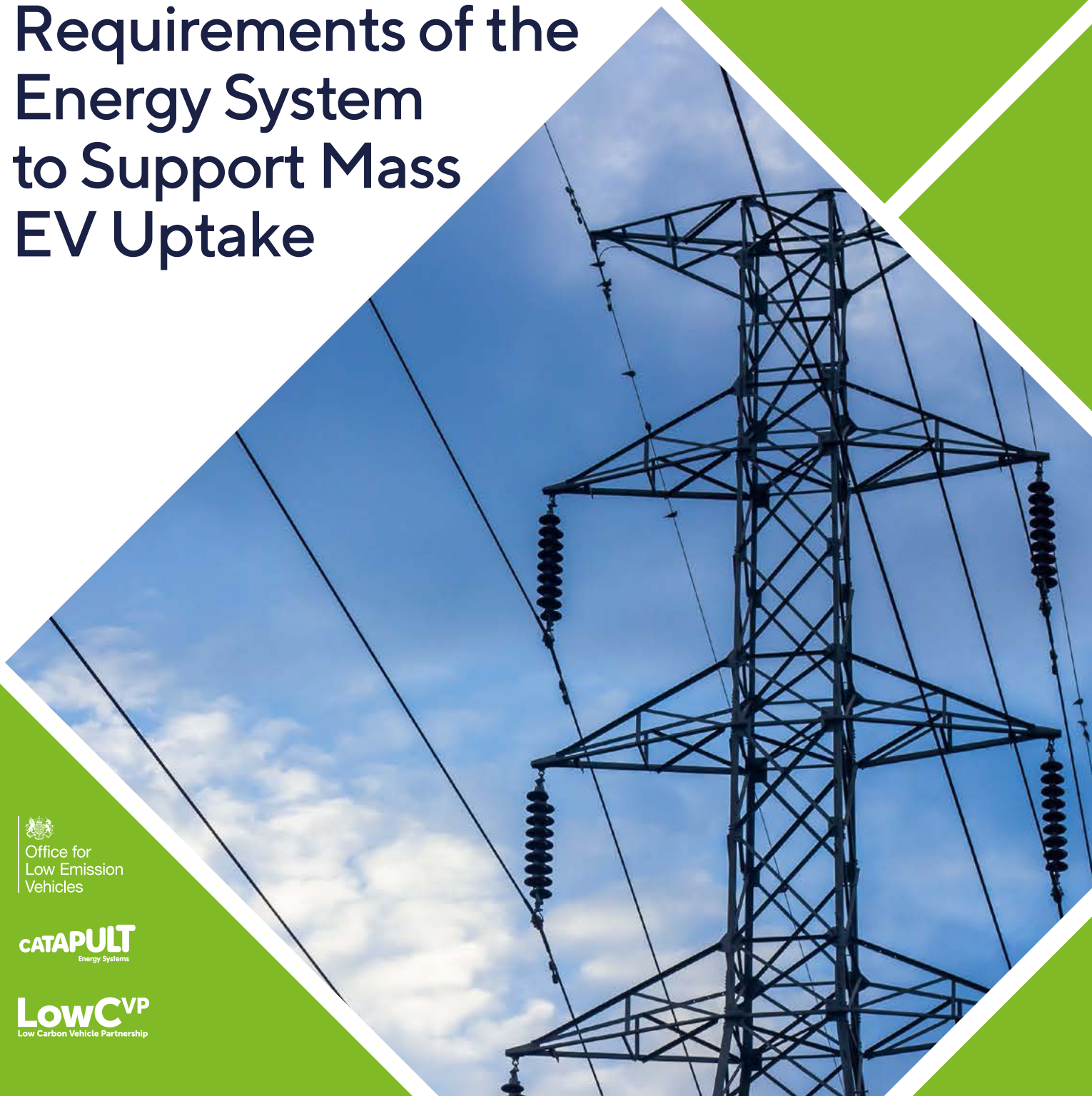
energy taskforce

Work Package One:

A Common Strategic Understanding of the Requirements of the Energy System to Support Mass EV Uptake



Office for Low Emission Vehicles

CATAPULT Energy Systems

LowCVP Low Carbon Vehicle Partnership

Contents

1 Introduction

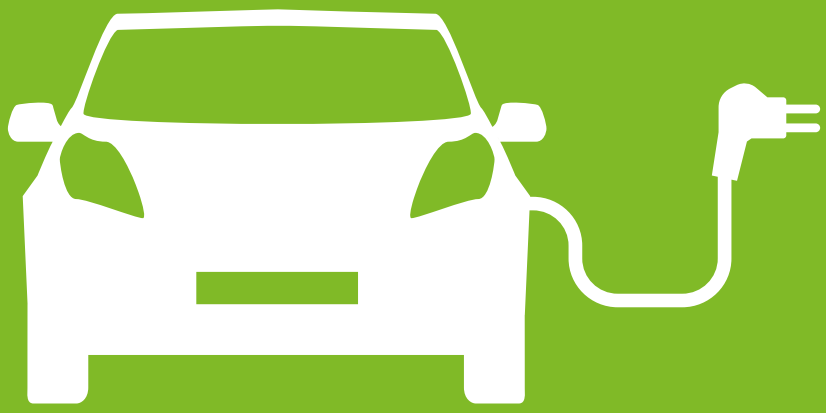
Introduction

The Electric Vehicle Energy Taskforce was set up to address a range of questions related to meeting the demands of the wide scale adoption of Electric vehicles (EV) on the electrical networks. The Electric Vehicle Energy Taskforce established four Work Packages to consider the following issues:

- Work Package 1 – A common strategic understanding of the requirements of the energy system to support mass EV uptake.
- Work Package 2 – Engaging EV Users in Smart Charging and Energy Services
- Work Package 3 – Smart Charging Technical Requirements
- Work Package 4 – Accessible Data for Decision Making

This is the report of Work Package 1 which was asked to focus on the broader strategic issues involved in preparing the GB electric network for the mass take up of EVs. The methodology, findings and recommendations of Work Package 1 are outlined in this report.

2 Context of Work Package 1



Context of Work Package 1

Aims and objectives

The aim of Work Package 1 has been to gain a common strategic understanding of the requirements of the energy system to support mass EV uptake. In so doing Work Package 1 has taken account of:

- Activity Ofgem is leading regarding future market arrangements.
- National Grid's Future Energy Scenarios as a basis to quantify future projections against which to develop recommendations.
- The National Infrastructure Commission's National Infrastructure Assessment.
- Other sources of evidence – including from an extensive literature review.

Work Package 1 has sought to provide a perspective on the following:

- A common understanding of the relative importance of the impacts that need to be addressed (e.g. reducing peak demand, reducing network reinforcement).
- Where financial benefits accrue, and risk is held, under different investment approaches.
- What the appropriate balance is between regulation and market mechanisms to encourage innovation.
- Taking a holistic view of the energy system to understand how it might evolve accounting for wider energy system changes, for example, decarbonisation of heat and decentralisation of power generation.
- How to ensure that the needs of EV and other energy users are simultaneously met.

Questions asked of Work Package 1

In order to fulfil its aims and objectives, Work Package 1 has been asked to address the following questions:

1. How can we ensure that the local network effects of EV uptake in the near term (i.e. before smart meter rollout is completed and smart tariffs are fully offered) and long term are managed in an effective and efficient way?
2. What are the barriers for EVs (in terms of smart charging and Vehicle to Grid (V2G)) accessing the energy markets?
3. Are changes required to metering/supply arrangements to accommodate new innovative business models associated with EV charging infrastructure, whilst ensuring that consumers' interests are protected?
4. How applicable are international examples (e.g. California, Norway) to GB in terms of overcoming network constraints and the adoption of smart charging?
5. Where do the investment opportunities lie, including for smart charging and V2G? Is intervention required? Are there opportunities to optimise costs or improve amenity that aren't being progressed? Are interventions needed to help overcome barriers?
6. How can we ensure that EV charging works in harmony with other changes to the energy system, such as decarbonising heat (especially if we don't know what these changes will be)?
7. What can be agreed about the shared long-term vision for the energy system requirements for mass EV uptake (e.g. the market arrangements, where the benefits will accrue and where costs should fall)?

Participants in Work Package 1

Work Package 1 was led by the Energy Systems Catapult (ESC) and has a core team comprising ESC staff from various relevant backgrounds and a consultant power system engineer.

The ESC Team comprised the following: David Bevan, Eric Brown, Mike Edgar, Susanna Elks, John Fox, Richard Halsey (Lead), Gordon Graham, Liam Lidstone, Alasdair Muntz, and Dave Openshaw (Millhouse Power Limited).

Additional contributions to the team were provided by Daniel Brown (REA), Tony Glover (ENA), Yselkla Farmer (BEAMA) and Marine Ratton Pimenta (LowCVP).

Throughout the programme, Work Package 1 has engaged with a wide range of stakeholders including: ABB, Aviva Investors, BEAMA , BEIS, BMW UK, Burns & McDonnell, Charging Around Britain Ltd, CMS Cameron McKenna Nabarro Olswang LLP, Cornwall Insight, Delta Energy & Environment, Drivenergy Ltd, EA Technology Ltd, Eaton, ELEXON Ltd, Energy Networks Association, Engenie, ESB Networks, Eversheds Sutherland (International) LLP, Gemserv, Geo Together, Greater London Authority, HSBC, Imperial College London, Innogy, Intel, National Grid (ESO), National Grid (TO), Newcastle Uni (CESI), Nissan Motor GB, Northern Ireland Electricity Networks, Northern Powergrid, Nuvve, Octopus Electric Vehicles, Ofgem ,OLEV, Pinsent Masons LLP, Pod Point, RAC Foundation, Renewable Energy Association, Ricardo Energy & Environment, Schneider Electric, Scottish and Southern Electricity Networks, Siemens, Tesla, The AA, UK Power Networks, UKPIA, UPS ,Vattenfall, Western Power Distribution. These stakeholders have either participated in workshops and/or responded to Work Package 1 outputs including Principles, Position Statements and Recommendations.

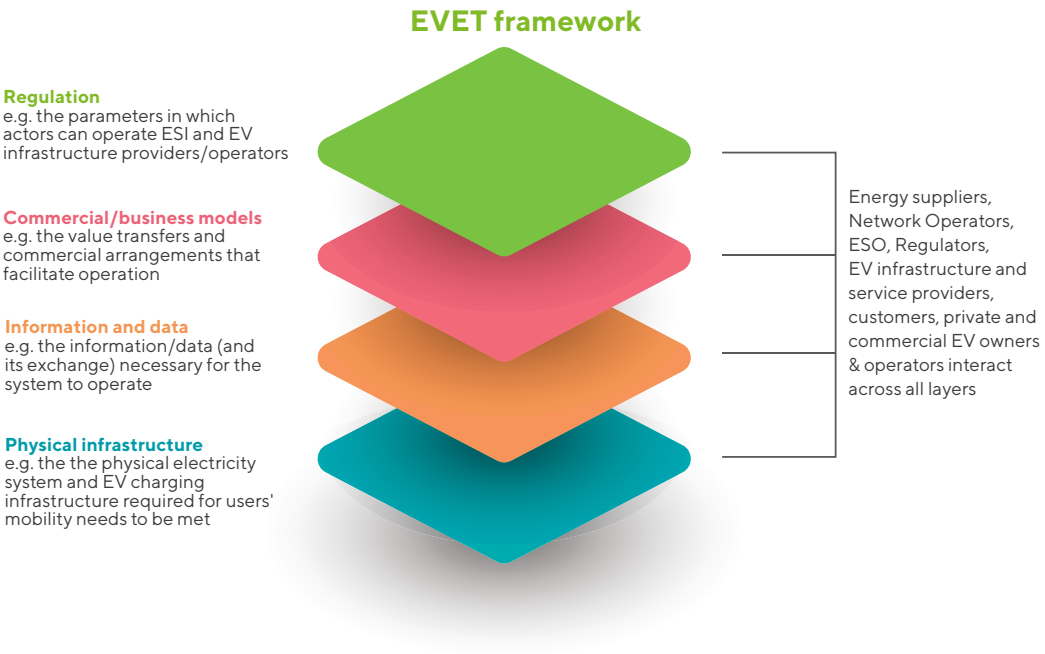
Methodology

The work package approach has been to consider the aims and questions in the round and take a holistic and futuristic view of the challenges and opportunities surrounding the integration of EVs and the supporting charging infrastructure with the electricity system. As a foundation for this approach, an extensive literature review has been undertaken to explore the current landscape from a technological, market and regulatory perspective – in particular, to identify current projects and initiatives that might influence the success of the transition to EVs and the integration of EVs with electricity system infrastructure. This has informed Work Package 1's understanding of the requirements of the energy system to support mass EV uptake and has provided a basis for Work Package 1's Recommendations. The overall methodology applied by Work Package 1 can be summarised as follows:

- Hold a stakeholder workshop with representatives from the electricity industry and the automotive sector to discuss potential challenges and opportunities surrounding mass EV take-up.
- Hold a kick-off workshop to agree the scope for addressing the seven Work Package 1 questions.
- Establish a set of high-level Principles as a foundation for addressing the seven Work Package 1 questions.
- Undertake a comprehensive literature review to capture evidence to support a set of high-level Positions which would underpin the high-level Principles.
- Establish and subsequently refine a set of evidence-based high-level Positions based on the outputs of two stakeholder workshops and a stakeholder webinar.
- Identify the issues which might be a barrier to the high-level Positions.
- Apply the EVET Framework to the high-level Positions to determine requirements against each layer of the EVET Framework.
- Identify the issues and key themes which emerge from the analysis.
- Make Work Package 1 Recommendations.
- Test Work Package 1 Recommendations with stakeholders (in some cases through bilateral discussions).
- Finalise Work Package 1 Recommendations.
- Align Work Package 1 Recommendations with the five EVET Themes.
- Apply MoSCoW analysis to Work Package 1 Recommendations to determine priorities and urgency.
- Participate along with other WP representatives in a Recommendation consolidation exercise based on the five EVET Themes (Work Package 1 focusing on "Developing and maintaining the charging infrastructure consumers need" and "Rewarding consumers for charging smartly").

The development of the Work Package 1 Recommendations has been considered in the context of the four EVET framework layers i.e.

- Regulation
- Commercial / Business Models
- Information and Data
- Physical Infrastructure



The Annex to this report includes a diagram expanding the physical infrastructure layer to illustrate the physical interfaces between EVs and the associated charging infrastructure, and the electricity system.

Work Package 1 has made three key Recommendations. For each of these Recommendations, MoSCoW (Must have, Should have, Could have, and Won't have) priority analysis has been undertaken at the above EVET framework level. Work Package 1's three key Recommendations and the associated MoSCoW analyses are included in the Annex to this report.

Complementary work has included:

- A comprehensive literature review to capture evidence to support Work Package 1's high-level Positions and ultimately inform Work Package 1's Recommendations.
- An international study investigating eight countries recognised as leading the EV revolution in order to identify possible learning points and best practice whilst recognising sometimes significant differences in terms of: electricity supply and demand characteristics; electricity network topography/geography; vehicle numbers; population densities; and also energy regulation and markets (albeit the purpose of the study is to help inform what policy and regulatory actions and resultant market structures elsewhere might aid efforts in the UK).
- Tipping Point Analysis to identify when significant tipping points might occur in terms of the capability of the electricity system to accommodate increasing levels of EV penetration, and hence when trigger points might be reached in terms of need for a significant change in approach (including from a technology, market or regulatory perspective). This analysis has helped inform the MoSCoW analysis referred to above.
- Analysis of the investment risks associated with identifying where financial benefits accrue, and risk is held, under different investment approaches. A stakeholder workshop has been held and the key outputs have been captured.

3 Current Position

Current Position

Overview and context

The EV sector and its stakeholders (manufacturers, infrastructure providers / Charge Point Operators (CPOs), Local and Transport Authorities) are developing business plans and environmental strategies for the rollout of EVs and EV charging infrastructure. However, they are doing so largely independently, and without sufficient information about the wider implications beyond their geographic area or the longer-term impacts that their actions will have for the success of the overall transition. For example, the Mayor of London has announced a 'London EV Infrastructure Delivery Plan' and a number of companies have announced major initiatives for rollout of ultra-rapid chargers on motorway networks. However, whilst there is some evidence of beneficial progress at a local or regional level, there is little evidence of a coordinated national strategy that will ensure the needs of all EV owners will be met irrespective of their geographic location, and the journeys they might need (regularly or occasionally) to make. There is a requirement for better information and incentives, so the local or regional initiatives are complementary rather than conflicting (distinct from competitive). The National Infrastructure Commission and others have called for a national EV charging network and a strategy to develop and deliver such a network. Whilst such a public EV charging strategy is essential if 'range anxiety' is not to be exacerbated by chargepoint 'access and queueing anxiety' the need is for an overall strategy that embraces at home, on-street, at work, en route and destination charging ensuring coordination and complementarity. Failure to achieve this objective might seriously deter EV uptake.

