Ricardo Energy & Environment

Smart Local Energy Systems International Research

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Background

Smart Local Energy Systems (SLES) are an increasingly important element of Scotland's energy system. Several technology push factors are driving this:

Increasingly affordable renewable energy systems that can be installed in a range of local settings, as shown by the list of Typologies;

- Falling costs and improving performance of energy storage systems;
- Smart Grid technologies that help SLES run as standalone microgrids or grid connected systems;
- Demand Side Response solutions to match local demand to local energy production;
- The transition to low carbon transport: electric bikes, cans and vans etc.;
- Increasing use of heat pumps as part of the transition to low carbon heat;
- Development of Smart Cities and Green Cities, with city authorities competing to attract investment based on their environmental credentials.

In addition there are important policy and market pull factors, including:

- National, regional and company level targets for carbon reduction and renewable energy;
- Policy and fiscal support schemes for renewable energy investments;
- Policy to improve air quality in urban areas;
- Demand from companies and individual consumers for low carbon energy solutions and affordable and secure energy supplies;
- Policy support in the form of targets and grant assistance and advice programmes.

So SLES are set to increase widely in Scotland.

Background

Many of the driving forces for the SLES market in Scotland will also be driving international markets. Though there will be many obvious, and less obvious, local driving forces.

Like Scotland many countries have targets for carbon reductions as part of their commitment to the IPCC Paris Accord. Their Nationally Defined Contributions (NDC) will have targets for renewable energy and policies to support this.

Specific examples of national focus and differences in national focus and driving forces include:

- Germany: Agencies in Germany have a long track record in international promotion of their supply chain via GIZ and KfW. These include focused marketing for Indonesia and the Philippines. The support mechanisms in Germany now require solar PV systems to have a battery, creating a market for German companies providing batteries such as Sonnen and inverters e.g. SMA.
- Japan: As well as a Feed in Tariff, Japan has specific support programmes for city mini grids, with companies such as Hitachi marketing Smart Energy Management Systems to connect and manage these. Japan also has programmes to increase resilience to disasters (by creating city mini grids) and to reduce diesel use on some of their islands.
- South Korea: Electricity prices in South Korea are low due to the dominance of nuclear power. However there are 63 islands which rely on diesel generation. This means there is a very high level of subsidy for the electricity consumer on islands. The response is to convert these to solar PV, wind, battery and fuel cell systems with companies such as Samsung developing these solutions.
- Mediterranean: Greece, Italy, Spain and France all have programmes to support development of SLES in their islands, and in some cases their island dependencies. These are motived by the need to address the energy needs of these islands and the supply chain opportunities.
- Small Island Developing States: There are many small islands who rely on diesel generation, with high electricity costs, restricted electricity supply and risks to security of supply. These islands face the same issues as many small Scottish islands. There are now local supply chain or maintenance capabilities – so solutions are imported and often funded by development banks.

Whilst these examples are focussed on two island typologies, the drivers for SLES on islands is strong, hence widespread. We explore this in more detail in this study.

Scope

The central aim of this study is to identify the niches that provide the best opportunity for Scottish businesses in the international market for SLES.

The opportunities for the Scottish SLES supply chain depend on a range of factors:

- The match of their SLES services in each Typology;
- The scale of markets for the typologies in different international regions and specific countries;
- The ease of supply and export barriers for specific countries, as shown by the Ease of Doing Business rankings;
- Evidence of past export success in the SLES and related sectors.

In this study, we review:

1) The existing Scottish project activity and Scottish capabilities

This was completed by reviewing a long list of SLES projects that have been delivered in Scotland. Each project is categorised in terms of the 10 technologies that Scottish Enterprise have identified and the 7 typologies.

2) SLES activity globally

Considering the short listed countries provided by Scottish Enterprise, we review examples of SLES projects in these countries to determine whether the projects in Scotland could be considered to be market leading. As assessment is made of the level of innovation that exists within these projects and how that compares to similar projects in the target market countries outlined by Scottish Enterprise.

3) Analysis and recommendations

Following a review of the exemplar projects and the international markets, an assessment is made of the opportunities and threats in each of the international markets to determine a priority for the target countries as a focus for Scottish companies.

Scope – Phase 2

Following an identification of the market leading SLES projects in Scotland, an assessment has been made of the potential market size

Phase 2 of our analysis, provides an estimate of the market size of the leading projects across three different markets:

- UK market
- EU market
- Global market

From this analysis, interventions that Scottish Enterprise and Highlands & Islands Enterprise could consider are provided.

Methodology

The following report details the work completed by Ricardo Energy & Environment under contract to Scottish Enterprise.

