08/23



# What's driving V2X adoption?

Consumer awareness of sustainability along with policies and market incentives are driving the sale of EVs. While EVs are a significant step towards environmental sustainability, the growing energy demand places considerable pressure on the power grid. Renewable energy sources such as solar and wind, while gaining momentum provide intermittent energy supply. For example, during evenings when demand is high, solar supply would be negligible. With millions of EV estimated to be sitting in idle while connected to a charger, there is an opportunity to utilise V2X technology to feed energy back into the grid or to other devices. It is estimated by 2030, the US V2G market will reach \$21bn.<sup>10</sup> while the UK market will be at £2.9bn by 2027.11

10 https://www.altenergymag. com/news/2022/11/01/vehicleto-grid-technology-marketsize-to-hit-usd-2143-billionby-2030-/38483/ 11 https://www. precedenceresearch.com/ vehicle-to-grid-technologymarket

### 4.2 V2X Market size

The growth of the EV market will drive the adoption and market growth of V2X technology. Policies, incentives and other market drivers are already in place for EV adoption which is expected to grow significantly in the next decade. Estimates show the EV market will grow from £388bn in 2023 to £952bn by 2030, a CAGR of 13.7%<sup>12</sup> with over 100 million passenger EVs expected to be on the road by 2026.<sup>13</sup> Similarly, the US will also see a significant increase<sup>14</sup> and with the UK expected to have 6.5 million EV on the road by 2030,<sup>15</sup> there is a compelling business case for V2X technology.

12 Research and Markets 2021, https://www.researchandmarkets.com/reports/5337979/global-electric-vehicle-market-by-component
13 BloombergNEF, Electric Vehicle Fleet set to hit 100M by 2026. https://about.bnef.com/blog/electric-vehicle-fleet-set-to-hit-100-million-by-2026-but-stronger-push-needed-to-stay-on-track-for-net-zero/

- 14 https://www.statista.com/outlook/mmo/electric-vehicles/united-states
- 15 https://www.autotrader.co.uk/cars/electric/future-of-electric-cars/
- 16 https://www.cenex.co.uk/case-studies/project-sciurus/
- 17 https://octopusev.com/powerloop
- 18 https://electricnation.org.uk/

The UK's V2G Programme, which ran from 2018 – 2022, installed over 650 bidirectional V2G chargers in homes and workplaces across the UK for buses and CHAdeMO enabled EV cars and vans to test technology in operational conditions. Real-world private EV owners and fleet EV drivers trialled a variety of commercial propositions including fixed and variable tariffs for charging and discharging. Consequently, UK EV drivers are now providing energy back to the grid from their EV batteries when they do not need to use their vehicles for transport, earning revenue and reducing their recharging costs. However, the V2X market is still in its infancy, with most progress being driven by innovation projects in the UK. Groundbreaking projects, such as Sciurus,<sup>16</sup> Powerloop<sup>17</sup> and Electric Nation,<sup>18</sup> now have domestic consumers enjoying V2X benefits on a commercial basis.

ectric-vehicles/united-states future-of-electric-cars/ ect-sciurus/

# **Different modes of V2X charging**

There are two main variants of V2X:

- DC V2X uses direct current (DC) to transfer power between the EV and the grid. The DC inverter is located in the charging point and typically has higher power transfer rates.
- AC V2X uses alternating current (AC) to transfer power between the EV and the grid. The inverter is located in the EV, and the grid connection is made through a specially designed AC V2G unit, which safely supports synchronisation.
- AC V2G can potentially reduce bi-directional charger costs, as it requires less hardware within the charger, whereas DC V2X has the potential for higher power transfer rates.

Under the DC variant, there are two different charging protocols used by different EV manufacturers.

- CHAdeMO was developed with bi-directional capability within the protocol. Most V2G trials to date have used this variant but it is now only used by a few EV manufacturers such as Nissan and Mitsubishi.
- CCS has become widely used by European and US EV manufacturers and is now mandated in Europe. Market forecasts suggest CCS will be the leading DC charging standard in future. CCS will have its V2X standard (ISO15118-20) finalised by 2025. Few EVs currently have V2X commercially available, but OEMs and EV charging manufacturers have started to develop CCS solutions in advance of the standard.

The Tesla designed NACS charging system is also based on ISO15118 communication standards and Tesla began opening NACS up to other EV OEMs in 2022.

Most major EV OEMs have announced that bi-directional capability will be implemented in their vehicles in the coming years, while some have commenced with vehicle-to-load solutions in the interim.



Several companies in the UK market are starting to offer V2X services, including **Octopus, KrakenFlex,** EV.Energy, Kaluza, Nuvve, CrowdCharge and Fermata as system and optimisation providers and Indra, Hangar19 and Turbo Power Systems as leading UK hardware providers. A small number of global V2X hardware products have been used in the UK.

