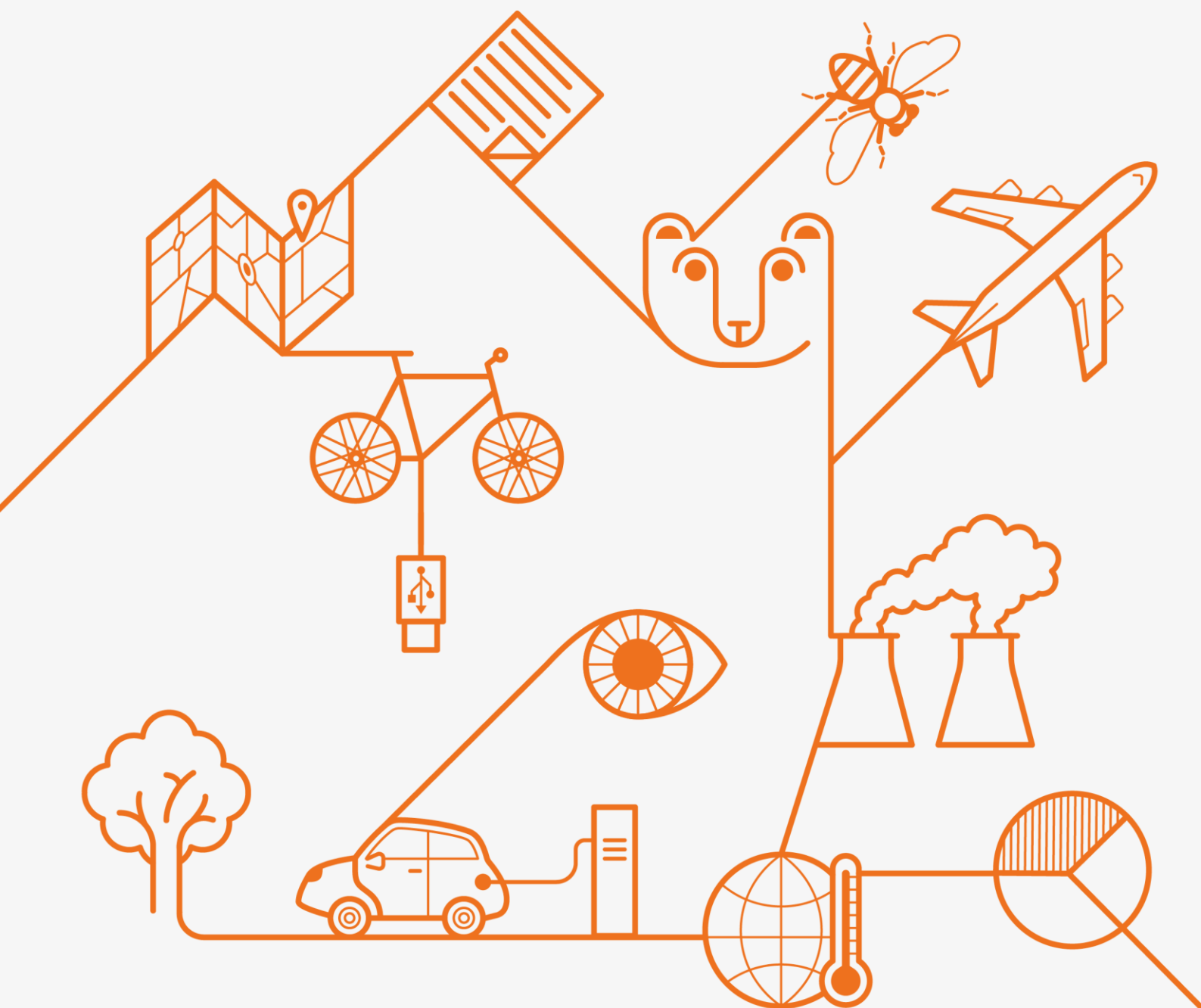


Energy Systems and Electric Vehicles

Prepared for: Transport Scotland, Victoria Quay, Edinburgh, Scotland

JULY 2016



Executive Summary

This report summarises research undertaken for Transport Scotland to review the interaction between energy systems and electrified road transport. This supports the Scottish Government's twin ambitions of encouraging widespread adoption of electric and plug-in hybrid vehicles (EVs/PHEVs) and developing a secure, sustainable and affordable electricity grid.

The report was informed by detailed research and two workshops that brought together a diverse range of stakeholders with expertise on energy systems and EVs. This identified a range of relevant issues and opportunities, from electrical distribution systems and smart grids to energy markets, from which a series of key areas for development and further integration between transport and energy systems were determined. The issues, opportunities and development areas identified are presented in this report, set in the context of the overall policy landscape.

The Scottish Government's Electricity Generation Policy Statement¹ calls for Scotland's generation mix to deliver: a secure source of electricity supply; at an affordable cost to consumers; be largely decarbonised by 2030; and achieve the greatest possible economic benefit and competitive advantage for Scotland.

Transport Scotland's Switched On Scotland Roadmap to Widespread Adoption of Plug-in Vehicles² expresses the ambition that the energy grid is sufficiently robust and well-managed to accommodate changes in demand, and that the potential of EVs to support the development of a cleaner and smarter energy system is realised.

These are complementary ambitions. This report shows that there are many interdependencies between EVs and the energy sector, and consequently the widespread adoption of EVs will have both positive and negative impacts on energy systems. Furthermore, energy policy and business models from the energy sector could offer the potential to accelerate the uptake of EVs. A proactive and integrated consideration of the areas identified in this report could therefore yield significant benefits in both sectors.

Key areas identified are:

¹ Scottish Government (2013), Electricity Generation Policy Statement: <http://bit.ly/1LzaVdh>

- Smart grids offer benefits to the electricity industry, consumers and wider society. EVs can be an important component within this system, with the potential to capture intermittent renewable energy and balance energy demand and supply.
- In terms of demand management, Scotland is expected to cope with increases in total electricity demand from future uptake of EVs, however there may be capacity constraints when considering the electricity network at the local level. Current development of centrally managed demand response strategies and data gathering and analytical intelligence for forecasting demand will help to address these constraints. Developing a charging point connection policy could also allow DNOs to maintain greater visibility and control over their networks.
- The increased adoption of EVs will provide storage capacity which can absorb intermittent loads from renewable generation, help integrate more micro-generation and increase energy efficiency. Second-life applications of vehicle batteries can also be beneficial in a wide variety of energy storage applications.
- There is an opportunity for Scotland to take a global lead in energy storage, an industry which is seeing a number of European energy companies engaged in research and development activity.
- In terms of domestic electrical infrastructure, Mode 3 charging – using a fixed and dedicated socket-outlet – is the preferred long term charging solution as the communication functionality of Mode 3 corresponds to the smart grid model which continues to develop. The increase of smart metering equipment in households and mode 3 charging included within new developments will help future-proof these buildings. Consumers are currently exposed to a number of different messages on charging, which may need to be clarified.
- There is the potential for technologies and business models that open up access to existing electrical outlets for commercial charging to create high-density public charging networks to support widespread operation of EVs.
- Vehicle-to-X applications are based on bi-directional charging, that is the ability to charge and discharge between vehicles and buildings, and are concerned with using stationary EVs as an electrical sink that can be drawn on as required. Such applications could see EVs providing energy for homes (V2H), buildings more widely (V2B) and for broader supply to the electric grid (V2G).
- There are many areas of the wider energy markets where EVs could have significant impact, such as community generation, balancing services, aggregator models, product bundling, and innovative financial mechanisms used by energy service companies. The full realisation of the benefits of integrating EVs into the energy market will rely on a mix of players in the industry exploring new business models and creating new value propositions for customers.
- Another important area of alignment is consumer behaviour change. There is considerable potential to align initiatives related to energy consumption and transport to promote the uptake of EVs and more general energy-awareness.

The Scottish Government's commitment to develop an integrated energy strategy - including heat, power and transport - represents an important opportunity to align these areas of policy. Given the clear interdependencies between transport and energy it is recommended that Transport Scotland and Scottish Government Energy continue to

work closely to develop and implement this strategy in a way that provides benefits to energy systems and accelerates widespread adoption of EVs.

To achieve this, it is recommended that Transport Scotland and the Scottish Government work with relevant partners from industry and academia to progress the following actions:

- Support collaboration between the different actors with a role in realising the potential of EVs in smart grids.
- Establish a dialogue on grid constraint to anticipate and deal with any potential issues resulting from charging of EVs.
- Explore how policies to promote the uptake of EVs could help Scotland take a leading position in new technologies and business models for energy storage.
- Continue to explore how planning and building regulations can be used to encourage the inclusion of charging infrastructure in new developments to maximise the benefits of smart grid integration.
- Investigate the opportunities offered by vehicle-to-X applications and how this might influence charging behaviours and impact on wider energy systems.
- Review important developments in energy technologies and business models, the likely influence on EV adoption, and how increasing numbers of EVs might stimulate further investments in this area.

Contents

1	Introduction	6
1.1	Purpose	6
1.2	Background.....	6
1.3	Structure of this Report	7
2	Policy Landscape.....	8
2.1	Introduction.....	8
2.2	The Energy Trilemma	8
2.3	Energy Consumption	13
2.4	Smart Meters	14
2.5	Tariffs	14
2.6	Community Energy.....	15
3	Electricity Distribution System and Smart Grids	18
3.1	Introduction.....	18
3.2	The Electricity Distribution System.....	18
3.3	Grid Connections	19
3.4	The Smart Grid	19
3.5	Smart Grid Technologies	21
3.6	Smart Meters and Home Area Networks	22
4	Demand Management	24
4.1	Introduction.....	24
4.2	Overall Capacity	24
4.3	Local Capacity.....	25
4.4	Peak Demand	26
4.5	Managed Charging	28
5	Energy Storage and Supporting High Renewable Grids	31
5.1	Introduction.....	31
5.2	Renewable Energy Challenges	31
5.3	Storage Capacity of Electric Vehicles	32
5.4	Links to Micro Renewables	34
5.5	Second-Life Potential for Vehicle Batteries.....	35
6	Electrical Infrastructure	37
6.1	Introduction.....	37
6.2	Wiring Regulations and Charging Modes	37
6.3	Open-Access Charging	40
7	Vehicle-to-X Applications.....	41
7.1	Introduction.....	41
7.2	Overview of Vehicle-to-X Applications	41

7.3	Vehicle-to-Home	43
7.4	Vehicle-to-Building	44
7.5	Vehicle-to-Grid	44
8	Energy Markets	46
8.1	Introduction	46
8.2	Grid Defection	46
8.3	Balancing Services	46
8.4	Aggregated Electricity Models	47
8.5	Bundled Energy Products and Services	49
8.6	Energy Service Companies	51
9	Conclusions and Recommendations	52
9.1	Policy Landscape	52
9.2	Electricity Distribution Systems and Smart Grids	53
9.3	Demand Management	53
9.4	Energy Storage and Supporting High Renewable Grids	54
9.5	Electrical Infrastructure	55
9.6	Vehicle-to-X Applications	55
9.7	Energy Markets	56
10	Appendix	58

1 Introduction

1.1 Purpose

This report provides an overview of the interplay between electrified road transport and energy systems in Scotland. This report supports the Scottish Government's twin ambitions of encouraging widespread adoption of electric and plug-in hybrid vehicles (EVs/PHEVs) and developing a secure, sustainable and affordable electricity grid.

The report draws on desk research, interviews and findings from two workshops that brought together 31 participants from across the public and private sector (see Appendix).

1.2 Background

Transport Scotland's Switched On Scotland Roadmap to Widespread Adoption of Plug-in Vehicles² expresses the ambition that:

"As an increasing number of plug-in vehicles enter the market it is essential to ensure that the grid is sufficiently robust and well-managed to accommodate any changes in demand. A further key opportunity is to fully realise the potential of plug-in vehicles to support the development of a cleaner and smarter energy system."

The roadmap goes on to identify four related enabling measures:

- The electricity network supports increased uptake of plug-in vehicles.
- Electrical infrastructure is futureproofed in new developments.
- Links between plug-in vehicles and renewable electricity are promoted.
- Managed recharging and advanced energy storage help balance the grid.

The following related actions for the Scottish Government to help achieve these ambitions are also identified:

- Transport Scotland to establish a multi-stakeholder group on energy systems to review the challenges and opportunities and prepare necessary guidance and advice for public and private sector organisations.

² Transport Scotland (2013), Switched on Scotland: <http://bit.ly/1GBxHtg>

- Scottish Government to consider how best to strengthen guidance for planning authorities relating to plug-in vehicle chargepoint provision in new developments as part of a review of Scottish Planning Policy.
- Scottish Government to continue to work with energy suppliers to encourage the deployment of tariffs and technologies to manage recharging behaviours and maximise the emission reduction benefits across Scotland.

1.3 Structure of this Report

This report first outlines the relevant policy landscape. The following chapters then identify a range of issues related to the following key areas of interplay between the energy sector and electric vehicles:

- Electricity distribution systems and smart grids;
- Demand management;
- Energy storage and supporting high renewable grids;
- Electrical infrastructure;
- Vehicle-to-X-applications;
- Energy markets.

Each chapter details the specific mechanisms, key players and processes related to these activities and important issues and opportunities for consideration.

Conclusions and recommendations are presented in the final chapter.

2 Policy Landscape

2.1 Introduction

This chapter describes some of the main policy areas that are related to both electric vehicles and energy systems in Scotland. This includes the energy trilemma which characterises the sometimes competing priorities related to policy objectives on energy security, carbon reduction and costs. This chapter also introduces a number of other relevant policy areas including energy consumption targets, smart meter provision, tariffs and community energy.

2.2 The Energy Trilemma

The Scottish Government's Electricity Generation Policy Statement³ calls for Scotland's generation mix to deliver: a secure source of electricity supply; at an affordable cost to consumers; be largely decarbonised by 2030; and achieve the greatest possible economic benefit and competitive advantage for Scotland.

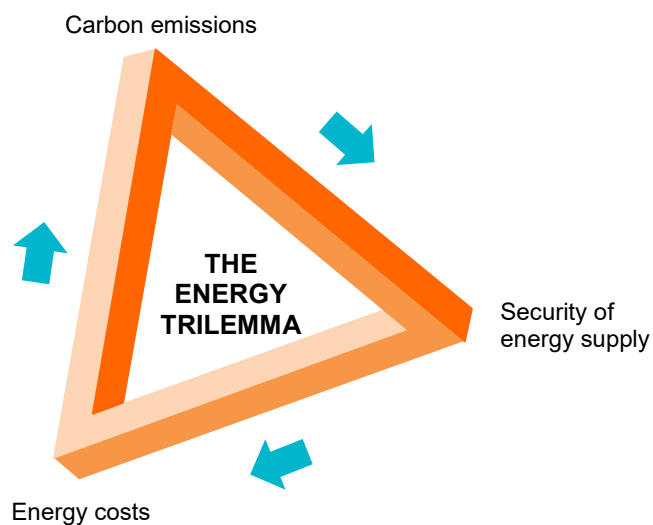


Figure 2.1 – The Energy Trilemma

This reflects the need to balance sometimes competing policy objectives, which are often referred to as The Energy Trilemma. As shown in Figure 2.1, this reconciles three factors: energy security, carbon emissions and energy costs.