In terms of efficiently meeting the electricity network capacity and capability requirements of a national EV charging network, coordination of rollout is essential. Sharing of future development plans between the EV sector and the electricity sector will ensure that the electricity system is developed in a coordinated manner ensuring capacity and capability is provided in a timely manner, as efficiently as practicable and that both connection and use-of-system costs are minimised. The regulatory framework (RIIO2, 3, and beyond) will need to develop accordingly. In particular it must ensure that sufficient attention is given to: the provision of cost-efficiency; performance incentives; uncertainty mechanisms; and the role of strategic/anticipatory network investment whilst managing the risk of investment stranding (if anticipatory network investment subsequently proves inadequate or unnecessary).

From the perspective of the national electricity system, relevant stakeholders, in particular Distribution and Transmission Network Operators and the System Operator (DNOs, TOs, and ESO) have a strong focus on electricity system operability issues and opportunities arising from the increased EV population in the short to medium term, and also the potential for the additional electrification of heat in the longer term. The continued development of an economic, coordinated and efficient electricity system will be closely linked to the ability to exploit the demand flexibility of EVs through technology, market mechanisms and commercial frameworks.

For EV users and operators, the potential demand flexibility from the elasticity of when, how often and at what rate consumers charge (or discharge for V2H / V2G purposes) EVs creates opportunities. This flexibility could allow consumers to supply services, either directly or indirectly, to the grid and to benefit through improved supply propositions.

Interoperability of chargepoints, both in an EV physical connection context but also from a data, commercial and communications perspective, will be essential, not only in addressing range, queueing and access anxiety but also in the essential integration of EV charging infrastructure with the national electricity system, and ensuring that EV users are able to benefit from electricity tariff product offerings and flexibility service opportunities.

[1] Shell, IONITY, Engie/ChargePoint, Engenie, BP Chargemaster, GRIDSERVE, Fastned, and Octopus Group have all announced major initiatives over the last 12 months – including in some cases partnerships with Energy Suppliers and vehicle manufacturers

4 Recommendations

Recommendations

Work Package 1 has developed three key Recommendations. A full description of these Recommendations including overall objectives, specific actions and requirements is included in the Annex to this report. However, Work Package 1 has identified one overarching recommendation which has emerged from the recommendations of the individual Work Packages:

The work of the Taskforce has highlighted a complex range of credible options, by various parties in the energy and EV services supply chains, to maximise the use of smart charging technologies for controlling the charge/discharge rate of EVs under various circumstances. These have the potential to benefit both consumers and the electricity system, whilst supporting the transition to EVs. However, unless managed through market and operational coordination, there is a risk of conflicts and lost synergies leading to missed opportunities for EV users and electricity system efficiency, and ultimately risks to electricity system stability. Individual Work Packages have offered a number of recommendations which together form a basis for further, more detailed, consideration and resolution.

Work Package 1 recommends that this work be taken forward as a priority by BEIS/OLEV, Ofgem and both the electricity and automotive sectors.

The following is a convenient summary of the three Work Package 1 Recommendations showing links to the summary recommendations in the EVET Main Report.

Recommendation 1: effective planning and coordination of the infrastructure

Provide forward visibility of proposed EV chargepoint connections to ensure sufficient electricity network capacity and capability is available at all voltage levels to support both the uptake of EVs and the future needs of national and local energy systems.

- A strategic planning capability convened by Government and comprising network, energy, transport, local authority, CPO and automotive sector stakeholders, should be established to define and agree an overall EV infrastructure strategy and take responsibility for forward planning and coordinated rollout of EV infrastructure in order to mitigate the risk of over-capacity or under-provision in different regions, and ensure the timely provision of electricity network capacity.
- A strategic planning capability would support local authorities in their activities forecasting EV uptake and delivering chargepoint infrastructure roll-out as part of wider local energy system planning including decentralised generation, storage and plans for the decarbonisation (potentially including through electrification) of heat.
- To achieve the best outcomes, planning and coordination should be undertaken both strategically at a national level, in support of and complementary to planning at a more granular, local level and with close alignment to local area energy, transport, spatial and emission reduction plans.
- Informed by the increased forward visibility of proposed EV chargepoint connections, RIIO-2 business plans should identify and justify the need for investment in additional electricity network capacity and capability, and Ofgem should consider mechanisms for encouraging future-proofing of new electricity infrastructure and for funding anticipatory / least regrets investment - with due regard to the need to manage the risk of asset stranding.

This Recommendation (along with other WP Recommendations) has formed the basis of the following EVET Main Report Proposals:

Proposal 4

Government and Ofgem, through the electricity industry technical and market code governance frameworks, should ensure overall operational coordination of industry parties seeking to exploit EV flexibility through smart charging technologies and electricity market products by 2021. Clear visibility as to which market products are in play must be evident to both industry and users at any time, as well as which transactions have occurred over a settlement period. It must also ensure that the operation of smart charging does not present a risk to the stability of the electricity system.

Proposal 19

The Government and Ofgem, as a matter of urgency, need to facilitate effective forward planning and coordination of the rollout of EV and electricity network infrastructure at a national and local level to meet consumer needs. This needs to be aligned nationally and to wider local area energy, transport and emission reduction plans and be implemented and used through RIIO-2 price control.

Proposal 20

Ofgem should ensure RIIO-2 price control supports well-justified anticipatory network investment, including LV monitoring, that benefits consumers and enables efficient and co-ordinated deployment of the network infrastructure necessary for EV charging (with due consideration paid to other future additional loads including from the electrification of heat).

Recommendation 2: market enablers

Ensure coordination of 'smart' EV charging to maximise whole energy system efficiency whilst meeting EV users' needs.

- Priority should be given to ensuring the development of coordinated market mechanisms which optimally leverage the inherent flexibility of EV demand, or supply (V2G and V2B); this has potential implications for industry code governance and its constitution.
- Further research and trials, based on informed EV take-up and charger usage projections, with sufficient populations to provide high levels of statistical confidence, should be undertaken to test the acceptability to EV users of voluntary and/or mandatory mechanisms for constraining (or time-shifting) EV charging to align with low carbon generation output and/or avoid peak demand periods.

This Recommendation (along with other WP Recommendations) has formed the basis of the following EVET Main Report Proposal:

Proposal 9
The Government and Ofgem must ensure that existing markets for flexibility are made accessible for EV drivers. They must also support the development of new co-ordinated and accessible markets for flexibility to compete with traditional networks and wider whole electricity system solutions by 2023 at the latest. Markets and price signals should maximise the opportunities for consumers to utilise their flexible resources, including EVs, and sufficiently reward them for offering demand flexibility services that support optimised network operations and investment, emission reductions and whole electricity system efficiency.

Recommendation 3: delivering secure interoperability

Deliver secure and interoperable EV charging infrastructure, uninhibited access to public EV charge points, and assured data protection and cyber security through agreed, and mandated as appropriate, codes, standards and protocols.

- With Government oversight, energy, transport and automotive sector stakeholders should establish interoperability codes, standards and protocols (and/or ensure that adopted international standards and protocols are sufficient) to enable legitimate access to EV charging data whilst protecting data privacy and ensuring cyber security. Government must mandate the application of such standards by all sector stakeholders.
- Public and private chargepoints should be designed to be capable of receiving and processing 'smart charging' signals (either directly or through metering communications infrastructure) to enable EV users and/or CPOs to engage with providers of multi-rate tariff and flexibility product opportunities.
- Public chargepoints should be capable of interrogation by legitimate 3rd parties for data retrieval and analysis, and with provision to send and receive electronic communications (either directly or through metering communications infrastructure).

This Recommendation (along with other WP Recommendations) has formed the basis of the following EVET Main Report Proposals:

Proposal 1

By no later than 2025 industry must have reached convergence on a preferred set of standards that meet interoperability requirements across the EV charging infrastructure. Government must intervene if this is not achieved. Government and industry should, as a matter of urgency, review, define and propose international standards for communications, data and security protocols in order to meet this goal. To support this work government should establish a body with industry to coordinate the involvement of industry stakeholders.

Proposal 3

Industry should enable roaming services to deliver a seamless EV charging experience between public chargepoints by end of 2021.

Linking Work Package 1 outputs and recommendations to the Work Package 1 specific questions

This section of the report illustrates how Work Package 1's three Recommendations address the seven specific questions asked of Work Package 1. Whilst the following highlights some of the relevant detail under each of the Recommendations, the full text of Work Package 1's three Recommendations - along with the associated MoSCoW priority analysis is provided in the Annex to this report.

1 **How can we ensure that the local network effects of EV uptake in the near term (i.e. before smart meter roll-out is completed and smart tariffs are fully offered) and long term are managed in an effective and efficient way?**

The literature review has provided evidence of potential impacts on the electricity system and networks. There is strong evidence that Electricity Network Operators are preparing to deal with mass - or localised clusters of - EV uptake. A number of R&D projects have trialled and developed Active Network Management solutions to increase electricity demand flexibility; flexibility platforms to enable DNOs to procure flexibility services (which EV operators might be well placed to participate in) and multi-rate tariffs to encourage EV charging at times other than during peak demand. In the longer term, it is key that Network Operators have forward visibility of proposed public EV charging infrastructure, and the associated impact on locational peak power demand, so that electricity network investment can be planned and executed in an efficient coordinated and economic way. To that end, Work Package 1 has recommended:

- A national strategic planning function that would help CPOs and local authorities to plan future public EV charging infrastructure, better map future public EV charging infrastructure to electricity networks, and hence help identify potential hot spots so that network reinforcement works can be out in hand, in good time. Recognising the complexity of establishing a national strategic planning function, Work Package 1 has prepared a 'Next Steps' recommendation and this is included as an Annex to this report.
- A regulatory framework that encourages the efficient and coordinated development of transmission and distribution infrastructure by allowing future-proofing investment in new network infrastructure as far as reasonably practicable – i.e. where the additional capacity beyond immediate need is justified on the basis of (probable) future EV charging and (possible) heat pump demand (and losses savings).
- That EV charging infrastructure providers share forward visibility of proposed EV chargepoint connections – including locations, numbers and types of charger, and power requirements (ideally account would also be taken of charge-at-work proposals where these might have a material impact on need for local public infrastructure).
- That Network companies publish information regarding network capacity headroom, emerging constraints, and plans for future network reinforcement and extensions (extending the scope of current Long-Term Development Statements and Heat Maps).

2 **What are the barriers for EVs (in terms of smart charging and V2G) accessing the energy markets?**

The literature review and feedback from stakeholder workshops demonstrates that a potential barrier to EVs accessing the energy markets (or at least being able to fully exploit the markets) is the complexity and lack of coordination of market structure – making it difficult to assess the risks and opportunities for revenue stacking through multiple system balancing and ancillary service offerings.

A short-term barrier is the delayed roll-out of smart metering and the use of profiled electricity consumption (for domestic and most SME customers) for settlement - which are barriers to Energy Suppliers widely promoting multi-rate and/or dynamic tariffs. Work Package 1 recommended:

- That priority should be given to ensuring that the current energy market structure results in the development of coordinated market mechanisms which maximise opportunities to leverage the inherent flexibility of EVs (including export capability).
- Ensuring open and accessible data (including production, demand and network utilisation) that will inform variable energy and use-of-system pricing and potential ancillary service products.

3 **Are changes required to metering/supply arrangements to accommodate new innovative business models associated with EV charging infrastructure, whilst ensuring that consumers' interests are protected?**

Whilst smart metering, half-hourly settlement and open data standards are all prerequisites to accommodating new innovative business models associated with EV charging. Once in place, the need is for Energy Suppliers, Service Providers and Non-traditional Business Model Companies to then respond to the opportunities. To that end Work Package 1 found the need for:

- Energy Supply businesses to offer a range of innovative tariff options – including static and dynamic Time of Use (ToU) tariffs (including tariffs that incorporate export payments for V2G) which allow customers to choose according to their scope and appetite for flexibility.
- Tariffs that better reflect network costs through time-of-day differential use of system charges (levied on Suppliers and reflected in customers' energy bills) and which more closely align retail price to spot market price variations (e.g. day-ahead dynamic tariffs).
- New service offerings from both incumbent and Non-Traditional Business Companies that extract further potential customer and system benefits by accessing flexibility markets (e.g. network constraint management) and system services (e.g. STOR, frequency response, etc.).
- EV-specific packages that use smart charging to maximise benefits from ToU tariffs and system service opportunities whilst allowing EV users to input their charging requirements hence ensuring there in no impact on their mobility plans.
- Strongly encourages consumers who are going to install, or already operate, a chargepoint to have a smart meter installed.
- In terms of protecting consumers' interests, Work Package 1 has recommended that Government ensures:
  - In line with Energy Data Task Force [1] principles, the adoption of open data standards and protocols by all relevant stakeholders including automotive, battery and chargepoint manufacturers, and EV infrastructure and electricity system operators, to ensure data and communications interoperability capability between all EVs and chargepoints (i.e. so that an EV operator is able to access the market for services and not be dependent on the offerings of the charge point provider).
  - The adoption of national and international standards as appropriate to ensure protection of data privacy and cyber security.

4 **How applicable are international examples (e.g. California, Norway) to GB in terms of overcoming network constraints and the adoption of smart charging?**

Work Package 1 has undertaken an international study of countries recognised as leading the EV revolution – i.e. France, Denmark, Japan, California, Norway, Netherlands, Germany and Singapore (a summary of the study is included in the Annex to this report).

The initial collation of information on key countries leading the EV revolution has highlighted the large body of work being conducted globally in this space. From an analysis of this work, three main implications have been identified:

i. There are benefits from drawing on international learnings - this work has highlighted the number of innovations and strategic demonstration projects taking place in countries worldwide. Considerable learnings about chargepoint standards, consumer chargepoint usage, consumer protection, smart tariff introduction, attractive consumer propositions, and data availability, could be garnered for the UK from these projects.

ii. System and market specific characteristics should be dominant in policy setting - whilst the mentioned learnings are useful, a key lesson extracted from the work is that system specific considerations mean that many of the approaches considered for other nations might not achieve the same desired outcome if implemented in GB. The structural differences between GB and other nations' energy infrastructure necessitates different approaches.

iii. There is significant opportunity to attract innovative business models to the GB market - the GB market structure facilitates a range of business models and opportunities to innovate through its liberalised electricity market, innovation funding streams, and regulatory environment. These strengths should be leveraged to ensure that some of the attractive technologies and models found through the research can be successfully integrated into the GB ecosystem. The whole ecosystem surrounding EV charging still has a number of aspects where international alignment at an early stage would be desirable, enabling lower costs as OEMs and market players require fewer changes to processes and products for application in different countries. GB should aim to remain present and engaged in international forums that discuss all aspects of EV infrastructure to ensure that the GB market is easily accessible to emerging business models.

5 **Where do the investment opportunities lie, including for smart charging and V2G? Is intervention required? Are there opportunities to optimise costs or improve amenity that aren't being progressed? Are interventions needed to help overcome barriers?**

Work Package 1 has engaged relevant stakeholders to identify investment risks and benefits from the perspective of both investment in EV public charging infrastructure and investment in electricity network infrastructure to supply EV public chargepoints.

From the perspective of Electricity Network Operators, the investment risk is that of over or under provision of network capacity (i.e. installing assets that are underutilised, become stranded or which later prove inadequate to meet demand). A further risk (to an optimal EV transition) is that Network Operators adopt risk-averse investment strategies leading to higher costs, and/or delays in connection, of public EV infrastructure. To that end Work Package 1 has recommended:

- The establishment of a strategic planning capability to take responsibility for forward planning and the coordination of the roll-out of EV infrastructure in volumes aligned to anticipated local and national need, and support local authorities in their activities forecasting EV uptake and delivering chargepoint infrastructure roll-out as part of wider local energy system planning including decentralised generation, storage and plans for the decarbonisation (potentially including through electrification) of heat.
- RIIO ED2 and ED3 provisions include uncertainty mechanisms related directly to supplying EV charging infrastructure allowing partial reopeners to enable ex-poste adjustments to DNOs' allowed revenues in respect of higher or lower than forecast requirements for network reinforcement. This would reduce the financial risk to DNO shareholders of under-forecasting investment in capacity, and the risk to consumers of over-forecasting.

Given the above, DNOs and TOs will have strong incentives to provide timely investment in network capacity which will facilitate cheaper and faster connections for public EV charging infrastructure and reduce the risk of local network constraints due to home EV charging. Further work is necessary to draw final conclusions regarding the investment risks from a Chargepoint Provider and Operator's perspective. Whilst there is evidence of an appetite for investment in prime (future high usage) locations such as motorway services, initial observations suggest that some form of subsidy or underwriting might be necessary to ensure sufficient provision of public EV infrastructure in areas of relatively low population and/or traffic density. It follows that quantifying the need for public EV infrastructure across the UK and comparing that with Chargepoint Operators' roll-out plans is an important first step in terms of optimising investment in public EV infrastructure.