In 2019, the UK became the first major economy to sign into law a net zero emissions target. Published in October 2021, the UK Government Net Zero Strategy sets out the UK's critical path to achieving

its target by 2050.<sup>19</sup> This overarching strategy detailed on a sectoral basis the underpinning approaches and resources to meet the collective ambition. The electrification of power generation, heavy industry, heating, and transportation is critical to realising emissions targets. To support this electrification, the Government committed to the decarbonisation of the electricity grid by 2035<sup>20</sup> with the launch of low-carbon and renewable technologies and the enhanced use of flexibility services to replace fossil fuel power generation. The UK government is making efficient use of its infrastructure by investing in flexibility services to reduce generation capacity requirements and minimising costs of grid reinforcement, estimated at savings of up to £10 billion per year.<sup>21</sup> Smart energy systems and changes to how energy is generated, used and stored all contribute to these avoided costs. The UK's V2X ambitions were announced in its January 2023 Electric Vehicle Smart Charging Action Plan.<sup>22</sup>

The UK Government's ambition for energy sharing from electric cars and vans is that:

• By 2025, innovation projects and technology scale-up will have reduced barriers to entry for consumers and V2X will become more commercially viable. More V2X-compatible vehicles, increasingly affordable V2X charge points, and appropriate tariffs and business models providing revenue opportunities to consumers will be available. Vehicle-to-Home and Vehicle-to-Building technology will be attractive with 'behind-the-meter' energy optimisation and time-of-use tariffs. Vehicle-to-Grid will increasingly compete in the markets and services within the energy system.

• By 2035, all new cars and vans will have zero emissions at the tailpipe, and a significant proportion of these are expected to be V2X-capable. In a zerocarbon power system, these vehicles will provide significant bidirectional flexibility both behind the meter and at local and national levels. Domestic and business consumers participating in V2X will plug in every time they are parked at suitable locations, allowing their car battery to discharge, saving on their energy bills and potentially earning money while helping to decarbonise and stabilise the energy system. The car battery will charge at optimal times during the parked period, enabling the driver to return to their vehicle and begin their next journey with the required charge while protecting battery life.

**<sup>19</sup>** UK Government (2021), https://www.gov.uk/government/publications/net-zero-strategy, accessed on 13/03/2023

**<sup>20</sup>** UK Government (2021), https://www.gov.uk/government/news/plans-unveiled-to-decarbonise-uk-power-system-by-2035, accessed on 13/03/2023

**<sup>21</sup>** UK Government (2021), https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021, accessed on 13/03/2023

**<sup>22</sup>** UK Government (2023), https://www.gov.uk/government/publications/electric-vehicle-smart-charging-action-plan, accessed on 13/03/2023

### 4.3 UK V2X innovation landscape

The Vehicle-to-Grid (V2G) Programme ran from 2018 – 2022 funded by the Department for Business, Energy and Industrial Strategy (BEIS) now known as the Department for Energy Security and Net Zero (DESNZ), and the Department for Transport (DfT)'s Office for Zero Emission Vehicles (OZEV). This first UK-supported innovation programme for bidirectional EV charging was delivered by Innovate UK, funding 20 business-led projects to develop and demonstrate V2G solutions in homes and workplaces across the country, in addition to earlier stage feasibility studies and collaborative R&D projects. Over 650 bi-directional chargers for buses and CHAdeMO protocol cars and vans were deployed to test V2G technology in operational conditions and data was used to deliver a study of user behaviour, technical feasibility and commercial benefits for stakeholders in the Vehicle-Grid Integration (VGI) ecosystem. Consequently, UK EV drivers are now providing energy back to the grid from their EV batteries when they do not need to use their vehicles for transport, earning revenue and reducing their recharging costs. This programme fostered the UK's growing V2G ecosystem, leading to further partnership opportunities and UK designed V2G equipment and flexibility services being introduced to the market.

plan for a Green Industrial Revolution, announced in 2021,<sup>23</sup> a £1bn Net Zero Innovation Portfolio (NZIP)<sup>24</sup> was established to accelerate the commercialisation of lowcarbon technologies, systems and business models in power, buildings, and industry. The NZIP seeks to bring down the costs of decarbonisation and stimulate investment and technological advancement, supporting green jobs and regional economic growth.

Under NZIP, the UK's V2X Innovation Programme has delivered 17 collaborative research and development projects and will be followed up by small-scale realworld demonstrations in 2024. The flagship V2X programme is facilitating the UK Government's Net-Zero targets while helping consumers to transition from petrol and diesel cars to ZEV.



# **Global efforts to achieve Net-Zero in transportation**

At COP26, hosted by Glasgow in 2021, the Zero Emissions Vehicle Declaration (ZEV Declaration) was launched by a leadership group of more than 100 countries, businesses, and organizations committed to driving forward a transition to a climate-neutral transportation sector. The Accelerating to Zero (A2Z) Coalition was founded at COP27 in 2022 to support signatories of the ZEV Declaration and to connect the world's leading organizations on zero-emission transportation. A2Z serves as a platform for signatories to coordinate, align activities, and amplify messaging as they fulfil their ambitious pledge that all sales of new cars and vans be zero emission by 2040, and by 2035 in leading markets. A2Z also provides implementation support for signatories, now numbering over 200, to develop and deploy ambitious zero-emission transportation policies and plans, showcases examples of leadership within the ZEV community, recruits new signatories, and monitors progress on the global transition. A2Z is a collaboration of the Climate Group, Drive Electric Campaign, the Government of the United Kingdom, and the International Council on Clean Transportation.