³ Scottish Government (2013), Electricity Generation Policy Statement: <http://bit.ly/1LzaVdh>

2.2.1 Energy Security

The Scottish Government has stated that ensuring adequate security of supply should be the first priority of energy policy.⁴ This recognises that public services, households and businesses all operate on the basis that a reliable supply of power will be available when needed at an affordable cost.

The security of electricity supply has been a key point of debate between the Scottish and UK government in recent years. The Scottish Government cites that Scotland is a substantial and reliable net exporter of electricity, with over a quarter of all Scottish generation exported in 2012.⁴ However, Scotland is part of a GB-wide energy market and therefore overall security of supply needs to be considered at the UK-level. This has led the Scottish government to raise concerns about the declining capacity gap between forecasted demand and generation in coming years. The next 10 years is expected to see 20% of the UK's existing electricity capacity come offline.⁵ As such, security of energy supply was the subject of a Scottish parliamentary enquiry which published its findings in October 2015.⁶

In addition to ensuring a reliable supply of electricity it is also necessary to ensure that the supply is of a defined quality. These quality thresholds relate to defined limits for frequency or voltage, outside of which equipment malfunctions (e.g. machinery running slower) or even failures could result. A large voltage deviation for example can cause reliability problems which should be avoided to ensure the good operation of electric appliances.⁷ Power quality is therefore essential to the electricity distribution network operators (DNOs) as well as to customers.

Another important aspect of energy security is import and export markets for energy. For electricity, there is a large focus on interconnects with other European countries as a means of ensuring a reliable supply of affordable electricity.

The UK is also dependent on imported fossil fuels for both electricity generation and road transport fuels. Although Scotland is a significant producer of oil, the United Kingdom has been a net importer of oil since 2006, with imports accounting for 37% of UK's oil demand

⁴ Scottish Government (2014), Assessing Scotland's security of supply in the GB Electricity market: www.scotland.gov.uk/Resource/0046/00461109.pdf

⁵ Spataru, C. et al. (2015), Long-term scenarios for reaching climate targets and energy security in UK: <http://bit.ly/1g6V5JX>

⁶ Scottish Parliament (2015), Economy, Energy and Tourism Committee, Security of Scotland's energy supply: <http://www.parliament.scot/parliamentarybusiness/CurrentCommittees/88139.aspx>

⁷ Clement-Nyns, K. et al (2010), The Impact of Charging PHEVs on a Residential Distribution Grid: <http://bit.ly/1C55AaR>

in 2012 – up from 30% in 2011 and 16% in 2000⁸ (Figure 2.2 below outlines where UK imports are sourced). The transport sector accounted for 71% of total oil consumption in the UK in 2011.

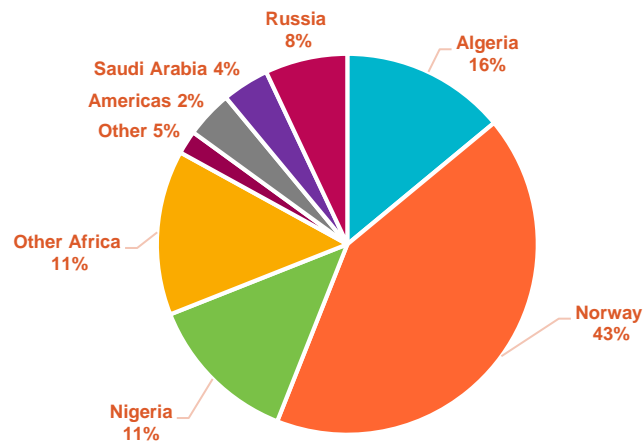


Figure 2.2 – UK crude oil imports by origin, 2014⁹

A recent study cites that electric cars could cut the UK's oil imports by 40% and reduce driver's fuel bills by £13bn if deployed on a large scale.¹⁰

2.2.2 Carbon Emissions

The reduction of carbon emissions has been prominent in Scottish energy policy. Scotland's 2020 target is to deliver the equivalent of at least 100% of gross electricity consumption from renewables by 2020. It is well on track to achieving this, at 46% in 2013.¹¹

Scotland is, however, a net exporter of energy, and therefore the Scottish Government has also clearly stated that it envisages thermal power continuing 'to play an important role' in Scotland's energy future.¹¹ The 2020 target is not a carbon intensity target and therefore there are no restrictions on the amount of fossil fuel generation in the system as a whole.

⁸ International Energy Agency (2014), Energy Supply Security: <http://bit.ly/1Lzb1Bz>

⁹ European Commission (2014), EU Crude Oil Imports: <http://bit.ly/1L4PQCL>

¹⁰ Cambridge Econometrics (2015), Fuelling Britain's Future: <http://www.camecon.com/FuellingBritainsFuture.aspx>

¹¹ WWF (2015), Pathways to Power: Scotland's Route to Clean Renewable, Secure Electricity by 2030: <http://bit.ly/1JkZpNd>

The latest available figures (2011) show that Scotland's grid intensity is approximately 271gCO₂/kwh, considerably less than the rest of the UK due to Scotland's high renewables sector.¹¹ Moreover, Scotland's 2030 target is to achieve power sector carbon intensity of 50gCO₂/kWh or lower.

Reduction in carbon emissions is a clear benefit also of electric vehicles. Emissions for grid powered EVs in coal based energy systems have been calculated to be four times greater than those with low carbon electricity¹². However, the carbon intensity of EVs is not just down to how the electricity used is generated, but also encompasses emissions for vehicle manufacturing, direct grid emissions and indirect grid emissions and losses.¹³ EV emissions for the UK have been calculated to be approximately 202gCO₂e/km from a broad mix of power sources.¹² This figure will likely be lower for Scotland due to its renewable energy capacity.

A key message is that with today's energy mix in Scotland, the carbon intensity of EVs is lower than equivalent fossil fuelled vehicles. Electric vehicles are also already at least twice as efficient as internal combustion engine vehicles (ICEs).¹⁴ As renewable energy capacity increases and dirtier power plants are retired; emissions will reduce further.

At the stakeholder workshops undertaken as part of this study, it was suggested that regular figures could be produced so consumers can see where charging will have the least CO₂ intensity. It was also suggested that it would be beneficial to account for the positive role of EVs in the wider energy system, for example considering their role for energy storage and for incorporating distributed energy resources (DER) in a smart grid system. These areas are considered in more detail in Chapter 5.

2.2.3 Energy Costs

The third and final aspect of the energy trilemma is cost. To ensure affordability, community-scale electricity is generally supplied within a market framework that seeks to balance costs and service levels, now and in the future. This places decision-making for network prices with an independent regulator, who considers investment proposals from monopoly network operators on behalf of customers. As electricity networks are capital-

¹² Shrink That Footprint (2013), Shades of Green: <http://bit.ly/1HwCWkY>

¹³ The carbon impact of electricity involves using a single static government conversion factor, based on an average of CO₂ emission per kWh of electricity used at the point of final consumption. This factor varies as the composition of the UK fuel mix changes. The website, Realtime Carbon measures the variations in carbon intensity. In one instance figures showed a 40% difference in intensity across a 24-hour period.

¹⁴ WWF (2011), UK viewpoint on electric vehicles: <http://bit.ly/1LHtXye>

intensive assets operated over decades, extensive regulatory frameworks provide clarity for all parties around the rules, costs and benefits for their interaction.

The normal functioning of markets suggests that a narrowing gap between available supply and demand for electricity will tend to exert upward pressure on the price of electricity.

The outlook of future electricity prices is affected by a number of political, economic and social variables and therefore can be hard to predict with certainty. Analysis by the National Grid identified future scenarios price ranges from an upper-bound of around £100 per megawatt-hour (MWh) in 2030 to a lower-bound where prices remain at £50 per MWh, similar to the level in 2014.¹⁵

The Department for Energy and Climate Change (DECC) projects that electricity prices will rise in the future,¹⁶ in line with a continuing trend of rising demand and tightening supply.¹⁷ However this is in contrast to ratings agency Moody's who predict they will remain low as a result of energy-efficiency gains, the impact of wind power and the reinstating of previously shelved gas power plants.¹⁸ It has further been noted that the DECC's projection is contradicted by the German experience which has seen lower prices as renewable capacity has increased.¹⁷

One factor that may cause prices to increase is the closure of plants UK-wide as a result of the EU's Large Combustion Plant Directive, which limits emissions of certain pollutants into the air from power plants with a thermal input equal to or greater than 50 MW, built after 1987.¹⁹ Existing plants operating before this date could either make the required upgrades to abate emissions, or opt-out, with the latter meaning they would need to close by the end of 2015 or after an additional period of 20,000 hours operation.¹⁹

¹⁵ National Grid (2014), Future Energy Scenarios: <http://ngrid.com/1s7Hy5S>

¹⁶ DECC (2014), Annex M: Growth Assumptions and Prices <http://bit.ly/1sDV4H>

¹⁷ Carbon Brief (2014), A detailed look at why the future of UK energy is so hard to predict: <http://bit.ly/1s0iRlz>

¹⁸ Moody's (2014), UK utilities face rising regulatory and political risk and flat power price environment: <http://bit.ly/1GNO0Vf>

¹⁹ European Commission, Large Combustion Plants Directive: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32001L0080>

2.3 Energy Consumption

In addition to the trilemma objectives of cost, carbon and security, a further important area of policy is energy efficiency.

Scotland has a target to reduce final energy consumption by 12% by 2020²⁰. However, analysis for the Scottish Government indicates that demand will increase by 18% to 2030, largely as a result of increased electrification of heat and to 2030.²⁰

The Carbon Reduction Commitment (CRC) Energy Efficiency Scheme²¹ is a UK-wide policy designed to incentivise investment in energy efficiency amongst large energy users in the public and private sectors. In Scotland, there are 132 full participants in the scheme²⁰.

As noted at the stakeholder workshops for this study, electrification of a vehicle fleet is a good example of an investment which can impact an organisation's target/obligation to reduce electricity consumption.

It was also reported that individuals may not explicitly think of their cars as using energy, therefore the challenge of promoting efficiency can be difficult. To address this, it was suggested that a holistic view that contextualises an individual's domestic and transport energy use could be beneficial in encouraging behaviour change to reduce overall energy consumption. For example, incorporating electric vehicles into Green Deal Assessments was proposed as a mechanism that would illustrate their wider potential in domestic energy-saving.

Another suggestion from the workshops was that billing mechanisms such as an electric vehicle road user charge or a GPS based system that monitored and charged drivers based on their travel profile could provide alternatives to raising taxes on electricity as a means of reducing consumption.

Moreover, it was advocated that for fleets, the wider value from using electric vehicles may help offset concerns about increased electricity consumption. Electric vehicles offer a significant opportunity for reducing carbon emissions and overall energy consumption from fleets as well as offering financial and operational benefits.

²⁰ Scottish Government (2013), Low Carbon Scotland – Meeting our Emissions Reduction Targets 2013-2017 – the Second Report on Policies and Proposals: <http://bit.ly/1GN708r>, p104

²¹ Carbon Reduction Commitment Energy Efficiency Scheme: <http://bit.ly/1J5SXNP>

2.4 Smart Meters

A further area of energy policy that offers a potential interface with electric vehicles is the roll out of smart meters. The UK Government has stated that every home in Scotland should be offered smart meters by 2019, further specifying that energy suppliers are responsible for procurement and installation. All domestic customers are set to be provided with a standalone smart meter display capable of delivering real-time information on consumption.²²

It was noted at the workshops that a number of energy suppliers are providing electric vehicle charging solutions for the home and that integration with the smart meter deployment could potentially reduce installation costs and enable monitoring of energy consumption from charging.

However, it was also noted that the smart metering programme is not commencing full scale roll-out until 2016 and that each energy supplier is fitting the meters at different rates and with geographical variation.²³ The scale and complexity of this programme may limit the potential for integration with chargepoint installations.

2.5 Tariffs

The Switched On Scotland Roadmap identifies that new consumer energy packages and tariffs can promote recharging at the optimal electricity price for the day and help to reduce the operating costs of electric vehicles. One such example of this is shown in the case study below.

Case study: Ecotricity's reduced tariff for EV owners

UK-based green energy supplier Ecotricity offers electric car owners a discount on their domestic electricity bills. The company, which markets itself as "The World's first green electricity company" states that this discount offers EV drivers the equivalent of at least 1,000 'free' miles of electricity each year. Launched in 2014, the tariff also gives customers free access to Ecotricity's 'Electric Highway' - a UK-wide network of over 175 charging points covering almost the entire motorway network in Britain.

However, the UK Energy Act 2013²⁴ sets a limit on the number of energy tariffs offered to domestic consumers, which is a potential barrier to the development of special tariffs for

²² Ofgem (2010), Smart Metering Implementation Programme: <http://bit.ly/1LHUAml>

²³ Smart Energy GB, How it's happening: <http://bit.ly/1CJE6Cf>

²⁴ Department of Energy & Climate Change (2013), The Energy Act: <http://bit.ly/1BGxGsu>

electric vehicles. The Act also requires the automatic move of customers from poor value closed tariffs to cheaper deals and requires the provision of information by suppliers to consumers on the best alternative deals available to them.

At a more basic level, savings on running costs for EVs are greatest when owners have access to an overnight low rate electricity tariff.²⁵ Time-of-use (TOU) tariffs have been found to encourage a change in consumer behaviour by shifting vehicle charging outside of periods of peak demand.²⁶ This can also offer energy system benefits by levelling the overall demand profile over a 24-hour period (discussed further in Section 4.4).

Discussion at the stakeholder workshops in this study suggested new types of energy tariff may be required to incentivise electric vehicle use. This may require introducing a second smart meter to monitor a separate supply for EVs with scope to apply innovative charging costs. It was further noted that simplifying or limiting energy tariffs could be counterproductive in that respect. Reference was given to Article 4.12 of Directive 2014/94/EU on the Deployment of Alternative Fuels Infrastructure which states that consumers are able to contract electricity for an electric car separately, enabling new business models to sell cars with an electricity subscription.²⁷

2.6 Community Energy

The Scottish Government has a stated ambition to maximise the benefits of renewable energy for communities. This recognises that communities can gain from renewables projects, over and above the energy generated and financial benefits. For example, renewable energy projects can bring increased community cohesion and confidence, skills development and support for local economic regeneration.

