URBAN FORESIGHT

REVIEW OF OPPORTUNITIES
ORKNEY'S ELECTRIC FUTURE

PREPARED FOR

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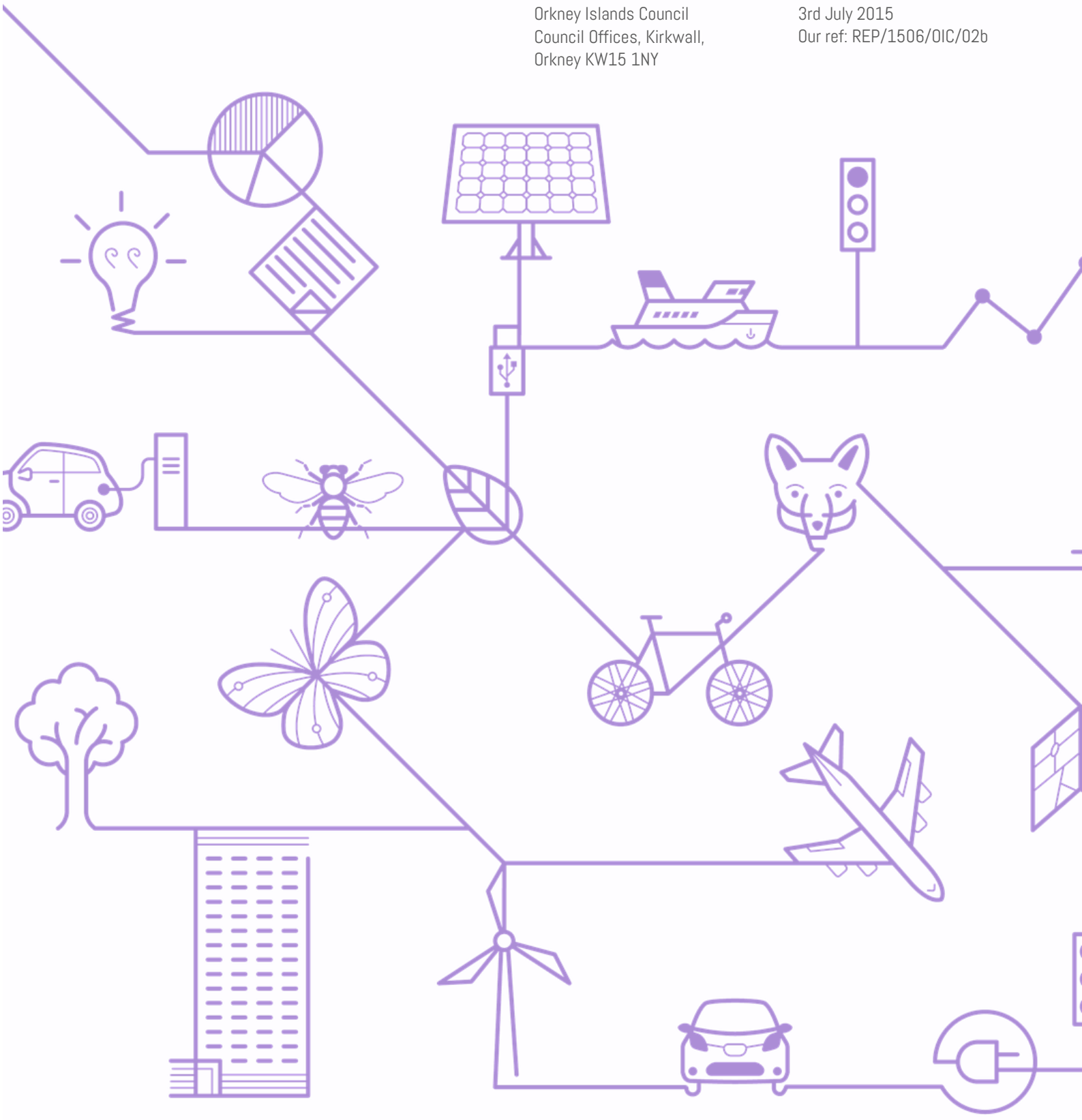

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Executive Summary

Orkney's Electric Future (OEF) is an ambitious project that integrates Orkney Islands Council's stated ambition to promote the uptake of electric vehicles (EVs) and more sustainable transport options with opportunities offered by Orkney's high renewable energy generation and wider benefits related to tourism.

This report explores the opportunities for Orkney to establish a lighthouse project to achieve this ambition and to integrate smart electric mobility and energy management initiatives in the Islands.

The first section of the report builds on the findings of the feasibility study and provides an analysis of Orkney's core strengths and available opportunities as gathered from consultations with key stakeholders.

Based on this analysis, it is found that Orkney is well positioned to become a test bed for new technologies, products, and services related to EVs and energy management. This is evidenced from Orkney's history of innovation and existing assets which range from: a community of local experts and engaged organisations involved in innovation and development of energy technologies; the high penetration of renewable energy generation in the Islands; to the UK's first Active Network Management System.

To capitalise on these identified strengths and opportunities, the OEF lighthouse project is broken down into four separate but complementary building blocks, namely: infrastructure and incentives, energy storage, energy management marketplace, and tourism and investment.

The report then presents a range of options and activities based on these building blocks, with case studies of best practices and exemplar business models from across Scotland and overseas. It is established that there are a number of locally-administered assets and powers that can be used to encourage EV adoption in Orkney, which include measures related to infrastructure provision, planning, car clubs, taxis and private hire vehicles, and education and promotion activities.

There are also a number of different storage technologies, such as power-to-power (P2P) storage and 'vehicle-to-x' applications, which could be developed and piloted in Orkney to absorb excess generation capacity. The report also reviews the elements required to create a marketplace for the intelligent management of energy, which include the development of business models and frameworks.

The final section of the report then establishes that there is potential to maximise the economic opportunities afforded by developments in EVs and energy systems in Orkney, particularly in the area of tourism. Car rentals, the use of intelligent transport systems for sightseeing, and green branding are identified as options Orkney could possibly explore.

This culminates in an outline design for the OEF lighthouse project. This highlights the potential for Orkney to become a 'Living Laboratory', providing a real-world test

bed for the identified range of new technologies, products, services and business models.

A separate implementation plan builds on this report and provides a detailed design of work packages, delivery structures, budgets and funding opportunities to establish a large scale lighthouse project in Orkney and to ensure a positive legacy from these investments.

Contents

Executive Summary **1**

1 Introduction **5**

1.1 Overview 5

1.2 Orkney's Electric Future 6

1.3 Methodology 6

1.4 Structure of the Report 7

2 Outline Design **8**

2.1 Introduction 8

2.2 SWOT Analysis 8

2.3 Building Blocks 9

2.4 Living Laboratory 10

3 Infrastructure and Incentives **12**

3.1 Introduction 12

3.2 Infrastructure Provision 12

3.3 Planning Measures 13

3.4 Integration with Public Transport 14

3.5 Car Clubs 15

3.6 Taxis and Private Hire Vehicles 17

3.7 Education and Promotion 18

4 Energy Storage **20**

4.1 Introduction 20

4.2 Benefits of Energy Storage for Orkney 21

4.3 Storage Capacity of Electric Vehicles 21

4.4 Second-Life Potential for Vehicle Batteries 22

4.5 Bi-directional Charging and 'Vehicle-to' Applications 23

4.6 Other Energy Storage Options 29

5 Energy Management Marketplace **33**

5.1 Introduction 33
5.2 Managed Charging 34
5.3 Pricing Signals 35
5.4 Microgrids and Grid Defection 36
5.5 Balancing Services 37
5.6 Aggregator Models 38
5.7 Bundled Energy Products and Services 40
6 Tourism and Inward Investment 41
6.1 Introduction 41
6.2 Car Rental 42
6.3 EV Sightseeing with Intelligent Transport Systems 43
6.4 Green Branding 44
7 Conclusion 45
Appendix 47
1. SWOT Analysis 47

1 Introduction

1.1 Overview

This report reviews opportunities for an ambitious project known as Orkney's Electric Future (OEF). This proposed project integrates Orkney Islands Council's stated ambition to promote the uptake of electric vehicles and more sustainable transport options with opportunities offered by Orkney's high-renewable energy generation and wider benefits related to tourism.

A separate feasibility study and implementation plan have been developed as part of this project:

- The feasibility study reviews the potential of the OEF lighthouse project. Different scenarios for EV uptake and the corresponding recharging infrastructure are also discussed;
- The implementation plan provides a detailed design of work packages, delivery structures, budgets and funding opportunities to establish a large scale lighthouse project in Orkney and ensure a positive legacy from these investments.

The figure below shows the structure of the three reports prepared for this project.

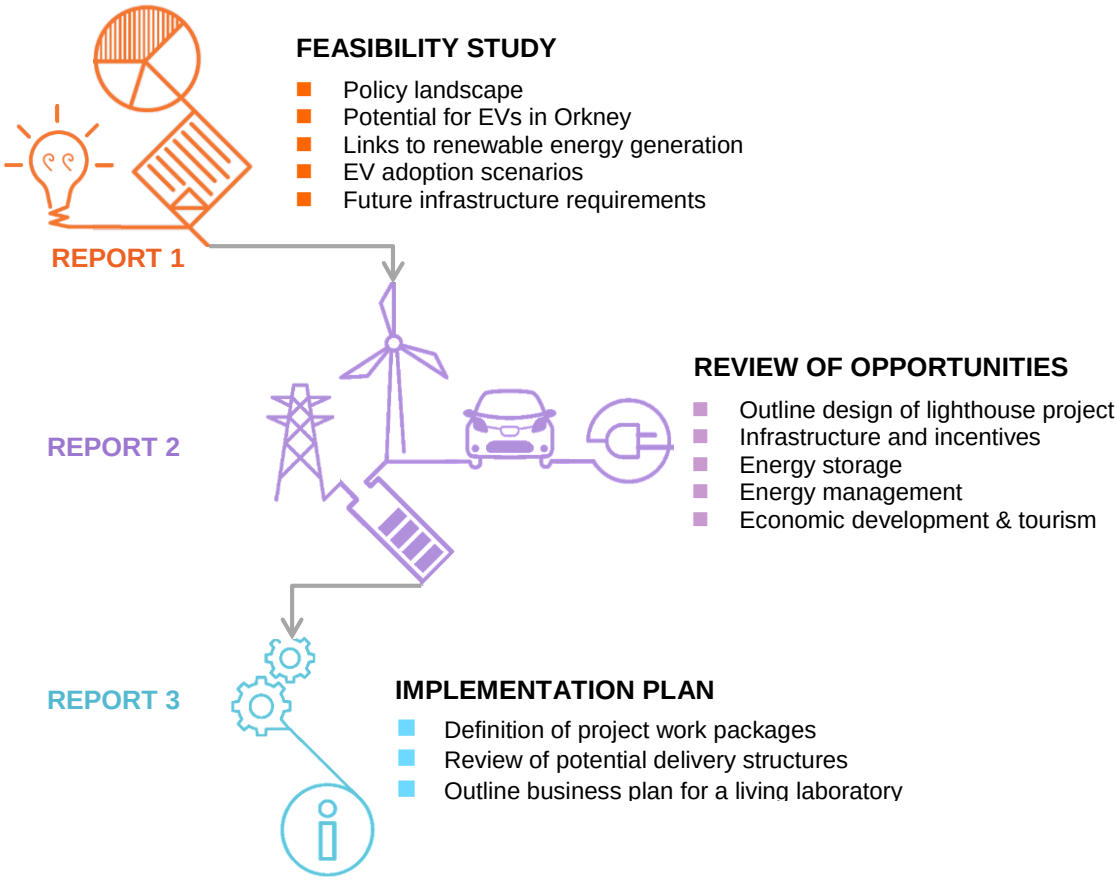

Figure 1.1 - Structure of the reports prepared for the OEF project

These reports have been prepared for Orkney Islands Council and are funded by the Edinburgh Centre for Carbon Innovation (ECCI) Smart Accelerator Sustainable Islands Project.