6 **How can we ensure that EV charging works in harmony with other changes to the energy system, such as decarbonising heat (especially if we don't know what these changes will be)?**

National Grid ESO's Future Energy Scenarios [2] provide some insights into the impact on the electricity system of both mass EV take-up and electrification of heat. National Grid's 'Two Degrees' scenario has been used as a basis for Work Package 1's analysis but in light of the Committee on Climate Change's May 2019 Net Zero report [3], National Grid ESO's new 'Net Zero' scenario needs to be given serious consideration. This includes local authorities adopting a holistic multi-vector approach to planning for future energy and transport infrastructure. An inherent risk is that if the electricity system focuses only on the impacts of EV demand and disregards other future loads such as electrified heat, network reinforcement will be insufficient in a number of locations which will inefficiently trigger further expensive reinforcements. To that end Work Package 1 has recommended:

- That Ofgem's RIIO ED2 and ED3 strategies provide a framework that allows for well justified anticipatory (or highly anticipatory) network investment in capacity and capability to serve proposed EV infrastructure (and in future heat electrification) as part of Ofgem's new Business Plan Incentive.
- A form of regulatory governance that embraces the whole of the electricity system (i.e. not limited to Transmission and Distribution asset investment) enabling the utilization of beyond the meter assets and technologies to provide value for consumers and to develop an efficient, coordinated and economic electricity system.

7 **What can be agreed about the shared long-term vision for the energy system requirements for mass EV uptake (e.g. the market arrangements, where the benefits will accrue and where costs should fall)?**

The question is closely linked to question 6, in that a shared long-term vision should embrace not only mass EV uptake but also credible scenarios for electrification of heat, distributed generation, electrical energy storage, and indeed energy vector supply and demand-side arbitrage (especially electricity-gas and electricity-heat). The overall objective is that, irrespective of where costs fall – either in the energy supply chain or in the provision of public EV charging infrastructure – benefits should ultimately accrue on an equitable basis to investors, EV operators (and energy customers as a whole) and the public at large. Whilst it is beyond the terms of reference for Work Package 1 to recommend how Government should conduct its fiscal policy, and the extent to which the costs of mass EV uptake should be socialised, the following are prerequisites to that objective:

- Market arrangements are sufficiently coordinated to ensure effective competition in provision of energy services offerings.
- Adequate provision is made for ensuring protection of customers' private data (but allowing legitimate parties to have sufficient visibility of energy consumption data to be able to design and offer attractive energy products).
- Network Operators are appropriately incentivised to adopt efficient investment strategies based on the long-term requirements of the energy system.

In that regard, a number of Work Package 1 findings of desirable outcomes are relevant to the question including:

- A market framework that ensures coordination of electricity market products (including energy, system balancing, network and system ancillary services) that maximise the potential of demand flexibility to support whole electricity system efficiency.
- A RIIO ET2 / ED2 framework which encourages ESO/DNO innovation in whole-system and energy transition solutions – including new commercial business models exploring the scope for exploiting flexibility in EV operation.
- Government imposing the adoption of national and international standards as appropriate to ensure protection of data privacy and cyber security.
- That public and private chargepoints are capable of data extraction and analysis by legitimate 3rd parties and with provision to send and receive electronic communications (either directly or through metering communications infrastructure).
- That private chargepoints be designed to be capable of receiving and processing 'smart charging' signals (either directly or through metering communications infrastructure) to enable EV users and/or CPOs to engage with providers of multi-rate tariff and flexibility product opportunities.

5 Appendices

Work Package 1 high-level principles and positions

High-level principles

The following high-level principles provide the context for a number of position statements that have been derived following an extensive literature review of projects, trials and initiatives which are relevant to the EV Task Force Work Package 1 core questions.

1 Priority is given to avoiding the electricity system becoming a barrier to mass EV uptake.
2 The electricity system should support activities that allow overall decarbonisation and cost benefits across transport and heat vectors to be realised.
3 Managing a successful ICE-EV transition is essential to future economic growth.
4 Leveraging flexibility of electricity demand is key to both maximising the contribution of zero-carbon generation and minimising electricity network capacity constraints.
5 EV and electricity customer choice should be maximised wherever practicable.
6 The social/societal impact of energy policy decisions related to ICE-EV transition must be fully considered.
7 The overall market design should allow a wide range of market participants and business models to compete.
8 The best overall outcomes will be obtained by taking a holistic perspective on the future of the energy system.

High-level positions

The high-level Positions that follow have been derived following an extensive literature review of projects, trials and other initiatives that are relevant to the ICE-EV transition and the specific questions that Work Package 1 has been tasked to address:

1 Leveraging the inherent flexibility of EV charging to reduce the impact on electricity system peak demand could materially reduce the scale of investment in network and generation capacity required to meet future EV charging needs.
2 Market mechanisms and products that encourage EV owners to avoid incurring additional energy system costs or provide energy services will be beneficial.
3 Co-ordination of ESO and DSO activities at the commercial and operational level will be important to ensure that technically, EV charging and flexibility services to the distribution network and wider power system is fully exploited whilst maintaining an efficient and secure system.
4 It will be important to consider the potential role of Strategic / Anticipatory investment (ahead of immediate need) in network capacity and capability to avoid network constraints becoming a future barrier to EV adoption, and how stranding risk should be shared between shareholders and customers. The stranding risk should also be viewed whilst considering the potential for electrification of space and water heating in existing and new homes – for example in existing off mains gas areas.
5 There are significant variations in current network capacity headroom, and constraints can be very location and voltage level-specific; hence advanced forecasts of required future capacity by EV charging infrastructure providers will help ensure coordinated and efficient investment in network capacity and other mitigation measures.
6 To ensure sufficient national coverage of EV chargepoints to meet EV users' requirements in terms of access to local, en route and destination charging, and slow, fast and rapid charging options, there is a need for an overall national strategy on the provision of a public EV charging infrastructure which embraces and coordinates Local Authority and CPOs' EV infrastructure roll-out strategies.
7 The ability of DNOs to access and aggregate consumption data (e.g. including smart metering time series data) will be key to monitoring the impact on local networks of trends in home EV charging activity.
8 Localised forecasting and monitoring of the network demand impact of EV charger connections will be important to predicting when distribution and ultimately transmission system tipping points can be expected.

9 The impact of Ofgem's decisions arising from its 'Targeted Charging Review' and 'Reform of Network Access and Forward-looking Charges' will need to be carefully considered in terms of the impact they might have on EV users' charging behaviour, and on network connection and use of system costs for EV infrastructure.

10 It is important to recognise the changing energy and transport landscape from digitalisation, decentralisation, decarbonisation and democratisation of energy supply and desire for improved local air quality.

A whole-system, cross energy vector approach will ultimately be required to optimise supply and demand-side arbitrage options and deliver customers' future energy needs efficiently and at minimum overall cost.

Full text of Work Package 1 recommendations

Recommendation 1

- Provide forward visibility of proposed EV chargepoint connections to ensure sufficient electricity network capacity and capability is available at all voltage levels to support both the EV transition and the future needs of national and local energy systems.

- Government should oversee development of a national strategic planning capability, comprising network, energy, transport, local authority, CPO and automotive sector stakeholders. This should be established to define and agree an overall EV infrastructure strategy and take responsibility for forward planning and coordinated roll-out of EV infrastructure in order to mitigate the risk of over-capacity or under-provision in different regions, and ensure the timely provision of electricity network capacity.
- Informed by the increased forward visibility of proposed EV charge point connections, RIIO-2 business plans should identify and justify the need for investment in electricity network capacity and capability, and Ofgem should consider mechanisms for encouraging future-proofing of new electricity infrastructure and for funding anticipatory/least regrets investment - with due regard to the need to manage the risk of asset stranding.

Overall objective of Recommendation 1

To facilitate a timely and coordinated roll-out of national public EV charging infrastructure through development of a national strategic planning capability, the overall aims of which would be to ensure:

- Sufficient forward visibility of future EV infrastructure to enable network operators to develop and maintain an efficient, coordinated and economic power system.
- Effective liaison with and between local and regional energy planning forums to ensure national and regional objectives regarding the provision of EV infrastructure are aligned.
- That planning for EV infrastructure is coordinated with wider energy transition objectives - including electrification of heat.
- That risks of shortfalls in the provision of public EV charging infrastructure are identified and addressed.
- An effective forum in which to build key transport/energy relationships – in particular regarding the coordinated development of EV charging and electricity network infrastructure.
- Coordination between the planning of major road infrastructure development and the roll-out of EV infrastructure.

Specific actions and requirements

- Government should oversee development of a national strategic planning capability via the appropriate Government department and comprising network, energy, transport, local authority, CPO and automotive sector stakeholders with a remit to define and agree an overall public EV infrastructure strategy to optimise the provision of public EV charging infrastructure (either privately or with government financial support) across the UK and mitigate the risk of over-capacity or under-provision in different regions.
- Where local and/or regional energy forums currently exist or are proposed, the national body would support these in providing a national perspective on EV infrastructure. The national body would seek to use the output of such forums to assess the extent to which with local and regional proposals are aligned with national EV infrastructure requirements and identify potential gaps. In cases where no local and/or regional energy forum currently exists, the national body would assess the risk to coordinated roll-out of EV infrastructure and recommend appropriate mitigating actions.
- A key component of this infrastructure strategy would be for the national body, in conjunction with local planning authorities and electricity network operators, to jointly take responsibility for the planning and coordination of roll-out of local and national EV infrastructure, and the timely provision of electricity network capacity. The national body would ensure this strategy aligns with plans for the wider energy system transformation, at both a local and national level, through its active engagement with key stakeholders.
- The creation and operation of a national strategic planning capability would remove a number of the key concerns raised by stakeholders. It would work to ensure:
  - There is no under-provision of public EV infrastructure in less populated areas, including those subject to seasonal peaks in traffic. For example, the population of Cornwall increases by some 60% in the summer holiday season and most of the additional population will be tourists arriving and touring by car.
  - There is a coordinated provision of rapid/superfast EV charge points at motorway services and along major trunk road routes which transcend the areas of many regional/local authorities. Albeit range anxiety may be declining as EV battery capacities increase, people who (even occasionally) have to make long journeys may still be put off switching to an EV unless they have confidence that rapid en route charging facilities will be readily available without queueing.
  - There is an adequate and coordinated provision of local EV infrastructure, given that over 30% [4] of homes do not have off-street parking facilities (or have off-street communal parking facilities with no access to an electricity supply; a common feature of current newbuild estates). To enact this will require a consideration of complex interactions; for instance, local destination fast charging facilities (e.g. supermarkets/retail parks) and at-work slow charging (for some) will generally need to be supplemented by local service station facilities offering rapid charging together with on-street slow charging.

- The strategic planning capability would ensure EV infrastructure is planned and delivered in a timely manner across all regions of the UK (in volumes aligned to anticipated local and national need) by providing national oversight which aligns with wider transport and energy system planning. The SPF would take direct responsibility for ensuring there is sufficient provision of EV charging facilities (in terms of number, capacity and distance between charging stations) across strategically important parts of the current and future planned national road network (especially motorways and major trunk roads). In this role, they would consider planned upgrades and extensions of such infrastructure. It is anticipated that these en route chargepoints would offer predominantly rapid or superfast charging facilities consistent with typical mid-journey break times.
- In addition to their national remit, the national body would oversee and support (or enable as necessary but not direct) local and transport authorities in their development of regional and local EV infrastructure (again taking account of regional and local development plans and consequent energy requirements) ensuring consistency and coordination between such authorities in terms of timely provision of public EV infrastructure aligned to regional/local need. This would include ensuring that residential areas with limited (or no) off-street parking facilities are catered for in terms of on-street or local service station facilities.
- The TORs for the national body would be specified so as not to override or interfere with competition in the provision of public EV infrastructure; rather the objective would be to ensure consensus is achieved (albeit regularly reviewed) on requirements for public EV infrastructure across UK, such

that investors in, and providers of, public EV infrastructure have clear visibility of the scope and required timelines for provision of public EV charging facilities. In this context, the national body would identify any geographic areas where provision of public EV infrastructure might present a weak business case for CPOs and hence where Government intervention might be justified.

- DNOs, TOs and ESO would be key stakeholders both at national and regional/local level in terms of:
  - Advising on existing and planned network capacity (and capacity/capability enhancement options) to supply the proposed EV infrastructure.
  - Gaining visibility of planned EV infrastructure to determine future network capacity and capability requirements, and hence being able to put in place plans for network reinforcements and extensions (including obtaining planning permissions and consents and managing procurement lead times).

- The beneficial outcomes of the proposed coordination through the strategic planning capability would be:
  - In EV users having confidence that their requirements for public EV infrastructure will be met (in terms of access, interoperability, queueing avoidance, etc.) and continue to be met (consistent with potentially rapidly increasing EV take-up volumes) irrespective of their geographic location and frequency/length of journey, and irrespective of whether they have access to home-charging facilities.
  - That electricity network development would be undertaken in an efficient, coordinated and economic way (consistent with TOs' and DNOs' license obligations) at both national (transmission), regional (EHV/HV) and local (MV/LV distribution) level, and that connections and supplies to individual EV chargepoints and charging hubs would be provided in a timely and cost-effective manner.

- The timely and cost-efficient provision of electricity network capacity is fundamental to achieving this objective. An important benefit of forward visibility of proposed EV chargepoint connections, in terms of timing, location, charger type (rapid ac, superfast dc, etc.) and maximum power requirements is that it would inform DNOs' and TOs' (and to an extent ESO's) RIIO-2 business plans in terms of network investment need and the emerging scope for flexibility-based services. Such visibility would also help avoid an ad hoc approach to electricity network connections of EV infrastructure and any associated upstream reinforcement, and hence ensure the continued efficient, coordinated and economic development of the electricity distribution and transmission systems. Longer-term intelligence regarding EV infrastructure development would inform the extent to which anticipatory/least regrets (or highly anticipatory)[5] investment might be justified in support of future transport (and heat) electrification, and would minimise the risk of stranded investment (i.e. arising from either over or under-capacity of installed infrastructure).
- A further benefit of forward visibility of proposed EV chargepoint connections would be to inform the development of appropriate RIIO-2 incentives and uncertainty mechanisms such that TOs and DNOs can confidently prepare RIIO-2 business plans on the basis of a common shared understanding of the beneficial role of strategically targeted electricity network investment in support of EV infrastructure (and future heat electrification). This would support the objective of Ofgem's RIIO-2 proposal for a new Business Plan Incentive.
- The outcomes of Ofgem's Review of Network Residual Charges and their Reform of Network Access and Forward-Looking Charging Arrangements[6] have the objective of achieving more efficient utilisation of electricity networks through more equitable and cost-reflective use of system and connection charges. The outcome of these arrangements has the potential to (respectively) alter the balance between different groups of customers in terms of meeting the costs of maintaining networks; and between developers of infrastructure (including EV infrastructure) and electricity customers in terms of meeting the costs of new (or increased capacity) electricity networks. Optimising the level of network would also help ensure equitability of risk and cost-sharing between network investors and electricity customers (and between EV users and electricity customers generally) in terms of the appropriate level of socialisation of costs of network infrastructure investment.

Recommendation 2

– Ensure coordination of smart EV charging through market mechanisms to maximise whole energy system efficiency, take full advantage of low carbon electricity production, and exploit opportunities to efficiently manage networks, whilst meeting EV users' mobility and other requirements, and providing financially beneficial opportunities to EV users who provide energy system services.

Overall objective of Recommendation 2

To enable EV users to capitalise on opportunities to reduce their overall energy costs associated with EV charging and to exploit opportunities for remuneration from providing flexibility-based whole electricity system services by ensuring that:

- EV users have full access to a range of multi-rate energy tariffs facilitated through smart meters and half-hourly settlement.
- EV users have the means to benefit from avoiding peak use of system charges when charging their EVs.
- EV users have opportunities for remuneration from providing flexibility-based system services to DNOs for network constraint management.
- EV users have opportunities for remuneration from providing flexibility-based system balancing and other services (such as frequency response) to the ESO and into the wider wholesale market.
- Potential conflicts arising from the simultaneous operation of markets associated with the above are minimised and that synergies are exploited.