As part of the UK government's ten-point

**<sup>23</sup>** https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

<sup>24</sup> https://www.gov.uk/government/collections/net-zero-innovation-portfolio

### 4.4 Policy and legislation in California

California is leading the way for Electric Vehicle (EV) adoption in the US, with CARB estimating that California accounts for 40% of all EV sales in the US.<sup>25</sup> The state has supported developing and deploying different types of charging infrastructure to meet users' varied needs.

Vehicle-Grid Integration (VGI), which is the term more widely used in the US, encompasses both managed charging (also known as V1G or smart charging) and bidirectional charging (V2Home & V2Grid) and is a vital tool for achieving California's decarbonisation and EV adoption goals.

California is pioneering V2X technologies in the US, including V2G and V2B. With climate change a major concern, from heatwaves and wildfires to winter storms, there is an urgent need to store and retrieve reliable electricity as a backup. The California Energy Commission estimated that if one in ten vehicles provided electricity to the grid, it would be equal to two additional Diablo Canyon nuclear power plants.<sup>26</sup> As a result, V2G regulations in California are already in place, which also cover solar power and stationary battery systems to store excess energy for use after sunset.

California is introducing legislation to support the growth of both EV and V2X technologies. The California Air Resources Board (CARB) has approved a rule requiring all new car sales in California to be zeroemission vehicles by 2035.<sup>27</sup>

California Bill SB233,<sup>28</sup> proposed by Senator Skinner, is currently going through the Senate committee review process. If approved this bill would require all new light-duty motor vehicles and school buses sold in California to have bi-directional capability by 2030.<sup>29</sup> Initial responses have already delayed the original 2027 target date and removed the associated proposal for charging infrastructure V2X requirements.

**29** https://sd09.senate.ca.gov/news/20230531-ca-senate-greenlights-senskinner%E2%80%99s-sb-233-using-evs-power-homes



### SB233

California Bill SB233, titled "Electric Vehicle Bidirectional Capability Act of 2023", would require all new electric vehicles sold in California to be bidirectional capable by 2030.

The Bill would also require the Energy Commission to set up a stakeholder working group to examine the challenges and opportunities associated with V2X technologies before 30th June 2024. It would be required to submit a report detailing the economic and technical feasibility and wider system benefits and impacts of V2X.

It is intended to support California's clean energy goals, increase flexibility of the grid and reduce peak energy demand, but some groups have opposed the bid citing concerns over the costs of implementation.



**<sup>25</sup>** https://electrek.co/2023/04/21/ca-hits-ev-target-ahead-of-schedule-its-not-the-first-place-to-do-so-and-wont-be-the-last/

**<sup>26</sup>** https://www.latimes.com/business/story/2022-07-27/electric-school-buses-in-el-cajonwill-send-power-to-the-grid

**<sup>27</sup>** https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035

**<sup>28</sup>** Bill Text - SB-233 Electric vehicles and electric vehicle supply equipment: bidirectional capability.

### 4.5 V2X Initiatives in California

Several pilot programmes are underway in California to assess the viability of V2X for energy storage and utilisation. The California Energy Commission has funded the use of electric buses which have a storage capacity five times that of electric cars to power Oakland Public Library.<sup>30</sup> In addition, San Diego, in partnership with San Diego Gas and Electric, has a pilot study trialling V2X with a fleet of electric buses where the revenue will benefit School Districts.<sup>31</sup> It is estimated that 95% of the costs for a fleet of eight buses were funded through State and Federal grants.<sup>32</sup>

Key stakeholders for the pilot programme include the US Environmental Protection Agency, the California Energy Commission, and the California Air Resources Board who supported the grants. Additionally, California Public Utilities Commission in San Diego Gas and Electric's territory has established an Emergency Load Reduction Program which pays business customers \$2 per kilowatthour if they can export power back to the grid or reduce their usage during energy emergencies.<sup>33</sup> California utility, Pacific Gas and Electric has received approval to establish the US' first V2G export compensation mechanism for commercial EV charging customers.<sup>34</sup> The Vehicle-Grid Integration Council, Electrify America and California Public Utilities Commission created this agreement. In particular, public and school buses are seen as an opportunity due to the economic benefits, as they have switched to EVs in greater numbers than consumer vehicles.

BMW is partnering with Pacific Gas & Electric to develop a testing programme for V2X technologies until 2026<sup>35</sup> in San Ramon at PG&E's Applied Technology Services Lab. The pilot looks specifically at the domestic market, with results showing that *"a vehicle-to-home connected EV is capable of providing roughly double the amount of renewable energy that a typical California household would be able to use on an average day, significantly increasing customers' ability to use more green energy daily"*.