1.2 Orkney's Electric Future

Orkney Islands Council has stated that the key outcome and vision of the OEF project is to achieve a sustainable future for transport in Orkney. It is envisaged that this could be achieved by establishing a 'lighthouse' project in the Islands.

More specific objectives stated by Orkney Islands Council and the key stakeholders consulted for this project are to:

1. Establish and promote a good practice low carbon transport option for the residents of, and visitors to, the Orkney Islands;

2. Study the feasibility of various options to support increased uptake of electric vehicles (EVs) on the Islands, including the concept of electric hire cars with driver information systems to be positioned at Orkney's main gateways and where energy is curtailed;

3. Determine how surplus energy produced locally can be used to power transport.

1.3 Methodology

This report is informed by the following key activities:

- A comprehensive desk study
- Interviews with key stakeholders (see Appendix A.1 of the feasibility study)
- A public forum held on 9th March 2015 in Kirkwall to present initial findings of both the desk study and the interviews and discuss potential challenges and opportunities
- A smaller, facilitated expert roundtable workshop on 10th March 2015 in Kirkwall which engaged key public, private and third sector stakeholders (see Appendix A.3 of the feasibility study) to help shape the design and scale of the lighthouse project.

1.4 Structure of the Report

The chapters of this report and the areas they cover are detailed in Table 1.1.

Table 1.1 - Structure of the report

CHAPTER	DESCRIPTION
Chapter 1	Presents the outline of the report.
Chapter 2	Presents the outline design for the OEF lighthouse project. It establishes four building blocks to delineate different activities and opportunities and describes how a Living Laboratory approach could be adopted.
Chapter 3	Outlines measures related to the first building block of the OEF lighthouse project: infrastructure and incentives.
Chapter 4	Explores the second building block which covers energy storage and reviews different storage technologies.
Chapter 5	Presents the third building block of the project which is concerned with the technologies, business models and frameworks required to create a marketplace for intelligent management of energy.
Chapter 6	Explores the final building block which deals with how Orkney can maximise the economic opportunities afforded by developments in electric vehicles and energy systems.
Chapter 7	Summary and conclusions.

2 Outline Design

2.1 Introduction

This chapter establishes an outline scope for the OEF lighthouse project. It commences with an analysis of the key strengths, opportunities, weaknesses, and threats facing Orkney. To address these challenges and capitalise on these strengths and opportunities, four building blocks are proposed to structure a review of potential activities within the OEF project. It is also proposed that a Living Laboratory approach is adopted, which is also explained in this chapter.

2.2 SWOT Analysis

In order to assess Orkney's openness to wider EV adoption, key stakeholders were consulted through interviews and a roundtable workshop. One of the key outputs of the workshop is the identification of opportunities and challenges of increasing EV uptake and positioning Orkney as a test bed for sustainable and intelligent transport. A synthesis of these strengths, weaknesses, opportunities and threats is discussed in detail in the appendix and is summarised in the table below.

Table 2.1 - SWOT analysis of Orkney

STRENGTHS	WEAKNESSES
■ Established renewables industry and expertise in research, development, demonstration and deployment ■ Home to UK's first Active Network Management System. ■ High rate of community and privately owned wind turbines, 10% of all wind turbines in the UK. ■ OIC's commitment to sustainable energy, improving efficiency, and reducing CO2 and fossil fuel dependence; compact geography, with short distances between locations, make Orkney well suited to EVs. ■ High level of EV ownership per capita compared to rest of Scotland (early market potential) and an active EV community ■ Third highest level of gross disposable income in Scotland ■ High community involvement ■ Active development trusts ■ Historic visitor attractions	■ Grid is at capacity ■ Independent projects and proposals originating in Orkney but driven by different stakeholders (sometimes competing for the same funding sources) ■ Car culture is an integral part of Orkney's identity – any perceived threat or change to this ease of movement could be a barrier. ■ Current lack of charging infrastructure for long distance journeys

OPPORTUNITIES	THREATS
■ Reducing lost revenue from curtailment ■ High fuel costs ■ High number of tourists per year – potential market for EV use. ■ New business opportunities in the EV and energy services space are available ■ People react positively when they experience riding or driving an EV ■ Car dealers and hire cars in Orkney ■ Isolated self-contained location ideal for a living laboratory, test bed for innovation ■ Potential to further establish Orkney's innovation and green credentials to attract further inward investment and tourism	■ Perceived high cost of EVs ■ Public's general aversion to change ■ Sensitivities about prioritisation of energy storage than heating ■ Seasonal trade in tourism resulting to low levels of activity in certain times of the year ■ Limited access to funding ■ Time-limited opportunities: Orkney's high renewable grid and active network management system expected to be less rare

2.3 Building Blocks

In order to capitalise on these identified core strengths and opportunities, the various elements of the OEF lighthouse project can be broken down into four separate building blocks to provide a structured approach that responds to the stated objectives of the project. As shown in Table 2.2, each of these building blocks addresses a specific challenge and requires different actions. Similarly, each area requires different expertise and skillsets, presenting options for specialisation and investment.

Table 2.2 - Proposed building blocks for the Orkney's Electric Future lighthouse project

BUILDING BLOCK	CHALLENGE	DESCRIPTION
Infrastructure and incentives	Increasing the number of electric vehicles in Orkney	The various measures that can be taken to encourage adoption of EVs in Orkney to achieve a critical mass of vehicles that meets the various objectives of the project
Energy storage	Increasing the energy storage capacity in Orkney	Maximising the energy storage potential across Orkney, in particular the new capacity offered by increasing numbers of electric vehicles
Energy management marketplace	Matching increasing storage capacity with renewable energy generation	Technologies and business models to aggregate and integrate available storage capacity and respond to changes in local generation and demand
Tourism and investment	Attracting inward investment and new economic opportunities	Maximising the economic opportunities related to these developments, with a particular focus on tourism and inward investment

The various measures and examples of good practice that could be adopted in Orkney to establish a lighthouse project based on these building blocks are outlined in the next four chapters. Prior to this, the Living Laboratory approach is explained to show how Orkney could establish itself as a test site for a range of new products and business models.

2.4 Living Laboratory

A Living Laboratory comprises two main ideas:

- Involving users in the creation and development of new products and services;
- Experimenting in real world settings as opposed to actual laboratories or simulations.

Living Laboratories typically employ a collaborative 'open-innovation' approach known as 'co-creation'. This usually combines insights from public and private sector partners, along with end-users, to create, validate, and test new services, business ideas, markets and technologies in real-life-contexts. In general, this typically comprises the following key elements:

- **Co-Creation**: co-design by users and producers.
- **Exploration**: discovering emerging usages, behaviours and market opportunities.
- **Experimentation**: implementing live scenarios within communities of users.
- **Evaluation**: assessment of concepts, products and services according to socio-ergonomic, socio-cognitive and socio-economic criteria.

As shown in section 2.3, the analysis of Orkney's strengths, opportunities, challenges and enablers based on insights gathered from stakeholder consultations, shows that Orkney possesses the essential characteristics and elements that could create a conducive environment for incubating pioneering ideas and projects. This makes Orkney an ideal location to establish a Living Laboratory that could deliver the overarching goals of the OEF lighthouse project.

Adopting the living laboratory approach would require that the OEF lighthouse project provides the necessary support and infrastructure to develop, test and validate products and business models in the islands. This entails the three main activities shown in Table 2.3.

Table 2.3 - Three main activities of living labs[1]

IDEATION PHASE	Scout high-potential ideas, concepts, and teams from research in university and business. The phase is completed with the commitment of a development project that brings together an executing team, the financial resources, and necessary sponsors at the match-making moment.
CO-CREATION PHASE	Where the living lab combines product/service development, user validation, and market positioning to prepare adoption of the solution, and entrepreneurship for the creation of a new venture. The living lab contributes coordination of the concurrently executed processes. The phase is completed with a financing deal in which innovation investors take over parts (or the whole) to further grow the venture and its product or service.
VENTURING PHASE	Follows standard investment processes after a project graduates from the living lab and is taken over by business angels or institutional venture capitalists. It is only in this phase that the created value becomes tangible and therefore living labs need to consider it, even though they might no longer be involved.

Living labs usually offer further support processes to underpin the activities in Table 2.3. This is often referred to as "innovation infrastructure" and includes collaborative IT infrastructures, quality management, and fundraising and grant management processes. As shown in Figure 2.1 these are mainly targeted towards the earlier ideation and co-creation phases.

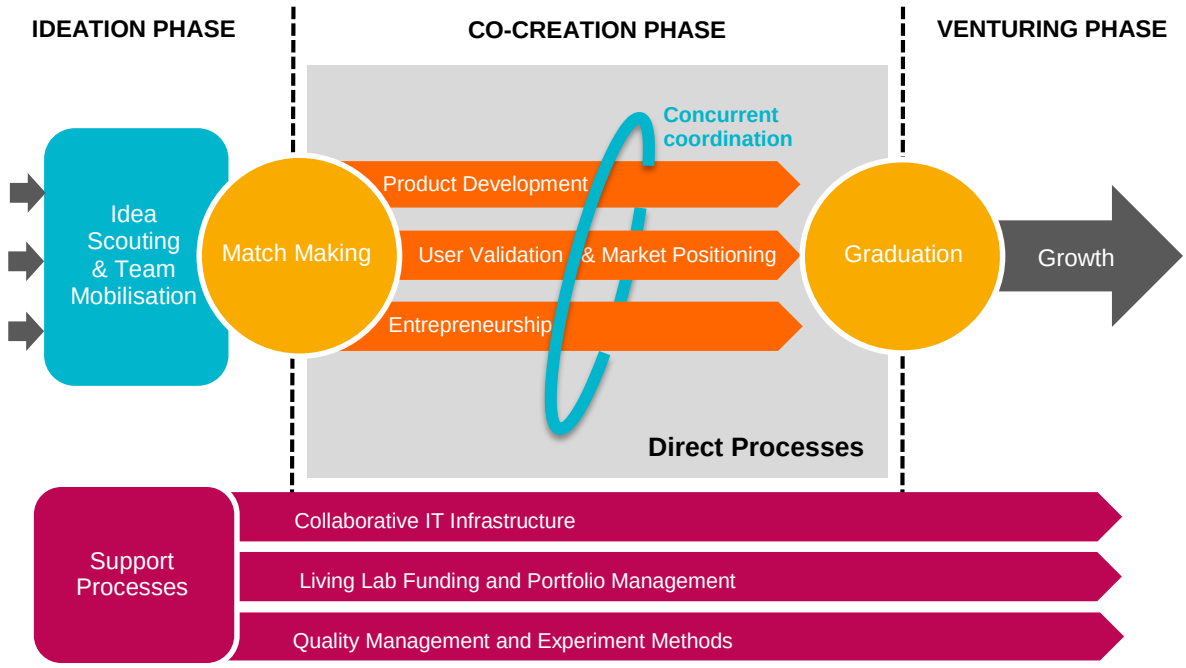

Figure 2.1 - Living lab model[1]

[1] Katzy, B., Designing Viable Business Models for Living Labs, Technology Innovation Management Review, 2012.

3 Infrastructure and Incentives

3.1 Introduction

This chapter outlines measures related to the first building block of the OEF lighthouse project: infrastructure and incentives. This provides Orkney Islands Council with a suite of options to encourage EV adoption in the islands.