Specific actions and requirements

- Priority should be given to ensuring that the current energy market structure results in the development of coordinated market mechanisms which maximise opportunities to leverage the inherent flexibility of EVs (including export capability). This would improve whole energy system efficiency whist continuing to meet the needs of EV owners/operators. The possible need for Government/regulatory intervention in the market should remain under continuous review.
- EV users who engage with smart charging (and energy customers who are able to flex their demand and/or generation or energy storage in other ways) will be able to take advantage of lower prices or income opportunities subject to the following developments:
  - Suppliers / Service Providers offering tariffs based on fixed or dynamic (e.g. day-ahead) multi-rate time-of-use energy charges that more closely reflect variations in real-time electricity market prices (e.g. reflecting seasonal and diurnal variability of renewable generation production) and hence enable EV users to align EV charging periods with lower price periods.
  - DNOs introducing use of system charges that reflect marginal cost of network capacity (i.e. through Red / Amber / Green price banding) based on daily / seasonal peak demand, potentially at a more localised level, again enabling EV users to align EV charging periods with lower use-of-system price periods.
  - Network organisations (including DNOs and the ESO) acting in a coordinated way to initiate EOIs / RFPs / ITTs for provision of flexibility services as an alternative to distribution and transmission network reinforcement to manage emerging network constraints, which may provide opportunities for EV users to contract with Aggregators and secure income for providing lexibility to those network organisations.
  - Aggregators / Flexibility Service Providers offering income opportunities to EV users (and energy customers generally) for providing flexibility to reduce system balancing costs at a national level – i.e. pre-gate closure based on marginal cost of system balancing (which might be positive or negative under some circumstances) and for providing post-gate closure (i.e. residual balancing) and other system ancillary services (such as dynamic and/or static frequency response).
  - Underpinning all of the above is provision of, and access to, data: the recommendations of the Energy Data Task Force (and those of Recommendation 3 below) will be essential to delivering the objectives of Recommendation 2.

- Further research and trials based on informed EV take-up and charger usage projections should be undertaken and with sufficient populations to provide high levels of statistical confidence. Albeit trials undertaken with early adopters (or pre-early adopters) of EVs have revealed useful insights into EV user charging behaviour and responsiveness to incentives, the results may not accurately represent behaviours of EV users in general. Moreover, early trials have generally been based on first or second generation EVs which tend to have smaller batteries and therefore less range, than the current, and presumably the future models, of EVs. Once EV sales begin to achieve mass market volumes (consistent with 5th carbon budget [7], FES [2] Two Degrees, and other scenarios) and once smart metering, residential customer half-hourly settlement, time-of-use tariffs, and relevant code modification proposals currently in train are established, further trials will be necessary to understand the flexibility of EV charging demand when general EV consumers operate smart chargepoints, and which incentives can increase this flexibility through engagement with smart charging. The Ofgem Network Innovation Allowance (NIA) is one appropriate source of funding for such work, as might be Ofgem's proposed new (for RIIO-2) innovation funding pot for strategic network-related energy system transition challenges [5].

  By extension, these trials also need to establish the acceptability to EV users of voluntary and/or mandatory mechanisms for constraining (or time-shifting) EV charging - specifically their appetite for relinquishing control of flexible appliances (including EV chargers) to provide system balancing and ancillary services. Such knowledge is key to understanding the scope for flexibility services as a sustainable economic alternative to additional electricity (generation and network) infrastructure, and how this scope can be increased through consumer approved propositions which incentivise flexibility in EV charging.
- More sophisticated assessments of local network capacity headroom by DNOs through: market research, engagement with relevant stakeholders, more granular load growth forecasting, enhanced network monitoring and modelling, and analysis of (aggregated) smart meter consumption and voltage profile data, would help highlight emerging, or anticipate future, network constraints. These may arise due to thermal rating limitations, voltage regulation, harmonic distortion levels, fault levels, or other key operational parameters. This sophistication could enable the implementation of innovative active network management solutions and/or flexibility services which might defer or obviate the need for expensive and disruptive conventional network reinforcement. It is imperative these capabilities are operated with the prevailing mind-set that EV infrastructure is provided where EV users need it, and network capacity / capability is enhanced as necessary.

  A further benefit of these assessments could arise from DNOs publicising the associated data (as recommended by the Energy Data Task Force) especially relating to higher voltage networks (for example in the form of Long-term Development Statements, Heat Maps and System Development Plans) as this could help prospective EV infrastructure providers to identify network hot-spots, and thereby avoid locations where costs of connections and/or network upgrades might be more costly and/or likely to incur delays.

Recommendation 3

– Deliver secure and interoperable EV charging infrastructure, uninhibited access to public EV chargepoints, and assured data protection and cyber security, through agreed and mandated codes, standards and protocols.

Overall objective of Recommendation 3

To develop, and/or implement codes standards and protocols (incorporating relevant BSC and SEC arrangements regarding metered data) in order to:

- Provide EV users with full access to public EV charging infrastructure – including on-street charging facilities, local forecourts, EV charging hubs and motorway service areas - by minimising commercial and/or physical interoperability issues.
- Enable legitimate parties (e.g. CPOs, Energy Suppliers, Aggregators, DNOs) to access data and implement smart charging mechanisms through public EV charging infrastructure.
- Ensure the protection of private and commercially confidential data.
- Provide the requisite level of cyber-security to prevent unauthorised access to data and smart charging.

Specific actions and requirements

- With Government oversight, energy, transport, CPO and automotive sector stakeholders should establish codes, standards and protocols (and/or ensure that adopted international standards and protocols are sufficient) in order to:
  - Allay possible range anxiety, exacerbated by additional chargepoint access and queueing anxiety. Interoperability standards and data protocols should be adopted to ensure EV users have access to sufficient public EV charging infrastructure, uninhibited by the need to hold multiple apps, cards and membership accounts, or by physical non-interoperable connection arrangements (i.e. accommodation of connector types for slow, fast, rapid and dc charging).
  - Enable access by legitimate parties to EV charging data for billing and settlement purposes, for network monitoring purposes, and to support the ongoing development and application of new tariffs, service-based products, and refined EV smart charging profiles (either through existing meter point and asset registers or a new central NCP register).
  - Ensure robust protection of data and data privacy to prevent unauthorised access and/or sharing of personal or commercially confidential data.
  - Provide sufficiently robust cyber security to preclude possible interference with electricity pricing and/or managed EV charging systems that could influence demand and EV charging patterns in a manner that might undermine electricity markets and/or pose threats to electricity system stability and security.
- Government must mandate the application by all sector stakeholders of such codes, standards and protocols.

MoSCoW prioritisation analysis of Work Package 1 recommendations

Recommendation 1

Provide forward visibility of proposed EV chargepoint connections to ensure sufficient electricity network capacity and capability is available at all voltage levels to support both the EV transition and the future needs of national and local energy systems.

MoSCoW Analysis

Framework Layer	Requirement	Short Term (by 2020)				Medium Term (2021-2025)				Long Term (2026-2030)			
		M	S	C	W	M	S	C	W	M	S	C	W
Regulation	Establishment of a strategic planning capability which would deliver forward planning and coordination of roll-out of EV infrastructure in volumes aligned to anticipated local and national need. This would be chaired by Government working in conjunction with regional and local energy and transport forums, and would comprise network, energy, transport, local authority, CPO and automotive sector stakeholders.		•			•				•			
Regulation	A regulatory framework that encourages efficient, coordinated and economic transmission and distribution by future-proofing investment in new network infrastructure as far as reasonably practicable – i.e. where the incremental capacity beyond immediate need is justified on the basis of (probable) future EV charging and (possible) heat pump demand (and losses savings)			•		•				•			
Regulation	Ofgem's RIIO ED2 and ED3 strategies to provide a framework that allows for well justified anticipatory (or highly anticipatory) network investment in capacity and capability to serve proposed EV infrastructure (and in future heat electrification) as part of Ofgem's new Business Plan Incentive				•	•				•			
Regulation	RIIO ED2 and ED3 provisions to include uncertainty mechanisms related directly to supplying EV charging infrastructure allowing partial reopeners to enable ex-poste adjustments to DNOs' allowed revenues in respect of higher or lower than forecast requirements for network reinforcement				•		•				•		
Regulation	A form of regulatory governance that embraces the whole of the electricity system including opportunities to exploit beyond the meter assets and technologies in developing an efficient, coordinated and economic electricity system – i.e. not limited to Transmission and Distribution asset investment				•	•				•			
Information and Data	EV charging infrastructure providers to share forward visibility of proposed EV charge point connections – including locations, numbers and types of charger, and power requirements		•			•				•			
Information and Data	Network companies to publish information regarding network capacity headroom, emerging constraints, and plans for future network reinforcement and extensions (extending the scope of current Long-Term Development Statements and Heat Maps)		•			•				•			

Recommendation 2

Ensure coordination of 'smart' EV charging to maximise whole energy system efficiency whilst meeting EV users' needs.

MoSCoW Analysis

Framework Layer	Requirement	Short Term (by 2020)				Medium Term (2021-2025)				Long Term (2026-2030)			
		M	S	C	W	M	S	C	W	M	S	C	W
Regulation	A market framework that ensures coordination of electricity market products (including energy, system balancing, network and system ancillary services) that maximise the potential of demand flexibility to support whole electricity system efficiency			•		•				•			
Regulation	A RIIO ET2 / ED2 framework which encourages ESO/DNO innovation in whole-system and energy transition solutions – including new commercial business models exploring the scope for exploiting flexibility from operation of EVs				•	•				•			
Commercial Business Models	Energy supply businesses offering a range of tariff options – including static and dynamic ToU tariffs allowing customers to choose according to their scope and appetite for flexibility			•			•			•			
Commercial Business Models	Tariffs that better reflect network costs through time-of-day use of system charges and which more closely align retail price to spot market price variations (e.g. day-ahead dynamic tariffs)			•			•			•			
Commercial Business Models	New service offerings from both incumbent and Non-Traditional Business Companies that extract further potential customer benefits by accessing flexibility markets (e.g. network constraint management) and system services (e.g. STOR, frequency response, etc.)			•			•			•			
Commercial Business Models	EV-specific packages that apply smart charging to maximise benefits from ToU tariffs and system service opportunities whilst allowing EV users to exercise options over constraints on mobility			•			•			•			
Information and Data	Further research and trials to be undertaken, once EV populations are sufficient for statistical confidence, to test the acceptability to EV users of voluntary and/or mandatory mechanisms for constraining (or time-shifting) EV charging to align demand with low carbon generation output and/or avoid peak demand periods				•		•			•			

Recommendation 3

Deliver secure interoperability of EV charging infrastructure, uninhibited access to public EV charge points, and assured data protection and cyber security, through agreed and mandated codes, standards and protocols.

MoSCoW Analysis

Framework Layer	Requirement	Short Term (by 2020)				Medium Term (2021-2025)				Long Term (2026-2030)			
		M	S	C	W	M	S	C	W	M	S	C	W
Regulation	Government mandating the adoption of open data standards and protocols by all EV infrastructure and electricity system stakeholders to ensure data and communications interoperability capability between all EVs and charge points		•			•				•			
Regulation	Government imposing the adoption of national and international standards as appropriate to ensure protection of data privacy and cyber security		•			•				•			
Information and Data	EV charging infrastructure providers ensuring consistent content of publicly available information on public charging points - including real-time availability - in an open and transparent format			•			•			•			
Information and Data	Public chargepoints to be capable of interrogation by legitimate 3rd parties and with provision to send and receive electronic communications (either directly or through metering communications infrastructure)			•			•			•			
Information and Data	Public and private chargepoints to be designed to be capable of receiving and processing 'smart charging' signals (either directly or through metering communications infrastructure) to enable EV users and/or CPOs to engage with providers of multi-rate tariff and flexibility product opportunities			•			•			•			
Physical Inf.	Chargepoints to be compatible as far as is reasonably practicable with all EVs in order to ensure sufficient and efficient national coverage of accessible charge points		•			•				•			
Physical Inf.	Incorporation of sufficient 'pay-as-you-go' options at all public EV public chargepoints or hubs to make apps and/or membership requirements optional				•		•			•			

Work Package 1 recommendation 1 – next steps

Current status

Charging Infrastructure

As at 23 September 2019, according to Zap-Map [8], there were 9,605 chargepoint locations with 15,274 devices offering 26,070 connectors in total. This compares with approximately 8,422 conventional fuel stations [9]. However, whilst this seems a favourable comparison, only around 20% of the chargepoints are currently 'rapid' (mainly 50kW) and very few of these are 'ultra-rapid'. Of the remainder, some 70% are fast (typically 7kW and 10% slow (3kW). It follows that the majority of current chargepoints would effectively be categorised as 'destination' charging facilities (or at best they might provide en route charging for those intending to take a break and needing only a small top-up charge) and time required to charge an EV (depending on state of charge) will typically be measured in several tens of minutes or hours. To put this into perspective, in energy terms, the current conventional refuelling network with around 64,000 fuel pumps has a maximum energy delivery capability of 96GW compared with 0.4GW of EV charging.

This limitation is further exacerbated by physical and commercial chargepoint interoperability issues which means that not all EV users are able to access (or use) all public chargepoints (nor are the majority of current EVs able to charge at ultra-rapid speeds). The current infrastructure is therefore unlikely to offer a practical solution for the great majority of those who regularly make long journeys.
A further issue is how the needs of those without off-street parking facilities (or those who are limited to communal parking with no access to a suitable electricity supply) will be provided. Estimates vary but figures suggest that over 30% of homes [4] fall into this category (and it is noticeable that many newbuild developments with a high proportion of affordable homes are exacerbating the issue). On-street parking facilities is one option but in the absence of any initiative from Local Authorities it is unlikely to be an attractive proposition form chargepoint providers.

Moreover, whilst (notwithstanding the above issues) there is an active market in provision of EV public charging infrastructure, the current approach is ad hoc in that there is no mechanism for planning and coordination of provision, other than in the context of internal strategies and business plans that infrastructure providers will be following, but which are largely invisible to other providers and the public as a whole – partly, no doubt, for reasons of commercial confidentially.

EV sales

While the EV market remains sluggish (as at June 2019 BEV sales represented 1.1% of the new car sales market with PHEVs at 1.0%) [10] the pressure on EV public charging facilities is limited (albeit range anxiety and lack of interoperability between providers of EV chargepoints continue to be issues that might be impacting BEV sales). However, as BEV sales begin to pick up (i.e. in volumes representative of the anticipated ICE-BEV transition over the period to 2040 when sales of new ICE vehicles will be banned) then range anxiety will potentially be compounded (or even overtaken) by chargepoint access and queuing anxiety. Meanwhile, private vehicle owners who have no off-street parking facility (or have only communal parking facilities with no access to a suitable electricity supply) will continue to be dissuaded from switching to a BEV (and may be reluctant even to consider a PHEV).

Energy / EV infrastructure planning

In terms of preparing for ICE-EV transition, there are a limited number of regional forums that are developing strategies and involving a range of key stakeholders, and (in some cases) considering the wider implications of decarbonisation of energy (e.g. for electricity production and heating as well as transport). One such forum is the London Mayor's 'London EV Infrastructure Delivery Plan' which brings together over 140 representatives from business, energy, infrastructure, government and the London boroughs, including energy suppliers and local DNOs to form an Electric Vehicle Infrastructure Taskforce. Whilst this is a good example of localised strategic planning for ICE-EV transition, it has a current planning horizon of 2026 and therefore only the beginning of the transition from ICE to EV. Moreover, there is little evidence of similar localised planning being widely adopted across the UK; neither is there an overall 'National EV Infrastructure Delivery Plan' that would take account of not only regional and local needs but also the need for provision of EV infrastructure over the national strategic road network – i.e. motorways and major trunk routes.

In that context it is to be noted that whilst a number of high-profile announcements have been made surrounding ultra-rapid charging facilities at motorway service areas, the motorway network accounts for just one percent of all the UK's roads compared with A-roads which make up around 12 percent of the country's road network (the remaining 87% being unclassified or minor B roads) [11]. Indeed, there are significant areas of the country (North of Scotland, Wales, East Anglia, East and West Midlands, and the West Country) which are remote from the motorway network and hence where the population relies on 'A' roads for longer journeys (for example a journey from the major ports of Felixstowe or Harwich to the Midlands currently involves some 140 miles of 'A' roads before a motorway is encountered).

A further factor, especially when considering less densely populated areas, is seasonal variations in traffic volumes. For example, the population of Cornwall typically increases by some 60% during the summer holiday period (and this population increase represents tourists, the vast majority of whom will be travelling to, and touring, Cornwall by car). It follows that EV infrastructure has to be capable of meeting any seasonal increase in demand for EV public charging.

Electricity network infrastructure

Notwithstanding strategic planning to ensure adequacy of EV public charging infrastructure, forward visibility of proposed locations of chargepoints is also essential to determine the adequacy of the electricity network infrastructure (including at a localised level of granularity) and where investment is likely to be needed. Whilst provisions such as partial reopener mechanisms (e.g. uncertainty mechanisms and volume drivers) can help mitigate risk to DNOs and TOs of under (or over) forecasting of demand from a regulatory settlement perspective, under Ofgem's new Business Plan Incentive DNOs in particular will need some degree of visibility of likely EV charging demand at a fairly granular (network-specific) level to underpin their base case submissions.