The BMW/PG&E programme will also consider wider benefits for the customer and the utility. The programme follows from BMW's ChargeForward initiative, where customers were offered smart charging tariffs. There will be a field trial of the V2X programme at BMW Group Technology Office in Mountain View, CA. There will also be a test fleet integrated with the grid to develop advanced use cases for commercialisation.

- **31** https://cleantechnica.com/2022/07/31/san-diego-electric-school-buses-shuttling-electricity-into-the-grid-now/
- 32 https://www.latimes.com/opinion/story/2023-03-12/vehicle-to-grid-car-batteries
- **33** https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/emergency-load-reduction-program
- 34 https://v2g.co.uk/2022/10/pge-announce-v2g-export-tariff-for-commercial-evs/
- 35 https://www.greencarcongress.com/2023/05/20230517-pge-bmw.html



<sup>30</sup> https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-014.pdf



# 05. California Innovation Landscape

The United States spends \$550 billion per year (2.8% of GDP) on research and development<sup>36</sup> with the majority (73%) funded and operated by the private sector. Consequently, public research funding, largely the domain of the federal government, is strongly focused on fundamental science rather than innovation. At the federal level, science funding is highly decentralised, with over 20 executive departments and agencies supporting research, the largest being the National Science Foundation (NSF), the National Institutes of Health (NIH), the Department of Energy (DOE), and the Department of Defense (DOD).

Federal funding complies with the Justice40 Initiative, a requirement of Executive Order 14008, which seeks to deliver at least 40 percent of the overall benefits from certain federal investments to disadvantaged communities.<sup>37</sup> The ability to ensure equality of access and provision has frequently been highlighted as a key consideration for many of the V2X innovation projects.

<sup>36</sup> https://www.gov.uk/government/publications/uk-science-and-innovation-networkcountry-snapshot-usa

**<sup>37</sup>** https://www.energy.gov/em/justice40-initiative

### 5.1 US Science & Innovation Priorities

The US has set out a number of policy goals relating to strengthening US science & innovation capacity. Those most relevant to the mission include:

- Increasing funding for clean energy innovations by \$10 billion
- The American Al initiative seeks to boost Al investments across many government agencies<sup>38</sup>

In addition, the American Green Jobs Initiative,<sup>39</sup> is part of a wider plan to address climate change while increasing R&D investment and job creation. The policy aims to:

- Provide investments into clean energy infrastructure
- Enhance investments into research and development
- Support workforce training to ensure the relevant skills are available to deliver the intended outcomes

Within California, the California Energy Commission (CEC) is a state-funded agency that has run R&D funding programmes in areas related to energy and EVs, including funding of some previous V2X projects.

The California Council on Science and Technology has a mission

'to engage leading experts in science and technology to advise State policymakers ensuring that California policy is strengthened and informed by scientific knowledge, research, and innovation.' <sup>40</sup> California has a group of leading universities who have expertise in energy and EV related themes including The California Institute of Technology (Caltech),<sup>41</sup> Berkeley College of Engineering<sup>42</sup> which is part of the University of California, which also manages the Lawrence Berkeley National Laboratory for the US Department of Energy's Office of Science. Stamford University and the University of Southern California (USC) also have leading engineering schools.

The University of California, Los Angeles has teams specialising in energy and electric vehicles and lead the Connected Autonomous Electric Vehicle (CAEV) consortium consisting of automotive companies, electric and autonomous transportation providers and electric power companies. <sup>43</sup>



**41** https://www.caltech.edu/about/at-a-glance#:~:text=Mission,through%20research%20

**<sup>38</sup>** https://www.gov.uk/government/publications/uk-science-and-innovation-networkcountry-snapshot-usa

**<sup>39</sup>** https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/

<sup>40</sup> https://ccst.us/about-ccst/

**<sup>41</sup>** https://www.caltech.edu/about/at-a-glance integrated%20with%20education.

<sup>42</sup> https://engineering.berkeley.edu/about/

<sup>43</sup> https://smartgrid.ucla.edu/CAEV/

### 5.2 Policies driving California's ZEV and V2X market

California Air Resources Board (CARB) has legislated to require all new car sales in California to be zero-emission vehicles by 2035. Bill SB-233 is currently being finalised, which would require all new electric lightduty motor vehicles and school buses sold in California to have bi-directional capability by 2030.