The UK Government released its first Community Energy Strategy in 2014 to help such initiatives grow, expand and inspire others, suggesting an important role for actors in this sector.²⁸ The strategy states that: “Community led action can produce energy, reduce energy use, manage energy demand and purchase energy. It can often tackle challenges more effectively than government alone, developing solutions to meet local needs, and involving local people. Putting communities in control of the energy they use can have wider benefits such as building stronger communities, creating local jobs, improving health and supporting local economic growth.”²⁸

²⁵ Energy Saving Trust, Electric Vehicles: <http://bit.ly/1uZiSI>

²⁶ UK Power Networks (2011), Impact and Control of EV charging: <http://bit.ly/1C1trbc>

²⁷ Eur-Lex, Progress towards completing the Internal Energy Market: <http://bit.ly/1CMif9N>

²⁸ DECC (2014), Community Energy Strategy: <http://bit.ly/1erF1tY>

At the industry roundtable for this study, the Low Carbon Networks Fund was suggested as a forum for stakeholders across Scotland to engage with DNOs and Ofgem on the opportunities available for community incentive energy projects. Doing so offers a potential investment opportunity for small projects to be scaled up.

Nesta has produced a report offering insight on community energy and its development in energy systems of the future. To make the most of emerging opportunities and technologies, it is recommended that local authorities and community groups work together to create long-term local energy strategies and forward-thinking policies.²⁹

Case study: Community energy and mobility, Fife, Scotland

The Hydrogen Office in Methil, Fife is home to the UK's first wind-electric van. Owned by Fife Shopping and Support Services (FS&SS) it is used to deliver groceries and pension payments to elderly residents in the area.

The initiative came about after FS&SS funding was reduced due to public sector cuts in 2010. In a bid to still provide the service at a reduced cost the electric van powered by community generated wind offered a long-term sustainable solution.³⁰

The van is powered from a charging point at Methil's Hydrogen Office, which is connected to a 750kW wind turbine that generates heat for the office and supplies a hydrogen producing electrolysis plant.³¹ The site has been offered as a point of charge overnight, and when not required by FS&SS it will be used by the Hydrogen Office as a demonstrator of logistically viable green technologies.

The electric van is significantly cheaper than a petrol equivalent previously used, costing an estimated £0.15 per day in contrast to the £7.20 of a petrol vehicle. Its CO₂ savings are also expected to be approximately 18 tonnes over the lifetime of the vehicle.³⁰

Discussion at the stakeholder workshop for this study highlighted that community generation is important to creating genuinely free carbon systems. However, costs are high for accessing the grid, which can be one of the biggest constraints to feasible community energy projects. DECC proposed a series of new measures in 2014 to support community projects generating up to 5MW including to reduce up-front costs and support fund-raising.³²

Some community energy projects may struggle to get off the ground in light of changes in tax relief announced by the Treasury in 2015, which sees the removal of incentives for building new renewable energy sources. Investors in community energy projects will no

²⁹ Nesta (2015), Local energy in an age of austerity: preserving the value of local and community energy: <http://bit.ly/1Pbdfat>

³⁰ Community Energy Scotland, FS&SS Community Electric Van: <http://bit.ly/1NidUV4>

³¹ SHFCA, Hydrogen Office in Fife Hosts First Wind-Electric Van: <http://bit.ly/1Lzblk1>

³² DECC (2014), Government Response to the consultation on support for community energy projects under the Feed-in-Tariffs Scheme: <http://bit.ly/1GQh11B>

longer be able to benefit from Enterprise Investment Schemes, the Seed Enterprise Investment Scheme or the Social Investment Tax Relief.³³

Case study: Community energy investment model, Solihull, England

Innovate UK granted funding to Encraft, Cenex and Solihull Metropolitan Borough Council for a community energy investment model for post-war housing which aims to develop a set of solutions giving communities greater control over their energy bills.³⁴

An integrated package of technical solutions is being applied to clusters of 5-20 buildings, supported by a commercial model which reduced energy costs for everyone over the lifetime of the technologies. The package of solutions includes the use of electric vehicles combined with local electricity generation from solar panels, new district heating systems, insulation and modern control technologies and energy storage.

The idea is that widespread deployment of this kind of solution across the country will lead to a stronger local supply chain for distributed energy technologies as well as faster transition to a more efficient national energy system and lower heating and electricity bills.³⁴

In addition, the full benefit of electric vehicle integration into community energy systems may not yet be fully realised as vehicle-to-‘x’ applications are still in their infancy (discussed further in Chapter 7). At present their application could be limited to providing transport and storing excess renewable energy. In the future, however, they may be used increasingly in demand management scenarios as the technology and applications to do so are further developed.

It was suggested in the stakeholder workshops for this study that Scotland’s prominent position in the UK’s renewable sector could see it ‘take the lead’ on incentivising local energy and community projects. A cited example was a Local Energy Challenge funded project in Orkney that uses excess electricity to produce compressed hydrogen³⁵. This is then converted to electric power for buildings and ferries at the local harbour.

³³ The Guardian (2015), Government to cut tax relief for community green energy schemes: <http://bit.ly/1iAhz5>

³⁴ Innovate UK (2015), Results of competition – Integrated Supply Chains for Energy Systems: <http://bit.ly/29VMtbJ>

³⁵ Local Energy Scotland, Orkney Surf ‘n’ Turf: <http://bit.ly/1MWrd3N>

3 Electricity Distribution System and Smart Grids

3.1 Introduction

This chapter briefly explains the electricity distribution system in Scotland and introduces the concept of a smart grid. It also illustrates how electric vehicles can form an important component of a smart grid.

3.2 The Electricity Distribution System

Electricity supply comprises two linked systems – transmission and distribution:

- **Electricity transmission** uses high-voltage networks (132,000 volts (132kV) to 400,000 volts (400kV) in Scotland) from the point of large-scale generation direct to large users and into the local distribution system. In Scotland, these high-voltage transmission systems are owned and operated by SP Energy Networks in southern Scotland and SSE Power Distribution Transmission in northern Scotland.
- **Electricity distribution** takes power from the high-voltage transmission system and distributes it to consumers. In Scotland, this system operates at between 240V and 33,000 volts (33kV). In the UK, there are 14 licensed distribution network operators (DNOs). The two Scottish DNOs are SP Energy Networks and SSE Power Distribution.

The movement towards smarter grid architectures is expected to result in the traditional role of distribution network operators evolving from management of a passive network to a distribution system operator (DSO) model that supports local balancing and system optimisation.³⁶

The industry roundtable undertaken for this study highlighted that DNOs often have limited visibility of EV customers asking for charge point connections and there is some concern that if this were to increase network safety could be compromised. It was suggested that movement towards a DSO approach, which offers more visibility and control on a network, would help to alleviate this. A number of individual projects are currently assessing DSO models.

³⁶ Department of Energy & Climate Change (2014), Smart Grid Vision and Routemap: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/285417/Smart_Grid_Vision_and_RoutemapFINAL.pdf

3.3 Grid Connections

A number of technical standards are in place to govern the requirements for grid connections. These standards serve several purposes:

- To allow the generator to synchronise with the voltage and frequency on the local distribution network.
- To protect the generator from any faults that may occur on the distribution network.
- To protect the distribution network from any faults that may occur on the generator.

3.4 The Smart Grid

The smart grid is not a single entity but rather defines a new model for electrical grid systems:

“Smart grid (n): a modernised electrical grid that uses information and communications technology to gather and act on information, such as the behaviours of suppliers and consumers, to improve the efficiency, reliability, economics, and sustainability of electricity.”³⁷

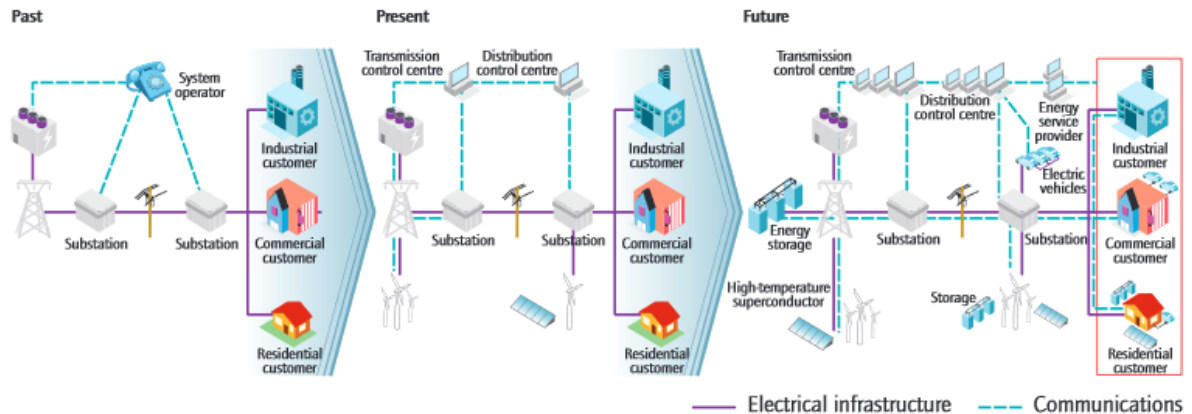


Figure 3.1 - Representation of a Smart Grid system³⁸

³⁷ Scottish Enterprise, Smart Grid: <http://bit.ly/1HjxIsN>

³⁸ International Energy Agency (2011), Smart Grids Roadmap: <http://bit.ly/1jWt6rD>

Case study: Orkney's Active Network Management System

2009 saw the introduction on Orkney of what can be considered the first smart grid in the UK,³⁹ allowing the exploitation of latent renewable energy capacity. Scottish Southern Electric Power Distribution (SSEPD) working in conjunction with the University of Strathclyde carried out research to address capacity constraints leading to the creation of the Active Network Management System (ANM).

This pioneering research laid the foundation for Smarter Grid Solutions, a global company based in the UK and US that specialises in ANM products and services. In addition, residents on Orkney have been able to unlock additional generation revenue previously curtailed. Orkney's reputation in this field continues to attract research and design expenditure from around the world with companies looking to innovate further on distributed generation.

An estimated 400 jobs on the Islands depend on renewable related activity⁴⁰ and Orkney is in a privileged position as 1 of only 3 designated power zones in the UK.⁴¹ Registered Power Zone were setup under Ofgem to research, develop and demonstrate technology associated with distributed generation. Exploiting this to its full potential offers the possibility of additional jobs and economic development for the Islands.

The term 'smart grid' can be perceived as representing an entirely new element within energy systems. However, in practice it may be more accurate to refer to the development of 'smarter grids', emphasising their enhancement through technological modification.

Smarter grids offer benefits to the electricity industry, consumer and to wider society⁴², with the smart grid market estimated to be worth USD\$65.4m by 2021⁴³ However, their success relies in part on being understood and engaged with by consumers. For example, experience with smart meters in the Netherlands found that failure can occur when the commercial aspects are considered to be more important than the interests and understanding of end users.⁴⁴

Research into consumer engagement of smart grid initiatives confirms the need for simple, clearly expressed, multi-channel communication with customers that accounts for their needs and desires.⁴² The most successful smart grid projects have started with a

³⁹ Scottish Southern Electric Power Distribution, Orkney Active Network Management Live: <http://anm.ssepd.co.uk/ANMGen.aspx>

⁴⁰ Orkney Islands Council (2014), Response to OFGEM Caithness to Moray Strategic Wider Works Needs Case Assessment: <http://bit.ly/1LzbALW>

⁴¹ OfGem (2006), The Innovation Funding Incentive & Registered Power Zones Annual Reports 2005/6: <http://bit.ly/1Kfgewv>

⁴² SmartGridGB (2013), Smart grid: A great consumer opportunity: <http://bit.ly/1N5iGbQ>

⁴³ MarketWatch (2016), Smart Grid Market Worth 65.4 Million USD by 2021: <http://www.marketwatch.com/story/smart-grid-market-worth-654-million-usd-by-2021-2016-07-13-92033110>

⁴⁴ Hoenkamp, R. et al. (2011), The Neglected Consumer: The case of the Smart Meter Rollout in the Netherlands: <http://bit.ly/1Cd9BKi>

public communication campaign to create awareness and publicise positive consumer experiences.

The US group Smart Grid Consumer Collaborative identified seven key elements to a successful campaign:⁴²

- Educate customers before deployment;
- Anticipate and answers questions before customers ask them;
- Facilitate community engagement programmes;
- Communicate how to shift usage to off-peak;
- Deploy user-friendly web portals;
- Offer user-friendly smart grid enabled technology; and
- Create authentic customer testimonials.

3.5 Smart Grid Technologies

Electric vehicles can serve as one component of technology within a smart grid system. Table 3.1 below illustrates some examples of different smart grid technologies and highlights the hardware and software elements associated with them.

Table 3.1 - Examples of smart grid technologies³⁸

Technology area	Hardware	Systems and software
Transmission enhancement	<ul style="list-style-type: none"> • Superconductors, FACTS, HVDC. 	<ul style="list-style-type: none"> • Provision of public recharging infrastructure. • Plug-in car grants. • Home charging grants. • Local measures and incentives.
Distribution grid management	<ul style="list-style-type: none"> • Automated re-closers, switches and capacitors, remote controlled distributed generation and storage, transformer sensors, wire and cable sensors. 	<ul style="list-style-type: none"> • Geographic information systems (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS).
Advanced metering infrastructure	<ul style="list-style-type: none"> • Smart meter, in-home displays, servers, relays. 	<ul style="list-style-type: none"> • Meter data management system (MDMS).
Electric vehicle charging infrastructure	<ul style="list-style-type: none"> • Charging infrastructure, batteries, inverters. 	<ul style="list-style-type: none"> • Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies.

Whilst it is true that the uptake of electric vehicles can increase the load on the grid, they also represent a tool to be used within smart grid systems. An increase in load also offers the capacity to capture more renewable energy and to help balance generation with

demand for cleaner and cheaper electricity.⁴⁵ In theory the utility company can provide more energy through existing infrastructure as a result, avoiding upgrades to transformer capacity. Comments at the industry roundtable for this study emphasised that a smart grid architecture can help maintain existing networks for a longer duration before upgrade is required. Much of the technology to accomplish this has been developed and is currently being tested.⁴⁵

Through networked chargepoint and in-vehicle telemetry, electric vehicles can connect to buildings such as homes and workplaces and the grid more widely. As such they may be used to provide reserve power in an emergency situation, store energy generated on-site and engage in optimised charging events for time of use demand response requests. Widespread adoption of electric vehicles can provide utilities with grid support to manage peak loads.

3.6 Smart Meters and Home Area Networks

Smart meters are a key smart grid technology.⁴² Smart meters can form part of a sophisticated bi-directional communications network that enables real-time monitoring and control of transmission, distribution and end-user consumer assets, such as electric vehicles, for effective coordination and usage of available energy resources.⁴⁶

The widespread installation of smart meters can allow electricity to be measured in people's homes and real-time communication of this data with the network.⁴⁷ An end-to-end technology solution such as this has been found to be significantly cheaper than changing the network to cope with increased demand.