This report covers the following sections

1. Task 1: Existing Scottish project activity and Scottish capabilities
2. Task 2: Smart Local Energy Systems activity across the world
3. Research Analysis

Following the initial phase of the work, we completed an assessment of the market size

4. Phase II – market size

Task 1: Existing Scottish project activity and Scottish capabilities

Methodology – Scottish project activity

Task 1a: Review list of Scottish projects

Source of projects

- Scottish Enterprise project database
- Local Energy Scotland LECF, IIF, grant funding project summaries
- Low Carbon Infrastructure Transition Programme project summaries
- Web based research and input from Ricardo team
- Total of 236 projects

Definition of typologies – update for this study

Title	Scottish Examples	Definition criteria
Islanded rural community	Gigha, Fair Isle, Colonsay, Orkney, Shetland, Lewis & Harris	Geographically separated from the mainland, although could be electrically grid connected
Remote green village/ remote rural village	Tomintoul, Brora, Lochgilphead	Low Population <10,000
Off grid green town	Oban, Stranraer, Keith	Not connected to gas grid Low Population
On grid commuter town	Kirkintilloch, Penicuik, Forfar	Medium Population > 10,000 Close (definition varies between country) to Large Population
On grid industrial town	Kirkcaldy, Ayr, Stirling	Medium Population > 10,000 Evidence of industrial activity
Large urban	Glasgow, Dundee, Livingston	Large population > 50,000
Industrial Park/Campus	Grangemouth, A1 industrial park, Universities	Industrial park, university campuses, business parks, hospital campuses. Campuses that might sit behind a single transformer. On gas grid

In this study, we utilised the previous typology terminology developed for Scottish Enterprise, however the same definition of the typology was not applied. The previous typology definitions includes 14 categories, across 4 bands (see Appendix). We have not applied the same banding here as all the data for each of the categories is not available across many other countries.

Methodology – Project categorisation

Initial proposed methodology to categorise projects to determine whether they could be considered “Best in Class” included:

- Project budget (provides an indication of total value and GVA to Scotland)
- Level of grant funding (indication of state of market)
- Proposed commercial model (as Govt. funded, then not expecting these to be commercially viable at present)
- Level of innovation (TRL)
- Project outcomes (eg carbon savings, cost savings, number of consumers benefiting)
- Project stage (feasibility, development, construction, operation)

In our original proposal, these factors were to be used to assess each project to determine whether these could be considered “Best in Class”.

As this information was not available across all of the projects in any online material or reports provided by Scottish Enterprise, Scottish Government, Local Energy Scotland or the projects contacted, an alternative methodology for categorisation was used, relying more on Ricardo technical expertise and knowledge of the market.

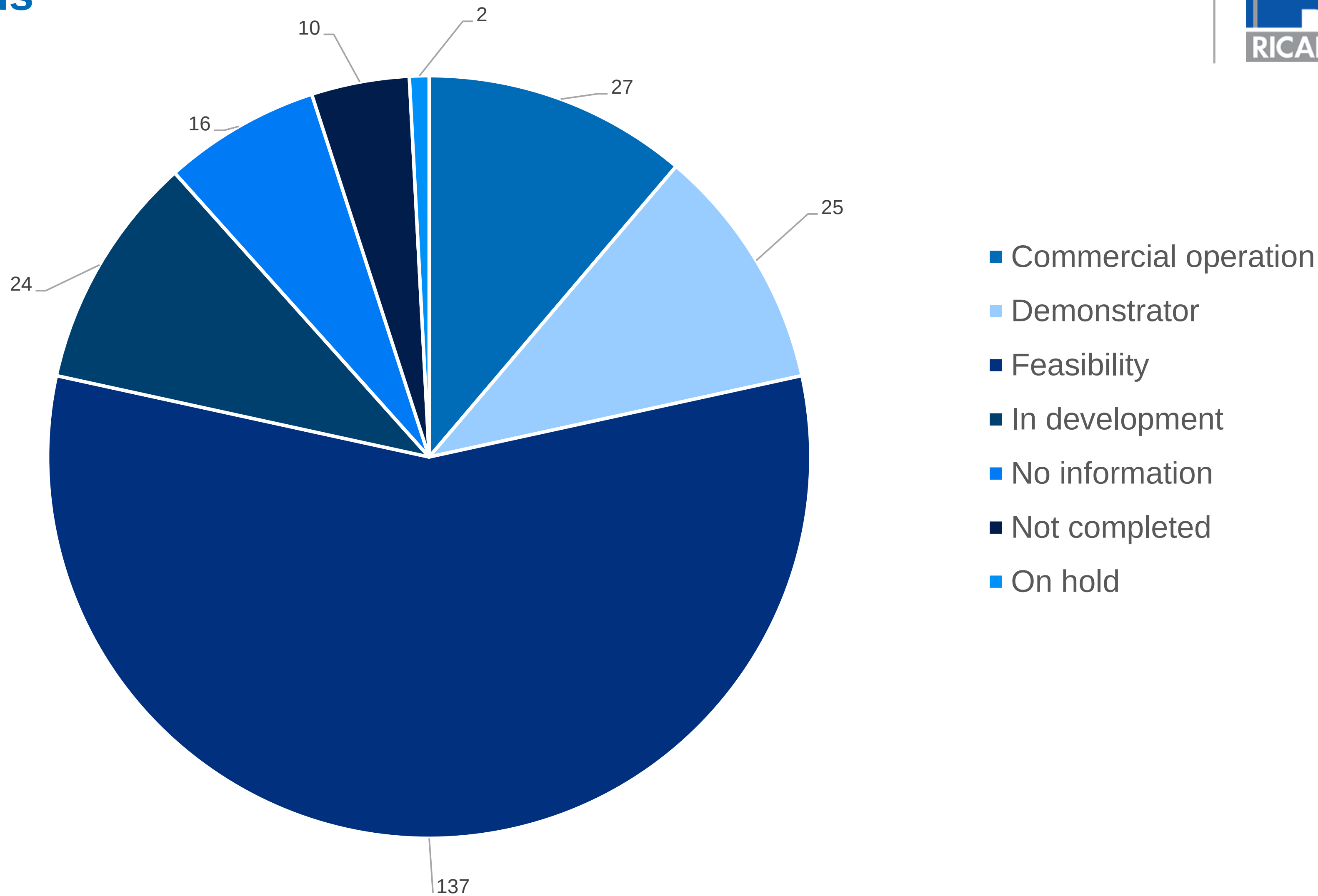
Methodology – Project categorisation and screening