In addition, wider policies and white papers support innovation growth in relevant areas. California's Climate Change Solutions Roadmap (2022)<sup>44</sup> was produced as a collaboration between CARB, CEC, and the California Department of Public Health (CDPH). It outlines a comprehensive plan for reducing greenhouse gas emissions in California by 85% by 2045. Six specific areas are listed as priorities including:

- Clean energy technologies: Prioritises the continued development and deployment of renewable, clean energy technologies, including solar and wind, while promoting energy efficiency measures.
- Energy efficiency: The roadmap seeks to find solutions to increase energy efficiency in buildings, appliances, and transportation.
- Transportation: Seeks acceleration of the transition to zero-emission transportation, covering electric vehicles (including heavy goods vehicles), public transport, and walking/cycling modes.
- Agriculture and forestry
- Water management
- Adaptation and resilience<sup>45</sup>

CalEPA (the California Environmental Protection Agency) provide an overview of tools, strategies and plans for climate solutions. The Zero Emission Vehicle (ZEV) Market Development Strategy 2022,46 from the Californian State Government brings together a series of important documents and strategies. The Market Development Metrics help to track progress against California's goals. The ZEV Pillar Priorities strategy implementation document 'identifies near term actions that will advance the ZEV market by creating market opportunities, removing barriers, and expanding shared knowledge.' It highlights four pillars crucial to market development from infrastructure rollout to user experience:

- Vehicles
- Infrastructure
- End-users
- Workforce



**<sup>44</sup>** https://ww2.arb.ca.gov/resources/fact-sheets/californias-2022-climate-change-scoping-plan-fact-sheet

**<sup>45</sup>** https://ww2.arb.ca.gov/resources/fact-sheets/californias-2022-climate-change-scoping-plan-fact-sheet



Numerous policies prioritise the equity of rollout in the growth of the EV market. The 2021 Californian Comeback plan,<sup>47</sup> along with the 2022 additions from the Californian Blueprint Plan,<sup>48</sup> targets packages of investments in infrastructure to tackle areas which have not received an equal proportion of EV charging points. The CEC's Transport Investment Programme<sup>49</sup> also targets investments in low income and disadvantaged communities, thus supporting Justice40 initiatives. R&D solutions to support sustainable growth of infrastructure in underserved communities would help to achieve these goals.

california-roars-back-governor-newsomsigns-100-billion-california-comeback-planto-accelerate-states-recovery-and-tacklepersistent-challenges/#:~:text=This%20 transformative%20budget%20includes%20 the,the%20state's%20most%20 persistent%20challenges. 48 https://calmatters.org/politics/2022/01/ california-budget-newsom/ 49 https://www.energy.ca.gov/ programs-and-topics/programs/ clean-transportation-program/cleantransportation-program-investment-

47 https://www.gov.ca.gov/2021/07/12/

CEC's Zero Emission Vehicle Infrastructure Programme <sup>50</sup> highlights a range of actions required, both short and longer term, to stimulate market growth. It references R&D projects funded or supported to help to meet the market needs.

Many public sector organisations have their own action plans to help zero emission transport growth, from CARB and CEC through to individual Community Choice Aggregators (CCAs) and utilities.

- 50 https://www.energy.ca.gov/publications/2022/zero-emission-vehicle-infrastructure-planzip
- 51 https://www.gov.ca.gov/wp-content/uploads/2023/05/CAEnergyTransitionPlan.pdf
- 52 https://www.californiaclimatejobsplan.com/jobscreation
- 53 https://dot.ca.gov/news-releases/news-release-2021-005

Building the electricity grid of the future: California's clean energy transition plan (2023)<sup>51</sup> sets a vision for a clean grid powered by 'low-cost, carbon free electricity' and transportation is zero-emission with convenient plug-in places for all. The Californian Climate Jobs Plan<sup>52</sup> seeks to grow industries to achieve their climate goals while creating a million new jobs.

The California Department of Transportation's Roadmap to a Zero-Emission Transportation Future (2021)<sup>53</sup> identifies key R&D themes including electrification of transportation, advanced vehicle technologies, infrastructure for zeroemission vehicles and public engagement activity to support the growth.

The National Academies of Sciences, Engineering, and Medicine's (NASEM) Report on Research and Development Priorities for the US Department of Energy (2022) identifies six priority areas for R&D, which includes energy security and climate change as two of the key areas for development. Energy and environment are also highlighted in the National Institute of Standards and Technology Strategic Plan to 2027<sup>54</sup> and the American Association for the Advancement of Science's (AAAS) R&D Vision for America (2020).**55** 

At a federal level, the Biden administration has prioritised policy to scale up Clean Energy growth. It has issued a range of mandates to support renewable energy infrastructure rollout, innovation and job creation opportunities.