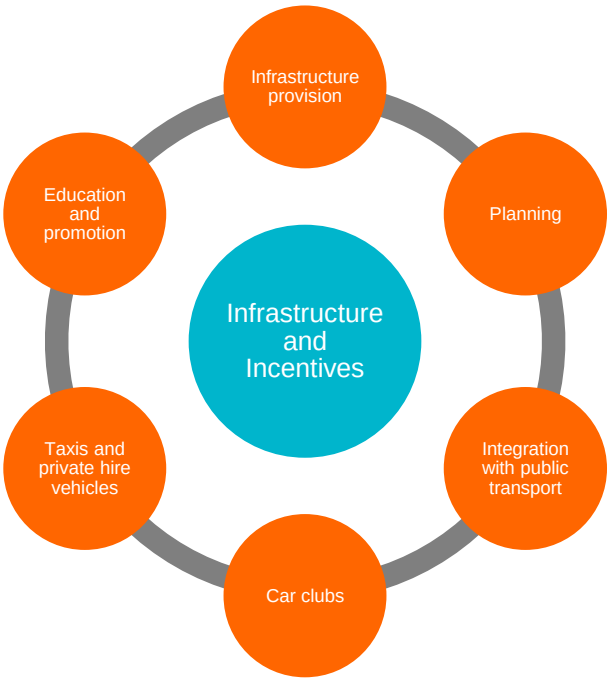

Figure 3.1 - Types of measures to promote adoption of electric vehicles considered in this chapter

3.2 Infrastructure Provision

The provision of recharging infrastructure is a key focus for many local authorities in the promotion of electric vehicles. The general availability and ease of access to this infrastructure can greatly influence the convenience and confidence associated with using an EV. This not only includes public infrastructure, but also the ability to recharge at work and at home. This can remove the need to regularly make a special journey or detour to refuel, ultimately making EVs more convenient to use than fossil fuelled vehicles.

The table below highlights some of the measures that can promote the installation of electric vehicle charging infrastructure as well as providing access to these charge points.

Table 3.1 – Infrastructure-related measures to promote EV adoption

MEASURE	DETAILS
Discounted electricity for recharging	Electric vehicle drivers have access to recharging at reduced cost/free for a limited period of time to encourage EV uptake
Access to recharging infrastructure	Council provide means for local residents to charge EVs as they enter the market
Grants/ loans	Council provides information on available government grants or loans to individuals and businesses wishing to install charge points

3.3 Planning Measures

Local planning controls and building regulations can be used to encourage increased adoption of electric vehicles. For example, using planning frameworks to make provisions for recharging infrastructure in new builds and major redevelopments can offer significant savings compared to retrofitting.

The table below outlines other possible measures in this area.

Table 3.2 – Planning measures to promote EV adoption

MEASURE	DETAILS
Specifications/ ordinances in development frameworks	Specify a minimum requirement for provision of EV spaces (and associated infrastructure) in new developments
EV specifications in building codes	Specify the need for EV vehicle readiness in new and renovated buildings
Permitted development rights for charging infrastructure	Electric vehicle charge point installation designated as a permitted development right
Infrastructure installation in rental properties	Makes a term in a lease, contract, security instrument, or similar, void and unenforceable if it prohibits or unreasonably restricts the installation of electric vehicle charging in a lessee's designated parking space.
Developer contributions	Planning obligations (section 106/ section 75), community infrastructure levy, highway contributions
Local Development Orders securing land for infrastructure	Using Local Development Orders to secure land for infrastructure

CASE STUDY: GREENWICH PENINSULA LOW EMISSION ZONE

The Royal Borough of Greenwich was the first local authority in the country to declare a Low Emission Zone (LEZ). The Greenwich Peninsula Low Emission Zone was established in 2004 as part of the long term regeneration of the Peninsula – one of the largest regeneration sites in Europe. Planning approval for the LEZ was authorized by the Royal Borough of Greenwich via the section 106 agreement for the site.

The zone was established as part of a strategy to prohibit the most polluting vehicles, whilst promoting use of the cleanest vehicles. The low emission strategy sets a minimum Euro standard for the majority of commercial vehicles entering the designated zone.

For residential vehicles other methods such as parking controls, car clubs and information provision are being used to ensure that the tailpipe CO_2 emissions are as low as possible.

Image credit: Royal Borough of Greenwich

3.4 Integration with Public Transport

Electric vehicles can be promoted as part of a more integrated transport network. For example, providing a convenient transfer from one island to another using ferry and EVs. This can be achieved by providing access to parking and infrastructure for EVs alongside public transport and at key transport hubs. This can make it more convenient and practical for many people to use public transport, as well as providing a targeted way to reduce emissions.

The table below shows measures that promote EV uptake related to building an integrated electric transport network.

Table 3.3 – Integrated transport measures related to promotion of EV adoption

MEASURE	DETAILS
Discounted and integrated travel	One integrated payment card for parking, park and ride, vehicle refueling/charging, car sharing, car hire and public transport
Discounted parking and recharging fee at carparks	Low emission vehicles permitted to park and recharge at carparks for free or at a reduced cost
Discounted car ferry tariff	Low emission vehicles permitted to travel for free/at reduced cost on car ferries
Travel plans	Supporting businesses in developing and implementing travel plans that make provision for EVs
Electrification of buses and ferries	Supporting bus and ferry operators to transition to an electric fleet through subsidies

CASE STUDY: EUROPE'S CLEANEST BUS FLEET

Schiermonnikoog in the Netherlands is a 10 mile long island located just off the Dutch mainland with only 1,000 permanent residents. Annually, the island hosts up to 350,000 visitors. Therefore the recent contract awarded to China based BYD to supply six long-range, all-electric BYD buses has answered issues relating to environment- and tourist-friendly modes of public transport. The island has also secured a 15 year maintenance contract from the bus manufacturer.[2]

The fleet has now been acknowledged as Europe's 'cleanest bus fleet' with buses capable of covering over 180 miles of range on a single charge and holding up to 70 passengers the island's bus service is now almost fully-electric in addition to boosting Friesland to be a leader of green transportation.

The goal of the electric bus project is to aid the overall aim for the island to be fully independent of fossil fuels. It has been recognised that over a third of carbon emissions in the region are a direct result of traffic and transportation. Therefore, by electrifying public transportation the province adopts more and more renewable sources of energy, ultimately benefiting air quality and local authority costs in terms of less fossil fuel imports and not having to fill up the buses.

Image credit: Spoorjan

3.5 Car Clubs

Local authorities often play an important role in the establishment car clubs and are also well placed to encourage car club operators to invest in electric vehicles. This can help to increase the number of EVs on the road, while reducing the total number of vehicles in a community. It can also provide greater visibility for electric vehicles, building confidence in new technologies and encouraging greater uptake.

Table 3.4 – Measures related to promotion of EVs in car clubs

MEASURE	DETAILS
Dedicated parking bays for low emission vehicle-based car sharing	Electric vehicle-based car club schemes allocated dedicated parking spaces
Electric vehicle-based car clubs	Development of car clubs whereby the fleet is made up entirely of low emission vehicles

[2] Autoblog.com, BYD sells six electric buses to Netherlands, 2012.

CASE STUDY: ISLAND OF TERSCHELLING, THE NETHERLANDS

The Dutch island of Terschelling has launched what is claimed to be the world's largest island based EV car sharing scheme with 65 Nissan LEAFs.[3] The scheme is operated by Schylge-E-Auto in collaboration with Friesland and Terschelling District Council as part the broader remit or an ongoing sustainability programme based in the Wadden Sea region.

Terschelling has been the ideal context for mass roll out of EVs due to the limited range of landmass: the island measures only 15km in length with a land area of 88 square kilometers. However there are 2,000 passenger cars registered on Terschelling which average around 30 hours per year on the road.

The car share scheme will give priority to the island's 4,800 residents and is expected to cover around 110,000 kilometres per year, ultimately serving 10% of the total mileage travelled on the island in one year. Through converting these miles to EV, the scheme is expected to save up to 15% on fuel consumption.

Residents are able to access available cars using a smartphone app and membership card charged at €0.19 per minute (€11.40 per hour) excluding VAT. Visitors are also able to access the cars but must rent them through a local ferry operator. Infrastructure around the island has been updated, with a network of charging points being installed to accommodate the current fleet and future ambitions to expand the fleet to 100 vehicles.

Image credit: EV Fleet World

[3] EV Fleet World, World's largest island based EV sharing scheme, 2014.

3.6 Taxis and Private Hire Vehicles

The taxi fleet in any given local area contributes significantly to the total vehicle miles travelled, with many short journeys concentrated in a small area. As such, incentivising owners of taxis and private hire vehicles to switch to EVs offers significant financial and environmental benefits. Making the switch to an electric taxi fleet can also serve as demonstrators to expose members of the public to the performance and financial benefits of EVs.

Table 3.5 – Measures related to promotion of EVs as private hire vehicles

MEASURE	DETAILS
Reduced fees for taxi and private hire licenses	Taxi & private hire firms pay less for licensing electric vehicles
Flexible licensing caps	The cap on Hackney carriage licenses given to a particular company could be removed/altered for electric vehicles
Minimum percentage thresholds	A requirement for a particular amount of electric vehicles in any given fleet
Dedicated low emission vehicle taxi ranks	Taxi ranks in certain area could be set aside for electric vehicle use only
Rebates and other incentives	Financial incentives to encourage purchase of electric taxis

CASE STUDY: DUNDEE'S ELECTRIC TAXIS

May 2015 saw the official launch of the UK's largest electric taxi fleet.[4] Supported through collaboration with Transport Scotland, the Energy Saving Trust, Dundee City Council and Nissan, the 35 Nissan LEAFs and 15 wheelchair accessible eNV200 electric vehicles are operated by taxi firm 203020 Electric which is part of the Tele Taxis Group.

The switch to EV technology will allow 203020 Electric and its drivers to make considerable savings on fuel and running costs. It has also helped the company secure new service contracts with environmentally aware organisations such as NHS Tayside.

A bank of five rapid chargers has been installed at the taxi company's headquarters to keep the new fleet in use round the clock. These chargers are also available for public use and are currently offered for free.

Image credit: Urban Foresight

[4] ECCI, Launch of Dundee's first and largest electric taxi fleet, 2015.

CASE STUDY: TAXIS IN YORK

Activities to promote low carbon taxis in York are integrated – licensing, financial and access incentives are on offer to encourage owners to opt for cleaner vehicles.

Since 2013, taxi owners in York have had access to half price taxi licensing, and the City of York Council is also offering drivers £3,000 towards the cost of a low emission vehicle – hybrid or electric – that emits 100gCO2/km or less. To be eligible, drivers must be registered to work in York. But taking efforts a step further, York is also home to the UK's first ever 'green' taxi rank, which is reserved solely for hybrid vehicles.

The efforts undertaken by the Council to date have largely been driven by the need to reduce air pollution. And working in partnership with Vantage Motor Group dealership in York, the city is delivering the first consolidated low emission taxi scheme.

The measures have enabled over 30 hybrid taxis to be incorporated into the fleet in York, including Hackney and Private Hires. The city's Streamline Taxis is also the first fully electric vehicle fleet in the city.

Image credit: City of York Council

3.7 Education and Promotion

Local authorities have an important role in building confidence and awareness in electric vehicle technologies. This requires engagement with individuals, organisations and key influencers in the public and private sector.

Table 3.6 - Measures related to education and promotion

MEASURE	DETAILS
Educational and promotional activities	Awareness campaigns to promote the benefits of electric vehicles
Advisory services	Providing tools and information on the use of electric vehicles
'One-stop shop'/promotion office	A single physical location to access more information, advice, guidance, permits and access cards for infrastructure (e.g. Kirkwall Travel Centre)
Information exchange	Measures to share/access information internally and externally to a local authority

CASE STUDY: ROTTERDAM

Rotterdam has established an Electric Vehicle Centre, which offers companies, and individuals the opportunity to test drive a range of vehicles and experience electro-mobility away from the pressure of a car show room. The centre also offers information about grants, charging, insurance and leasing.