It is considered possible for over 50% of households to adopt electric vehicles through optimised charging without network change.⁴⁸ This can be achieved by a vehicle charging outlet being connected to the smart meter in the residence using a digital signal communicated through the consumer's Home Area Network (HAN).⁴⁸ The HAN provides a means for digital devices to communicate with each other and is particularly relevant for energy management.

⁴⁵ Navigant Research (2014), How EVs Can Aid the Smart Grid: <http://bit.ly/1ywLB1s>

⁴⁶ Masoum, A.S. et al. (2011), Smart load management of plug-in electric vehicles in distribution and residential networks with charging stations for peak shaving and loss minimisation considering voltage regulation: <http://bit.ly/1GT2BP9>

⁴⁷ DIUS (2013), Demand management of electric vehicle charging using Victoria's Smart Grid: <http://bit.ly/1fiZAKE>

⁴⁸ Hoog, J. et al (2013), Demonstrating Demand Management: How Intelligent EV Charging Can Benefit Everyone: <http://bit.ly/1BGz4LB>

If demand is high, or in the event of an emergency, a signal can be sent from the network operator to a customer's smart meter to reduce or temporarily stop the charging of the vehicle. In addition, the charging terminal may be connected to the internet so network operators can inform vehicle owners when a demand response event is going to take place. Notifications could be received through an online account, smartphone or on the charging terminal interface itself.⁴⁸

Similar load control programs are being used in the United States to reduce peak demand in relation to the use of air conditioning units during hot summer afternoons. These programs are a considerable financial incentive to customers with annual benefits of up to \$200.⁴⁹

Communication between the utility and smart meters allows the exchange of relevant information such as price signals or tariff information with customers.⁵⁰ In addition, the consumer is aware of electricity usage costs, can manage their consumption habits and take control of so-called smart appliances, such as electric vehicles.

It has been suggested that the present operational benefits of smart meters are largely realised by the utility rather than consumers.⁵¹ However, work is being undertaken to enhance the value of smart meter data for consumers through what is known as Non-intrusive load monitoring (NILM).⁵¹ NILM monitors changes in the current and voltage to the consumers' home or business, dissecting the electric meter load curve to diagnose the performance of specific appliances and systems that are embedded within it. Each appliance has a unique signature that can be deduced from the load curve of the entire building. This allows the individual components of a load to be unpacked into its respective parts.⁵¹ This allows the active monitoring of energy usage associated with specific connections, such as an electric vehicle.

⁴⁹ Clearly Energy, Residential Demand Response Programs: <http://bit.ly/1RCdGct>

⁵⁰ Gungor, V.C. et al. (2013), A Survey on Smart Grid Potential Applications and Communication Requirements: <http://bit.ly/1JBjndU>

⁵¹ Rocky Mountain Institute (2015), Non-Intrusive Load Monitoring Can Enhance Smart Meters, Save Energy & Money: <http://bit.ly/1lFZlXr>

4 Demand Management

4.1 Introduction

This chapter outlines how managed charging of electric vehicles can help avoid stresses on the grid. This considers the overall capacity of the grid, concerns related to local grid capacities and peak demand, as well as managed charging strategies to help control the additional load created by electric vehicles.

4.2 Overall Capacity

Research has shown that even a complete electrification of the European vehicle fleet would result in additional demand of around 10-15%⁵², suggesting that Scotland should cope comfortably with increases in absolute power demand from future uptake of electric vehicles.

Research also suggests misconceptions about the potential of electric vehicles to overwhelm the grid may stem from a misunderstanding of the energy use required to charge and run EVs.⁵³ Feedback from the stakeholder workshops for this study suggested that contextualising this increase relative to other electricity demands may help placate concerns about a widespread uptake.

Analysis of the grid conditions in California showed that local grids need upgrades to serve electric vehicles less than 1% of the time.⁵⁴ However in the case of vulnerabilities, such as at local distribution transformers, the utility could, as a strategy, express to customers that it is aware of the issue, highlight any planned upgrades and then work to reinforce grid loads if necessary.

Demand Side Response strategies (see Section 4.5) also offer the potential to support high levels of penetration without the need for network reinforcement.⁵⁵ Furthermore, the potential for electric vehicles to incorporate additional generation capacity from distributed energy resources (DER) is an example of EVs assisting the grid rather than adding further stress. These are discussed in further detail in Chapters 7 and 8.

⁵² Essen, H. V. and Kampman, B. (2011), 'Impact of Electric Vehicles – Summary Report: <http://bit.ly/1s1xWeG>

⁵³ Clean Technica (2014), Grid Capacity for EVs is Actually Not a Problem, Studies Find: <http://bit.ly/1fCAAAX>

⁵⁴ Plug-In Vehicles: For Utilities, More Opportunities than Challenges: <http://bit.ly/1bhYuMK>

⁵⁵ Element Energy (2009), Strategies for the uptake of EVs and associated infrastructure implications: <http://bit.ly/1geoXEh>

It was highlighted at the industry roundtable for this study that DNOs have undertaken a price review until 2023 which accounts for the introduction of low carbon technologies such as EVs. It is expected that the impact on the distribution system will be relatively small. However, there is some uncertainty about when vehicle numbers will increase to a level where this impact may be more significant. It was noted that for the energy industry to make educated forecasts of demand, it will be necessary to access intelligence on the anticipated drivers of increased EV uptake. Examples discussed included the expected decreases in purchase price and plans to introduce new incentives.

A further issue raised was that absolute numbers of vehicles on the road may not be the best indicator of likely short-term impact on the grid. For example, high mileage vehicles such as taxis and buses are likely to recharge more frequently and therefore need to be considered in demand forecasts.

4.3 Local Capacity

There are capacity constraints when considering the electricity network at the local level. For example, a concentration of electric vehicles connected in one area being fed by the same substation can cause stresses on the grid, such as power overloads and feeder congestions.

Insight from the stakeholder workshops for this study highlighted that there are no specific problems with the grid at present, however the point at which the level of EV uptake becomes an issue will vary geographically across Scotland. It was discussed that quality of supply issues such as voltage drop due to cluster charging may be more of a problem than the overloading of transformers. This raised the question as to whether DNOs should be enabled to ensure quality of supply issues are minimised.

It was reported at the industry roundtable that creating greater DNO visibility of new grid connections for EVs would assist in network control. Such an approach would ideally go beyond the consideration of EVs simply as a connection but rather would integrate them into a broader local energy balancing process (discussed further in Section 8.3).

It was also discussed that it is not in the interest of the DNOs to permit access for every EV connection. An industry-wide process to safeguard the network through control mechanisms that prevents localised issues would be beneficial in addressing this.

One such basis for this could be the DNOs' heat maps that identify network infrastructure at a distribution level. These outline the areas where a connection can be made and provide details of the individual capacity of substations. There are plans to increase this level of detail, and they could potentially be used to assess where certain connections may be problematic.

As well as considering the grid impact of individual vehicles charging, it is also necessary to consider the capacity of local grids to support increased deployment of fast and rapid chargers. This includes both the need to reinforce local networks to support widespread deployment of rapid chargers, as well as the significant additional strain on the grid caused by rapid charging at times of peak electricity demand.

It was discussed at the stakeholder workshop that chargers with various levels of power are being installed across Scotland. This includes standard chargers (3-7kW), fast (7-22kW), rapid (43-50kW), and Tesla Superchargers (120kW). It was cited that it could potentially be challenging to find suitable locations for chargers that require a three-phase⁵⁶ power supply and that in some cases these may also require upgrades to local distribution networks. Furthermore, many of these chargers are being installed in urban and suburban communities which may place additional demand on already stressed grids.

It was further noted that UK grid capacity has narrowed in recent years, so adding a high load to the grid in a short period of time could be problematic. Ofgem's recent Electricity Capacity Assessment Report notes that although the National Grid is expecting a decline in demand over the course of the next five winters (2014/15-2018/19), this is cancelled out by deteriorations on the supply side as a result of plant closures and mothballing.⁵⁷ Margins are expected to drop to their lowest in 2015/16 and improve thereafter.

A key recommendation from the workshops was that a dialogue on grid constraint should be established between individuals working in both the distribution and transmission networks to anticipate and deal with any potential issues resulting from charging of electric vehicles.

4.4 Peak Demand

There are variations in the capacity of grids at different times of day, as well as seasonal variations. These peaks in demand are currently met by activating 'peaker' power plants when base load plants have reached their capacity. As these peaker plants are only in sporadic use they demand a higher running cost, making this electricity more expensive and typically generated from high carbon fossil fuels.

Demand, and therefore cost and carbon intensity, differs from weekdays to weekends, months and seasons amongst a number of other variables. The average daily demand

⁵⁶ Single-phase and three-phase are electricity supplies. A single-phase supply is smaller than a three-phase supply meaning you cannot use as much power.

⁵⁷ Ofgem (2014), Electricity Capacity Assessment Report 2014: <http://bit.ly/1t7CdyR>

profile for a UK winter's day for example is higher than a summer equivalent because more energy is being generated for heating purposes. Demand profiles also vary when broken down to illustrate domestic, commercial and industrial use, with each having a unique load profile. An example demand profile is illustrated in Figure 4.1 below.

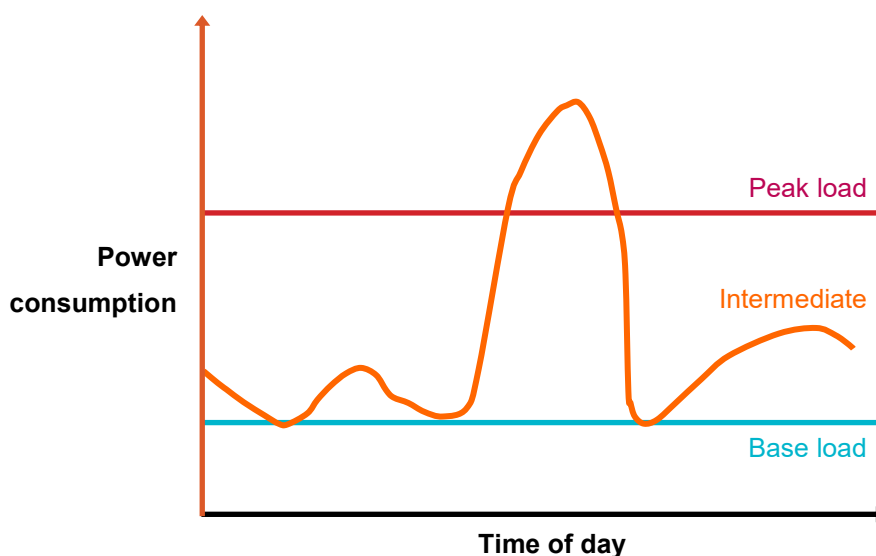


Figure 4.1 – Changes in electrical demand over a day period indicating levels of base, intermediate and peak load

Users typically plug in their vehicles at set times of the day – for example when arriving home from work – causing a spike in electricity demand at that time. A simulation of an uncontrolled charging scenario found that this tendency to plug-in at peak times of the day could mean that a 10% uptake of electric vehicles would pose a risk to some networks if no changes were implemented.⁴⁸

Case study: SSE electric vehicle trials

Scottish & Southern Energy (SSE) has been involved in EV trials, case studies and academic research into the impact of EVs on the electricity network⁵⁸. The key conclusions from these studies are that 90 per cent of EV charging is expected to take place at home, with the balance in workplaces or public chargepoints.

Because domestic recharging predominates, the research, carried out by the University of Strathclyde, concentrated on the effects on the low voltage (LV) domestic supply networks. These studies found that the existing LV networks can support up to around 30 per cent penetration of EVs, even with 32 Amp charging, provided that the bulk of the charging is done overnight when there is spare capacity on the network. When drivers are provided with simple controls and beneficial tariffs to recharge overnight, the vast majority of the charging is done at that time.

Conversely, in the absence of these incentives, drivers tend to plug in their vehicles on arriving home from work, creating additional demand in the early evening. This coincides with

⁵⁸ Huang, S. et al (2012), Potential Impact of Uncoordinated Domestic Plug-in Electric Vehicle Charging Demand on Power Distribution Networks: <http://bit.ly/1Sx5Bv7>

existing peaks on the network and even low penetrations of EV could cause overloads on the low voltage network.

To cope with even higher demand from EVs, smarter charging methods need to be developed to spread the load over the whole of the off peak period. SSE is carrying out further work with EA Technology into control mechanisms for EV charging that can maximise the potential of the existing networks.

The National Grid currently employs a system known as Triads for large industrial users of electricity with the aim of reducing consumption and their energy charges over peak periods. The triads are defined as the three-half hours of highest demand on the UK's electricity transmission system between November and February each year, calculated by settlement data analysed after the event. This data is used to work out charges for the following 'Triad season', and in order to avoid charges, customers need to avoid the potential peaks. This helps flatten demand across the whole winter period.⁵⁹

The charges are £16-£39 per kilowatt depending on the customers' location in the country, multiplied by their average demand during the three Triad half-hour periods. The scheme is generally welcomed by large industrial users because it offers the opportunity to reduce overall energy bills, by switching off at a time that might coincide with a peak demand event. If charges were based on energy use throughout the year, bills would likely be higher.⁵⁹

It was discussed at the workshops that it may be possible to consider this mechanism or elements of it in a scaled down application, for example, for large fleets or communities where electric charging is high, depending on how peak demand changes in the future.

4.5 Managed Charging

Centrally managed demand response strategies are being developed to address the cluster effect where multiple electric vehicles charging in a community can place a strain on local distribution grids. Managed charging discourages drivers from plugging-in their vehicles at times of peak demand.

One such example is an energy supplier time of use (TOU) tariff. Price variations for charging at different times of the day have shown to be effective at controlling when users charge.⁶⁰ Alternatively a tariff might be structured in a slightly more fluid way that

⁵⁹ National Grid (2015), Triads: Why three is the magic number: <http://bit.ly/1I8aGp8>

⁶⁰ Idaho National Laboratory (2015), The EV Project: <https://avt.inl.gov/sites/default/files/pdf/EVProj/ResChargingBehaviorInResponseToExperimentalRates.pdf>

informs consumers a day, week or hour ahead of when a cheaper rate may be⁶¹, encouraging them to charge around specific periods as a result of predicting demand.

Vehicles can also be programmed to begin charging at a set time when preferential pricing begins, therefore acting as a financial incentive for users. Similarly, the charging of vehicles can be remotely interrupted (i.e. paused) to reduce the costs of charging at a specific time.