<sup>54</sup> https://www.nist.gov/system/files/documents/2023/01/27/MEP\_Strategic\_2023-2027\_ plan\_508\_final.pdf

<sup>55</sup> https://www.aaas.org/news/snapshot-us-rd-competitiveness-2020-update



# 5.3 UK-US Science and Innovation Cooperation

The UK and US have a strong track record for collaboration on science and innovation projects. In 2017 the two countries signed a government-to-government Science & Technology Agreement, which outlines a commitment to collaborate on world-class science and innovation. In 2020 the UK and US agreed a Statement of Intent to jointly develop programmes in artificial intelligence R&D. 56

Science and technology cooperation was reaffirmed as a core tenet of the bilateral relationship in the New Atlantic Charter. In June 2023, the Atlantic Declaration for a Twenty-First Century US-UK Economic Partnership was announced to enhance collaboration in key science and innovation challenges. The Atlantic Declaration and accompanying Action Plan set out key innovation areas across economic, technological, commercial and trade relations (White House 2023).57

It highlights five pillars of the partnership including:

- ensuring US-UK leadership in critical and emerging technologies,
- advancing ever-closer cooperation on our economic security and technology protection toolkits and supply chains,
- partnering on an inclusive and responsible digital transformation,
- building the clean energy economy of the future, and
- further strengthening our alliance across defence, health security, and space. (White House 2023)<sup>58</sup>

The approach includes exploring joint efforts and collaborative R&D in various critical and emerging technologies. Particularly relevant to the V2X theme is the statement related to partnering on a Joint Clean Energy Supply Chain Action Plan, to support clean energy transition including EVs.

<sup>56</sup> https://www.gov.uk/government/publications/uk-science-and-innovation-networkcountry-snapshot-usa

<sup>57</sup> https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/08/theatlantic-declaration-a-framework-for-a-twenty-first-century-u-s-uk-economic-partnership/ 58 https://www.whitehouse.gov/briefing-room/statements-releases/2023/06/08/theatlantic-declaration-a-framework-for-a-twenty-first-century-u-s-uk-economic-partnership/

### 5.4 Key in-country stakeholders

The GEM team had the opportunity to engage with leading experts and organisations in California. The meetings provided invaluable insights in the R&I challenges for V2X in California, and the policy and regulatory aspects which could drive growth and adoption.

### California Senate Assembly – Committee on Transportation

Committee jurisdiction includes California High-Speed Rail Authority, California Highway Patrol, California Transportation Commission, Department of Motor Vehicles, Department of Transportation (Caltrans), driver's licenses, freight, regional transportation agencies, transit authorities, intercity rail, mobile sources of air pollution, fuels, rules of the road, state highways, local streets and roads, vehicles, aircraft, bicycle and pedestrian facilities, and vessels. The GEM team met with a consultant to the Transportation Committee to discuss CA's existing and proposed policy in EV and EV charging, including Bill SB233's history and aims regarding V2X. This meeting helped to identify CA's biggest challenges in transport decarbonisation, energy security and equality, which were followed up in subsequent stakeholder meetings. Initial discussions identified possible sources for UK-CA joint programme funding and opportunities for UK lessons and expertise to be shared with CA.

#### California Air Resources Board (CARB)

The California Air Resources Board are a state government-appointed body for monitoring and reducing the harmful effects of air pollution. They are the lead agency for climate change programs and oversee all air pollution control efforts in California.

CARB sets the state's air quality standards, verifies automakers' emissions compliance and studies the costs and benefits of pollution controls across California.

This meeting enabled the GEM team to get an overview of the policy drivers and regulation plans being developed to deliver CA's carbon neutrality targets by 2045 and their plans for the forthcoming fiveyear budget. CARB representatives shared their perspectives on V2X opportunities, which included interest in school bus and light freight solutions, and the viability of incentives or credits for V2X participation.



### California Energy Commission (CEC)

The California Energy Commission is leading the state to a 100 percent clean energy future for all. As the state's primary energy policy and planning agency, the Energy Commission plays a critical role in creating the energy system of the future - one that is clean modern and ensures the fifth largest economy in the world continues to thrive.

The commission provides grants and funding support to advance the state's clean energy transition and is the research arm of California Public Utilities Commission (CPUC).

There was a positive discussion on the potential partnership for future bilateral calls. The CEC team outlined the previous and currently funded projects and emphasised the appetite to move past pilot studies into scalable solutions and demonstrators to unlock the market. A range of potential themes and areas of interest to explore further with projects were considered.



# California Independent System Operator (Cal ISO)

The California Independent System Operator maintains reliability on one of the largest and most modern power grids in the world and operates a transparent, accessible wholesale energy market. They provide open and non-discriminatory access to the bulk of the state's wholesale transmission grid, supported by a competitive energy market and comprehensive infrastructure planning efforts.

California ISO explained its role within the ecosystem. It detailed the challenges of significant variability in supply and usage throughout the day and the year, which often impacts more than the peak load challenge. Modelling, customer incentives, metering requirements and grid codes were discussed in detail.

# California Public Utilities Commission (CPUC)

The CPUC regulates privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation. It is the key regulator in California for electrification to help accelerate electric vehicle adoption.

CPUC's regulation of investor-owned utilities provides them an overview of the challenges and opportunities for smart grid, V2X and EV adoption.

The CPUC meeting centred on their three priority areas of technology enablement, rates and demand flexibility. They also shared information on their policy framework and potential updates which could support V2X uptake.