Project status

- **Feasibility**: this covers any funded studies that are developing project concepts, options appraisals, market research. As largely desk based studies, these were not considered further. There may be useful UK market information in these projects that could be used to determine potential project opportunities
- **In development**: the project has been approved and awarded funding and is in planning, procurement, construction. Where it was considered there was a level of innovation, these projects were considered
- **Demonstrator**: project is operational, with support from public sector (ie grant funding). Successful delivering of this project may results in a commercially viable proposition. These projects were considered further.
- **Commercial operation**: project is operating commercially, with examples of similar projects such as this being delivered elsewhere in the UK or internationally. These projects were considered further.
- **No information**: minimal information provided on the project eg project name, but no further information on the scope or status of the project. These projects were not considered further.
- **Not completed**: project is no longer being taken forward. These projects were not considered further.
- **On hold**: project was successful in gaining funding, however is not progressing any further than current status. Information on the reason why was not reviewed. These projects were not considered further.

The accompanying spreadsheet detailing the project status is available with this report.

Project status

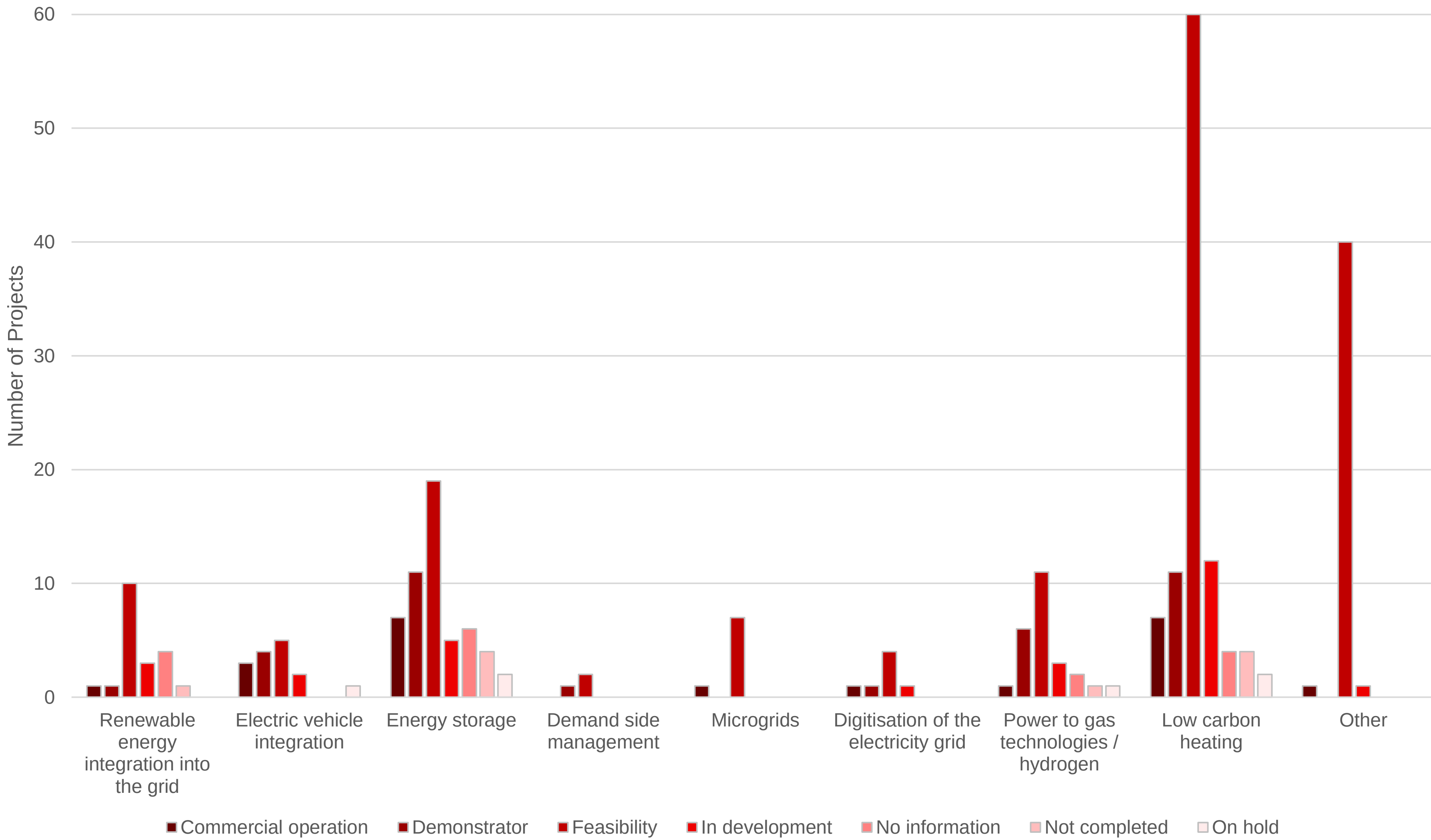


Note: This does not represent all of the feasibility studies that have been completed on projects that end up in commercial operation or demonstrators, as we did not have all feasibility studies across all potential funding routes eg LCITP, Ofgem NIC, SE/ HIE funded studies. This only includes feasibility studies provided by Scottish Enterprise and Local Energy Scotland