Image credit: Rotterdam, www.zeroauto.nl

CASE STUDY: EV PROMOTION BY LOCAL AUTHORITIES IN SCOTLAND

The **Scottish Borders Council** has held a series of electric vehicle roadshows inviting members of the public and local business to speak to council staff and vehicle manufacturers, as well as test drive a selection of electric vehicles. The scheme is run in partnership with the Energy Saving Trust, and the Commercial Services department of the Council has jurisdiction over this area.

Fife Council is working in partnership with local organisations on an outreach programme that demonstrates the link between renewables as a source of energy and transport through school workshops. By engaging children with the technology, including electric vehicles, they can spread the word on the benefits to parents and family. Thirty thousand school children have been through the workshops and feedback has been positive.

Image credit: Scottish Borders Council

4 Energy Storage

4.1 Introduction

Batteries in vehicles can be considered a valuable asset, particularly when combined with renewable energy sources. Effective energy storage provides the potential to mitigate instances of over- and undersupply by implementing EV strategies concerned with providing energy for homes (V2H), for buildings (V2B), and for broader supply to the electric grid (V2G). These applications, along with energy storage technologies, will be explored in this chapter.

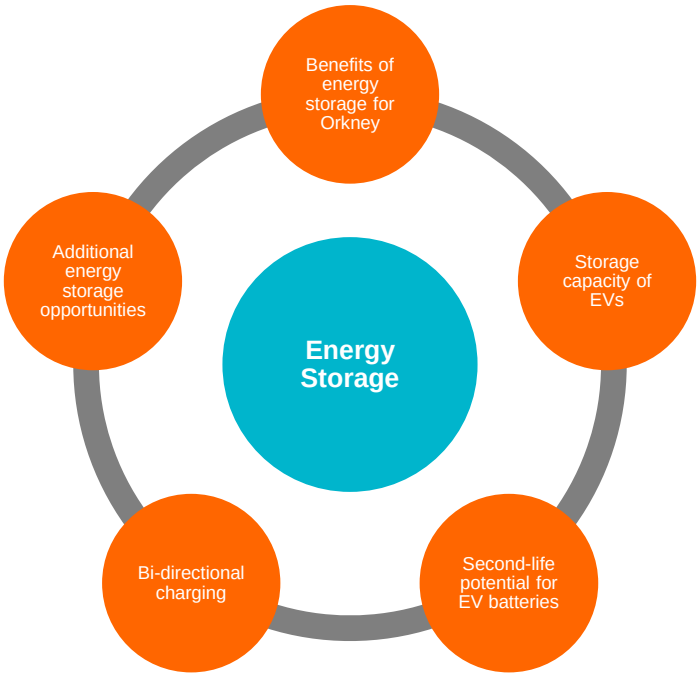

Figure 4.1 – Potential areas of development/ specialisation related to energy storage

4.2 Benefits of Energy Storage for Orkney

The ability to effectively store energy is a challenge to governments and communities across the world. Indeed, the global industry for energy storage has been reported to be worth $100bn over the next few years.[5] This suggests that there is considerable potential to commercialise solutions and expertise developed to meet the challenges that Orkney faces today. As discussed in chapter 4, Orkney has produced more energy than the current demand, leading to grid curtailment and annual losses amounting to millions.

Energy storage supports load-levelling or load management, distributed generation (DG) for peak shaving, power quality (PQ) and end-use reliability. Most importantly, electricity storage technologies can optimise the existing generation and transmission infrastructures while also preventing expensive upgrades. Electricity storage devices can also manage the power fluctuations from renewable resources and thus aid the use of several renewable technologies and their large-scale penetration into the network.[6]

As well as the local storage potential, the profiles of the individuals and businesses that are receptive to such technologies are likely to match those of early adopters of plug-in vehicles. Furthermore, recharging with electricity from micro renewables will reduce the running costs of plug-in vehicles.

4.3 Storage Capacity of Electric Vehicles

As more plug-in 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 plug-in vehicle are shown in Table 4.1.

Table 4.1 – Examples of the storage capacity of plug-in vehicles

VEHICLE	BATTERY STORAGE CAPACITY
GM Volt plug-in hybrid EV	16.5 kWh
Nissan LEAF pure electric vehicle	24 kWh
Tesla Model S pure electric vehicle	85 kWh
BYD pure electric bus	324 kWh

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 5.2) to encourage drivers to recharge at times of high renewable production but low overall demand.

[5] BBC News, 'Energy Storage: The key to a smarter power grid', 2014
[6] IEA-HIA, Wind energy and hydrogen integration, 2011.

Other methods of energy storage that help balance the grid include solid state and flow batteries, flywheels, compressed air energy storage, thermal and pumped hydro-power.[7]

4.4 Second-Life Potential for Vehicle Batteries

Under normal operating conditions EV batteries can be expected to last approximately 8-10 years.[8] However, even after batteries have reached the end of their useful life in electric vehicles, there are still some valuable applications for which they can be used. One such application is a storage facility that connects a series of cells into a 'plant' to help integrate variable renewables and store electricity.[9]

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.

Image credit: www.ecowatch.com

In the near term, the residual value of second-life batteries could help lower upfront costs of plug-in vehicles, as automakers, leasing companies and consumers factor in the resale value as part of a reduced purchase price. Preliminary studies indicate that a used 24 kWh Nissan LEAF battery could provide the vehicle owner with up to $2,400 (c. £1,562) in resale value, while a Tesla Model S owner could sell the 85 kWh battery pack for up to $8,500 (c. £5,535).

[7] Energy Storage Association, 'Energy Storage Technologies'
[8] Handberg, K. 'Environmental Impacts of Electric Vehicles...', 2012
[9] UCLA, 'Reuse and Repower...', 2014

4.5 Bi-directional Charging and 'Vehicle-to' Applications

Bi-directional charging is the guiding principle behind 'vehicle-to-X' (V2X) applications, including:

- Vehicle-to-home (V2H)
- Vehicle-to-building (V2B)
- Vehicle-to-grid (V2G)

These various applications use the battery of a plug-in vehicle as a power supply, to 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 tariffs based on maximum usage. Advanced metering infrastructure and associated software allow energy flows to be managed through automated monitoring and decision-making.[10]

4.5.1 Vehicle-to-Home (V2H)

The principle of V2H applications is to use the EV as a local energy store and source. This provides residents with power in the event of power outages, to power a mobile generator and other portable devices, 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;[11] the capacity of a Nissan LEAF's lithium-ion battery is 24kWh[12] and therefore V2H offers significant potential to provide power for homes in their entirety.

More important to Orkney, however, is the potential of V2H to fully exploit the micro-generation of renewable energy. As highlighted in section 4, the high prevalence of micro-generated wind resource makes Orkney an ideal candidate for considering V2H applications. By utilising EVs in this way, users can charge their vehicles when renewable supply is highest and discharge them to their home when supply is low. Better management of generated energy in this way will help address issues of curtailment and ultimately provide opportunities to earn revenue for residents living in areas of high micro-generation.

V2H applications include the use of optimised charging. The scope of this application can be fully realised through the widespread use of smart metering technology in conjunction with TOU (Time of Use) demand response tariffs to manage loads. As a component of a 'smart grid'[13] it will allow network operators to measure electricity in people's homes, and real-time communication of this data can be fed back to the network.

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[10] Nissan, Zero Emission Mobility, Roadmap for RES Integration, 2014.
[11] Department of Energy & Climate Change, Energy Consumption in the UK, 2014.
[12] Nissan, 2015 Nissan Leaf Specification
[13] "*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*" – Scottish Enterprise

A vehicle charging terminal connected to the smart meter in the home uses a digital signal communicated via the Home Area Network (HAN).[14] The HAN provides a means for digital devices to communicate with each other, and is particularly relevant for energy management. In a demand response scenario, 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 can be connected to the internet, allowing network operators to inform vehicle owners when a demand response event is due to take place. Notifications could be received through an online account, smartphone or on the charging terminal interface itself.[14]

The 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.[15] 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, etc. 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.[14]

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 (ca. £135).[16]

CASE STUDY: NISSAN 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, and together the partners and residents of the community are showcasing the potential for smart energy management and electric vehicle integration.

[14] Hoog, J. et al, Demonstrating Demand Management: How Intelligent EV Charging Can Benefit Everyone, 2013.
[15] Handberg K. and Owen G. Electric Vehicles as Grid Support in Beeton D. and Meyer G, *Electric Vehicle Business Models: Global Perspectives*, 2015.
[16] Clearly Energy, Residential Demand Response Programs

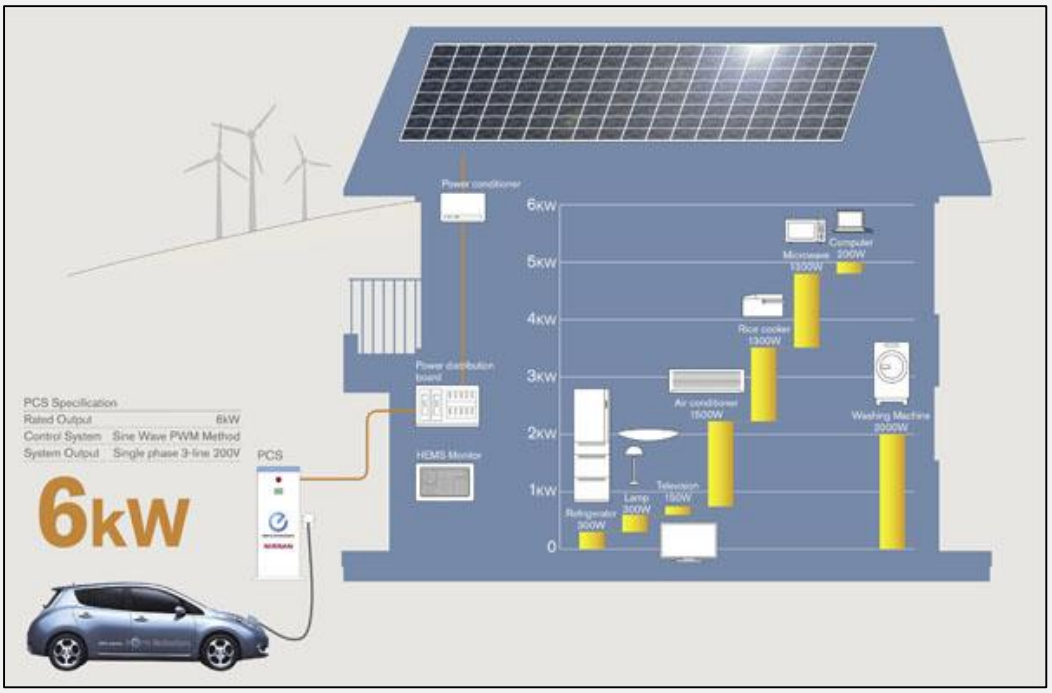

Figure 4.2 - LEAF to Home Structure

Figure 4.2 above illustrates the capability of a typical Nissan LEAF to provide simultaneous power to nearly all electric devices.

The 60kg unit is capable of completely charging a Nissan LEAF battery, from empty, in four hours. It has a peak power output to the LEAF of 6kW, at a conversion efficiency of at least 90%. When, conversely, the PCS is charging a domestic dwelling from the LEAF the unit is capable of matching the 6kW, and again at a conversion efficiency of 90%.