An ability for users to override demand response events autonomously (even if this incurs additional costs) will help ensure the success and acceptance of optimised charging.⁶¹ An overview of charging level and control functionality whilst away from the vehicle is also important – i.e. the current level of charge, expected completion time. It has been estimated that an end-to-end technology solution like this could be implemented for a tenth of the cost of modifying the network as part of an unmanaged charging scenario.⁶²

The development of smart grid infrastructure and policies is allowing more enhanced demand response to be realised.⁶³ Experience in Washington, USA suggests that the savings made from smart demand response could be US \$200 billion over the next 20 years as it can reduce the need for constructing additional power generation, transmission lines and new pipelines.⁶⁴

In the UK, network operators and suppliers have been contributing to developments that consider the infrastructure required for off peak charging of electric vehicles.⁶⁵ The deployment of advanced metering infrastructure and charging systems makes it easier to control the timing and rate of vehicle charging in demand response scenarios.⁶⁶

⁶¹ Massachusetts Institute of Technology (2011), The Future of the Electric Grid: <http://bit.ly/1NeMSxD>

⁶² Handberg, K. and Owen, G. (2015) Electric Vehicles as Grid Support in Beeton, D. and Meyer, G. Electric Vehicle Business Models

⁶³ Wang, J. et al. (2011), Impact of PHEVs on power systems with demand response and wind power: https://www.researchgate.net/publication/227415730_Impact_of_plug-in_hybrid_electric_vehicles_on_power_systems_with_demand_response_and_wind_power

⁶⁴ Conca, J. (2015), Forbes: 'Demand Response' Is How The Smart Grid Will Save Us Billions: <http://onforb.es/1BO37QA>

⁶⁵ Energy Networks Association (2012), Smart Demand Response: A Discussion Paper: <http://www.energynetworks.org/news/press-releases/archive/2012/july/smart-demand-response-a-discussion-paper.html>

⁶⁶ Li, C. (2013), Synergistic Control of Plug-in Vehicle Charging and Wind Power Scheduling: <http://bit.ly/1KTb3me>

Case study: My Electric Avenue

The My Electric Avenue (MEA) project tested monitoring and control technology by recruiting 'clusters' of EV users, both residential and business. All people in a cluster were fed by the same local electricity substation feeder. The 'cluster trials' aimed to simulate a 2030 network; and were located in both residential situations (home charging) and in business situations (fleet cars charging at work).

The project has provided essential learning about managing the strain on the electricity distribution network from the anticipated increased uptake of electric vehicles. It also delivered a cost-effective solution to Distribution Network Operators that reduces the need for network reinforcement and allows a faster uptake of EVs. MEA also monitored EV users as individuals rather than clusters ('social trials') for behavioural and socio-economic data - i.e. their driving and charging habits were recorded.

EA Technology who led the trial developed monitoring and control technology that offers a solution to reduce network reinforcement, and to support EV market growth. This solution will delay, and in some cases avoid, the need for additional electrical infrastructure - which would be costly and disruptive, as well as taking significant time - to accommodate the forecast increase in EVs.

It was highlighted at the industry roundtable for this study that DNOs intend to pursue a managed charging, network innovation project that builds further on the results of MEA.

Furthermore, research presented by the IEEE demonstrates the potential use of control algorithms that can be used to create a greater synergy between electric vehicles and wind energy, by throttling charging power back and forth to eliminate wind intermittency.⁶⁶ This is implemented through three layers of control:

1. Top-level control minimises generation cost and finds scheduling of non-renewable generation and wind power.
2. The middle-level designates charging power to individual vehicles based on their state of charge and plug-off time.
3. The bottom-level uses feedbacks to control vehicle charging in real-time to regulate grid frequency.

A pilot project by a utility company in California, USA integrates electric vehicles into the wholesale energy market, aggregating stationary storage systems with the charging demands of fleets at five locations throughout the San Diego County.⁶⁷ Software remotely controls the assets, balancing the participant's charging needs whilst identifying opportunities to provide demand response services to the grid.⁶⁷

⁶⁷ Transmission & Distribution World (2015), SDG&E Integrates EVs and Energy Storage into California's Energy and Ancillary Service Markets: <http://bit.ly/1HMEveT>

5 Energy Storage and Supporting High Renewable Grids

5.1 Introduction

This chapter outlines how electric vehicles can be used as a source of flexible energy storage and to support Scotland's ambition to increase the deployment of renewables.

5.2 Renewable Energy Challenges

There are certain characteristics of renewable energy generation which present challenges in integrating them into the grid.

5.2.1 Intermittent Supply

The intermittent, variable supply characteristics of renewable energy resources create significant challenges for their integration into the grid and widespread adoption. Figure 5.1 illustrates how the generation of renewable energy can vary compared to demand on a typical day, with instances of over-generation and under-supply.

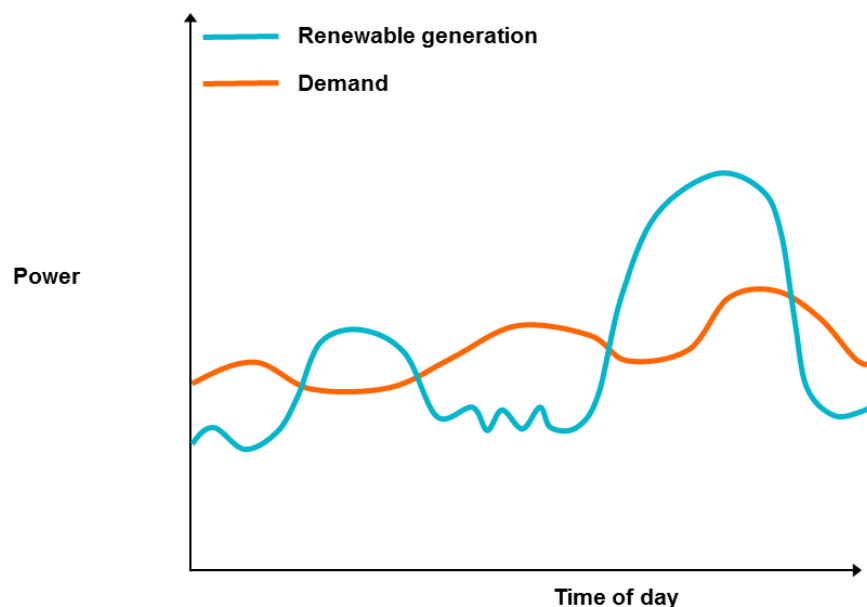


Figure 5.1 – An illustration of the possible variation between renewable generation and electricity demand in a day

The unpredictability of renewable generation can often limit how much of this energy is used in an energy system.

5.2.2 Curtailment

Curtailment is where operational or grid constraints force generators to accept less renewable energy than is available. This is a particular challenge in isolated grids, such as remote islands, where there is limited opportunity to export this energy to where it is needed.

Case study: Curtailment in Orkney

Experience in the Orkney Isles highlights that there is a sound economic argument for matching renewables and electric vehicles. In 2013, 103% of the local demand from the islands was generated from renewable sources, predominantly community owned on-shore wind turbines. Despite having the world's first active network management system, which controls the changing generation and demand loads to extend the amount of renewable energy that can be absorbed by the grid, Orkney's network is heavily constrained. It is estimated that there is approximately 5MW of renewable energy that cannot be absorbed at peak times. This requires that turbines have to be curtailed. As a result of this curtailment, the community estimated that around £3 million of revenue was lost.

5.3 Storage Capacity of Electric Vehicles

The ability to effectively store energy is a challenge to governments across the world. Indeed, the global industry for energy storage has been reported to be worth \$100bn over the next few years.⁶⁸

As more electric vehicles are adopted, and made available as a supplementary storage resource, the grid will benefit from a flexible storage capacity to absorb the intermittent loads from renewable generation. Examples of the storage capacity of different types of electric vehicle are shown in Table 5.1.

Table 5.1 – Examples of the storage capacity of electric vehicles

Vehicle	Battery storage capacity
GM Volt plug-in hybrid	16.5 kWh
Nissan LEAF pure electric vehicle	24 kWh
Tesla Model S pure electric vehicle	85 kWh
BYD pure electric bus	324 kWh

In principle the benefits of energy storage are obtained through the use of electric vehicles as a resource for V2X mechanisms (see Chapter 7), emergency supply, ancillary services (see Chapter 8) and dynamic sourcing and distribution of mixed energy sources.

⁶⁸ BBC News (2014), Energy Storage: The key to a smarter power grid: <http://bbc.in/1f6mMRQ>

The widespread proliferation of smart grids will help realise these applications, incorporating a variety of customers into the market including:

- Individual electric vehicle owners;
- Corporate customers such as fleet managers and employees using EV parking;
- Retail and semi-public customers such as carsharing and rental companies, hotels and restaurants, service stations and commercial car park operators;
- In the public sector: municipalities, utility providers and government facilities.

Patterns of vehicle use (and electricity consumption by EVs) are unlikely to correlate with renewable energy generation. Accordingly, optimised charging strategies will be required (see Section 4.5) to encourage drivers to recharge at times of high renewable production, but low overall demand.

Other methods of energy storage to help balance the grid include solid state and flow batteries, flywheels, compressed air energy storage, thermal and pumped hydro-power.⁶⁹

Case study: Demand response for EV charging in California, USA

California has committed to sourcing 33% of renewable electricity by 2020⁷⁰. A study in 2012 examined the potential of using demand response to manage intermittent renewable generation.⁷¹ Evaluation showed that with some changes, demand response could be used to increase the integration of wind and solar energy - preventing the ramping up or down of fossil fuelled combustion turbines that would otherwise be used to balance the variability of renewable resources.

The International Energy Agency explains that: “Governments can help accelerate the development and deployment of energy storage technologies by supporting targeted demonstration projects for promising storage technologies and by eliminating price distortions that prevent storage technologies from being compensated for the suite of services they provide.”⁷²

In 2015 Ofgem launched its Flexibility Project, recognising a need to take a more holistic approach to system flexibility and to develop a strategy that enables and enhances the efficient provision and use of flexible sources across Great Britain’s electricity system.⁷³ Energy storage constitutes one of these flexible sources. It was noted at the industry

⁶⁹ Energy Storage Association, Energy Storage Technologies: <http://bit.ly/1BGO1xk>

⁷⁰ Union of Concerned Scientists, California’s Commitment to Renewable Energy: <http://bit.ly/1NlzZme>

⁷¹ Perlstein, et al. (2012), Potential Role of Demand Response Resources in Maintaining Grid Stability and Integrating Variable Renewable Energy under California’s 33 Percent Renewable Portfolio Standard: <http://bit.ly/1BGNZpg>

⁷² International Energy Agency, Energy Storage Technology Roadmap: <http://bit.ly/OBitkQ>

⁷³ Ofgem (2015), Open letter: facilitating efficient use of flexibility source in the GB electricity system: <http://bit.ly/1SwWFpB>

roundtable for this study that more work should be done to consider how to enable change and to assess the legislative and regulatory barriers in this area.

Increasing energy storage in Scotland would greatly increase the efficiency of its energy system and could reduce the cost of payments made to wind farm operators, requested to power down when generation is inconvenient.⁷⁴

A study by the Jimmy Reid Foundation found that investment of approximately £1.5 billion could create a network of energy storage plants across the country.⁷⁴ These could be funded by using constraint payments paid to operators for shedding surplus energy, increasing the efficiency of infrastructure and investing money that would otherwise be used to manage peak time generation capacity. 4000-5000 jobs in manufacturing, assembly and operation stand to be created with potential for Scotland to take a global lead in this industry, exporting knowledge, skills and expertise.⁷⁴

Energy storage can also be installed at or near charging stations. This can reduce the amount of generation, transmission and distribution capacity used at peak times to charge vehicles, allowing off-peak energy to be utilised and reducing the overall cost of service.⁷⁵

The workshop discussions undertaken for this study highlighted the case of Germany which has used clean energy to meet 100% of total power demand on a number of occasions. It was noted that energy storage at this scale is becoming complicated from a business model perspective.

Moreover, it was discussed that grid service and frequency balancing is where immediate value is generated, whereas the benefits of storage take longer to accrue. It will help local distribution networks meet short-term peaks but community buy-in is required to succeed.

5.4 Links to Micro Renewables

The integration of electric vehicle storage into smaller energy systems also provides some potentially significant benefits. As well as the local storage potential, recharging with electricity from micro renewables will reduce the running costs of electric vehicles, creating a compelling incentive for owners to generate their own electricity and hence supporting government ambitions to encourage more homes and businesses to invest in

⁷⁴ The Jimmy Reid Foundation (2014), The Future of the Energy Storage industry in Scotland: <http://bit.ly/1HkJ4GF>

⁷⁵ Energy Storage Association, Electricity Storage and Plug-In Vehicles: <http://bit.ly/1NTnCgW>

micro renewables. The profiles of the individuals and businesses that are receptive to such technologies are likely to match those of early-adopters of electric vehicles.

Micro-generation is an important part of Scotland meeting its target for renewable electricity demand. This is recognised by a Scottish Government target of achieving 500 MW from community and locally owned renewable energy generation by 2020.⁷⁶ It has also committed to reducing its final energy consumption by 12% by 2020, a target which will benefit greatly from the energy efficiencies which micro-generation can allow.

Case study: InnoVentum Griaaffe 2.0 Hybrid Wind-Solar Power Station & Carport

Swedish company InnoVentum has created a hybrid power station capable of connecting to EVs and buildings to supply them with wind and solar energy. The Giraffe 2.0 is comprised of a wooden structure supporting 24 solar modules and a mounted wind turbine, with space for two EVs to park underneath. It is capable of generating 13,800 kWh/year even in countries with lower solar radiation.

Suitable for various applications and relatively quick and easy to install, the Giraffe 2.0 can connect to the grid in remote areas, function as a charging location for EVs, as a bus station or as an educational renewable energy installation. The company also offer an online monitoring platform that can be accessed on portable devices such as a smartphone or tablet. Here users have full control of power production, are able to compare changes and weather data over time to understand variations in performance.

In addition, under the Home Energy Scotland Renewables Loan Scheme, up to £10,000 is available for owner occupiers who want to install a domestic renewables system⁷⁷, providing an opportunity to incorporate an electric vehicle into a domestic energy supply chain. It may be appropriate to highlight this application more explicitly to encourage the use of funding in this way.