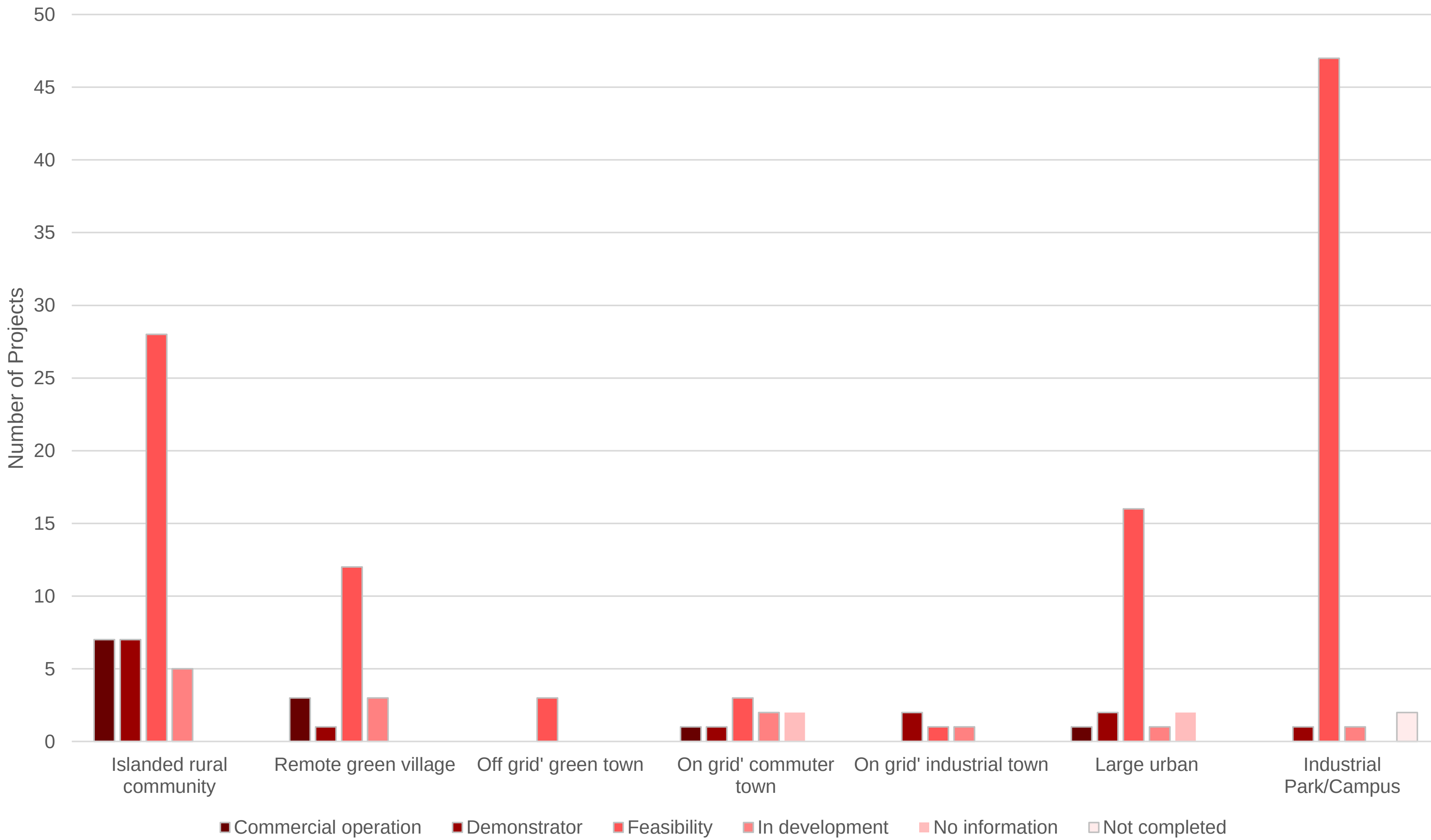
Project status

Summary

- Of the 241 projects reviewed, 137 were feasibility studies so were not considered further (focus here is on capital projects). We therefore reviewed available information on 88 projects (37% of the total projects identified).
- 52 projects are currently operational (27 commercial operation, 25 demonstrator).
- There are another 24 projects in development that once completed could be revisited to determine their potential for replication
- 10 of the projects were not completed. Of these a number had been awarded capital funding. Some information is available on why they did not progress
- The operational projects had not all been operational for long enough to confirm they were operating as expected in terms of performance and efficiency, so assumptions were made about the success of this.