This capacity to provide power can be applied to all currently available models. Once the PCS is connected then power can be supplied when and where it is required. The unit is mainly tailored for providing power to the LEAF owner's own home, but other applications include providing power to work sites, campsites, beaches and disaster areas.

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 2012.[17] 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.

A PCS box cost £4,100 when it launched in March 2012. Nissan hopes prices would decrease as uptake widens.[18]

[17] Nissan, 'Zero Emission Mobility, Roadmap for RES Integration', 2014.
[18] Autocar, Nissan LEAF can power your home, 2011.

4.5.2 Vehicle-to-Building (V2B)

V2B applications are similar to V2H, but are applied to 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 algorithms[19] 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, which should be addressed during implementation.

Nissan has successfully been using V2B technology at its Advanced Technology Centre in Atsugi, Japan since July 2013. It allows up to six 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).[20]

4.5.3 Vehicle-to-Grid (V2G)

There is potential in the use of EVs to provide ancillary services such as frequency response and spinning reserve – to maintain stability and reliability during surges of supply and demand.[21] The efficiency and fast response time of batteries, coupled with their potential wide distribution through a network, have positioned EVs as advantageous to providing grid support.[21]

These balancing or ancillary services are considered further in Section 5.5 as part of the marketplace building block of this project.

Implementation can occur centrally through an aggregator body 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[22], or through a decentralised model with individual control algorithms for each EV

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[19] García-Villalobos J, et al. *Delivering Energy from PEV batteries: V2G, V2B and V2H approaches.* Renewable Energy and Power Quality, 2015.
[20] Renault Nissan, '[Nissan LEAFs can now power the office…](#)', 2013.
[21] Perlstein B. et al, '*Potential role of demand response in maintaining grid stability…*' in Beeton D and Meyer G, *Electric Vehicle Business Models,* 2015.
[22] Bessa J.R, and Matos A. M, *The Role of an Aggregator Agent for EV in the Electricity Market*. 7th Mediterranean Conference and Exhibition on Power Generation, 2010.

overseen by the owner. This application would rely on the use of pricing signals to influence charging behaviour. Furthermore, research has found that battery size has a limited effect on revenue generated in contrast to the power of the charger, therefore the availability of power not energy can be considered important to a V2G operator's market participation.[23]

The longer-term zero-emission vision is for EVs to be at the centre of a fully integrated system whereby owners can participate in wholesale energy markets using the power stored in the batteries of their electric vehicles, and thus significantly reduce their cost of operation. In a shorter term scenario, the EV user not only decides when and where they want to charge their EV, but also how best they spend and re-sell the energy stored in their EV, receiving tangible financial benefits in terms of energy savings, while at the same time maximizing the use of green energy.

CASE STUDY: MASS MARKET V2G SYSTEM, MADRID, SPAIN

Nissan and Endesa, an Enel Group subsidiary, signed a ground-breaking agreement at the 85th Geneva International Motor Show that paves the way for a mass-market V2G system. The two companies have pledged to work together to deliver an innovative business model designed to leverage this technology.

The two companies have agreed to collaborate on the following activities:

- Introduction of V2G services in the European market
- Exploring the use of 'second life' EV batteries for stationary applications (including households, buildings, grid)
- Designing and evaluating potential affordable energy and mobility pack offers

Nissan Europe expect the initiative to further accelerate the EV market and reduce the total cost of vehicle ownership. Utilising the battery's power storage capability will allow for smarter and more responsible management of demand and supply in local power grids.

The V2G system comprises the Endesa two-way charger and an energy management system that can also integrate such off-grid, and renewable, power generation such as solar panels and wind turbines. Using this equipment, a Nissan LEAF or e-NV200 owner can connect to charge at low-demand, and cheap tariff periods, with an option to then use the electricity stored in the vehicle's battery at home when costs are higher, or even to feed back to the grid with a net financial benefit. Electricity generated by solar panels or wind turbines can be used to charge a vehicle, to power the home or business, or to feed back to the grid.

On March 12, 2015, as the culmination of the V2G system development, together with Nissan as automotive partner, Endesa hosted a full demonstration of the market-ready and low cost system in Madrid.

Image credit: www.frevue.eu

[23] 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.

CASE STUDY: EV2G, UNIVERSITY OF DELAWARE

The University of Delaware's (UoD) Centre for Carbon-Free Power Integration has become a figure at the forefront of research into the field of V2G technologies. The UoD states that the modern EV has the capacity to supply in excess of 10kW. The university has coupled with energy suppliers, car manufacturers and energy system operators in order to trial this technology.

eV2G is a partnership, set up between the UoD and NRG Energy, a major energy wholesaler in the USA, investigating V2G mechanisms. The programme began in September 2011 and became active in 2013. The projects aim was to understand the regulatory standards, infrastructure and technological requirements of drawing power from EVs if required, and also the benefits to EV owners.

A number of vehicle manufacturers are also contributing to the programme's research. BMW has donated 15 electric MINIs, while Honda has donated a PHV Accord, and the UoD has also paired up with AutoPort Inc., which specialises in car processing. AutoPort were engaged in order to modify the cars for the Ev2G project, and by September 2014, the company had been provided with 60 EVs and PVHs to modify.[24]

On the 27th of February 2013 the eV2G project became the first V2G technology to sell power to the grid from electric vehicles.[25] It has been predicted that once this program is rolled out to the public EV owners the will be a potential revenue stream of $150 per month per vehicle.

Figure 4.3 - EV2G MINI Tandem Connections
Source: Winder, 2014

The UoD's work has centred on the technology's ability to be used to support grid balancing techniques; other work has included a study identifying a possible $190,000 (ca. £127,627) saving from the purchase of an electric school bus with bi-directional charging instead of a conventional diesel model. Indicative revenue stream for V2G technology is at $150 per month per vehicle.[25]

There is some scepticism of the V2G mechanism as it is not understood what level of impact the higher rate of charge and discharge would have on the capacity of the EV's battery. It is also unclear whether V2G will only be viable prior to the commercialisation of stand-alone stationary energy storage technologies, or whether the two can work in tandem with each other.

[24] Winder, J., Autoport turns cars into powerplants, 2014.
[25] Clean Technica, eV2G marks milestone selling electricity to PJM grid, 2013.

4.6 Other Energy Storage Options

Other energy storage options that may also be considered for Orkney include power-to-power (P2P) storage technologies. Energy storage fulfils three functions: to charge, to hold, and to discharge energy. P2P storage is where the energy carrier that is charged and discharged is electricity.

The types of P2P storage technologies discussed below include flow batteries, Li-ion, pumped heat energy storage, and pumped hydro.

All of these storage technologies are able to manage electricity in high renewable energy scenarios.[26] In this section, focus is given to each option's advantages and disadvantages and their indicative costs.

4.6.1 Flow Batteries

Flow batteries are rechargeable batteries using two liquid electrolytes, one positively charged and one negative, as the energy carriers. The electrolytes are separated using an ion-selective membrane, which under charging and discharging conditions allows selected ions to pass and complete chemical reactions.[27]

Table 4.2 - Advantages and disadvantages of flow batteries

ADVANTAGES	DISADVANTAGES
■ Less sensitive to higher depths of discharge ■ Able to tolerate a large number of charge/discharge cycles ■ Reduced likelihood of the cells output being reduced to that of the lowest performing cell ■ Virtually unlimited capacity	■ Low energy density ■ Not commercially mature

Flow batteries can be used for many grid applications such as: Load balancing, standby power and the integration of renewable energy sources. However, there is a limited number of worldwide commercial installations to date.

Figure 4.4 - Sankey diagram for flow batteries[27]

[26] European Commission, Commercialisation of energy storage in Europe, 2015.
[27] Arup, Five minute guide: Electricity storage technologies, n.d.

4.6.2 Lithium ion (Li-ion) Batteries

Lithium ion (Li-ion) batteries are a type of rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge, and back when charging. The EV industry almost solely utilises lithium-ion batteries for energy storage. This type of battery is also commonly used in consumer electronic products, where a high energy density is required. The technology can be scaled up to distribution scale size, and is commonly used in electric vehicles, and the deployment of which is expected to drive down cost and improve performance. Research and development is on-going in various other chemistries of the battery type with a view to improving performance and reducing the cost.[27]

Table 4.3 - Advantages and disadvantages of lithium-ion batteries

ADVANTAGES	DISADVANTAGES
■ Li-ion batteries have an extremely high energy density, in the order of 400 Wh/l ■ Li-ion batteries are able to tolerate more discharge cycles than other technologies ■ High efficiency	■ Li-ion batteries have a higher cost than other technologies ■ Negative effects of overcharging/ over discharging ■ Potential for issues associated with overheating

Lithium ion batteries can be used for many grid applications such as: frequency regulation, voltage regulation and the integration of renewable energy sources.

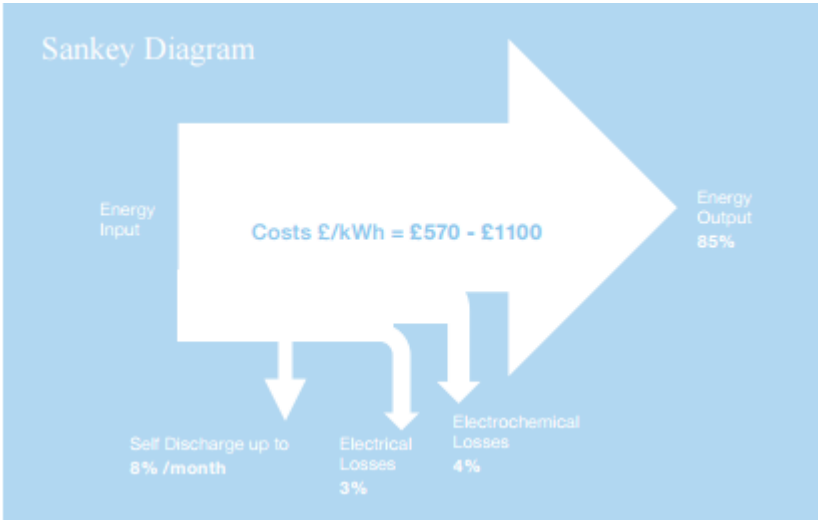

Figure 4.5 - Sankey diagram for lithium-ion batteries[27]

4.6.3 Pumped Heat Electricity Storage

Pumped Heat Electricity Storage (PHES) uses electricity to drive a storage engine connected to two large thermal stores. To store electricity, the electrical energy drives a heat pump, which pumps heat from the "cold store" to the "hot store" (similar to the operation of a refrigerator). To recover the energy, the heat pump is reversed to become a heat engine. The engine takes heat from the hot store, delivers waste heat to the cold store, and produces mechanical work. When recovering electricity the heat engine drives a generator.[27]

Table 4.4 - Advantages and disadvantages of pumped heat electricity storage

ADVANTAGES	DISADVANTAGES
■ Thermal - mechanical system with long life ■ No external emissions or hazardous materials ■ Virtually unlimited number of charge/ discharge cycles ■ Low cost	■ Not commercially mature: first commercial plant in place in 2014 ■ Potentially large footprint

PHES can address markets that require quick response times. The system uses gravel as the storage medium and so offers a very low cost storage solution. There are no potential supply constraints on any of the materials used in this system. Plant size is expected to be in the range of 2-5 MW per unit. Grouping of units can provide GW-sized installations. This covers all markets currently addressed by pumped hydro and a number of others that are suitable for local distribution, for example, voltage support.