5.5 Second-Life Potential for Vehicle Batteries

Widespread uptake of electric vehicles will bring with it an increased production of batteries. Under normal operating conditions these batteries can be expected to last approximately 8-10 years.⁶² However, those no longer suitable for use in electric vehicles can retain up to 70% of their initial capacity, potentially operating for a further 10 years in a second-life application.⁷⁸ There are therefore still some valuable applications for which they can be used. There is a wide variety of potential energy storage applications, such as: a storage facility that connects a series of cells into a 'plant' to help integrate variable

⁷⁶ The Scottish Government (2012), Microgeneration Strategy for Scotland: <http://www.gov.scot/Publications/2012/06/9678>

⁷⁷ Energy Saving Trust: Home Energy Scotland Renewables Loan Scheme: <http://www.energysavingtrust.org.uk/scotland/grants-loans/renewables/loan-scheme>

⁷⁸ Renewable Energy World (2015), Battery Second Use Offsets EV Expenses, Improves Grid Stability: <http://bit.ly/1JQjkpy>

renewables and store electricity⁷⁹; reducing the need for new distribution and transmission investments; providing ancillary services (see Section 8.3); and shaving peak loads.

Case study: Second-life EV batteries in Osaka

On Yume-shima Island in Osaka, Japan, the Sumitomo Corporation is harnessing the potential of redeploying spent EV batteries by building the “world’s first large-scale power storage system utilising used batteries collected from electric vehicles.” This prototype 600kW/400kWh system includes 16 used lithium-ion EV batteries. Over a period of three years, the system will measure the smoothing effect of energy output fluctuation from the nearby “Hikari-no-mori” solar farm.

The project has been developed under a joint venture between Sumitomo and the Nissan Motor Company known as “4R Energy Corporation” to create new business models for used lithium-ion EV batteries. Nissan expects that the “glide path” for a normal LEAF’s battery degradation will be down to 70%-80% capacity after five years, with up to 70% of their capacity remaining after 10 years of service as a car battery. This would make these batteries ideally suited for grid energy storage.

Research suggests these applications are currently at a pre-commercial stage, with a number of energy companies across Europe engaged in R&D projects. Spanish energy company Endesa, for example, worked with the local authorities in Malaga to deploy a storage system for a 50kw fast-charging station. This was part of the European Commission funded Green eMotion project and encompasses the use of a second-life Renault EV 50 kW battery integrated into a fast-charging station. Capable of charging a vehicle to 80% in 15 minutes, the local government is using the station for the number 16 bus as part of Project Victoria, a separate wireless induction charging trial.⁸⁰

In the near term, creating applications for used batteries could help lower upfront costs of electric vehicles, as automakers, leasing companies and consumers factor in the resale value as part of a reduced purchase price. Preliminary studies indicate, for example, that a used 24 kilowatt hour Nissan LEAF battery could net the vehicle owner up to \$2,400 in resale value, while a Tesla Model S owner could sell the 85 kilowatt hour battery pack for up to \$8,500.⁸¹

The stakeholder workshops identified that developments in this area require incentives to support early research and to help bring products and services to the market.

⁷⁹ UCLA (2014), Reuse and Repower: How to Save Money and Clean the Grid with Second-Life Electric Vehicle Batteries: <http://bit.ly/1GNmRUH>

⁸⁰ Endesa (2015), Endesa gives electric car batteries a second life in charging points: <http://bit.ly/1K0z2Q5>

⁸¹ Renewable Energy World (2015), Battery Second Use Offsets EV Expenses, Improves Grid Stability: <http://bit.ly/1JQikpy>

6 Electrical Infrastructure

6.1 Introduction

This chapter outlines the links between electric vehicles and electrical infrastructure. This considers: wiring regulations; the different modes of electric vehicle charging; the provision of necessary electrical infrastructure in new developments; and the potential to open-up existing electrical outlets for use by electric vehicles.

6.2 Wiring Regulations and Charging Modes

The growth in markets for EVs will both demand and be supported by the provision of necessary wiring and electrical infrastructure for recharging in residential and commercial buildings.

A key requirement is to ensure that recharging is safe. Household appliances do not typically exceed 2 kilowatts, while an electric vehicle may charge at 3 or 7 kilowatts. Consumers therefore need to be made aware of the risks of handling such equipment to ensure responsible recharging through a domestic electrical system which complies with the UK national wiring regulations (BS 7671). This specifies that a dedicated circuit should be provided for the connection of electric vehicles⁸² similar to those required for other appliances such as power showers and electric cookers. Service conduits should also be fit for purpose and suitable for the load – accounting for carrying capacity, voltage drop and protection against overcurrent⁸³ and installation must be by a qualified professional.

Electric vehicle owners primarily have two options for charging at home and other buildings:

1. **Mode 2 charging** – using a non-dedicated circuit and socket outlet. This mode uses an adaptor lead to bridge the vehicle charging cable to a common household socket.
2. **Mode 3 charging** – a fixed and dedicated chargepoint installed in the home or building.

⁸² Institute of Engineering and Technology (2011), Observation codes used for periodic inspection and testing of electrical installations within the scope of BS7671:2008 (2011): <http://bit.ly/1SPOMZn>

⁸³ Institute of Engineering and Technology (2011), Appendix 4 of Amendment 1 of BS 7671:2008: <http://bit.ly/1RoEi5v>

Consumer advice on charging infrastructure

Consumers are currently exposed to varying advice when it comes to EV charging. For example, energy provider Npower does not recommend the use of a standard 13-amp socket,⁸⁴ and Nissan note that EVs must be charged on a dedicated circuit and meet all current regulations.⁸⁵ Similarly, the Energy Savings Trust refers to mode 3 charging as the best practice approach for workplace and home charging because it is safest and quickest, and refers to mode 2 charging as encompassing the use of a “*specialist cable, including a residual current device.*”⁸⁶

In contrast, the Scottish Government through its Greener Scotland campaign states that a 13-amp household socket can be used, but also advises the use of a dedicated circuit. Conversely OLEVs Go Ultra Low campaign cites the use of a 3-pin domestic socket as a “last resort”, not to be used as a regular chargepoint.⁸⁷

This suggests that there is scope for improving the clarity of messages on charging setups within homes and other buildings.

Table 6.1 outlines the pros and cons of different charging modes⁸⁸. In the mode 3 scenario the vehicle is connected to a 16A or 32A single phase AC supply with additional conductors incorporated into the charging cable to allow communication between the vehicle and charging equipment.⁸⁹ The communication functionality is particularly important because it works in accordance with the smart grid model. With the increase of smart metering equipment in households, mode 3 charging included within new developments will help future-proof these buildings within the smart grid context.⁸⁹

There is therefore an opportunity in these early stages of simultaneous grid enhancement and chargepoint installation to roll-out smart charging infrastructure that will complement the future energy system without the need for modification or retrofit in the future.

⁸⁴ Npower, Electric vehicle programme – FAQs: <http://www.npower.com/home/about-npower/terms-and-conditions/>

⁸⁵ Nissan, How to Charge Your Nissan Leaf: <http://bit.ly/1eVIfNL>

⁸⁶ Energy Saving Trust (2013), Learn how plug-in vehicles can work for you: <http://www.energysavingtrust.org.uk/sites/default/files/Plug%20In%20Vehicles.pdf>

⁸⁷ Go Ultra Low, How do I power? Equipment: <http://bit.ly/1qwWDxc>

⁸⁸ Mode 1 is not suitable for the charging of an electric vehicle because residual current device (RCD) protection is not guaranteed at all outlets and is necessary for a safe charging system.

⁸⁹ The IET (2012), Experts Highlight EV Charging Roadmap: <http://bit.ly/1MpyZg0>

Table 6.1 – The pros and cons of different modes of charging infrastructure⁹⁰

Charging mode	Pros	Cons
Mode 2 (Non-dedicated circuit and socket-outlet, cable-incorporated RCD)	<ul style="list-style-type: none"> • Low installation cost. • Interoperable across UK residential properties. • RCD protection guaranteed. 	<ul style="list-style-type: none"> • Slow charge (8-12 hours). • Susceptible to the misuse of extension leads and adaptors not capable of withstanding the current of an EV charge. • No communication or smart functionality.
Mode 3 (fixed and dedicated chargepoint)	<ul style="list-style-type: none"> • Fast Charge (1-4 hours) • Chargepoint to vehicle communication. • Smart charging functionality. • Control and protection functions permanently installed. • Load controller. • Suitable for domestic and public installations. 	<ul style="list-style-type: none"> • Additional cost of fixed installation. • Tethered cables provided by domestic installation will be specific to the owners' vehicle and inlet on the car side. • Private mode 3 chargers can only be installed in certain types of buildings. Off-street parking or a garage is required.
Mode 4 (rapid, dedicated chargepoint, DC connection)	<ul style="list-style-type: none"> • Rapid charge (20 mins approx.) • Control and protection functions permanently installed. • Chargepoint to vehicle communication 	<ul style="list-style-type: none"> • Unsuitable for domestic installations. • Higher installation costs. • Higher load on local electricity network.

A particular area of consideration is the provision of chargepoints in new builds and major redevelopments, which can offer significant savings compared to retrofitting. A number of local planning authorities around the world are implementing policies to encourage or mandate the installation of charging infrastructure in new developments.

Case study: EV ready buildings, Koto, Japan

Japan's Koto City, located on the waterfront of Tokyo Bay, recently set a policy of installing charging stations at 10% or more of parking spaces in newly constructed condominiums. Koto has placed significant emphasis on multi-unit dwellings, in which 80% of its population currently resides. Every year, approximately 70 new apartment blocks are constructed in Koto.

By installing charging stations at the time of construction, the city is able to make better provision for the changing needs of its citizens, significantly reduce costs, simplify the installation process, and avoid any future disruption to residents.

⁹⁰ BEAMA (2015), Guide to Electric Vehicle Infrastructure: <http://bit.ly/1IKel1j>

6.3 Open-Access Charging

Technologies and business models that open up access to existing electrical outlets for commercial charging could instantly create high-density public charging networks to support widespread operation of EVs.

However, standard electrical outlets cannot separately meter energy drawn by EVs or properly monetise individual charge events. There are various possible solutions to this, for example: individuals and businesses could charge a fee for providing access to electrical outlets; expenses could be reimbursed for the many fleet vehicles that will be recharged overnight at the employee's home; and costs could be apportioned for using shared outlets at condominiums and workplaces.

Such outlets will probably normally be limited to low-voltage charging and this will not replace all public charging needs. Nevertheless, mobile metering technologies built into vehicles or charging cables, with the supporting communications infrastructure, business models, and legal frameworks, could provide an effective means to increase the charging opportunities for electric vehicles.

Case study: Ubitricity

Berlin-based start-up Ubitricity has developed a solution that builds the intelligence of revenue-grade metering into the standard charging cable that comes with every electric vehicle. This provides access to Ubitricity "socket-systems," which are bolted onto the existing electrical outlets that are abundant throughout cities. The mobile meter attached to the charging cable tells the outlet to accept the charge and keeps track of how much electricity is used. This information is then sent back to Ubitricity via a cellular connection and passed on to the relevant utility.

Ubitricity has launched a number of pilot projects throughout Germany. In Berlin, the company is working with the Verband der Automobilindustrie (VDA) to install socket-systems in street lights throughout the city. In Frankfurt, Ubitricity has formed a partnership with Welcome Hotels, which will begin to offer the technology at all of their locations.

Going forward, Ubitricity sees great potential in workplace charging. According to Ubitricity, some 1 to 2% of the approximately 10 million street lights throughout Germany could immediately be refitted with charging spots (single phase AC), as their grid connection and position allow for charging day or night. The approximately 300,000 street lights that are exchanged or renewed per year present the next opportunity for cost-effective roll-out of charging infrastructure.

7 Vehicle-to-X Applications

7.1 Introduction

This chapter sets out the potential for electric vehicles to provide power to homes, buildings and to export electricity to the grid. The effects of these applications on energy markets are included in the discussion in Chapter 8.

7.2 Overview of Vehicle-to-X Applications

Vehicle-to-X applications are concerned with using stationary electric vehicles as an electrical sink that can be drawn on as required. Batteries in vehicles can be considered a valuable asset particularly when combined with renewable energy sources. As described in Chapter 5, effective energy storage provides the potential to mitigate instances of over and undersupply, with EVs providing energy for homes (V2H), buildings more widely (V2B) and for broader supply to the electric grid (V2G). These uses are described in the sections below, and are summarised in Table 7.1.

Bi-directional charging is a guiding principle behind vehicle-to-X applications, as it allows charge and discharge between vehicles and buildings. The ability to use the battery of an electric vehicle as a power supply could help grid operators balance demand and supply fluctuations and offset peak building loads to reduce the energy bills of households and businesses that are charged according to tariffs based on maximum usage. Advanced metering infrastructure and associated software allow energy flows to be managed through automated monitoring and decision-making.

Today, research into the activity of European energy providers suggests commercial vehicle-to-X applications are still in their infancy, with the majority of energy providers assessed primarily engaged in research and development. The future opportunities for energy providers are however significant.

Table 7.1 - Summary of vehicle-to-X applications outlining their limitations and example projects⁹⁰

Details	Vehicle-to-Home (V2H)	Vehicle-to-Building (V2B)	Vehicle-to-Grid (V2G)
Characteristics	<ul style="list-style-type: none"> Operates at a home level. Comprised typically of one electric vehicle. Reduced electricity bills. Access to emergency power. Easy to implement. Source of energy in isolated houses. Interaction with larger systems. Integration of distributed energy resources (DER). 	<ul style="list-style-type: none"> Operates at building level. Suited towards small vehicle fleets. Improves local DER integration. Reduced electricity bills. Source of backup power. Easier demand prediction in terms of vehicle fleets. Less investment required. 	<ul style="list-style-type: none"> Large scale regional operation. Potential to supply ancillary services. Reactive power support. Potential to improve grid reliability. An aggregator may be used for effective implementation. Should consider the development of new business models. Requires electricity market participations. Offers large scale renewable energy integration.
Limitations	<ul style="list-style-type: none"> Not suited to residential blocks, only for single family homes. 	<ul style="list-style-type: none"> User willingness required. Complex operation Poor market integration. 	<ul style="list-style-type: none"> Complex operation. Complex prediction of vehicle demand. Large number of vehicles involved. Communication infrastructure required. User willingness required. Lack of regulation framework. Further industry guidance needed.
Example Projects	<ul style="list-style-type: none"> Toyota V2H Power System⁹¹ Nissan LEAF to Home⁹² Honda Smart Home⁹³ 	<ul style="list-style-type: none"> Nissan LEAF to Building⁹⁴ 	<ul style="list-style-type: none"> Amsterdam, Nieuw-West (Smart city project)⁹⁵ US Air Force, Los Angeles⁹⁶ University of Delaware V2G School Bus⁹⁷ The Nikola Research Project⁹⁸

⁹¹ Toyota, Toyota Develops V2H Power System: <http://www2.toyota.co.jp/en/news/12/06/0604.html>

⁹² Nissan, Vehicle to Home Electricity Supply System: <http://bit.ly/1BGOBeI>

⁹³ Honda, Honda Smart Home US: <http://www.hondasmarthome.com/>

⁹⁴ Renault Nissan (2013), Nissan LEAFs can now power the office, as well as the home: <http://bit.ly/1e7MtBD>

⁹⁵ Amsterdam Smart City (2014), Pilot Vehicle2Grid starts in Amsterdam Nieuw-West: <http://bit.ly/1BGOIXf>

⁹⁶ Berkeley Lab (2013) Los Angeles Air Force Base Vehicle to Grid Pilot Project: <http://1.usa.gov/1CykDo9>

⁹⁷ Urban Foresight (2014), EV City Casebook: http://urbanforesight.org/wp-content/uploads/2015/07/urbanforesight_ev_casebook.pdf

⁹⁸ Nikola, The Nikola Research Project: <http://bit.ly/1eLMkoj>

7.3 Vehicle-to-Home

The principle of V2H applications is to use the EV as an energy source by charging and discharging it as needed. Doing so affords residents emergency power in the event of power outages or simply to provide electricity for homes on a daily basis. The average energy consumption for a UK household in 2013 was 11.5kWh per day.⁹⁹ The capacity of a Nissan LEAF's lithium-ion battery is 24kWh¹⁰⁰, therefore it offers significant potential to provide power for entire homes.