Note: Projects that include more than 1 technology are shown multiple times, so more than 241. The number of district heating projects identified in operation or demonstrator is 9.



Note: Projects that include more than 1 technology are shown multiple times, so more than 241.

Project status – by technology area

Summary

- Energy storage counted for the largest number of projects in commercial operation or operating as a demonstrator, closely followed by low carbon heating
- EV integration is the next largest number of capital projects
- Only a small number of other capital projects across different technologies
- The “other category” capital project is Xanthella. This project uses power to supply LEDs that are used in a photoreactor to produce algae.

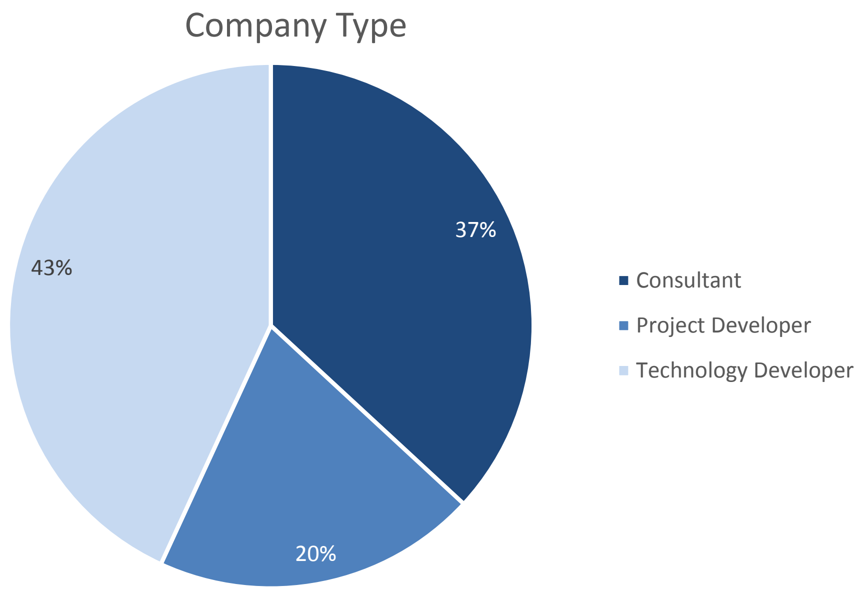
Methodology - Scottish Capabilities

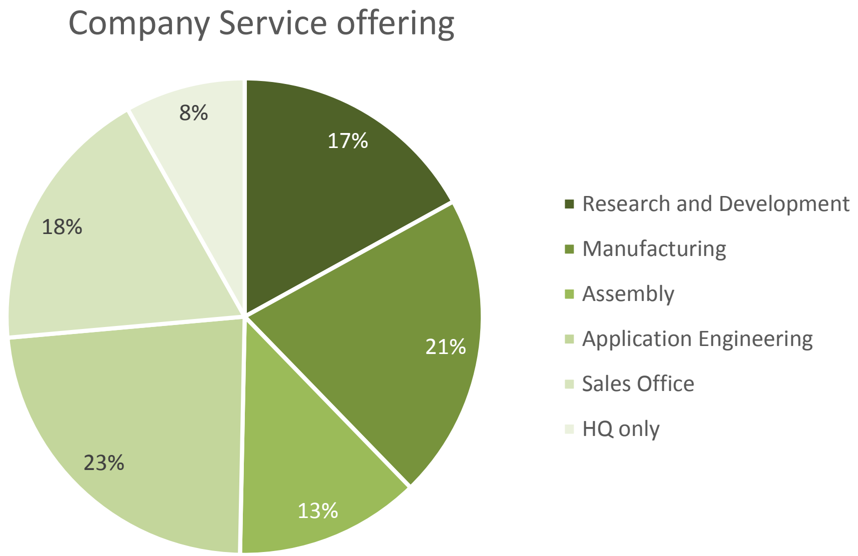
Task 1b: Review list of Scottish companies active in local energy sector