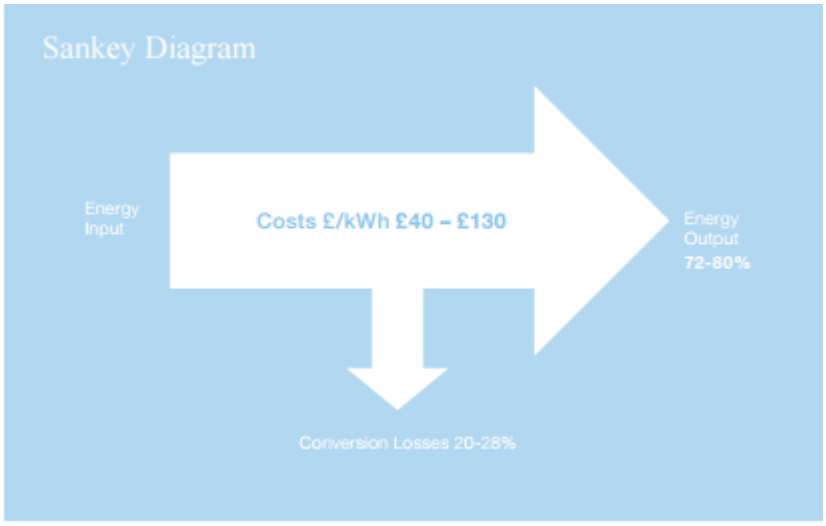

Figure 4.6 - Sankey diagram for pumped heat electricity storage[27]

4.6.4 Pumped Hydro Energy Storage

Pumped hydro storage is currently the most established utility scale method for energy storage with approximately 99% of the world's grid energy storage being pumped storage. A pumped storage scheme uses the differential in height between two reservoirs to store energy. Pumped hydro storage schemes can either operate using reversible pump-turbines or hydro turbines and separate pumps depending on the conditions at the site. During periods when electricity demand is lower, electricity is purchased from the grid and used to pump water from the lower reservoir to the higher one, during periods of high demand this water is released and allowed to return through the pumps now acting as turbines in order to generate electricity.[27] Development areas for this type of storage option include: underground pumped storage, use of the sea as lower reservoir, offshore energy islands.

Table 4.5 - Advantages and disadvantages of pumped hydro energy storage

ADVANTAGES	DISADVANTAGES
■ Mature large scale technology ■ Large power and energy capacity ■ Fast response times	■ Geographically constrained ■ Limited potential for new sites (in UK) ■ Away from demand centres

Pumped storage is commonly used for peak load generation, but can also be used for black starting electricity grids in the event of a complete system failure and for providing fast reserve response for grid frequency control. The largest pumped storage scheme in the UK, Dinorwig in North Wales can store 9.1 GWh of energy and can ramp up from zero to 1.32 GW of output in 12 seconds. Today, Dinorwig is operated not as a peaking station i.e to help meet peak loads, but rather as a STOR - Short Term Operating Reserve, or Fast Response plant, acting in response to short term rapid changes in power demand or sudden loss of power stations.

Figure 4.7 - Sankey diagram for pumped hydro energy storage[27]

5 Energy Management Marketplace

5.1 Introduction

The third building block of the project is concerned with the technologies, business models and frameworks required to create a marketplace for intelligent management of energy. This is a commercial layer that sits on top of Orkney's existing active network management system and the increasing energy storage opportunities developed in the previous building block. The marketplace provides a way for generation, storage and end-users to be dynamically linked and incentivised to effect necessary behaviour changes. This chapter considers a range of opportunities in this area to explain the potential for specialisation and to pilot the development of new products and services.

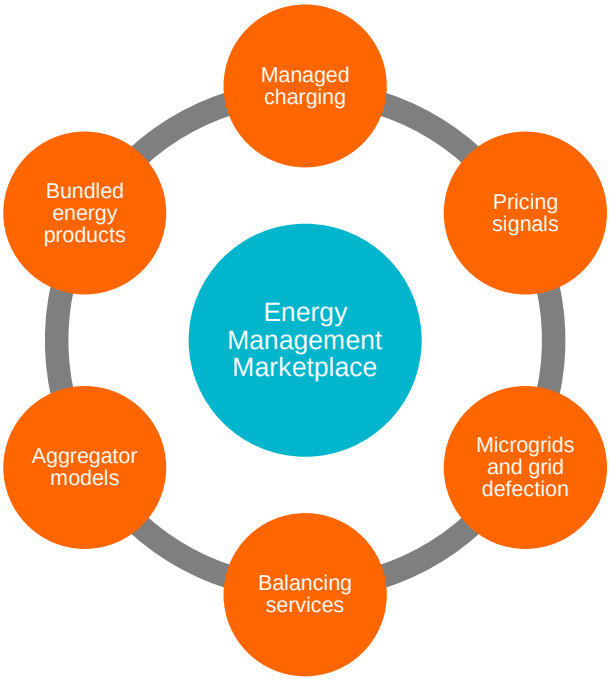

Figure 5.1 – Potential areas of development/ specialisation related to establishing an energy management marketplace

5.2 Managed Charging

Centrally managed demand response strategies are being developed to influence when EV drivers plug-in their vehicles. These can be set to respond to peaks in renewable energy generation/ dips in demand, as well as providing a way to avoid stresses on local grids which might result from clusters of vehicles charging in a community.

One example of a managed charging strategy 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 the times at which users charge.[28] Alternatively, a tariff might be structured in a slightly more fluid way that informs users a day, week or hour in advance of when a cheaper rate may be available[29], 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, creating a financial incentive for charging in this way. Similarly, the charging of vehicles can be remotely interrupted (i.e. paused) to reduce the chance of incurring additional cost when peak tariffs take effect.

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. An overview of charging level and control functionality whilst away from the vehicle is also important, such as the current level of charge and expected completion time. 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.[30]

Data gathering and analytical intelligence to forecast and control any increased demand from plug-in vehicle charging will reduce the need for additional expansion and reinforcement of local distribution grids. Trials around the world are showing the potential to shift demand to times of day that are more favourable to energy systems. Influencing behaviours in this way requires innovative communication and reward strategies that motivate positive behaviours, as well as international demand response standards to guide such developments.

[28] ECOtality North America, 'The EV Project', 2013
[29] Massachusetts Institute of Technology, 'The Future of the Electric Grid', 2011
[30] Community Energy Scotland, 'FS&SS Community Electric Van.'

CASE STUDY: KYOTO, JAPAN

In Kyoto (Kansai Science City), Japan, an EV Charging Management Centre (EVC) has been established to study ways to control the demand curves from electric vehicles in a defined community. The EVC collects data such as location and remaining battery level of 100 EVs connected to a 3G network, and forecasts power demand for battery charging. Next, the EVC sends out DR (demand response) requests to EV drivers via email and car navigation system displays, asking them to avoid charging their vehicles, or to charge their vehicles during specified time frames at a given location. If participants adhere to DR requests, they are provided with shopping points as an incentive.

The project is part of a wider $11.8 million initiative led by Mitsubishi Heavy Industries, with the EVC operating alongside home and building energy management systems to optimise energy supply and demand for the entire community. The attempt to distribute demand response requests was started in the winter of 2012 and showed high conformance rates amongst the trial participants. During a three-hour peak demand period, a recharging volume reduction of approximately 12% was achieved in the summer of 2013.

5.3 Pricing Signals

The CARWINGS smartphone application is available to Nissan LEAF owners. It is a means of receiving data from the vehicle as well as being able to remotely control a number of features including:

- Checking battery energy level;
- Control the starting and stopping of charging;
- Identify when charging has been completed,
- Control in-car heating and air conditioning before reaching the vehicle, as well as setting automated climate control conditions. Figure 5.2 show a screenshot of this function within the application;
- Check estimates of remaining driving range.

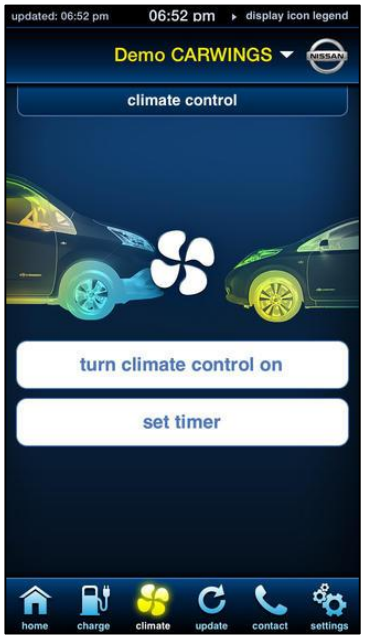

Figure 5.2 - CARWINGS A/C Control

The app is also capable of keeping the driver up to date on available charging stations within the local area. Unless otherwise specified by the driver, the app will automatically update every three months with the latest data on charging networks. However, when battery capacity drops below 15% this function is automatically initiated to ensure the driver has directions to their closest station.[31]

The cloud-based information system provides a user-friendly way for LEAF owners to access data, which is also available through an online account via PC. The

[31] Nissan, How does it work

application also allows users to track driving history in order to monitor trends in usage.

Nissan is not the only company providing a smartphone app offering to EV owners. Volkswagen's full electric e-Golf and e-Up! can be complemented through the 'Car-Net' app, which offers approximately the same functionality as Nissan's CARWINGS app.[32] Other car manufactures including Fiat, Ford Honda, Prius, BMW, Tesla, Toyota, Ford and Volvo also offer smartphone information systems for their EVs and PVHs.[33]

5.4 Microgrids and Grid Defection

As an isolated grid with high-renewable energy generation, it is possible that Orkney could provide a test bed for cities and communities that are considering 'defecting from the grid.'

The premise is that energy generated within communities, including streets, parishes or even entire islands, can be self-sustaining without the need to receive energy transmission from other locations—i.e. disconnected from the National Grid.

With micro-generation rapidly increasing[34], particularly with the encouragement of feed-in tariffs and an expected increase in EVs, reliable and independent models of supply can be realised without a utility provider.

Energy generated in this way is expected to increase.[35] In particular, new collaborative consumption business models that allow shared access to assets, property, resources, time, skills and services through online platforms services is transforming traditional economic practices.[36]

[32] Volkswagen, 2014.
[33] SAC EV, Smartphone apps for EVs
[34] Dept. for Energy & Climate Change, 'Microgeneration Strategy', 2011.
[35] Dept. for Energy & Climate Change, 'Community Energy Strategy: Full Report', 2014.
[36] Dept. for Business, Innovation & Skills: 'Unlocking the Sharing Economy', 2014.

CASE STUDY: ALAMEDA, CALIFORNIA

Imergy Power Systems California recently announced their participation in a microgrid project funded by $1.5 million funding supplied by the Californian Energy Commission. [37] The goal of the project ultimately to enable the Chabot-Las Positas Community College District to integrate renewable energy sources into its facilities so as to curb peak power and achieve greater control over energy supply within the campus.

Through a combination of bolstering existing solar generation by providing additional battery storage and establishing smart grid structures, it is estimated there will be $75,000 of annual energy savings for the district. The Microgrid blueprint will also serve the broader remit of providing experiences and results concerning the operation of such a system therefore providing other institutions with empirical data to evaluate, plan and implement microgrids combining energy management systems and energy storage.

The project has ultimately been designed to demonstrate how microgrids can enable colleges and universities to independently maintain control over their own energy consumption, therefore translating to maintaining better control over energy costs.

Image credit: Storage.pv-tech.org

5.5 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 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.[38]

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.

Plug-in vehicles as a 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, and are less constrained by the limitations on EV storage volumes and depths of discharge.

Participation in ancillary services markets would likely take place via an energy aggregator (see Section 5.6) to enable multiple vehicles to be pooled and traded into the market.