However, for DNOs there is also a logistical consideration in having the capability to ramp-up sufficiently to meet the demand. There is also a significant risk that if network investment is piecemeal (dealing with only the immediately foreseeable demand) then overall development of the network will fail the 'efficient, coordinated and economic' test. This is essential to avoid an uncoordinated ad hoc approach to network development leading to more expensive connections, connection delays, and inefficient provision of overall network capacity.

Investment in electricity networks is primarily undertaken by regulated Transmission and Distribution Companies (TOs and DNOs). TOs and DNOs are currently preparing their business plans for RIIO-2 which will take effect from April 2021 for TOs and April 2023 for DNOs. RIIO-2 will cover 5 years. Whilst TOs and especially DNOs are involved in many studies and research projects to understand both the impact of EV charging on their networks and the potential for innovative active network management solutions, lack of visibility of future EV infrastructure (in terms of location and power demand) will limit their ability to identify where on their networks capacity limits might be breached and to quantify the overall level of network investment that will be required over the RIIO-2 period and beyond.

Problem statement

To summarise the issues that Work Package 1 Recommendation 1 is aiming to address: in the absence of a Strategic Planning Forum there is a risk that:

- There will continue to be a lack of visibility of plans for future public chargepoints and associated EV charging infrastructure.
- Significant areas of the UK might experience shortfalls in the provision of public chargepoints and EV charging infrastructure capacity.
- Other (more densely populated or high traffic volume) areas might be relatively over-invested in public chargepoints and EV charging infrastructure in the short-medium term in comparison to rural or low traffic volume areas.
- Emerging shortfalls in public chargepoints (especially rapid chargepoints) might go undetected until it becomes apparent that sales of EVs (in particular sales of BEVs) in parts of the country are lagging behind other areas – or that public EV charging transactions (and hence revenues to CPOs) are below expectations.
- Current best practice examples of local and regional planning for EVs (for example the 'London EV Infrastructure Delivery Plan') might be overlooked and hence not replicated and/or might be limited to a short-medium term horizon (indeed the London EV Infrastructure Delivery Plan has a planning horizon out to only 2026).

- Areas for which prospective Return On Investment (ROI) is preventing investment by CPOs in EV Infrastructure might go undetected and hence opportunities to boost investment through appropriate incentives or subsidies might go unrecognised.
- TOs and DNOs will lack information to the level of detail necessary to enable them to present in their RIIO-2 business plans to Ofgem robust and well justified proposals for supplying EV infrastructure. This has a number of knock-on effects including:
  a Ofgem will have limited quality of information from TOs and DNOs to support their new Business Plan Incentive – which in turn might result in suboptimal allowed revenues (albeit uncertainty mechanisms might mitigate the 'allowed revenues' risk of under or over forecasting to some extent).
  b In the absence of forward visibility of future EV infrastructure, TOs and DNOs will be unable to plan network investment effectively – resulting in uncoordinated and inefficient investment in network capacity and/or a potential stranding risk due to under or over investment in capacity.
  c Network connections to EV charging hubs might be delayed and/or result in more expensive connection charges.
  d Electricity customers as a whole might be subjected to higher than necessary use of system charges (as a direct consequence of suboptimal network investment).
- The combined effects of all the above might be to adversely impact sales of EVs - potentially to the extent that Road to Zero objectives and targets are missed.

Proposed way forward

The immediate requirement is to establish the current status and prospective scale of the challenge from a quantitative rather than purely qualitative perspective, in other words, undertaking a gap analysis both in terms of local and regional strategic planning for ICE-EV transition and decarbonisation generally, and in terms of currently proposed EV infrastructure across UK. As well as identifying weaknesses and shortfalls, there would be benefit in identifying current strengths and how these might be built on and replicated. Given that a lack of anticipatory investment in local or regional public EV infrastructure (i.e. in advance of anticipated future EV volumes) might act as a barrier to BEV sales, reasons for any such underinvestment should be explored as this might indicate where chargepoint providers feel unable to currently make a business case (i.e. based on prospective ROI). This might indicate where some form of investment incentive (or subsidy) might be appropriate.

The following table sets out a logical sequence of actions (albeit some will be iterative in nature: for example actions 6 and 7 would ideally be undertaken in parallel with actions 2-4, allowing a degree of iteration in terms of optimisation of EV infrastructure and chargepoint location and need for electricity network upgrades).

The following table sets out a logical sequence of actions.

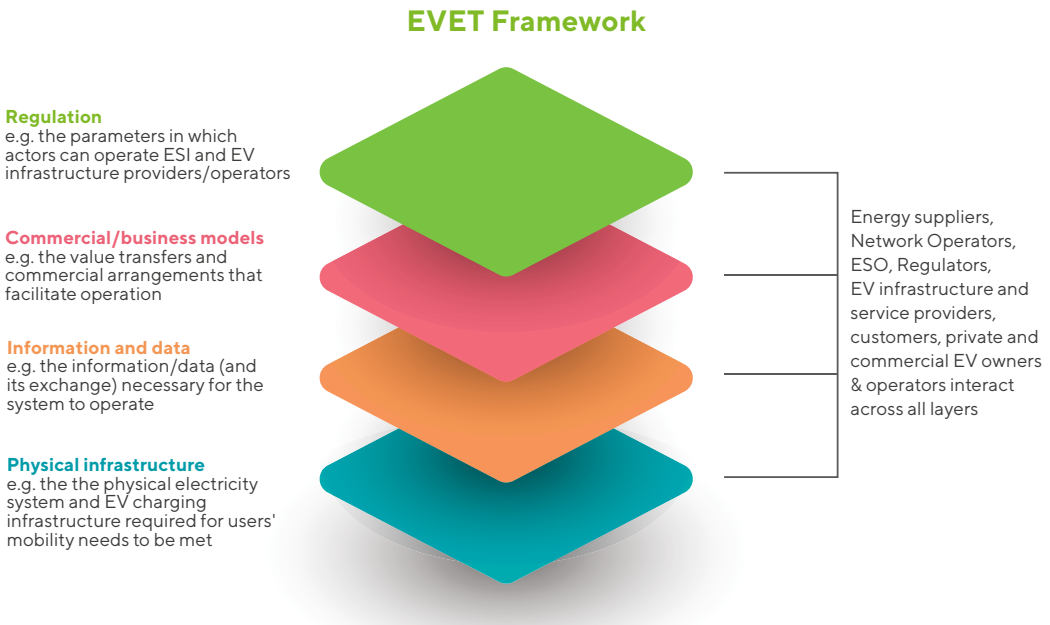
1	An appraisal of the current landscape and need for national public chargepoint infrastructure based on available data – e.g. car ownership, population, traffic volumes, journey types, housing mix, etc. (and assuming ICE/EV conversion rates consistent with the Government's 2040 aspirations).
2	An evidence-based study of existing and planned provision of chargepoint infrastructure based on current roll-out plans by regional forums, CPOs and Motor Manufacturers – including plans for forecourts, charging hubs, on-street parking etc.
3	A gap analysis based on the above – i.e. where current plans fall short of indicated need (or indeed where no meaningful planning is taking place).
4	An analysis of the underlying causes of any prospective gaps (or excesses) in chargepoint infrastructure – e.g. where the market looks weak (remote areas intuitively being the most vulnerable) or particularly strong (in which case the risk might be over-provision).
5	An assessment of where subsidised (or otherwise supported) targeted investment might be necessary.
6	In conjunction with the above, an assessment by TOs and DNOs of currently available and planned network capacity to support EV infrastructure – both currently proposed and identified as necessary but not yet proposed.
7	An assessment by TOs and DNOs of the most effective, coordinated and economic way of addressing shortfalls in network capacity (and/or capability).

Landscape study

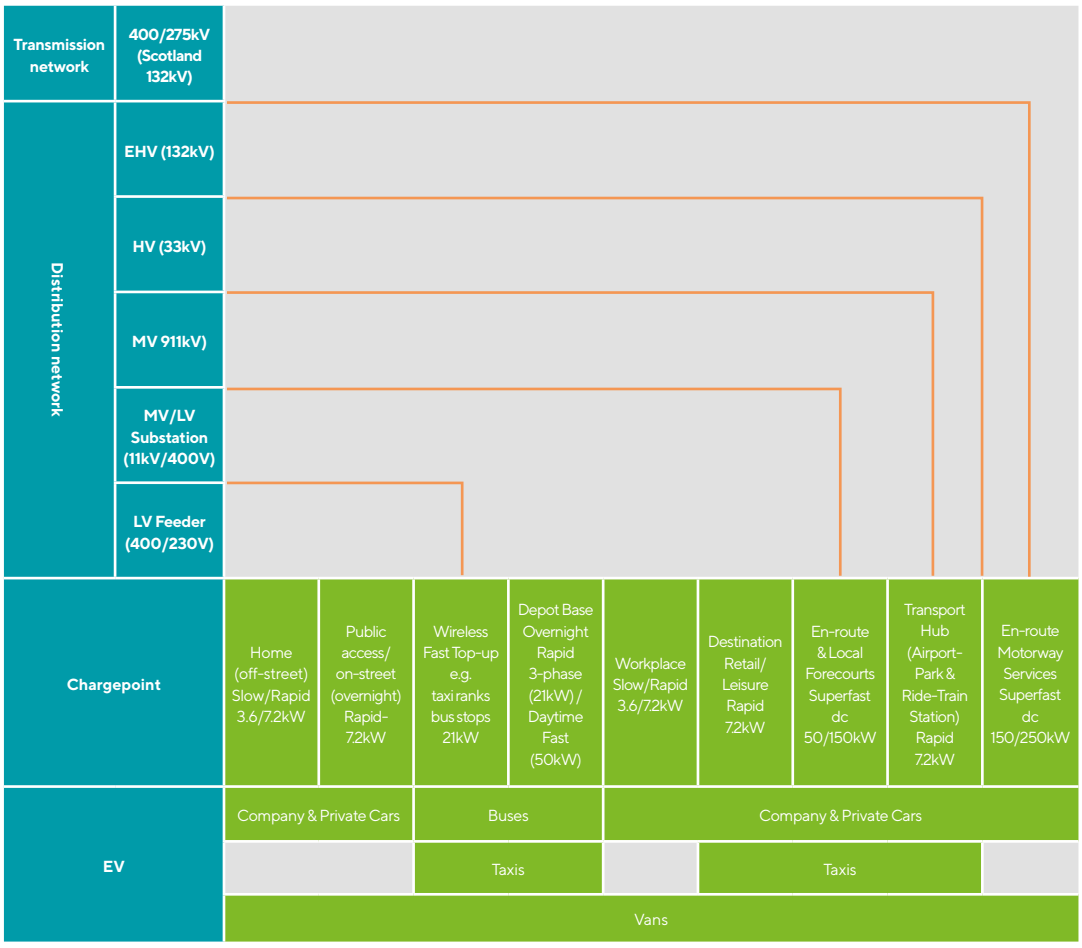
In terms of timescale, given the current number of initiatives for provision of EV infrastructure, it would seem prudent as a first step to commission, as soon as practicable, a formal proposal (including scope and TORs) for a landscape study to address the above. The recipient and potential funding source for such a study would be determined by Government but the assumption would be that OLEV and/or BEIS would be the primary sponsor(s).

The results of the study would determine the urgency for putting in place a Strategic Planning Forum (SPF), the composition of such a forum, and the means by which the forum would interface constructively with such Regional / Local EV (and/or energy) forums that exist. It would also identify areas where the lack of a Regional / Local EV (and/or energy) forum might be a barrier to efficient and coordinated planning of both EV infrastructure and the associated electricity network infrastructure, and hence where the SPF should initially apply its focus.

Expansion of the EVET framework 'physical infrastructure' layer



Expanding the physical infrastructure layer illustrates the physical interfaces between EVs and the associated charging infrastructure, and the electricity system.



Note: network connection/PCC voltages shown are illustrative – in practice many factors will determine the voltage and point of connection

Summary of implications from international case study analysis

The initial collation of information on key countries leading the EV revolution has highlighted the large body of work being conducted globally in this space. It has also highlighted distinct elements which must be considered to fully support the proliferation of EVs, the work being conducted in these areas and the potential for shared learnings between countries. The sections below preliminarily outline these distinct areas, the learnings gathered from this work and the potential learnings which could be gathered moving forward.

1 Benefits from drawing on international learnings

Direct learnings from projects

This work has highlighted the number of innovations and strategic demonstration projects taking place in countries worldwide. Considerable learnings about chargepoint standards, consumer chargepoint usage, consumer protection, smart tariff introduction, attractive consumer propositions, and data availability, could be garnered for the UK from these projects. More specifically, considerable work is being undertaken to develop the methodologies and understanding which networks will require to efficiently integrate EVs into the grid. It should be ensured that these opportunities are not missed and there is continual highlighting and collating of these learnings from such work before possibly disseminating and exploring the UK implications (considering the similarity of the UK to the study's country of origin). This is particularly important considering the international nature of the automotive companies operating in this market. Furthermore, whilst the market is still in its initial stages, global companies will be looking for countries to develop their business within. If the UK falls behind the developments occurring globally, it is likely to become less attractive for these first movers.

Case study – two considered approaches for chargepoint provision

A pressing discussion in the EV landscape is understanding the appropriate degree of government support and intervention for both EV uptake and chargepoint installation. These policies need to balance stimulating investment, with the risk of stranded assets and insufficient charging technology. Considering the policies which have been introduced in other countries can highlight the effect of different policies and further this conversation.

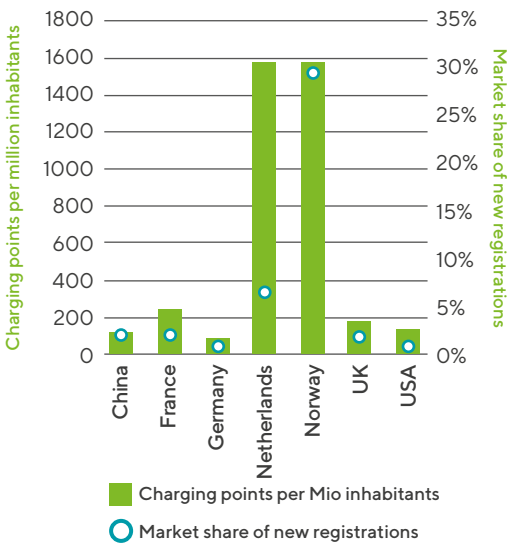
There is a number of distinct elements/phases of the EV roll-out which may require different mechanisms and degrees of government support. In the first stage of the transition, the government could work to ensure sufficient chargepoint infrastructure is available to enable all UK citizens to easily operate an EV and by extension to eradicate range anxiety. This is the 'coverage' approach highlighted by EUROPA. After this enabling stage, the number of EVs in the UK must increase at a considerable rate. This may require incentives for consumers to purchase EVs or education for people to understand the numerous benefits of EVs. Finally, as the EV fleet population increases, the number of chargepoints must increase (and the infrastructure underpinning their capability must also be ready, including power grid, data and market supporting systems) in kind to ensure EV chargepoint availability remains in line with consumer expectations and requirements. These three distinct issues may require very different support.

Alternatively, the government could facilitate the installation of chargepoints based on consumer demand; deemed by EUROPA as the 'demand' orientated approach. In this scenario the government could again stimulate EV uptake through financial incentives and must again ensure that EV charging infrastructure develops in accordance with the increase in EV population.

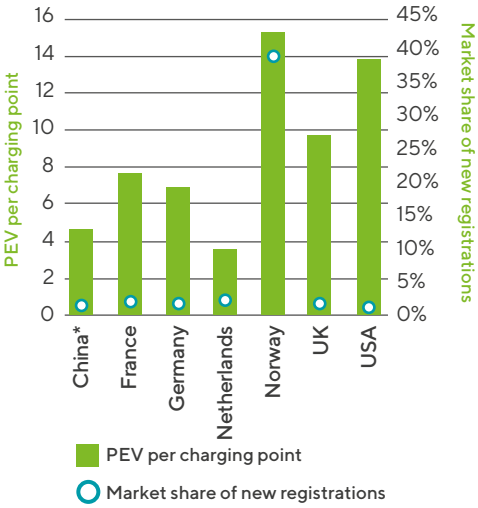
The relevant policies could vary significantly between these two different approaches and for both subsets of elements. Therefore, it should be acknowledged that a number of policies are required to balance these different elements. As EV populations and policies develop around Europe with consideration of these different stages, the UK should continue to lead in this space and garner learnings from parallel work. By assessing the effect of different government interventions throughout the EU, [12] suggests chargepoint availability in conjunction with financial incentives and awareness campaigns has a desirable impact.

The European Commission recommends one public chargepoint for 10 vehicles; though some work has suggested the number of chargepoints per 1million inhabitants is a better metric to ensure EV uptake is enabled. The figures below [12] show the values for these metrics in 2017, this shows some correlation between chargepoint availability and EV market share, however it is clear other factors are influencing uptake.