- Initial company list provided by Scottish Enterprise
- Screened against SII to identify any potential missing companies
- Categorised Scottish Enterprise/ HIE
- Identified companies that have been bought out or insolvent
- Analysis based on web search of company capabilities and experience, so reliant on accuracy of company websites and Ricardo understanding.

Total companies	192
Scottish Enterprise	177
Highlands and Islands Enterprise	15

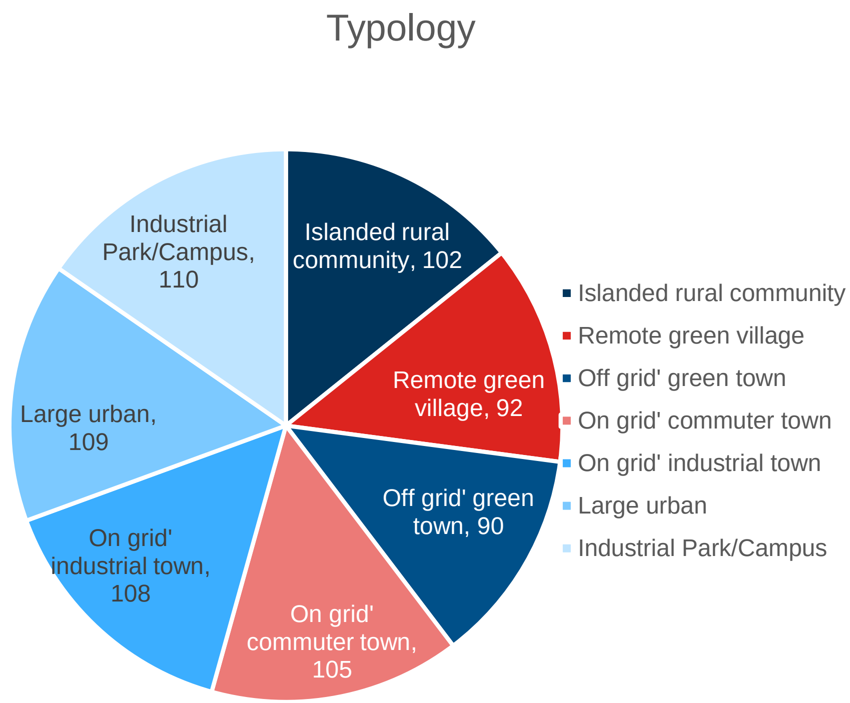
Company capability with Local Energy Systems

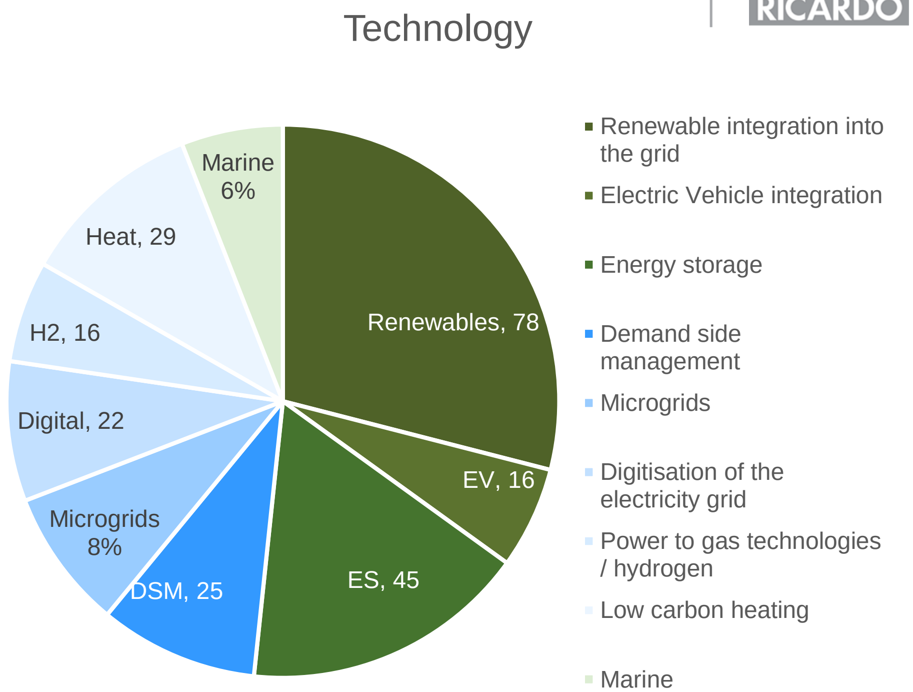




- Accompanying this report is a spreadsheet that categorises over 150 business by company type, service offering, typology that company has experience working in and technology focus.