### Pacific Gas and Electric Company (PG&E)

The Pacific Gas and Electric Company is one of six investor-owned electric utilities in California and are improving electrification infrastructure for domestic and commercial customers. PG&E offer EV Time of Use tariffs and have partnered with CEC and CARB on a pilot project rolling out charging infrastructure for school busses, to encourage wider adoption of EV.

The GEM team were informed of their range of projects in the V2X space, including ideas on tariffs, grid code limitations and metering requirements.

### Gridscape

Gridscape Solutions is a software and service company that specialises in designing and developing a broad range of smart energy solutions for enterprises. This includes supplying microgrids and supporting EV fleet electrification infrastructure.

Gridscape offered an insight into the challenges and solutions to developing efficient and affordable electrification infrastructure.

# Sacramento Municipal Utility District (SMUD)

SMUD is the US's sixth-largest, communityowned, not-for-profit electric service. SMUD is a recognised industry leader for its innovative energy efficiency programs, renewable power technologies, and sustainable solutions for a healthier environment.

At the cutting edge of developing publicprivate EV programs across its service territory, SMUD provides information about EV choice and accessing EV charging.

SMUD provided detailed information on grid code impacts including Rule 21, tariffs, incentives for flexibility and initial findings from V2X pilot projects.



#### Vehicle-Grid Integration Council (VGIC)

Vehicle Grid Integration Council is a USbased advocacy group to advance the rollout of electric vehicles and smart EV charging through policy development, education, outreach, and research.

VGIC provided insights into policy processes in the US, their areas of advocacy focus, their perceptions around customer engagement and opportunities for international collaboration.

#### Fermata Energy

Fermata Energy focuses on the adoption of electric vehicles and decarbonisation of the transportation industry. Fermata offer consumer focused bidirectional charging technology, to support grid resilience and deploy renewable energy resources quickly.

#### Marin Clean Energy (MCE)

MCE is a not-for-profit public agency supplying clean energy across four Bay Area counties, with a strong focus on community engagement. As part of this, MCE offers energy storage for critical facilities and income-tied rebates for electric vehicles.

MCE provided insight into how community energy providers are supporting consumer adoption of ZEV and challenges with grid implementation.

#### Kaluza

Kaluza supplies real-time energy costs to manage a household and vehicle's energy consumption to reduce costs and reduce use of non-renewable energy. Their Al and integration with European energy companies allows them to work with in-home smart technology to improve the efficiency of energy use.

#### Nuvve

Nuvve supplies V2G software and technology to consumers which improve energy efficiency and reduce costs. Nuvve's Vehicle Smart Link works with their NERA software to manage vehicle energy use to calculate how much capacity is available to sell back to the grid before the vehicles next trip.

#### Peninsula Clean Energy

Peninsula Clean Energy is a community-led electricity provider for San Mateo County and the City of Los Banos, with a focus on supporting EV charging and improving electrification infrastructure. It was formed as a Community Choice Aggregation (CCA) program, providing customers with environmental and economic benefits.



### Silicon Valley Clean Energy (SVCE)

Silicon Valley Clean Energy is a public, not-for-profit agency that provides clean electricity for 270,000 residential and business customers across the Silicon Valley. Their eHub provides support and rebates for consumers to utilise clean electricity generation and transition to electric vehicles.



# 06. Collaboration Opportunities

### Joint Collaborative research and innovation is key to unlocking the V2X market in the UK and California

There is an appetite for Joint UK-California innovation programmes in the V2X sector in areas including:

- Equitable rollout of charging infrastructure with a focus on residential V2X charging
- ii. Demonstration and testing of smart multi-modal charging hubs

iii. Fleet V2X

iv. Innovative business models for Tariff design.

While all areas are critical for development, the mission identified fleet V2X to be an area where the UK can learn from California. The US has adopted fleet EV and is trialling V2X with school buses which is directly benefitting underprivileged communities. Development of regulations and approaches to achieve a more consistent approach to grid connection approval and installation process is vital to facilitate V2X uptake. The connection issue has been widely acknowledged by both UK and US stakeholders as delaying market development. While some UK distributed network operators (DNOs) have made progress, more can be done to make this consistent across the country. A harmonised approach between California and the UK will help businesses design products suitable for approval in both markets.

#### EV battery life is critical to V2X adoption

EV battery life is a key concern for UK consumers and impacts their likelihood of adopting V2X technologies. Research into the impact of V2X on EV battery health, to provide consumer confidence through performance transparency, has developed further in the US and California. CA is considering mandating data sharing on battery state of health. This could be an area for both R&D collaboration and regulation standardisation across both territories. The UK has companies already developing strongly in the battery health space which offers commercial opportunities.

#### Business support programmes are required to help companies expand into the California market

An accelerator programme customised for the California market would benefit UK companies in the V2X space. It would help them understand California's landscape and regulatory restrictions in more detail and enable them to tailor their products/ services to suit that market. For example, UK businesses must comply with the US product and installation regulation. This means UK businesses must make product adaptions to comply with the US's National Electrical Code (NEC).