Relation of charging point density per million inhabitants and market share in 2016



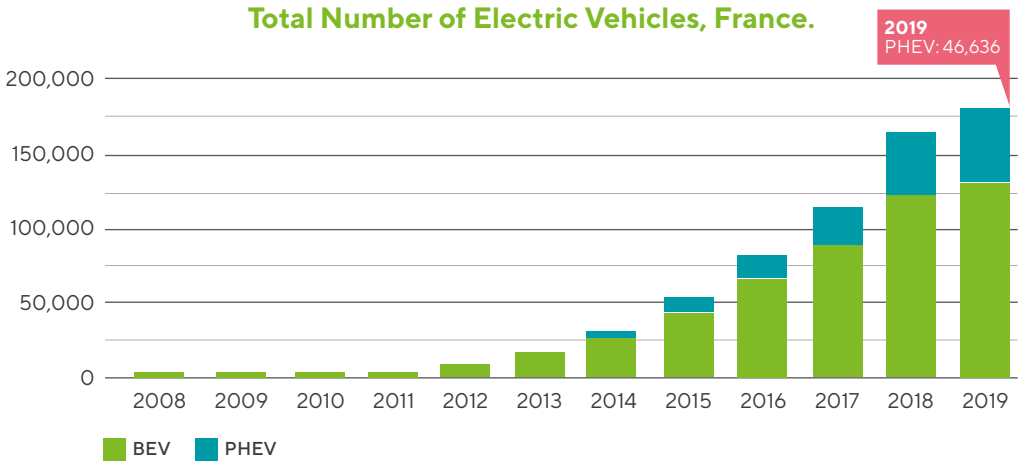
Relation of PEV per charging point and market share in 2017



Source: EUROPA, Research for TRAN Committee -Charging infrastructure for electric road vehicles [12]

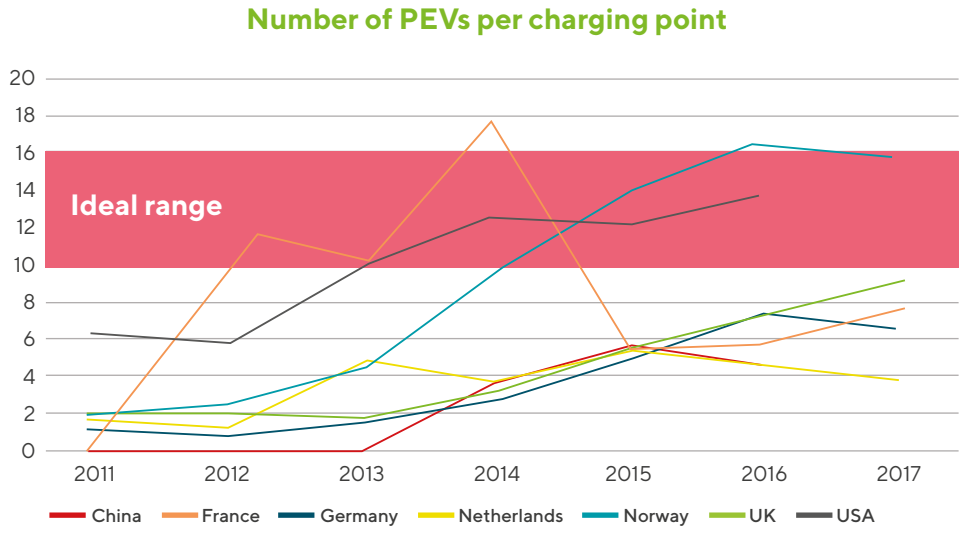
*For China, data from 2016 was used

An example of widespread EV chargepoint installation coinciding with a considerable increase in EV market share is France. In 2017, the number of charging points in France increased significantly, from 1,700 to 9,865. This acceleration was achieved by the deployment of local Government networks, partly financed by the State, and the proliferation of private initiatives. The graph below shows the increase in EV market share since that dramatic increase in charging infrastructure.



However, Harrison and Thiel [17] suggest charging infrastructure has less effect on EV uptake than financial incentives while the EV population is still under 5% of the total vehicle fleet. This will clearly vary between populations and depend on the availability of private chargepoints, habits and situation of first movers (i.e. two car households) and a number of other factors. Some merit in this argument can be seen in the Norwegian case study. Norway clearly stands out as the world leader in EV uptake and this rapid market expansion has been linked to the direct customer financial incentives, such as tax reductions and non-financial privileges, introduced by the government.

The graph below shows the Netherlands and Germany have managed to maintain a lower EV/charge point ratio than other countries.



Source: EUROPA, Research for TRAN Committee -Charging infrastructure for electric road vehicles [12]

Despite the links suggested above, it will not be possible to extrapolate the findings on the necessary ratios of EVs to chargers (to reduce range anxiety) from right now into the future due to the differences between first movers and the majority of the market. In addition, the need for adequate chargepoint provision in all locations cannot be accurately represented in these values.

2 Importance of system specific characteristics

Whilst the above learnings are useful, a key lesson extracted from the work is that system specific considerations mean many of the approaches considered for other nations would likely not achieve the same desired outcome if implemented in GB. The structural differences between GB and other nations' energy infrastructure necessitates different approaches.

Historical and geographical network differences

Firstly, there are physical differences in the networks – the different historical drivers of distribution networks mean many nations have lower concerns about capacity, or weather and heating patterns mean electric heating is either already in place or not liable to cause an increase in network flows which change prospective investment strategies. The islanded nature of the system as opposed to, for instance, the European system, means there are different system risks present that may require different responses in the context of EV infrastructure.

Demand and generation characteristics

The nature of demand patterns and the generation stack is also a key factor in a sensible response to EV uptake; other nations may have a higher amount of dispatchable generation in future years, or EV charging times may not naturally align with the traditional peak demand to the same degree it is expected to in GB. The amount of flexibility expected within the system is key to the level of system capacity and capability needed; this factor can vary widely from market to market, driven by traditional consumer expectations, technology availability, heating and cooling requirements throughout the year, quality of housing stock, and a number of other factors that vary widely.

Industry structure

GB's electricity industry structure, with a legally separated System Operator, privately owned network companies, the RIIO arrangements, the liberalised energy market, and the supplier hub model also creates different opportunities and challenges than other nations. Policies developed to ensure the energy infrastructure is ready for mass uptake will need to respect both the existing and potential future structures to be successful; thus, direct transplants from other nations where, for example, there is more direct state control over energy production, would likely flounder.

Government targets

GB has amongst the most ambitious targets for decarbonisation, and these give rise to different future scenarios that may require a high rate of EV uptake through the next decade. These scenarios, especially coupled to the GB grid, and the particular dynamics of how its generation and demand characteristics are likely to change, will result in particular requirements for GB's infrastructure that are unlikely to closely resemble those of other nations.

Implications for applying international policies in the GB context

With the above considerations, GB's difference in requirements for EV infrastructure strategies means that caution should be exercised before employing approaches that may have proved – or in the future prove – successful in international contexts. It does not mean they cannot be successful in GB, only that analysis and comparison of the relevant system characteristics (such as penetration of intermittent generation, nature of typical market players, rules for flexibility access, and other factors mentioned above) in both GB and other markets should be considered before implementation.

3 The GB opportunity to attract innovative business models

Impact of the market environment on innovation

Numerous projects have tested a range of technologies and business models in different markets to gauge their effectiveness and learn lessons about their impact on markets, grids and consumer experiences. This is a critical body of knowledge to draw upon, as discussed above. This also highlights the importance of the market environment in enabling these projects to occur, and in the future become business as usual. The environments most conducive to these innovations provide clear rules, funding opportunities, and access to skills, infrastructure, and data.

GB as a destination for innovation projects

The GB market structure facilitates a range of business models and opportunities to innovate through its liberalised electricity market, innovation funding streams, and regulatory environment. These strengths should be leveraged to ensure that some of the attractive technologies and models found through the research can be successfully integrated into the GB ecosystem. The presence of leading-edge technologies and business models in the GB market will maximise the likelihood of a successful transition, potentially driving down infrastructure costs, improving consumer experiences or enabling additional use cases of the system.

Achieving synergies through international cooperation

Some aspects of chargepoint standards are starting to converge in the global markets already – there are already a limited number of connector types starting to dominate, for example. However, the whole ecosystem surrounding EV charging still has a number of aspects where international alignment at an early stage would be desirable, enabling lower costs as OEMs and market players require fewer changes to processes and products for application in different countries. GB should aim to remain present and engaged in international forums that discuss all aspects of EV infrastructure, to influence the form and content of standards and ensure the GB market is easily accessible to emerging business models.

Investment risks and opportunities: workshop

Work Package 1 was tasked with exploring 'where financial benefits accrue, and risk is held, under different investment approaches' within its terms of reference. To explore this, the concept was split into two distinct sections; where risk and benefits could accrue for:

- **Energy networks** reinforcing infrastructure due to increased loading under different investment approaches.
- **Government** facilitating EV chargepoint proliferation under different investment approaches.

These two questions were discussed at a workshop held at ENA's offices on 5 June 2019. This workshop was organised to further the thinking on the different investment approaches available for Network Operators or EV infrastructure providers and the associated risks. Prior to the workshop Work Package 1 created resources for the day which were circulated as discussion materials. The workshop was attended by representatives from OLEV, Ofgem, ENA, National Grid, BEAMA, chargepoint operators and investment funds.

The workshop was divided into two sessions based on the split described above. Included below is the initial discussion material set out in table 1 below created for the first session with a summary of the discussion which took place at the workshop, a list of the investment approaches discussed in the second session (these represent possible routes and do not reflect the views of Work Package 1) and a summary of the discussion. (The statements recorded below do not necessarily represent the views of Work Package 1 however, the engagement with and feedback from stakeholders has been helpful in informing and articulating Work Package 1's Recommendations.)

Discussion Material for Session 1- the investment risks and opportunities to Network Operators in providing the electricity network infrastructure to support EV charging.

Different network investment approaches – Table 1

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Planned	**Domestic home and/or street charging – slow/fast**	DNOs undertake granular forecasting of likely EV home-charging demand to prioritise areas of the network for pre-assessment of demand growth and available network capacity headroom. Types and probable timings of interventions are assessed – including smart technologies and flexibility service opportunities that might avoid or defer conventional reinforcement need for interim fallback option of EV chargers being controllable via an Esprit type solution, considered primarily as a risk-hedge to deal with unanticipated clusters of EVs or where demand requires major reinforcement (e.g. MV injection)	DNOs update RIIO ED1 business plans according to preassessment of investment need and assess resourcing and procurement implications. DNOs prepare RIIO ED2 business plans on basis of pre-assessment and put in place procurement strategies based on assessed ED2 volumes. Ofgem consider implications for DNO revenues to cover socialised investment – including possible re-openers for ED1 and uncertainty mechanisms for ED2. Ofgem consider the need for / benefit of a specific EV-related incentive scheme	ED1 revenues might be insufficient to cover ED1 requirements unless Ofgem agree re-opener DNO ED2 risk is managed assuming Ofgem allow sufficient ED2 provision of revenues to meet targeted investment and appropriate uncertainty mechanisms. DNOs need to have developed smart technologies and flexibility platforms to meet Ofgem's expectations in terms of minimising need for conventional reinforcement. Being permitted to include Esprit type solutions as a temporary backstop provides a hedge against unanticipated localised demand growth due to EV home charging.	Increased certainty over future revenues (and/or uncertainty mechanisms) and future incentive framework de-risks DNOs' positions (with possible improved credit rating and cost of capital which will benefit customers). Increased certainty over future EV-related demand helps inform future flexibility and ancillary service requirements and hence potential synergies between ESO and DSO procurement of services. Remaining uncertainty over electrification of domestic heat may require additional RIIO ED2 investment and/or uncertainty mechanisms.	Risk of inability of DNO to deliver required level of local network reinforcement or smart solutions in time, resulting in network failures and/or constraints on EV home / street charging. Esprit style backstops could prove unviable due to customer non-acceptance or insufficient scope for demand shifting whilst still meeting EV charging requirement.	Smart solutions carry infant mortality risk – and hence might result in increased asset failure and quality of supply risk and/or higher levels of corrective network investment. Flexibility platforms might be more successful than anticipated leading to higher Totex Incentive Mechanism benefits (for consumers) but negative TIM if found to be less successful or unsustainable.	Ideally, certainty over future EV charging demand will be sufficient to ensure that the networks can be made ready in time and don't prevent / delay installations of home / on-street EV chargers. Insufficient network capacity and/or excessive reliance on Esprit style backstops could undermine take-up of EVs.	Certainty that the network will be capable due to smart technologies and proven flexibility platforms. Risk of degradation to (or higher cost of maintaining) EV charging service levels if smart solutions fail and/or flexibility arrangements prove unsustainable due to declining customer interest in providing flexibility services.	Supply chain boost and derived exportable expertise could benefit wider economy. Relies on developments to existing regulatory arrangements (incentives / uncertainty mechanisms) but existing framework provides a helpful foundation. Higher socialised network investment levels will drive increases in DUoS for customers generally (including those without an EV) but 40-year regulatory depreciation will soften customer impact.	Evidence of planned network investment approaches: See DNO published Long-Term Development Statements and Regional Development Plans RIIO business plans

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Planned	**Local public charging (en-route or destination) and employee at work charging – Fast/ rapid** (including retail outlets and wireless charging for commercial / transport fleets with regular short-term parking locations – e.g. delivery vehicles / buses / taxis at depots or transport transition hubs)	DNOs engage with EV commercial and public EV infrastructure / charge-point providers and relevant stakeholders (e.g. LAs / TAs) to understand EV charge-point rollout plans – similarly retail and work locations where EV charge-points are to be installed. DNOs undertake forecasting / network specific assessments of likely requirements for new or reinforced connections at MV / LV including HV / MV upstream reinforcement implications. DNOs incorporate assessments in regional system development plans / LTDSs. DNOs update heat maps as a broad indicator of network capacity headroom / constraints to EV infrastructure providers and stakeholders. Ofgem consider the need for / benefit of an additional EV-specific element to existing connections incentives	DNOs update RIIO ED1 business plans according to preassessment of investment need and assess resourcing and procurement implications. DNOs prepare RIIO ED2 business plans on basis of pre-assessment. DNOs assess need and develop business cases for ED2 least regrets anticipatory investment aimed at meeting future anticipated EV charging demand hotspots in an efficient, coordinated and timely manner. Ofgem consider implications for DNO revenues to cover socialised investment – including possible re-openers for ED1 and uncertainty mechanisms for ED2.	ED1 revenues might be insufficient to cover ED1 network reinforcement requirements unless Ofgem agree re-opener. DNO ED2 risk is managed assuming Ofgem allow sufficient ED2 provision of revenues to meet targeted investment and incorporate appropriate uncertainty mechanisms. DNOs assess need and develop business cases for least regrets anticipatory investment aimed at meeting future anticipated EV charging demand hot spots in an efficient, coordinated and timely manner.	Risk of technically stranded asset investment if least regrets / anticipatory investment proves either unnecessary or insufficient (for example to address heat electrification) – Ofgem might require DNOs to carry a portion of such risk. Risk of inability of DNOs to deliver required level of upstream reinforcement in time – resulting in P2/6 security breaches. Risk of being unable to meet new / reinforced connections requirements within incentive timescales – resulting in connection incentive penalties.	Risk of inability of DNO to deliver required level of upstream reinforcement / procure flexibility services in time in time – resulting in reduced security and/or increased risk power of outages. Risk of DNOs being unable to meet new / reinforced connections requirements within required timescales – resulting in connection delays.	Smart charging technologies sufficiently advanced and proven in an operational environment for DNOs to implement with confidence. Conversely smart charging regimes based on public EV charging infrastructure might be less successful than anticipated leading to need for application of constraints on permissible demand offtake and/or further reinforcement of connections.	Increased certainty over future EV charging demand is sufficient to ensure that the network will be capable and doesn't prevent or delay installations and connections of en-route / destination EV chargers	A local network of en-route EV fast / rapid charging hubs might be a prerequisite to take-up of EVs for private and commercial use by consumers who do not have access to off-street or on-street charging. A possible risk is that smart charging regimes based on public EV charging infrastructure might be less successful than anticipated leading to need for application of constraints on permissible demand for some networks.	Prospective EV purchasers – especially those unable to charge at home - have lower anxiety over charge-point access / queuing -encouraging higher EV adoption.	