Company capability – typology and technology





- Each company capability extends across a large number of different technologies and typologies, so the total number of companies in the chart adds up to more than the number of companies assessed
- There is little distinction between company capability across different typologies, largely because companies do not distinguish themselves in such a way
- The number of companies promoting capability in heat was low compared to the proportion of heat demonstrator projects

Task 2: Smart Local Energy Systems activity across the world

Countries Examined

- Canada
- Chile
- China
- Denmark
- Estonia
- Finland
- Ireland
- Japan
- Latvia
- Lithuania
- New Zealand
- Norway
- Russian Federation
- Sweden
- United States

The countries were initially identified in a preceding study as being countries that had a high number of similar typologies to those found in Scotland. As a consequence, they were considered to be potential markets to implement local energy system projects similar to those implemented in Scotland.

Countries Examined Methodology

- Local Energy Systems are considered to comprise a mix of generation and demand of one or more vectors, for example microgrid/ private wire systems, heat from power or transport from power
- In assessing the shortlisted countries to prioritise their potential as a market for Local Energy Systems, the following considerations were made:
  - Local energy system policy drivers such as:
    - Targets for electricity/ heat generated from low carbon sources
    - Targets for EV rollout
    - Targets for smart meter rollout
  - Ease of doing business assessing information from “Getting the Deal Through” (https://gettingthedealthrough.com/)
  - Grid status
    - How integrated the transmission/ distribution network is?
    - What level of investment is expected over the next 5-10 years?

Typology mix: how prevalent a typology is in each country

Meaning	Scale	Marker
Small market	<10	✓
Medium market size	10-100	✓✓
Large market	>100	✓✓✓
Scottish Enterprise focus typology		
No data = to obtain data would require GIS data analysis and identification of		

*Green villages/towns		Marker
>100	Low	✓
100-5,000	Medium	✓✓
<5,000	High	✓✓✓

†Off-gas grids	Marker
Low % of households off-grid 10-20%	✓
medium % of households off-grid 20-50%	✓✓
high % of households off-grid 50+%	✓✓✓

Country Name	Islanded rural community	Remote green village*	"Off grid" green town†	"On grid" commuter town	"On grid" industrial town	Large urban	Industrial Park/Campus
New Zealand	✓	✓✓	✓✓✓	✓	0	✓✓	✓✓
Denmark	✓✓	✓✓	✓✓✓	✓✓	✓	✓✓	✓✓
United States	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓
Norway	✓✓	✓	✓✓✓	✓✓	✓	✓✓	✓✓
Sweden	✓	✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓
Estonia	✓✓	✓	✓✓✓	✓	no data	✓	✓
Finland	✓✓✓	✓	✓✓✓	✓	✓	✓	✓✓
Lithuania	✓	✓	✓✓✓	✓	✓	✓	✓
Ireland	✓✓	✓	✓✓✓	✓✓	0	✓	✓✓
Canada	✓✓✓	✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓✓
Latvia	N/A	✓	✓✓	✓	✓	✓	✓
Japan	✓✓✓	✓✓	✓	✓✓✓	✓	✓✓✓	✓✓
Russian Federation	✓✓	✓✓	✓	✓✓✓	✓✓	✓✓✓	✓✓✓
Chile	✓✓	✓✓	✓✓	✓	✓	✓✓	✓
China	✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓

The cells highlighted in yellow are those that were highlighted by Scottish Enterprise as key target typologies for Scottish companies

Canada

Policy Drivers

- GHG reduction targets: 40% by 2030, 80% by 2050, relative to 2005 levels.
- 50% Renewable Energy (RE) integration by 2030 (Currently 17.4%)
- FITs (Ontario only)
- 30% EV sales by 2030 – current EV sales are 0.59%
- Renewable energy and heating/cooling targets are set at a sub-national level.

Network Context

- Mains supply @ 120VAC / 60Hz
- North American Grid (35 interconnectors with USA)
- 250 Inhabited islands. Many undersea cable connections.
- 291 remote (off grid) communities – 251 diesel generators
- Transmission and distribution infrastructure needs $98.1 billion by 2030
- 49% smart meter penetration.