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[37] Imergy.com, Chabot-Las Positas College microgrid project, 2013.
[38] For more info see: http://energystorage.org/energy-storage/energy-storage-benefits/benefit-categories/grid-operations-benefits

5.6 Aggregator Models

A decentralised energy economy, as seen in the UK and across the EU more widely, has led to a liberalised and price receptive energy market. The proliferation of small energy enterprises can further 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: an aggregator agent may take responsibility for these resources to sell into the electricity market. The aggregator acts as a middleman, between the distribution network operator to whom it can provide ancillary services and the individual generators.[39]

CASE STUDY: INDEPENDENT ELECTRICTY 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.[40]

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 acts as an intermediary and receives 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 more the business model allows the supply to 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.

The alignment of managed EV charging/discharging and aggregation services is likely to be in the form of DNOs using aggregators as a source of generation or load control, with EV users communicating their driving needs and the aggregator managing this accordingly. In such a model, an aggregator agent can take various forms including:

- 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.[41]
- 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

[39] Bessa J.R, and Matos A. M, The Role of an Aggregator Agent for EV in the Electricity Market. 7th Mediterranean Conference and Exhibition on Power Generation, 2010.
[40] Vandebron, How does it work?
[41] Kempton, W. and Tomic, J. 'V2G Power Implementation', 2004.

exchange for some or all of the profits generated, or a mobile network operator may provide the tracking and communication functionality associated with the billing of smaller distributed transactions.[42]

- A **package deal** aggregator sees an agent acquire the EV battery, with the owner constrained to charging the vehicle at specific times agreed with the agent. In exchange, the user receives a preferential rate, maintenance and discount rates for charging and parking in their EV.[42]

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.

CASE STUDY: ORKNEY DEMAND-RESPONSE AGGREGATOR PILOT

In Orkney, Rousay, Egilsay and Wyre Development Trust (REWDT) is leading a pilot project designed to test the technical capabilities of a demand-response aggregator. This is in collaboration with Hoy Energy Ltd, Community Energy Scotland (CES), SGS—the gatekeepers of Orkney's Active Network Management system, and with SSE. The following are the aims of the demonstration project:

- Increase local electricity consumption to reduce the curtailment of the 900kw turbine on Rousay which is impacted by a 40% curtailment rate;
- Increase the resilience of the Hoy 900kw turbine; and
- Test the technical and communications settings and user-acceptability of the solution.

REWDT partnered with VCharge, an aggregation provider based in Rhode Island, United States. CES have also collaborated with SSE and SGS, the operators of ANM and guardians of the signals behind it.

SGS intervene by giving access to curtailment signals or codes. VCharge provide and optimise the system which is entirely based on broadband links.

It works by installing EV charging points that are remotely controlled and allowing responses to real-time generation and curtailment data through monitoring equipment. In this scenario, the aggregator receives real-time information on curtailment and generation forwarded to them from the ANM via an IP address.[43] Ideally, the aggregator will have information on battery capacity and available load for dispatch to increase the effectiveness of the system. During curtailment, the charging points will be activated to try and reduce the impact. During low periods of generation, the charging points will avoid activation unless the EVs are at risk of lacking charge.

In addition, the aggregator will collect data on energy consumption, turbine generation and curtailment to provide rebate payments for customers.

[42] Guille, C. and Cross, G. 'A Conceptual Framework for V2G Implementation', 2009
[43] Community Energy Scotland, 'Tender for Demand Side Management', 2014

5.7 Bundled Energy Products and Services

A number of vehicle manufacturers and energy companies around the world have formed alliances to capitalise on the potential of combined products related to electric vehicles.

Bundled service offerings provide a way to make plug-in 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 delivering these products and services individually. 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 plug-in vehicles to new customer segments in both the private and commercial fleet markets, enhancing the benefits and ease of switching to EVs and plug-in hybrids.

CASE STUDY: SNUGG HOME

In Boulder, Colorado, U.S., 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 (c. £515) 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 (c. £10,306) on energy costs. This is a real business model with a real value proposition to drivers and homeowners."

6 Tourism and Inward Investment

6.1 Introduction

The final building block explores how Orkney can maximise the economic opportunities afforded by developments in electric vehicles and energy systems.

Given the importance of tourism to the local economy, this chapter primarily focuses on opportunities in this area. This recognises the close links between tourism, reputation and measures to protect the natural environment. It also reconciles that tourism in itself is also a major source of emissions, especially when visitors to Orkney invariably have to travel a considerable distance to reach the islands.

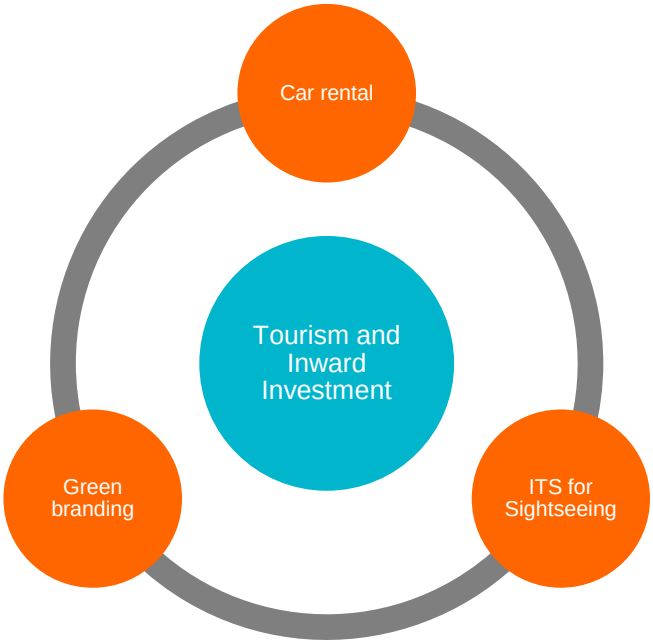

Figure 6.1 – Potential areas of development related to tourism and inward investment

6.2 Car Rental

EV car rentals offer a unique opportunity for tourists to experience Orkney, which already has a reputation for being a leader in renewable energy in the UK. Driving a green car around the tourist sites reinforces this existing reputation and further promotes Orkney as a Green Islands destination. In addition to providing an opportunity to educate tourists about the benefits and experience of driving EVs, this also serves as a jump off point for the promotion of sustainable tourism.

Figure 6.2 - Renault Zoe
Source: What's On & Where to Go

Figure 6.2 shows Steve Sankey demonstrating the Renault Zoe purchased for his family's local self-catering business in South Ronaldsay. Guests can hire the EV at £250 per week, a comparable price to other car rental companies on the island, and Steve's business is thought to be the first to offer such a service in Orkney. "Our self-catering cottage has a Green Tourism Scheme gold award, with all its power provided by our wind turbines and solar panels," said Mr Sankey. "Offering electric car hire to our guests who come to Orkney because of its clean, unspoiled environment, seemed a logical next step for us. It's a first for Orkney and, as far as we're aware, a first for a self-catering business in the UK."[44]

CASE STUDY: ECO-TRAVEL NETWORK

In England's Lake District, the Eco-Travel Network programme rents ultracompact all-electric Renault Twizys to engage local residents and tourists. [45] The programme is funded by the Sustainable Development Trust with sponsorship from Renault UK and a local car dealership. It provides short-term rental of EVs to access remote parts of the Lake District and provides public charge points powered by renewable energy to support these journeys. The scheme operates 40 informal 13amp charge points for Twizys in the National Park based around pubs, cafes and visitor attractions.

The Eco-Travel Network largely works in collaboration with local hotels and tourist centres. However, it also operates rotational trials of the Eco-Travel Network in other areas such as Knoydart and the Isle of Eigg.

These rotations of the Twizys typically last for three month periods at a time, with blogs and social media enabling better engagement with the local audience. The network also regularly hosts outreach events in the local community such as attending local festivals.

[44] What's On & Where To Go, 2015.
[45] Eco-Travel Network

6.3 EV Sightseeing with Intelligent Transport Systems

Provision of real-time information through intelligent transport systems (ITS) to EV drivers can help extend driving distances, enable easy access to charge points, enhance the driving experience, and optimise vehicle performance.

ITS have also been used for sightseeing tours, displaying information about tourist attractions, as soon as the vehicle comes within range of the transmitter called an ITS spot or beacon. This is made possible through telematics: the coupling of telecommunications and information delivered to the driver through in-car displays.

Goto Islands in Japan have fully incorporated 'driving tours of the future' through EV rental cars that are equipped with built-in satellite navigation system and ITS. This enables tourists to receive real-time driving information such as route specific battery forecasts, the nearest charging stations, and information on the local tourist spots.

In Orkney, an intelligent transport system would be useful not only for tourists but also for local EV drivers.

CASE STUDY: GOTO ISLANDS, JAPAN

In 2010 the Island of Goto introduced 140 EVs, most of which are solely used as rental cars by tourists.[46] These EVs also supported the added element of trialling 'driving tours of the future' through the in-built sat-nav system and ITS. Business owners were given preferential rates including maintenance plans to encourage EV rental take up. The integrated ITS enabled the implementation of services such as guiding the driver to local tourist spots and charge points in addition to giving route specific battery forecasts. Information on the local area is updated by residents and businesses via a connected website.

In order to prepare for the initial EV roll out, the island installed 15 rapid chargers in 7 locations, principally concentrated in tourist spots or port terminals, with distribution distances ranging between 20km and 50km. The project allowed for usage data to be collected in addition to observing an environment wherein EVs are a part of everyday life, measuring what level of smart grid integration, infrastructure or road access would be necessary to accommodate EVs in the future.

Initial figures revealed that 35,000 people made use of EV rental cars during the period from April 2010 to January 2012, with a rental peak in August 2011 of 398 rentals in one week. Integrated ITS within EV rentals proved to be a success within the area of in tourism, in addition to highlighting areas of grid and infrastructure that need improvement to fully facilitate a situation of mass EV use on a daily basis.

Goto's EV project has revitalised the local economy, in addition to supporting Goto's bid to become recognised by UNESCO as a World Heritage Site for its commitment to ecological preservation. The project also allows for a broader scope encompassing renewable energy use in addition to the establishment of a system for regional smart grid integration with EVs.

[46] WorldEVCities.org, Goto Islands, 2015.

Analysts have estimated that approximately 90% of plug-in electric vehicles in 2013 had on-board telematics systems, with the expectation that this will increase to 94% by the end of 2017, equating to annual sales of telematics units in the region of US$1.4 billion.[47]

6.4 Green Branding

The Danish Island of Bornholm's "Bright Green Island" strategy, a community-led undertaking with a vision to become 100% sustainable and carbon-free by 2025, has been underway for several years now and could provide invaluable best practice guide for green branding, in addition to showcasing tried and tested island business models. Bornholm has successfully positioned itself as a test island for renewable energy technologies, EVs, and green energy experiments, having partnered with global companies such as IBM and Siemens. The island continues to attract inward investment and create jobs from these projects. As the Bright Green Island, Bornholm has proven that its renewables industry and test island positioning can be a major tourist and investor draw, attracting over DKK 200 million in investments and DKK 1.33 billion in tourist spending.[48]

Orkney could follow a similar strategy by adopting a green brand; for example, Bornholm calls itself the 'Bright Green Island', the Isle of Wight is the '*eco-island*: The hub of a sustainable future', and Samso is the 'Energy Self-sufficient Island.' This will enhance Orkney's green brand recall and will help establish the Islands as the UK's premier destination for innovations in renewables and smart mobility. Options for Orkney's brand name may include: Smart Energy Islands; Smart and Green Islands; Green Energy Islands; or Smart Mobility and Energy Islands.

CASE STUDY: BORNHOLM, THE BRIGHT GREEN ISLAND

The Bornholm municipality has, together with local industry, public and other authorities, established the "Bright Green Island" strategy for Bornholm focusing on energy and environment with the goal to become a 100% green and sustainable society by 2025.[49] With a population of 44,000, the Danish island is located in the Baltic Sea.