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Planned	**Major EV charging hubs / motorway / trunk road – rapid / superfast charging**	TOs and DNOs jointly engage with prospective EV commercial and public rapid / superfast charging EV hub providers and relevant stakeholders (e.g. LAs / TAs and major service stations) to understand rapid / superfast charging EV charge-point rollout plans. TOs / DNOs undertake forecasting and network specific assessments of likely requirements for new or reinforced connections at EHV / HV including EHV / Transmission upstream reinforcement implications. ESO / TOs / DNOs jointly consider implications for major upstream EHV / transmission investment (including for security and power quality) and competitive options for provision. ESO / TOs / DNOs jointly consider ancillary service requirements / opportunities from major rapid / superfast charging hubs.	Establishment of structured joint planning liaison meetings between all stakeholders to maintain an updated medium to long-term development plan / risk register and shorter-term connection priorities. Continuous review of opportunities for T&D optimised investment. DNOs update RIIO ED1 business plans according to preassessment of investment need and assess resourcing and procurement implications. TOs and DNOs prepare RIIO ET2 / ED2 business plans on basis of pre-assessment. TOs / DNOs assess need and develop business cases for ET2 / ED2 least regrets anticipatory investment.	T&D investment needs might be insufficiently covered by current ET1 / ED1 business plans. Risk of lead times (including planning consents / wayleaves / environmental impact assessments) for T (and EHV D) network provision leading to delays in providing connections / reinforcements.	Risk of inability of DNO to deliver required level of upstream reinforcement in time – resulting in P2/6 security breaches. Risk of being unable to meet new / reinforced connections requirements within incentive timescales – resulting in connection incentive penalties	Risk of inability of TO to deliver required level of transmission reinforcement / extensions in time. Risk of inability of DNO to deliver required level of upstream EHV reinforcement and HV connections in time.	Coordinated joint planning liaison should minimise network extension, reinforcement and connection delays.	Increased certainty over location and electricity demand requirements of future EV rapid / superfast charging hubs is sufficient to ensure that T&D network investment will be sufficiently timely to avoid delays in installations and connections.	A national network of en-route EV rapid / superfast charging hubs might be a prerequisite to take-up of EVs for private and commercial use by consumers who need to undertake occasional or regular high mileage journeys.	Prospective EV purchasers have lower range anxiety and have greater confidence of access / avoided queueing at motorway / trunk road rapid / superfast charge-point hubs - encouraging higher EV adoption by those who need to undertake occasional or regular high mileage journeys.	

Note: in practice the following network investment approaches will be subsets and/or typical components of the above overall 'planned' approach – but described separately to draw out specific characteristics, requirements and risks

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Ad hoc	All Types	An essentially reactive strategy whereby the DNO processes new or reinforced connection requests with little or no forward planning or liaison (elements of this are bound to occur even under an overly proactive strategy due to previously unforeseen opportunities or issues).	DNOs have systems in place to respond quickly to connection / increased demand requests arising from home, on-street, en route or destination chargepoint installations. DNOs are subject to connections performance incentives (for en route and destination chargepoints) built into the regulatory framework.	Workable short-term approach whilst EV take-up rates and chargepoint connections volumes remain low. Unsustainable as a medium to long-term strategy leading to inefficient, uncoordinated and uneconomical electricity system development.	The approach will miss opportunities for coordinated longer-term electricity system development and might result in higher costs and delays in providing connections and/or network capacity.	Meets immediate needs of connections at acceptable cost so long as connections volumes and imposed network demand levels are low.	Ad hoc approach will eventually lead to longer-term suboptimal electricity network development leading to higher costs for all consumers.	Achieves immediate needs for connecting EV chargepoints and hence ability of consumers to adopt EVs.	Higher costs and delays in providing connections could delay EV adoption.	In the medium / long term prospective EV adopters likely to retain range / public chargepoint access and queuing anxiety or be put off by delays in providing network capacity for home / street charging.	Evidence of DNO capability to respond: See Ofgem RIIO ED1 Annual Reports - DNO performance against connections incentives.
Smart grid solutions	All Types	Generally used in conjunction with flexibility platforms – using a menu of compatible approaches.	Continual research and development of technologies – including through NIA / NIC (or other) incentive mechanisms aiming to raise TRL to 8 or 9 with full-scale network proving trials.	A menu of available smart technology solutions with positive CBAs that can release network capacity and avoid or defer the need for more expensive / disruptive conventional reinforcement. Development of risk management strategies for new technologies based on FMECA.	Totex Incentive Mechanism benefits through reduced costs of network capacity and/or capability. Risk of underperformance or infant mortality of smart technologies with limited track record and hence potential unforeseen corrective expenditure.	Totex Incentive Mechanism benefits shared with customers (reducing DUoS and/or connection charges).	Smart grid solutions will mature (and become more refined and cost-effective) and continue to play an important role in providing network capacity and capability alongside conventional network investment.	Potential to provide faster cheaper EV chargepoint connections and provision of network capacity.	Will continue to help DNOs manage network costs and quality of supply performance cost-effectively.	EV users and consumers generally benefitting from improved EV charge-point access and overall quality of electricity supply.	Evidence of Smart Grid Technology development: See DNO Innovation websites.

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Avoided / deferred investment through incentivising flexibility	All Types but especially where EV charging is constrained to specific chargepoints (especially where serving specific vehicles such as fleets) where an overall managed charging regime can be established.	Several mechanisms possible including generalised ToU, use of system charging and flexibility contracts (typically availability and utilisation payment structure) for constrained networks (Presumably limited to system emergencies where either demand needs to be constrained to retain supplies or in order for supplies to be successfully restored). Generally used in conjunction with smart grid technologies – using a menu of compatible approaches. DNOs could contract direct for flexibility or through an Aggregator – or an Energy Supplier might offer tariffs combining multi-rate energy and use of system pricing.	DNOs undertake structured trialling of flexibility market mechanism which seek to combine the management of network constraints with wider electricity system benefits. DNOs develop Flexibility Frameworks and tender for services in constrained areas of their networks. ToU system pricing (LC14 statements) dependent on smart metering rollout and hh settlement based on metered volumes.	DNOs able to benefit financially from avoided / deferred network investment through Totex Incentive Mechanism.	Unlikely to be sustainable as a sole approach – will need to combine with smart / conventional network investment as EV charging demand increases.	Reduced costs of and delays to providing connections where network reinforcement would otherwise be necessary Customers benefit financially (lower DUoS charges) from avoided / deferred network investment through Totex Incentive Mechanism.	Unlikely to be sustainable as a sole approach – will need to combine with (socialised) smart / conventional network investment as EV charging demand increases.	Can accelerate EV chargepoint connections in the shorter-term.	Remains an important element of the overall network strategy reducing costs and delays of connection of EV chargepoints.	Avoided connection delays boosts confidence in viability of EV take-up by prospective early adopters.	Evidence of incentivising flexibility: See DNO published Flexibility Frameworks and ITTs. See EVET Work Package 1 Literature Review for various examples of DSR for network constraint management through contracts and ToU tariffs.

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Avoided / deferred investment through chargepoint locational pricing	All types but especially street charging and new public chargepoints.	Several elements including locational (deep) connection charges and locational ToU use of system charging (ref Ofgem's reform of network access and forward-looking charges).	Ofgem possible acceptance of legitimacy of locational DUoS (as well as connection charge) pricing.	Limited scope in the shorter term due to need for smart meter roll-out and hh settlement to uphold ToU DUoS pricing regimes.	Scope depends on customer engagement with ToU tariffs and price signals (elasticity of demand).	Benefit in having visibility of network locations with higher / lower connection and/or use of system costs.	Enables EV infrastructure providers to prioritise EV chargepoints where CBA is highest. Potential to disincentivise EV infrastructure investment where networks have limited capacity headroom.	Locational pricing complements DNOs' heat maps and LTDS in identifying where network capacity exists to connect EV chargers with less cost and/or delay.	Should ensure more EV chargepoints located where network capacity is sufficient (less where it isn't) hence reducing cost if EV chargepoint provision overall. Conversely might constrain provision of EV chargepoints in locations where needed due to higher connection / DUoS costs leading to continued range anxiety.	Potential 'acceptability' risk of postcode lottery. OK for specific new infrastructure such as public on-street charging supply points but less acceptable to individual domestic electricity customers (if applied to domestic tariffs and/ or if network costs passed through to users of on-street charging facilities).	See Ofgem TCR (Review of Network Residual Charges). DNO published LC14 Statements
Delayed/ deferred investment through constraining max demand	All Types potentially – but mainly applicable to LV networks supplying home and/or street charging.	Directly constraining demand at specific parts of the network through direct controls (as opposed to flexibility agreements / incentives) in order to avoid thermal overloading of assets or to maintain supply voltage within statutory limits DNOs apply conventional load limiting techniques such as voltage reduction during constraint periods (and/or) ... DNOs install control systems which interact directly with customers' appliances – for example EV chargers / water heating – to limit demand and/ or shift demand to an unconstrained period.	DNOs require ability to monitor LV circuit loading – through substation monitoring and aggregated smart metering data (load and voltage). Interaction with customers' appliances requires customer opt-in – possibly in return for a constraint payment. Prerequisite is being able to ensure customers are not materially inconvenienced as a consequence of load limiting or shifting	Protects DNO's assets from unexpected increases in domestic demand (e.g. due to EV charger clustering). Potential reputational damage if some customers suffer inconvenience (potential impact on DNO Broad Measure of Customer Service incentive).	If implemented only as a backstop measure pending urgent reinforcement, then limited financial benefit to DNOs. If accepted as part of an active network management regime then potential DNO benefits in terms of deferred reinforcement.	Protects customers from supply interruptions due to unexpected demand. Some financial benefit in terms of reduced network investment (hence lower use of system prices). Potential income for customers from constraint payments	Additional financial benefit to customers if implemented as part of an active network management regime – i.e. reduced use of system charges due to lower network investment and also due to reduced demand in DUoS Red Band periods. Potential for customers to also benefit from reduced ToU peak energy charges.	Perception of inadequate network capacity for home (or street) charging could dissuade customer take-up of EVs. Customers might be reluctant to relinquish control – irrespective of any financial inducement (such as constraint payments).	If accepted by customers as a permanent measure, then potential to avoid delays to EV home charging pending network reinforcement.	Helps contain increases in use of system prices. Perception of customer inconvenience.	See 'My Electric Avenue' LCNF2 project close-down report.

Different network investment approaches – Table 1 (continued)

Network Investment Approach	Charging point type and strategy name	Explanation of relevant approach	Requirements	Investor's (electricity network assets) Financial Benefits and Risks		Investors (government and consumers) Financial Benefits and Risks		Does it support this specific charger deployment (supportive of the automotive industry)? (RAG)		Other non-financial benefits and risks	Related Evidence
				Pre- relevant tipping point	Post-relevant tipping point	Pre relevant tipping point	Post relevant tipping point	Pre relevant tipping point	Post relevant tipping point		
Delayed/ deferred investment through emergency control	All Types	Continuation of constraining max demand approach (above) but extended to include other chargepoint types and limited to emergency actions due to system events (e.g. loss of generation or unplanned circuit outages).	ESO or DNOs have the ability to reduce demand in a controlled manner – or immediately if necessary (e.g. system major loss of infeed). Implemented through DSR capability, voltage reduction and (if necessary) demand disconnection. HEMS and EV chargers might require AI to avoid system impact of cold pick-up load following a shutdown.	Trade-off between potential increase in 'loss of load probability' and avoided cost of network capacity and generation to secure the system. Underlying principle that the balance should be justified on a CBA basis. Test of risk acceptability to customers based on 'value of lost load' and (low) likelihood of needing to implement emergency measures.	Likely to remain part of overall system management regime due to the financial benefits (conferred to customers) of avoided system (generation and network) investment.	Protects customers from potentially extended supply interruptions in exchange for the possibility of very occasional short-term emergency demand reductions.	Potential benefit to customers of DNO being able to temporarily disconnect discretionary demand (e.g. EV charging) in preference to partial system shutdown (e.g. operation of low frequency demand disconnection relays) or even voltage reduction.	Helps maintain network and wider electricity system costs and hence electricity charges (and hence EV running cost).	Approach likely to become more refined / discriminatory (minimising customer inconvenience) as experience gained in managing demand during system emergencies Overall impact on EV experience likely to be minimal.	Reduced probability of partial or total system shutdown.	See ENWL 'Class' LCNF2 project as an example of using networks assets for rapid demand control and fast frequency response.
Speculative/ anticipatory	All types but generally limited to anticipatory HV / EHV upstream network reinforcement ahead of need.	Presumes network investment committed on a 'probability of need' basis prior to confirmation of capacity need.	Assumes credible evidence that network extensions / additional capacity likely to be required in a given location – and that anticipatory investment will avoid connection delays and/or subsequent uncoordinated / inefficient ad hoc investment.	Financially viable to DNOs only if investment is recognised by Ofgem as efficient. Carries technically stranded investment risk if either additional capacity subsequently proves unnecessary or inadequate. DNOs will avoid financial asset stranding risk only if the whole of the investment is added (at least initially) to the RAV.	Whist purely speculative investment is unacceptable, anticipatory least regrets investment is a legitimate element of overall network investment strategy, but the principles will need to be agreed with Ofgem – including the appropriate apportionment of risk between investors, customers and EV infrastructure providers.	Provision of timely, efficient and adequate network capacity for EV chargepoints is likely to require an element of anticipatory investment otherwise connections of EV chargepoints could be delayed and hence deter prospective EV adopters.	The need for least regrets investment might give way to more firmly based anticipatory investment once a national strategy for public EV charging infrastructure is agreed - whereupon roll-out of EV infrastructure and electricity network investment can then be coordinated.	Provision of sufficient public EV charging infrastructure might be critical to overcoming range anxiety of prospective EV adopters Delays in roll-out of EV infrastructure due to insufficient anticipatory network investment could delay EV take-up.	As public EV infrastructure becomes more established and EV volumes grow, continued sales of EVs might depend less on range anxiety and more on access and queueing anxiety. Anticipatory investment based on confirmed EV infrastructure roll-out plans will help avoid EV chargepoint connection delays.	Potential to contribute to ensuring sufficient EV infrastructure to overcome range, access and queueing anxiety.	See Ofgem RIIO2 Business Plans Initial Guidance Document.

Discussion of different investment approaches

The above tables capture the essence of the means by which Britain's electricity networks will be prepared for the EV transition. The tables cover various network investment approaches for meeting the energy needs of recognised options for EV charging and the impact of tipping points.

Network investment approaches

Whilst the tables consider various approaches to network investment, it should be recognised that an overall network investment strategy will necessarily be a combination of approaches. The dominant approach will be one of 'planned' development of the power system based on forecasting of future requirements for connections (or accommodation at existing network connection points) of EV chargepoints and a continuous forward assessment of power system capacity and capability. A planned approach is essential to ensure the development of an efficient, coordinated and economic power system and, in particular, the timely and economic provision of network capacity and capability to meet the needs of EV users and their preferred options for EV charging.

In practice, network operators (mainly DNOs and IDNOs but in some cases also TOs) will need to have both proactive and reactive approaches to network investment, recognising the embryonic but quickly evolving expansion of EV charging infrastructure comprising chargepoints ranging from home or on-street charging, local EV charging hubs (e.g. at service stations, workplaces, transport transition points and retail outlets) to major trunk road and motorway rapid and superfast charging stations. Under current arrangements, it will be difficult for DNOs (and TOs) to assess future needs for network capacity and capability, and hence difficult to plan network investment efficiently. The risk is of delays to connections of EV charging hubs; uncoordinated and inefficient network development leading to more expensive connections and/or future use of system costs; and the potential for technically stranded network investment (e.g. if the network capacity provided proves subsequently to be either unnecessary or insufficient).

A potentially contentious issue (for consideration by DNOs, TOs and Ofgem) is the role of 'anticipatory' investment (i.e. investment based on informed longer-term forecasts but ahead of immediately foreseeable need) and how such investment should be funded and/or where any stranded investment risk should lie. Whilst purely speculative investment would be difficult to justify, failing to apply a 'least regrets' approach would run the risk of delays to provision of essential network reinforcements or extensions to serve EV charging infrastructure. A further risk is that failing to provide sufficient upstream network capacity might lead to more costly connections and/or lead to proposals for EV hubs being abandoned on economic grounds. The issue is recognised by Ofgem and their May RIIO-2 Sector Specific Methodology Decision paper outlines possible approaches.

Finally, innovation in provision of network capacity headroom and functional capability will be key to the economic provision of EV charging infrastructure. DNOs, TOs and ESO have been actively developing new technologies through innovation funding and their challenge will be to implement these as business as usual in a timely and efficient manner, having proven their suitability and reliability through network trials and further development as necessary to achieve Technology Readiness Level 9, (proven and ready for deployment). DNOs are also now seeking to implement flexibility platforms whereby network capacity and system capability can be effected through Distributed Energy Resource (DER) technologies providing flexibility (modulating and reshaping net demand). EV charging infrastructure (and EVs themselves) might be particularly suited to providing flexibility and hence reduce, defer or even avoid the need for investment in network capacity. Exploiting such capability will depend on equivalent complementary smart functionality being incorporated in EV chargers and also the development and maturity of market systems to provide the necessary financial incentives for EV users. The completion of the smart meter roll-out programme and implementation of mandated half-hourly settlement for existing profile class 1-4 customers will be key to the introduction of more flexible / agile multi-rate (including dynamic) energy tariffs and cost-reflective use of system charges (i.e. reflecting marginal cost of network capacity at times of peak demand). Such measures will make it more practical for flexibility providers to build portfolios based on relatively small but aggregated sources of flexibility, including small businesses and domestic customers.