V2H offers the potential to exploit micro-generation of renewable energy. This is particularly salient in locations such as the Orkney Islands where the high prevalence of micro-generated wind resource makes it an ideal candidate for considering V2H applications. By using EVs in this way users can charge their vehicles when renewable supply is highest (peak shaving) and discharge them to their home when supply is low (valley filling). Better managing generation in this way can help address issues of curtailment and ultimately generate revenue for residents living in areas of high micro-generation.

Case study: LEAF to Home, Kitakyushu, Japan

In July 2012, the city of Kitakyushu announced a partnership with Nissan Motor Company, of Japan, to develop and commercialise an EV power supply system called "LEAF to Home." The vehicle to home (V2H) system pulls electricity from the LEAF's rapid charging connector via a PCS (Power Control System) that is connected to the household's distribution board. The system has enough output to allow all household electronics to function at once and provides a stable supply of electricity at peak times of the day where household electricity usage is known to increase. The battery can be recharged at night, when electricity demand and pricing is much lower, or during the day, with linked rooftop solar panels. There are over 225 households and 50 workplaces involved in the Kitakyushu Smart Community Project to date. Together the partners and residents of the community are showcasing the potential for smart energy management and electric vehicle integration.

The "LEAF to Home" programme is part of a larger initiative called the Smart Community Project, in which Kitakyushu is developing an energy management system that can adjust electricity demand and supply according to real-time signals from grid operators. It is within this framework that V2H technology can play an even larger role in balancing fluctuations on the grid, filling in gaps in renewable energy variability, and providing an overall resiliency benefit to the electricity system.

In Japan bi-directional charging equipment has accounted for some 5% of the Nissan Leaf's sales since August 2012¹⁰¹. Increased uptake coincided with the aftermath of blackouts and power outages caused by the devastating earthquake and tsunami in 2011. This resilience strategy highlights the importance of considering localised factors when implementing measures.

⁹⁹ Department of Energy & Climate Change (2014), Energy Consumption in the UK: <http://bit.ly/1CK3IAk>

¹⁰⁰ Nissan (2015), Nissan Leaf Specification: <http://bit.ly/1eLLBnc>

¹⁰¹ Nissan, Zero Emission Mobility, Roadmap for RES Integration, 2014

7.4 Vehicle-to-Building

V2B applications build on the V2H principles, using EVs in communal buildings such as offices, schools, universities and leisure centres. V2B utilises the regular and predictable operation of fleets at these buildings to better manage and store power from distributed energy resources such as wind and solar. In addition, power can be sourced from this store as a means of backup generation in the case of an emergency.

Such a setup is implemented through what is known as the Building Energy Management System (BEMS) that centrally controls the charging of vehicles through optimisation algorithms¹⁰² to save energy through peak power reduction, save money for organisations and prevent service interruptions. The regular patterns of employees working hours and the operation of their vehicles is what offers this application significant potential. Limitations to consider are the conflicting use of EVs as transport and storage and the time for meaningful transfer of charge to take place.

Nissan has successfully been using V2B technology in its Advanced Technology Center in Atsugi, Japan since July 2013. It allows up to six of their LEAFs to connect to a building's power distribution board. Power is sourced from the cars when peak demand is highest (and most expensive) and the vehicles are charged when demand is lower, ensuring they are fully charged at the end of the day for the employee commute. A reduction of 25.6 kW in peak summer periods of energy use has been observed with no impact on driving patterns – an annual saving of nearly ¥500,000 (ca. £2,800)⁹⁴.

7.5 Vehicle-to-Grid

The cumulative impact of 'vehicle-to-X' applications is the regional connectivity between EVs and the electrical grid. V2G in principle is concerned with using stationary electric vehicles as an electrical sink that can be drawn on when required by the wider electric grid.

Global sales of electric vehicles are estimated to have been 462,000 in 2015¹⁰³ and pilots testing vehicle-grid integration are on the increase¹⁰⁴ suggesting a prominent role for electric vehicles in the electricity market. An aggressive scenario predicts up to 4.2 GW of power could be provided worldwide to grids from electric vehicles by 2024.¹⁰⁵ Moreover, a

¹⁰² García-Villalobos, J. et al. (2015), Delivering Energy from PEV Batteries: V2G, V2B and V2H approaches.

¹⁰³ Bloomberg New Energy Finance (2016), Electric vehicles to be 35% of global new car sales by 2040: <http://bit.ly/1Q3mLgh>

¹⁰⁴ Navigant Research (2015), Vehicle-grid Integration Services Revenue is Expected to Reach Nearly \$21 Million by 2024: <http://bit.ly/1GiYI4B>

¹⁰⁵ Navigant Research (2015), Vehicle Grid Integration: <http://bit.ly/1GiYI4B>

recent report by Navigant Research suggests that revenue generated from Vehicle-grid integration services is expected to reach nearly US \$21 million by 2024, growing from US \$335,000 in 2015.

Specifically, there is potential for EVs to provide ancillary services such as frequency response and spinning reserve, to maintain stability and reliability during surges of supply and demand¹⁰⁶ (see Section 8.3). The efficiency and fast response time of batteries coupled with their potentially wide distribution through a network make EVs an attractive option for providing grid support.¹⁰⁶

Implementation can occur centrally through an aggregator body (see Section 8.4) that manages the charge and discharge of vehicles within its remit – purchasing electricity from EV users and providing ancillary services to the Distribution Network Operator (DNO). Alternatively, a decentralized model can be used with individual control algorithms for each EV overseen by the owner – this application would rely on the use of pricing signals to influence charging behaviour.¹⁰⁷

Research has found that battery size has a limited effect on revenue generated in contrast to the power of the charger, ergo the availability of power not energy can be considered important to a V2G operator's market participation.¹⁰⁷

Discussion at the stakeholder workshops for this study noted that the greatest value of V2G applications may be around frequency response rather than the arbitrage component. Frequency response synchronises generation assets for electrical grid operation by holding the alternating current frequency within a specific measurement. It is fulfilled through the ramping up/down of generation assets.¹⁰⁸ These elements exist now, however the mechanisms to derive value from them do not without the asset base being monetised. To fully realise V2G, market structures and regulatory frameworks need to adapt to facilitate the demonstration and commercial deployment of smart grids and V2G technologies.¹⁰⁹

¹⁰⁶ Perlstein B. et al (2015), Potential Role of Demand Response in Maintaining Grid Stability and Integrating Variable Renewable Energy under California's 33 Percent Renewable Portfolio Standard: <http://bit.ly/1HjJx21>

¹⁰⁷ Harris, C.B. and Webber, M.E. 'The sensitivity of vehicle-to-grid revenues to plug-in electric vehicle battery size and EVSE power rating': PES General Meeting, 2014

¹⁰⁸ Energy Storage Association, Frequency Regulation: <http://bit.ly/1MhVbL1>

¹⁰⁹ International Transport Forum (2012), Smart Grids and EVs: Made for Each Other?

8 Energy Markets

8.1 Introduction

This chapter outlines the links between electric vehicles and wider energy markets. This includes community generation, balancing services, aggregator models, product bundling, and innovative financial mechanisms used by energy service companies.

8.2 Grid Defection

Distributed electricity generation, especially solar photovoltaics, is rapidly spreading across Scotland and getting much cheaper¹¹⁰. Distributed electricity storage is doing the same, thanks largely to mass production of batteries for electric vehicles. The convergence of these two technologies creates a situation where connection to the grid becomes optional for some customers, without compromising reliability and increasingly at prices cheaper than utility retail electricity¹¹¹.

This is essentially a “utility in a box” model, with a self-sustaining, stand-alone power system that is managed in isolation and disconnected from the national grid. The premise is that energy generated within a community, be that a street, suburb or even entire cities, can be self-sustaining without the need to receive energy transmission from other locations.

Energy generated in this way is expected to increase.¹¹² In particular new collaborative consumption business models that allow shared access to assets, property, resources, time, skills and services through online platforms services are transforming traditional economic practices.¹¹³ It will therefore be increasingly important to understand the role of electric vehicles within this ecosystem, and how this potential may create new opportunities to encourage widespread uptake.

8.3 Balancing Services

Grid operators use balancing or ancillary services to maintain stability and reliability in the face of dips and surges in the balance of electricity supply and demand. There are a

¹¹⁰ DECC (2011), Microgeneration Strategy: <http://bit.ly/1GNo1iS>

¹¹¹ Rocky Mountain Institute (2014) The economics of grid defection: When and where distributed solar generation plus storage competes with traditional utility service

¹¹² DECC (2014), Community Energy Strategy: Full Report: <http://bit.ly/1bsg9kT>

¹¹³ DBIS (2014), Unlocking the Sharing Economy: <http://bit.ly/1By7cEn>

range of ancillary service products that reflect the varying timescales over which this response is required, including frequency response, spinning reserve, regulation and load following/ramping.¹¹⁴

Due to the specific and critical needs addressed by ancillary services, their value tends to be significantly higher than equivalent amounts of energy supplied as capacity. Payments for ancillary services include payments for availability and for delivery.

Electric vehicles as grid storage resources are potentially well-suited to ancillary services that require fast response times and are of short duration. These requirements are a good match for EV storage technology characteristics.

Participation in ancillary services markets would likely take place via an energy aggregator (see section 8.4) to enable multiple vehicles to be pooled and traded into the market.

In the last five years the UK Government has been pursuing a programme of Electricity Market Reform, which has now seen the introduction of a Capacity Market, an EU first. Its purpose is to ensure security of electricity supply by providing payments for reliable sources of capacity, supporting the development of more active demand management and encouraging investment to replace older power plants and provide backup for intermittent and inflexible low carbon generation sources.¹¹⁵

Furthermore, generation returns have historically been focused on wholesale energy, but this is set to expand to encompass three sources of generation: energy market, capacity market and ancillary services, with the latter playing an increasingly important role over the next few years with the closure of gas-fired power plants.

8.4 Aggregated Electricity Models

A decentralised energy economy as seen in the UK and more widely across the EU has led to a liberalised and price receptive energy market. The proliferation of small energy enterprises in this market could lead to a scenario where these distributed energy resources are amalgamated into one entity, to be drawn upon as a whole. This is known as electrical aggregation, where an aggregator agent takes responsibility for these resources to sell into the electricity market. The aggregator acts as a middleman between

¹¹⁴ Energy Storage Association, Grid Operations Benefits: <http://bit.ly/1GHnFY2>

¹¹⁵ UK Government (2015), Electricity Market Reform: Capacity Market 2015: <http://bit.ly/1SkutRH>

the distribution network operator who it can provide ancillary services for, and the individual generators.¹¹⁶

It is clear to see where the managed charging and discharging of EVs could fit in this picture. DNOs may use aggregators as a source of generation or load control with EV users communicating their driving needs and the aggregator managing this accordingly. An aggregator agent could take various forms and work under different business models, such as the following examples:

- A **fleet aggregator** of EV power for V2G services could be a fleet manager with one location of vehicles connected to a single network point.
- An **electricity retailer** aggregator is a model whereby the agent has individual business partnerships with a dispersed group of EVs whose power is sold through the market. Here the aggregator has no control over how the vehicles are used but may use financial incentives to influence charging behaviour.¹¹⁷
- An **independent company** such as a car services provider, battery manufacturer or mobile phone network may provide their services in exchange for the profit generated from providing V2G transmission. A battery manufacturer for example may provide a replacement battery in exchange for some or all of the profits generated.
- A **package deal** aggregator would see the agent acquire the EV battery and the owner constrained to charging the vehicle at specific agreed times. In exchange they receive a preferential rate, maintenance and discount rates for charging and parking in their EV.¹¹⁸

For generators who would normally have excess energy curtailed, the introduction of an aggregator agent to exploit their EV capacity offers the opportunity to create extra revenue.

¹¹⁶ Bessa J.R, and Matos A. M (2010), The Role of an Aggregator Agent for EV in the Electricity Market. 7th Mediterranean Conference and Exhibition on Power Generation, 2010

¹¹⁷ Kempton, W. and Tomic, J. (2004), V2G Power Implementation: <http://bit.ly/1RKVWvC>

¹¹⁸ Guille, C. and Cross, G. (2009), A Conceptual Framework for V2G Implementation: <http://bit.ly/1JiHKI3>

Case study: Independent electricity producers, Netherlands

A start-up company in the Netherlands is encouraging consumers to buy electricity directly from independent producers. Vandebron has created an online market place for 100% renewable energy under a collaborative consumption model that omits utility companies completely.¹¹⁹

As part of this sharing economy users have the flexibility to choose their energy source, be that wind, solar, hydro or bio-energy, all of which is generated within the Netherlands. Producers set their own price for their electricity whilst Vandebron act as an intermediary and receive a monthly subscription fee of 10 euros. As the fee is fixed, whether households consume more is not important in terms of profits. In fact, the less consumption that occurs from one source, the further the supply can be spread out amongst several users.

A deregulated Dutch energy market sees production and transmission facilities separated into different entities meaning any company is able to produce and sell power.

8.5 Bundled Energy Products and Services

Bundled service offerings provide a way to make electric vehicles more cost competitive, an appealing lifestyle choice, and part of a personal energy or mobility management programme. Packaging multiple products and services into a single offering can provide scale efficiencies that allow suppliers to deliver them at lower cost than they would be on their own. This approach provides a way to better serve and expand existing customer bases, while offering enhanced or differentiated products at a lower cost.

Such convenient and cost effective packaging of multiple products could introduce electric vehicles to new customer segments in both the private and commercial fleet markets, enhancing the benefits and ease of switching to EVs.

The roll-out of such initiatives will rely on a mix of players in the industry creating new value propositions for customers and subsequently introducing new products or service packages to the market. A number of vehicle manufacturers and energy companies around the world have already formed alliances to capitalise on the potential of combined products related to electric vehicles.