In recent years, business centre Bornholm has succeeded in attracting international businesses to the island. Danish universities and companies like IBM and Siemens have looked to Bornholm as a test island for renewable-energy technologies such as wind turbines, green energy experiments, electric cars, and energy efficient houses. In their Bright Green Island strategy, they integrate Energy Tours into how they package Bornholm into a green island destination.Projects are currently underway in order to further saturate the use of renewable energy within Bornholm's power grid, in addition to utilising EV batteries as a form of storage, with the motivation to be an entirely energy independent island by 2025.

Image credit: www.brightgreenisland.com

[47] Stojaspal, Telematics and electric vehicle technologies, 2013
[48] ClusterDevelopment.dk, Bornholm in figures, 2015.
[49] Bright Green Island, 2013.

7 Conclusion

This report explores the potential for Orkney to establish a lighthouse project known as Orkney's Electric Future (OEF) that integrates smart mobility and energy management. Its stated objectives as articulated by Orkney Islands Council and key stakeholders consulted in this study are to:

- Establish and promote a good practice low carbon transport option for the residents of, and visitors to, the Orkney Islands;
- Study the feasibility of various options to support increased uptake of electric vehicles (EVs) on the Islands, including the concept of electric hire cars with driver information systems to be positioned at Orkney's main gateways and where energy is curtailed;
- Determine how surplus energy produced locally can be used to power transport.

An outline design for the OEF lighthouse project is established based on the analysis of Orkney's core strengths and available opportunities, which is informed by insights gathered from consultations with key stakeholders.

With its history of innovation and existing assets, Orkney is well positioned to become a test bed for new technologies, products, and services related to EVs and energy management. These assets include a community of local experts and engaged organisations involved in innovation and development of energy technologies, the Active Network Management System and the high penetration of renewable energy generation in the Islands.

In order to capitalise on these identified strengths and opportunities, the various elements of the OEF lighthouse project are broken down into four separate but complementary building blocks, namely: infrastructure and incentives, energy storage, energy management marketplace, and tourism and investment.

These building blocks provide a structured approach that responds to the stated objectives of the OEF lighthouse. Each building block addresses a specific challenge and requires different actions. Similarly, each area requires different expertise and skillsets, presenting options for specialisation and investment.

A range of options and activities are presented with case studies of best practices and exemplar business models from across Scotland and overseas:

- **Infrastructure and incentives** – there are a number of locally-administered assets and powers that can be used to encourage EV adoption in Orkney. This includes measures related to: infrastructure provision, planning, integration with public transport, car clubs, taxis and private hire vehicles, and education and promotion activities.

- **Energy storage** – there are a number of different storage technologies that could be developed and piloted in Orkney to absorb excess generation capacity. These include 'vehicle-to-X' applications and power-to-power (P2P) storage technologies.

- **Energy management marketplace** – future energy systems will also require the development of business models and frameworks to create a marketplace for intelligent management of energy. This would build on Orkney's existing Active Network Management System and the increasing energy storage opportunities in the previous building block. This marketplace provides a way for energy generation, storage, and end-users to be dynamically linked in order to respond to changes in local energy generation and demand.

- **Tourism and inward investment** – there is potential to maximise the economic opportunities afforded by developments in EVs and energy systems in Orkney, particularly in the area of tourism. Other related areas identified include car rentals, the use of intelligent transport systems for sightseeing, and green branding.

This outline design of the OEF lighthouse project highlights the potential for Orkney to become a 'Living Laboratory' for a range of new technologies, products, services and business models. This would establish the islands as a real-world test bed for the above technologies and business models.

Building on the opportunities reviewed in this report, a separate implementation plan has also been developed to provide a detailed design of work packages, delivery structures, budgets and funding opportunities to establish the OEF lighthouse project and to ensure a positive legacy from these investments.

Appendix

1. SWOT Analysis

Orkney's key strength: Orkney's resources and expertise

There are a multitude of opportunities within the realm of advancing electric mobility in Orkney. Orkney's strengths lie in its high level of local interest in innovative solutions. Over the years, it has proven its expertise in the renewables industry. With Orkney's Electric Future, Orkney has the potential to expand this expertise into low carbon transport solutions that not only is beneficial to the environment but also complements the energy profile of the Islands.

Orkney can also capitalise on its isolated, self-contained location which makes it ideal for companies to pilot and experiment their new technologies and business models in a real-world environment. Organisations can even "downsize" further by focusing on one of the inner or outer isles if their experiment requires an even smaller sample size. Because Orkney is home to world-class organisations in the renewables industry as well as active development trusts on the islands, companies can rely on expert support from residents who can also provide valuable local knowledge.

The unique position of Orkney in terms of its active community energy generation also lends itself as an interesting case for pilots that explore energy security, grid defection[50], and energy services. These energy services like curtailment service providers (CSP), energy service companies (ESCO), demand-response management services, and energy aggregators, are still in its infancy stage and would benefit from a test bed where technical, social and commercial trials can be reliably conducted. They can also hugely benefit from the high level of domestically owned small turbines and the awareness of energy usage. If these pilots and trials are carried out in Orkney, not only would they increase Orkney's profile but they would also contribute to the alleviation of curtailment in the Islands as well as create jobs and facilitate inward investment.

Orkney's challenge: Orkney-wide strategic planning of projects

As it stands, a number of projects ranging from testing demand-response technologies to feasibility of hybrid ferries have been conducted in multiple locations in Orkney. These projects all have important desired outcomes that would benefit Orkney, especially its overall goal of alleviating curtailment of renewable energy generation. However, due to limited funding opportunities, these projects often have to compete against each other for the same funding grant. The Local Energy Challenge Fund, for example, in its most recent call for proposals, received 18 project proposals from

[50] Grid defection occurs when a house, building, community, or island, disconnects from the national power grid because it generates enough energy to be self-sustaining.

Orkney.[51] While this is a positive indication on the level of participation of local development trusts and organisations based in Orkney, due to the competitiveness of these funding grants, it is likely that only a number of proposals will be successful. Even if projects in Orkney have a higher potential compared to proposals from other areas in the country, judging panels of funding awards have discretion as to the geographical distribution of the Challenge Fund across Scotland.[51] In order to increase the chances of securing funding for most of the projects in Orkney, a strategy worth considering would be to determine whether opportunities to share resources or integrate objectives exist among all the projects. This would open up the possibility to make a stronger case for grant funding applications. Another option would be to disseminate funding opportunities in Scotland, UK and Europe, and coordinate plans among organisations to apply for these.

Orkney's opportunity: EV tourism

Tourism to the Islands also presents an opportunity to increase EV use in Orkney. Every year, thousands visit the different historic sites in Orkney. Electrification of car hires would expose tourists to EVs and enhance Orkney's image as a green and smart island. This would expand Orkney's visitor profile beyond the history and archaeology enthusiasts to include innovation and sustainability aficionados. It would also increase confidence in EVs among local residents as they see more frequent use of the EVs both by public and private sector fleets. As more residents try EVs, they would learn more about the advantages of driving one. This has started to happen with dedicated EV sales personnel based in Orkney and the formation of a passionate group of EV drivers. This valuable network of EV early adopters would be a good resource for potential EV drivers, and can help allay any of their misconceptions about EV ownership.

Orkney's key enabler: Engaged community of experts

Orkney is home to world-leading organisations in renewables and community energy. They have been very active in bringing in new technologies in the Islands through a range of innovation projects. Local development trusts are also very involved in developing innovative solutions that benefit their respective communities. This highly engaged community of organisations puts Orkney in an ideal position to establish a living laboratory in order to better align and integrate all the activities in the Islands. Orkney's edge is that other islands in the UK or even Europe do not enjoy the same breadth and depth of expert organisations concentrated in one locale. This, coupled with a supportive Council, would make Orkney a conducive environment for incubating pioneering ideas and projects, and an attractive hub for investment.

[51] Local Energy Challenge Fund, Programme orientation and workshop, 28 April 2015.

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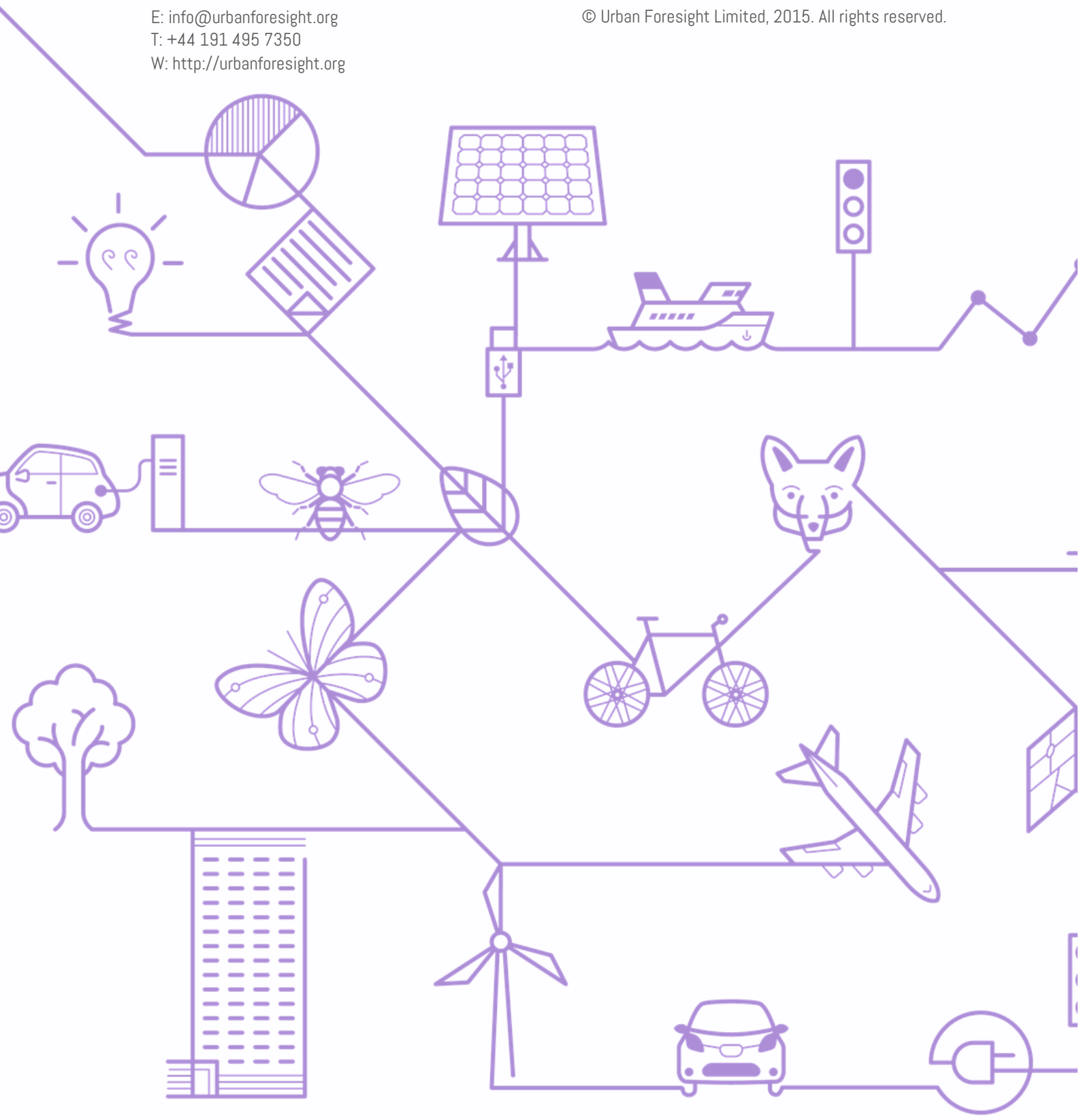
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