Tipping and trigger points

The tables refer to investor risks both pre- and post-relevant tipping points. Whilst this is helpful in terms of understanding how investment strategies will evolve, in practice the demarcation is somewhat artificial and arbitrary. In terms of network capacity headroom, the point at which individual networks (substations and circuits) reach their tipping point will vary widely depending on current headroom and rate of (peak) demand growth. For example, LV networks which will feel the most immediate pressure from home and on-street charging will typically have a range of utilisation levels (i.e. in broad terms peak demand / capacity) of between 20% and 110% with the peak of the distribution curve typically occurring at between 50 and 60% utilisation. It follows that those highly utilised networks experiencing rapid and sustained demand growth due to EV charging (and other sources of demand growth such as heat pumps) will reach their tipping points much sooner than less utilised networks experiencing only moderate demand growth. Upstream networks (i.e. MV, HV, EHV and Transmission) will generally reach tipping points at a later stage due to lower diversity factors and their inherent levels of designed-in redundancy for security of supply purposes (albeit security of supply standards will ultimately dictate the tipping point).

An investment trigger point is reached when it becomes apparent that an existing network investment strategy or methodology is no longer optimum or sustainable (at least as a stand-alone strategy or methodology). In terms of network investment, DNOs already recognise that a trigger point has been reached with regard to LV networks (i.e. those which are anticipated to require intervention due to EV demand growth). Conventional reinforcement relies on cable overlays and/or transformer replacements, both of which are costly and (the former in particular) disruptive in terms of public inconvenience. They are also labour intensive which might create supply chain challenges. DNOs have therefore been developing a range of smart technologies which have the capability to at least defer conventional reinforcement cost-effectively (i.e. on an NPV basis). A further trigger is the development of flexibility markets as a means of constraining or time-shifting peak demand. As mentioned above, the completion of the smart meter programme and the introduction of half-hourly settlement will be a further trigger point for the development of multi-rate tariffs which might help shift demand away from peak times and/or towards times when renewable generation output is high.

Key investment risk factors and mitigations

The main investment risks for network operators (DNOs and TOs) revolve around the regulatory framework (currently RIIO1 but RIIO2 from Apr 2021 for TOs and from Apr 2023 for DNOs). The ability of network operators to efficiently finance their network investment depends on several factors including maintaining an investment grade rating (i.e. Moody's and Standard & Poor's) and hence securing finance at an efficient cost of capital. A further factor is submitting well justified business plans which give Ofgem confidence that their proposed network expenditure is necessary and efficient. Well justified business plans will attract a higher Information Quality Incentive (IQI) rate which in turn will provide greater scope for DNO shareholders to benefit from efficiencies arising from the Totex Incentive Mechanism (TIM) whereby efficient savings (investment and operating costs) are shared between shareholders and customers (i.e. DNOs that submit better forecasts in their business plans of the costs they expect to incur during the price control receive a higher TIM rate).

Various other incentives provide opportunities for DNOs to increase their revenues, but also receive lower revenues if they underperform. Incentives which are particularly 'in play' from the perspective of supplying and connecting EV infrastructure and managing demand growth are: Interruption Incentive Scheme (IIS), Connections Time to Connect (TTC) and Time to Quote (TTQ) incentives, the Incentive on Connections Engagement (ICE) which applies to higher voltage connections (larger EV rapid or superfast charging hubs might be an example) and the Broad Measure of Customer Service (BMCS) incentive. The Innovation Stimulus will encourage DNOs to discover and develop new technological and/or commercial means to manage higher demand – for example as a consequence of EV take-up. Innovation funding schemes (NIA and NIC) allow DNOs and TOs to de-risk innovation by allowing them to recover up to 90% of their costs through increased revenues. Successful innovation implemented as business as usual could enable DNOs and TOs to reduce costs of delivering outputs and hence benefit both shareholders and customers through the TIM.

A factor which might come more into play for RIIO2 is the concept of strategic or anticipatory investment. From their RIIO ED1 Strategy consultation Ofgem received significant stakeholder feedback that current policy prevents the timely roll-out of capacity for large development schemes. In their RIIO 2 sector specific methodology Ofgem acknowledges that the energy system transition, from changing behaviours to advancing technologies, generates uncertainty around the future demand for electricity (and gas) and that this could lead to asset stranding risks. Equally, asset stranding risk could occur as a consequence of strategic investment that subsequently proved unnecessary or inadequate (i.e. because demand had been over or underestimated respectively). Given the need for the electricity system to support a nationwide and potentially rapid roll-out of EV charging infrastructure it is reasonable to assume that an element of complementary strategic / anticipatory investment in electricity infrastructure might become necessary if delays in supplying and connecting EV charging infrastructure, and/or inefficient costs of connection, are to be avoided. The classic regulatory methodology for protecting both Network Operators and customers from risks arising from forecasting errors (e.g. predicting the rate of peak demand growth and hence the need for network reinforcement) is to apply uncertainty mechanisms (effectively partial price control reopeners) so that DNOs' or TOs' revenues can be adjusted during a price control period. This mechanism also prevents DNOs or TOs making windfall gains under the TIM in the event that network investment proves unnecessary – e.g. due to lower than anticipated demand growth.

Finally, in terms of cost of capital (CoC) risk (i.e. the risk that Ofgem might under or over-estimate CoC in their final settlements) there is already a trailing indexation mechanism for cost of debt which provides protection for both network investors and customers in the event that Ofgem's ex-ante assessment proves inaccurate. A similar provision in respect of cost of equity (or return on equity – RoE) is a further risk-mitigation option for RIIO 2.

It follows from all the above that DNOs and TOs should be able to manage risk to an acceptable level provided they are able to forecast network investment requirements with reasonable accuracy and provided they submit strong evidence of the need for investment in their business plans, and hence secure a satisfactory RIIO 2 settlement in terms of allowed revenues. A further proviso is that they are then able to deliver the required investment and outputs efficiently and innovatively and perform strongly against the above-mentioned incentives.

From the perspective of Government, customers and the automotive industry, the investment risk they carry is of DNOs and TOs failing to meet their requirements for provision of timely and cost-efficient network capacity to meet their needs for EV charging. EV infrastructure providers / CPOs in conjunction with Local / Transport Authorities and other stakeholders can help mitigate that risk through providing accurate forecasts of future energy and connection requirements at a granular level. That in turn will enable DNOs and TOs to accurately identify future network constraints and hence plan the necessary development of their systems in an efficient, coordinated and economic manner, in terms both of physical assets to deliver capacity and capability, and market mechanisms (such as flexibility platforms) that will help moderate growth in peak demand.

Overview

Table 1 helpfully breaks down network investment approaches according to type of EV infrastructure served. Whilst this is helpful in terms of highlighting specific characteristics and differences, it is important to recognise that the overall network investment strategy will need to take an holistic view, simultaneously catering for all types of EV charging options and ensuring the most efficient, coordinated and economic development of the power system to serve the overall national EV charging infrastructure. That in turn requires a network investment strategy that is fundamentally based on a forward planning approach but recognising the need for agility and innovation in dealing with shorter-term (or unanticipated) demands on the power system. It also requires a flexible regulatory framework which is both able to deal with uncertainty in a manner which shares risk appropriately between investors and customers, and also reduce the risk of asset stranding due to over or under-forecasting of future required network capacity. Strategic network investment which provides a foundation of network capacity and capability in areas anticipated to see high demand growth due to EV infrastructure will also be key to avoiding an over-reliance on 'ad hoc' approaches which might give rise to prohibitively high connection costs and ultimately result in inefficient, uncoordinated and uneconomic development of electricity networks. Coordination between EV infrastructure providers / stakeholders and network operators in terms of sharing development plans and future requirements will be helpful to DNOs and TOs in terms of preparing well justified RIIO 2 business plans and identifying strategic investment needs, which in turn will be essential to achieving the overall 'Road to Zero' objective in an efficient and coordinated manner.

Workshop – First session

The following captures the discussion at the first session:

- Other risks to the system are uncoordinated network investment and/or under-provision of EV infrastructure in sparsely populated areas (or where network upgrade costs are high).
- It should be emphasised that the strategies also impact risk borne by consumers.
- ED1 has no specific EV reopener – hence concern that RIIO ED2 is 'too late' for DNOs to begin strategic investment – i.e. if EV related regulation only enter into force when ED2 does (2023) that may be late to be commencing some activities.
- There is a real risk that networks do stall deployment of EVs, and a consensus that this is what we want to avoid (as in the Work Package 1 principle).
- Network access rights were a recurring theme – e.g. charging hubs taking up the last of the network capacity might lead to unfair outcomes – i.e. if for example the next charging hub to request a connection triggers network reinforcement.
- Ofgem forward-looking charges and network access needs to reconcile and balance different drivers (cost-reflective charges but ensuring charges fall equitably across all customers).
- The issue of fuel-poor households subsidising EV related network upgrades is difficult; partly because if RIIO is the main mechanism for remunerating the networks for enabling EVs, by the nature of RIIO the cost would fall on all bill-payers.
- Cannot ignore heat – trigger point for reinforcement needs to take reasonable account of probable future longer-term capacity requirements – but recognising stranding risk (otherwise stranded investment can arise due to under-provision of capacity).
- More shallow connection charges and greater socialisation of reinforcement would reduce connection costs – particularly where the existing infrastructure is weak and the CPO (perhaps as first comer) has to meet a high proportion of the upstream reinforcement as well as sole-use assets - but then those costs would appear on customers' bills (not just EV users and CPOs).
- One possible model is that Government underwrites some of the cost of providing connections and capacity initially - but CPO then takes the responsibility once revenues are sufficient to cover ongoing costs, amortisation and operating profit.
- This approach still involves socialisation of costs (i.e. through taxation) but resolves the potential issue of fuel-poor customers subsidising infrastructure providers (and/or affluent customers who can afford an EV) through increased energy bills.
- RIIO-2 proposed that much lower CoC is a potential issue as network investors might then revert to 'low risk' investment strategies and disregard riskier anticipatory investment.
- More sophisticated risk-sharing mechanisms may be necessary in RIIO ET2 / ED2 – where the current Totex Incentive Mechanism approach means additional costs are split roughly 50/50 between consumers and investors; a different ratio (i.e. greater risk on network companies) might be appropriate for highly anticipatory investment where stranding risk is higher.
- Given that network upgrades are 'chunky,' an issue is that immediately after investment, the increased capacity headroom could permit additional lower cost connections to be accommodated – until the new capacity is used up – and hence a new trigger point is initiated resulting in higher connection charges thereafter (until further reinforcement is carried out).
- For example, once network capacity is provided (e.g. provision of EHV or Transmission capacity at Motorway Service Areas) it might encourage other connections to follow – for example solar PV farm and storage connections.
- It follows that forward- looking charges and network access arrangements would ideally 'smooth' the chunkiness of connection charges according to available capacity and instead make timing of connections less time-critical from a cost perspective (e.g. part of socialised network reinforcement cost added to subsequent connection charge).

Key themes from the first session discussion:

- Data/Risk sharing mechanisms.
- T-D boundary should not be a barrier to optimised network investment.
- In terms of investment strategies, future electrification of heat cannot be ignored.
- A strategy that de-risks without closing off innovation and disruptive models is needed.
- The past is not like the future (analogies in other sectors, especially the mobile networks, provide important lessons - remembering that the value is generated 'at the end of the wire' (i.e. the application – not the network).
- How reinforcement costs are spread must be carefully considered to ensure a fair transition for consumers and to incentivise efficient actions from chargepoint operators.

Second session

Prior work and discussion on the investment risks and opportunities to Government from different approaches to supporting EV infrastructure deployment.
The second session was to discuss the potential investment approaches, along with the risks and benefits, for Government if it decided to intervene in the deployment of chargepoints. This exercise acknowledged that there is a key question in EV roll-out of where, and whether, the Government should invest in EV charging infrastructure but did not work or intend to resolve this question but to establish "...where financial benefits accrue, and risk is held, under different investment approaches" if the government chose to do so.

Prior to the workshop the following were raised as previous approaches for supporting infrastructure development:

- PPP
- National regulated asset
- Subsidies
- Regional franchise
- Cap and floor

Before the workshop it was asked that stakeholders discuss the following:

- How these approaches could be tailored to be suitable for chargepoint support; as these approaches can take very different forms and the details of each recommendation is likely to determine its end relevance and performance.
- Which would be suitable for each type of chargepoint proposition i.e. national rapid chargepoints or residential on-street chargepoints.
- The financial benefits and risks for government.
- The financial benefits and risks for third parties.
- Other non-financial benefits and risks.

The following captures the discussion at the second session:

- Current apparently high level of per capita EV infrastructure investment (i.e. no. charging stations cf. EV numbers) is not necessarily a guarantee that investment will be ramped up as EV take-up increases.
- Also – there are currently significant interoperability issues – i.e. only certain cars can connect at certain chargepoints.
- It is acknowledged that suggested investor models included in Table 1 are 'solutions' before risk is understood (whereas, logically, risk should be understood before considering investment models) - and that PPP and Regional Franchise model examples have some historic high-profile failures. Nevertheless, it is useful to consider the characteristics of such models and how elements of those models might be applied to reduce risk of different EV infrastructure investment scenarios (note: it may be considered a bit 'political' to speak too explicitly about things like PPP vs subsidy).
- It is not clear whether without some sort of mandate / incentive / contractual obligation that sparsely populated areas of GB would attract sufficient EV infrastructure investment – and that could delay EV take-up.
- Current CPOs are securing a market position – rather than investing for returns at this stage – hence their appetite for further investment will be limited until the market matures and EV volumes increase.
- Large corporate energy companies, on the other hand, tend to have a longer-term (e.g. 20 year) horizon for EV infrastructure investment, as oil and gas seen as declining markets, and they can afford the initially loss-making investment. Smaller CPOs on the other hand need a guaranteed (and earlier) return which might make them reluctant to invest in lower populated / lower traffic volume areas.
- It follows that a possible consequence of a free market approach, but with no protection for the smaller investors, is that large corporate energy companies might ultimately monopolise the EV infrastructure - including buying up smaller CPOs (subject to CMA approval).
- Again, one possible model is that Government underwrites EV infrastructure investment to create a 'minimum viable product' – once revenues begin to flow. The CPO would from that point be solely responsible for managing costs (note: this model cannot apply to CIF projects) – advantage is that it doesn't require much change to existing structures, so can be done quickly and is reversible.

- A reflection on the mobile network analogy that was instructive: different components of the system may well have different risk profiles and therefore attract different investors - the segmentation in the mobile networks world enabled investment. As an illustration: VC may expect higher risk for 7 year payback, while Infra funds may be comfortable with lower risk and 15 years - and different components of the system may match needs.
- Nationalisation of public EV infrastructure cannot be dismissed at this stage – especially given the Labour Party's 'Bringing Energy Home' proposals (which advocate nationalisation of electricity networks and that new REAs would take responsibility for rolling out the UK's electric vehicle charging infrastructure).
- A suggested division around EV infrastructure, whilst discussing what Government might own? wires -> everything up to the charging unit -> the charging unit.
- A key theme: don't be siloed when investing for transport decarbonisation (aligning well with our existing thinking) - Stranding risk ever a problem - not thinking just about EVs is essential to manage this.
- What investors really want (drawing on analogous renewable world) is visibility of the pipeline of projects - so they'll have more certainty - if they'll get subsidies, for instance (this avoids possible duplication of design and planning effort – note: also valuable information for DNOs).
- Classification of risk suggested: development risk (most pressing problem); early market risk (medium term, consider); long-term market environment (don't worry about) - suggestion of considering a 'risk timeline' that is akin to tipping point analysis?
- Another division to look at is that of Cornwall vs Cobham - do we need portfolio-based thinking where high utilisation areas (i.e. Cobham) support coverage in low utilisation areas (i.e. Cornwall) Note also that population of Cornwall increases by 60% in summer holiday period – and the additional population will be mainly tourists travelling by car.

  Group interested to know 'why are people investing now'- use the stakeholder base we've built to look at this.

Key themes from the second session discussion

- Before an appropriate investment approach can be decided the current deployment approach from chargepoint operators and investors should be better understood.
- A clear area which may require support is rural locations which are not profitable be it now or in the future.
- Approaches should be taken which can be rolled back or modified in the future when chargepoint operation is profitable.
- The market should be closely monitored to ensure monopolies do not form which result in poor propositions for consumers.
- Thinking should not be siloed to 'electric vehicle provision' but must think more widely about mobility provision.

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