¹¹⁹ Vandebron, How does it work?: <https://vandebron.nl/>

Case study: SnuggHome

In Boulder, Colorado, U.S.A, SnuggHome, a residential energy efficiency company, is working with banks to develop a product that combines the financial advantages of an electric vehicle with cost savings that can be achieved with home energy services.

According to the company, a typical Boulder household will spend, on average, a total of \$800 per month for home electricity, natural gas, as well as vehicle fuel costs and loan payments. SnuggHome found that a bank could match or undercut those costs with a combination of an electric vehicle, a home energy efficiency retrofit, and a rooftop solar system.

SnuggHome's model provides a means to combine the financial benefits of these technologies and services, creating a financial package that rolls all technologies and services into one loan. "The loan is paid off in less than five years. And after those five years, customers never have to pay for petrol for their car or electricity for their house, as long as they live there," says SnuggHome CEO, Adam Stenftenagel. "And over the next five years, they'll save over \$16,000 on energy costs. This is a real business model with a real value proposition to drivers and homeowners."

Although their position in the value chain for e-mobility services is still unfolding, energy companies in particular are likely to have an important role. Installing chargepoints in homes and workplaces will provide them with an opportunity to exploit and potentially grow their customer base by bundling products or services. In Scotland, electric vehicles could be integrated into the already strong presence of micro-generation and community energy products. Furthermore, although current policy from DECC has seen the Feed-In-Tariffs for renewable energy generation scheme paused, should it resume, integration with EVs could enhance this further.

In addition, a directive of the European Parliament which the UK Government is legally subject to states an obligation to, "Ensure that consumers have the right to contract electricity simultaneously with several suppliers so that electricity supply for an electric vehicle can be contracted separately."¹²⁰ This provides another incentive to energy companies to bundle their products to offer attractive 'all-inclusive' packages to consumers. The cost and practical considerations of this arrangement, such as the introduction of a second Meter Point Reference, are not yet clear. Insight from the industry roundtable suggests DNOs will need to interact with the Government to address any issues that may arise.

¹²⁰ European Parliament (2013), Proposal for a directive of the European Parliament and of the council on the deployment of alternative fuels infrastructure: <http://bit.ly/23IGR6u>

8.6 Energy Service Companies

The Energy Service Company (ESCO) model has been successfully applied in renewables and energy efficiency markets and has been one of the main contributors to the rapid growth in these sectors. The approach may therefore offer similar potential to support the uptake of electric vehicles.

ESCOs use an innovative financing model, known as 'energy performance contracting' to implement projects and deliver energy efficiency, or renewable energy generation. The income from the cost savings, or the renewable energy produced, is then used to repay the costs of the project and the initial investment. The ESCO provides the capital, expertise and manpower to implement the project (all of which are often cited as barriers to such initiatives) and takes on the risk as it does not receive its payment unless the project delivers energy savings as expected.

Upfront capital, expertise and necessary manpower to implement projects are also key barriers to many fleet operators from investing in electric vehicles. It would therefore seem that the ESCO approach offers a potential means to encourage uptake in electric vehicles in the same way that it has supported growth in the renewables sector.

Case study: ESCO models for fleets

In the City of Indianapolis, Indiana, Mayor Greg Ballard has instituted an ambitious mandate to move the entire municipal fleet off oil by 2020. In the period 2014-16, the city will deploy over 425 EVs in its fleet, making it the largest U.S. fleet electrification effort to date. Leading this initiative is a start-up called Vision Fleet Capital, which both optimises fleets for electrification and provides vehicles through innovative financing structures.

Vision Fleet's model borrows from the structure of energy performance contracts (EPC), power purchase agreements (PPAs), and other similar models. This contracting approach is supporting the deployment of EVs across six city departments: Department of Water and Power, Code Enforcement, Police, Fire, Probation, and the Coroner's office. Through a low-risk, total-cost-of-ownership model, the company guarantees savings to the city and captures additional shared savings when operational performance measures are exceeded.

9 Conclusions and Recommendations

Increasing uptake of electric vehicles and developing a secure, sustainable and affordable electricity grid are complementary objectives. This report shows that there are many interdependencies between electric vehicles and the energy sector. The widespread adoption of electric vehicles will therefore have both positive and negative impacts on energy systems. Furthermore, energy policy and business models from the energy sector could offer the potential to accelerate the uptake of EVs. A proactive and integrated consideration of the areas identified in this report could therefore yield significant benefits in both sectors.

Key findings from this review are summarised in the following sections, along with recommendations for action.

9.1 Policy Landscape

Scotland has committed to a largely decarbonised electricity supply by 2030 that is affordable to consumers whilst achieving economic benefit and advantage for the country. This will require addressing the often competing policy objectives of maintaining energy security, whilst keeping carbon emissions low and ensuring accessible and affordable energy across the population. Furthermore, whilst Scotland remains set to have a strong renewable sector, research⁵ suggests that the overall energy security of the UK is likely to decrease in the coming years.

Increasing uptake of electric vehicles has the potential to reduce carbon emissions however their carbon intensity has to be considered within the wider context of Scotland's generation sources. Greater reductions in carbon emissions will be achieved as the energy sector uses cleaner energy sources.

The national roll out of smart meters will make monitoring of energy consumption clearer for the consumer, enabling people to better manage their energy use.

Community energy is a growing area of generation and is considered important in creating genuinely carbon free energy systems. The community action behind such schemes, and the business models utilised, often align with the motivators and opportunities for the integration of electric vehicles, for example in related community transport schemes.

The Scottish Government's commitment to develop an integrated energy strategy - including heat, power and transport - represents an important opportunity to align these areas of policy. Given the clear interdependencies between transport and energy it is

recommended that Transport Scotland and Scottish Government Energy continue to work closely to develop and implement this strategy in a way that provides benefits to energy systems and accelerates widespread adoption of EVs.

9.2 Electricity Distribution Systems and Smart Grids

Electric vehicles are an important component of a smart grid system with the potential to capture renewable energy and balance energy demand and supply. Bi-directional charging of electric vehicles, smart metering, and real-time monitoring and control of transmission, distribution and end-user consumer assets will in combination provide for more effective management of energy assets and resources.

While there is widespread agreement on the potential offered by EVs in smart grids, realising this potential and the attendant benefits will require engagement with actors across the energy, automotive and ICT sectors. It will also ultimately require the participation of consumers.

It is therefore recommended that the cross industry dialogue initiated to inform this study is sustained to support collaboration between the different actors with a role in realising the potential of electric vehicles in smart grids.

9.3 Demand Management

Scotland is expected to cope with increases in total electricity demand from future uptake of electric vehicles.⁵² However, there may be capacity constraints when considering the electricity network at the local level. This is because users typically plug in their vehicles at set times of the day, causing spikes in electrical demand which could pose a risk to some networks if no changes are implemented. Cooperation between DNOs, energy retailers, Scottish Government and other players in the industry will be required to effectively manage this.

Centrally managed demand response strategies are being developed to address the cluster effect where multiple electric vehicles charging in a community can place a strain on local distribution grids. Reliability and price based demand response programmes may offer an opportunity to incorporate increasing amounts of renewable energy generation into the grid.

Data gathering and analytical intelligence to forecast and control any increased demand from electric vehicle charging could reduce the need for additional expansion and reinforcement of local distribution grids. This will improve both visibility and control on

networks. An industry-wide safeguarding process to prevent localised issues would be beneficial.

Developing a charging point connection policy could also allow DNOs to maintain greater visibility and control over networks.

To achieve this, it is recommended that a dialogue on grid constraint should be established between individuals working in both the distribution and transmission networks to anticipate and deal with any potential issues resulting from the charging of electric vehicles.

9.4 Energy Storage and Supporting High Renewable Grids

As more electric vehicles are adopted and made available, these will offer storage capacity to absorb intermittent loads from renewable generation. However, this will require controlled charging of electric vehicles to ensure consumption matches available generation.

Increasing energy storage is expected to increase the efficiency of Scotland's energy system. This could realise benefits such as reducing the cost of payments made to wind farm operators who are requested to shut down when excess generation cannot be absorbed. Using electric vehicles at locations that have localised energy generation could result in a reduction of transmission and distribution capacity used on-peak to charge vehicles.

The incorporation of electric vehicles into the energy system as a storage asset could help integrate more micro-generation and increase energy efficiency by reducing energy use by consumers. Scotland's prominent position in the UK's renewable sector could see it take the lead on incentivising local energy and community projects.

Second-life applications of vehicle batteries can be beneficial in a wide variety of energy storage applications, including reducing the need for new distribution and transmission investments, providing ancillary services, and shaving peak loads. Research suggests such applications are currently at a pre-commercial stage with a number of energy companies across Europe engaged in R&D projects.

It is recommended that Transport Scotland and the Scottish Government engage with industry and academia to explore how policies to promote the uptake of electric vehicles could help Scotland take a leading position in the development of new technologies and business models for energy storage. This should also explore how legislation, procurement planning, training and investment can accelerate these developments in line with the expected increase in electric vehicles.

9.5 Electrical Infrastructure

Widespread adoption of EVs requires necessary electrical wiring and infrastructure in homes and buildings across Scotland.

Electric vehicle owners primarily have two options for charging - mode 2 and mode 3. Mode 2 charging, which consists of using a non-dedicated circuit and socket outlet, is not always considered safe. However, it was reported in this study that consumers are exposed to a number of different messages on charging, which may need to be clarified.

The British Electrotechnical and Allied Manufacturers Association (BEAMA) has identified that mode 3 charging – using a fixed and dedicated socket-outlet – is the preferred long term solution. Of particular importance is the communication functionality as this corresponds to the smart grid model. The increase of smart metering equipment in households and mode 3 charging included within new developments will help future-proof these buildings.

There is the potential for technologies and business models that open up access to existing electrical outlets for commercial charging to instantly create high-density public charging networks to support widespread operation of EVs.

It is recommended that the Scottish Government continues to explore how planning and building regulations can be used to encourage the inclusion of charging infrastructure in new developments.

9.6 Vehicle-to-X Applications

Bi-directional charging is a guiding principle behind vehicle-to-X applications, allowing charge and discharge between vehicles, buildings and the grid. Advanced metering infrastructure and associated software allow energy flows to be managed through automated monitoring and decision-making.

Vehicle to Home applications can use the EV as an energy store and support micro-generation technologies. Better managing generation in this way can help address issues of curtailment and ultimately generate revenue for residents.

Building on this, Vehicle to Building capabilities in communal buildings such as offices, schools universities and leisure centres can utilise the regular and predictable operation of fleets to better manage and store power from distributed energy resources such as wind and solar.

It is recommended that Transport Scotland and the Scottish Government engage with industry and academia to explore the opportunities offered by vehicle-to-X applications and how this might influence charging behaviours and impact on wider energy systems.

9.7 Energy Markets

The increasing availability of low cost energy storage, largely as a result of mass production of EVs, combined with the increase in distributed energy generation, creates a situation where connection to the electric grid becomes optional for some customers, without compromising reliability and increasingly at prices cheaper than utility retail electricity. The impact and role of EVs in supporting the development of a “utility-in-a-box” model should be further investigated, as this could make EVs even more financially attractive and enable individuals and communities to independently manage their own energy resources.

Electric vehicles as a grid storage resource are potentially well-suited to ancillary services that require fast response times and are of short duration. The UK Government’s recent Electricity Market Reform is likely to see ancillary services playing an increasingly important role over the next few years. Continued investigation and implementation of mechanisms such as time-of-use tariffs and storage for arbitrage will support the creation of frameworks for these services to be provided.

Participation in ancillary services markets would likely take place via an energy aggregator. This sees the proliferation of small energy enterprises into one entity to be drawn on as a whole. The aggregator acts as a middleman between the distribution network operator who it can provide ancillary services for, and the individual generators. DNOs may use aggregators as a source of generation or load control.

Investments in network infrastructure can be more reactive than proactive. Although forecasting can provide DNOs with some insight, uncertainty around when, where and how much to invest in networks remains. Consumer behaviour will therefore ultimately drive the market and there may not be substantial change until there are significant numbers of EVs creating a tangible demand.

Energy companies are likely to play a significant role in e-mobility services, with alliances formed between other industry players such as vehicle manufacturers. This may lead to the bundling of energy products with mobility services, making electric vehicles more attractive and cost effective.

Another important area of alignment is consumer behaviour change. There is considerable potential to align initiatives related to energy consumption and transport to promote the uptake of EVs and more general energy-awareness.

Bringing all of these various strands together, it is recommended that Transport Scotland and the Scottish Government work with relevant partners to review important developments in energy technologies and business models. This should consider the impact of these developments on the prospects for EV adoption and how increasing numbers of electric vehicles might stimulate further investments in this area.

10 Appendix

The participants of the Scottish Government public-private stakeholder workshop on electric vehicles and energy systems held on 24 April 2015 are listed below:

Name	Organisations
Martin Hale	ABB
Laurence Chittock	Aston University
Benny Talbot	Community Energy Scotland
Bob Murphy	Edinburgh College
Iain Macleod	Energy Saving Trust
Senan McGrath	ESB eCars
Matthew Lumsden	Future Transport Systems
James McKenzie	Scottish Government's Electricity Division
Nigel Holmes	Scottish Hydrogen and Fuel Cell Association
Sandra Purdie	Scottish Power
Michael Rieley	Scottish Renewables
Ewan Swaffield	Transport Scotland
Laurence Kenney	Transport Scotland
Zak Tuck	Transport Scotland
Craig Morton	University of Aberdeen
David Beeton	Urban Foresight
Mia McMillan	Urban Foresight
Adam Suleiman	Urban Foresight

The participants at the second stakeholder workshop held on 18 January 2016 are listed below:

Name	Organisation
Zak Tuck	Transport Scotland
Damon Hewlett	Scottish Government
Heather Stewart	Scottish Government
Laurence Kenney	Transport Scotland

Hannah Smith	Scottish Renewables
Nina Ballantyne	Scottish Government
Emilio Tejedor Esobar	Scottish Power
Adam Suleiman	Urban Foresight
Senan McGrath	ESB/Eurelectric
Angus McRae	SSE
James Veaney	Ofgem
Michael Lambert	SSE
Neil Watson	Scottish Power Energy Networks
Gerard Boyd	Scottish Power
Frank Clifton	SSE
Melissa McKerrow	Energy UK
David Beeton	Urban Foresight

The Core, Science Central, Bath Lane,
Newcastle upon Tyne, NE4 5TF, United Kingdom

Registered in England & Wales No. 07705420
VAT No. 179 2207 93

E: info@urbanforesight.org
T: +44 191 495 7350
W: <http://urbanforesight.org>

© Urban Foresight Limited, 2016. All rights reserved.