### A UK-US industry steering group to lead globally in V2X and facilitate cross-border innovation

With the success of the UK-US industry roundtable in the mission there was an appetite to form a steering group with leading experts from industry, government and policy to unlock new market opportunities. A UK-US steering group in V2X will help resolve critical innovation bottlenecks as well as mitigating regulation and operational issues.



### Challenges in implementing residential V2X infrastructure

Equity is important in EV charging deployment. Affordability, accessibility, reliability, location, safety and related economic opportunities must be considered to ensure that EV benefits and costs are fairly distributed across society. Addressing the variation in at-home charging capabilities is a priority area for both UK and US. This includes supporting renters, residents in multi-unit dwellings, or residents without dedicated parking. EV drivers who cannot park and charge/discharge at their own property should not be excluded from benefitting from commercial V2X opportunities.

In urban areas, there is limited physical space on residential streets and insufficient grid capacity for all households to charge at once. Therefore, a number of solutions are being explored in the UK to mitigate local grid reinforcement costs:

- Connection of on-street charge points to home energy supplies, also enabling V2X.
- Development of shared public charging infrastructure close to residential areas, which could also provide V2X services to the grid, nearby buildings or other vehicles.

These options require a detailed analysis of the business case to establish equitable shared benefits in both US and UK.



### Interconnection regulations

The UK and US have specific technical standards that regulate the interconnection of small-scale generators and distributed energy resources (DERs) to the electricity grid. These are covered by Rule 21 in the US and G98/99/100 in the UK. The specific rules and requirements are dependent on the assets and size of generation.

The aim of both pieces of legislation is to ensure that devices which can add electricity into the network can be connected to the grid safely and reliably, whilst also protecting the grid from potential risks such as voltage fluctuations and overloading. They contain complex sets of rules covering requirements for voltage control systems and protection devices, alongside setting out the testing and documentation requirements to prove compliance.

The current legislation is designed for assets such as solar panels and static batteries, meaning some of the requirements and processes are not optimally designed for the V2X context. This has led to issues getting approvals agreed in a timely manner in both the UK and US and restricts market growth.

### Product design requirement to comply with the US' National Electrical Code (NEC)

Different regulations between the UK and US may require some product adaptions for UK suppliers moving into the Californian market. The NEC stipulates that:

- Chargers must be able to communicate with the grid, whereas the UK require smart functionality.
- Chargers must be installed on a dedicated circuit with a minimum of six-gauge wire, whereas the UK does not legislate the minimum wire gauge.
- EV chargers must be protected by a ground fault circuit interrupter (GFCI). The UK regulations do not specifically require GFCI protection, but they do require that the charger be protected by a residual current device (RCD).





# 07. Potential Barriers to Collaboration

### AC V2G is currently not supported in California

AC V2G is not possible within the regulatory framework in the US. While this is a key barrier to V2X rollout in California, it offers an opportunity to jointly work with Californian stakeholders on standards and regulations. This would help remove barriers to market entry and open up new opportunities for UK businesses developing AC V2G technology.

### Grid balancing demands are significantly different between California and the UK

Unlike the UK, which balances across a single entity, the California market has multiple utilities that can operate different signals based on their local needs. The whole system needs balancing across these areas to avoid misaligning flexibility activity. There is also the Western Interconnection balancing, and links to the national network.<sup>59</sup> This adds a layer of complexity to the tariff and demand flexibility signalling issues which are absent in the UK market.

### California has stringent environmental regulations

These regulations cover energy efficiency, pollution and wider environmental performance and apply to all businesses irrespective of whether it operates in the state. Specific legislation includes the California Environmental Quality Act (CEQA) which places requirements on businesses to assess their operations' environmental impacts before they can proceed. While this does not prevent collaboration, any joint projects need to be mindful of the requirements.

**<sup>59</sup>** https://www.epa.gov/green-power-markets/us-grid-regions



# **08.** Conclusions

The GEM identified a number of opportunities for collaborative V2X R&D programmes to help overcome key barriers and create new business opportunities. Key themes of interest include equitable rollout, fleet solutions, unlocking the public onstreet and shared residential opportunities and smart multi-modal transport hubs. In addition, new approaches to tariff design to deploy energy flexibility present opportunities for consumers to benefit from the changes in domestic, fleet and heavy freight markets. It is vital for both geographies to align regulations and grid codes to facilitate cross-border collaboration and innovation activities, and to support the launch of new products and services in both markets. Topics highlighted as high-priority include interconnection regulation, overcoming barriers to AC V2X, metering, carbon credit approaches, utility regulations and data standards.

Developing scalable solutions is vital to capturing the opportunities highlighted in the report. Innovate UK's Global Business Innovation Programmes (GBIP) and Global Incubator Programmes (GIP) provides the perfect opportunity for shared learning and helping companies to expand their market horizons.

There is a good opportunity for the UK to be world leaders in V2X development and market adoption. There is a clear intent and interest by public and private Californian stakeholders to engage with UK in joint innovation activities in V2X.





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