Smart Local Energy Systems

- Leader in Smart Grid technology (large supplier base) – list of top 10 suppliers provided in the Appendix (potential inward investment opportunities)
- Set of standards for smart grid development – setting a roadmap from the government on the integration of smart grids into Canada, sector leading as only a few other countries have set standards.
- Vision: Network of smart microgrids – 10 research institutions, 8 utilities and 24 technology providers/end customers to install smart grid infrastructure.
- 20 finalists in Smart City challenge – a government led competition that gave financial rewards to cities that had adopted smart city initiatives. First prize - $50 million CAD, 2 prizes of $10 million CAD and $5 million CAD for cities with populations <30,000.
- 5 example Island Energy Systems: Ramea (using wind and diesel to fulfil demand, excess electricity is stored as hydrogen), Lasqueti (uses solar, wind, micro-hydro and diesel generators for power), Prince Edward Island (25% of electricity supplied via wind, proposing new wind projects for 2019), Lasqueti (installed solar, diesel and battery hybrid system with prototype “smart control”) and Wolfe Island (location of 86 2.3MW wind turbines).

Chile

Policy Drivers

- 30% reduction of GHG emission intensity of GDP below 2007 levels by 2030. Chile's current mitigation is insufficient to meet this target.
- Renewable Electricity targets:
  - 60% by 2035 and 70% by 2050
  - Currently 46% (10,910MW, 2018).
- Electric vehicles, by 2050:
  - 40% of private vehicle fleet
  - 100% of public vehicles
- Feed in Tariffs – Agreed upon a case-by-case basis, price is determined by the market.
- Chile is promoting the use of biomass district heating projects funding $38 million in projects. DH included in Chilean National Decontamination Plan and Presidential Plan.
- In a competitive market, lower costs are the primary driver of energy system change, Chile offers tax relief for RE generation.

Network Context

- Mains supply @ 220VAC / 50Hz
- Two separate distribution networks
- Electricity demand forecast to double over 20 years.
- Extension plans for grid expansion and reinforcement to support RE, adding over 6,200km of transmission line and 24,700 MVA of transformer capacity.
- Transmission and distribution infrastructure investment of USD 7.5 billion over 10 years
- Current transmission network constraints restrict renewable generation at peak power.
- Very competitive market – 98 zonal projects competitively tendered in Oct/Nov 2017.
- 395MW of distributed generation (<12MW) compared to total 23,718MW total
- Limited storage
- Mining represents 30% of total electricity demand.

Smart Local Energy Systems

- Smart City Santiago (Smart meter roll out underway): 50,000 smart meters installed, conducted by Chilectra, a distribution company in Santiago and Enel Group (Italy). Chilean Government mandated the deployment of 6.5million smart meters up to 2025.
- 2 examples of Island Energy System: Easter Island plans to install solar PV to aid agriculture activity and Chiloe Islands – cleared to build 42 wind turbines an investment cost of $250 million US.
- 1 example of isolated town microgrid: Ollagüe, a smart microgrid, power management and energy storage system utilising wind, solar and diesel generation.
- > 100 electric buses in operation in Santiago.

China

Policy Drivers

- China aims for renewable energy to make up 35% of its energy mix by 2030. In 2017, renewables made up 26.4%.
- Reduce carbon intensity of its GDP by 40-45% by 2020 (relative to 2005).
- Government has introduced a policy dictating 12% of vehicles manufactured in China must be electric vehicles.
- Wind FiT - price depending on wind endowment of the region EUR 0.052 – 0.062/kWh.
- China aims to increase its renewable heat consumption by 200% (95 Mtoe) as part of the Government's 13th Five-Year Plan (2016 to 2020) - through solar thermal, geothermal and biomass.

Network Context

- Mains supply @ 220VAC /50Hz
- Current smart meters installed is estimated around 330 million units.
- SGCC and CSG are in control of almost all power transmission and distribution across China.
- SGCC has developed infrastructure development plan to make the grid more accessible to RES sources.
- SGCC and CSG to make a combined investment of £188 billion (1670 billion RMB) in the Chinese power grid between 2016 and 2020.
- 433 inhabited islands.

Smart Local Energy Systems

- Sino-Singapore Eco-City Smart Grid Demonstration Project – a prototype of potential future smart grid services in cities.
- The State Oceanic Administration has set a goal to increase research and development in ocean installations, such as tidal, to be integrated with solar PV as part of microgrid systems for islands.
- Woody Island (Yongxing Island) has an microgrid system made up of diesel generators and solar PV.
- Many other smart energy system examples however, information is difficult to obtain.

Denmark

Policy Drivers

- GHG reduction targets: 20% reduction by 2020 compared with 2005, 80-95% GHG reduction by 2050 compared with 1990 levels.
- 30% RE by 2020, 50% by 2030 (Currently Renewable Electricity RE-E, 43.4%)
- FITs (being phased out)
- Danish government developed a plan so that 100% of the country's electricity and heat will come from renewable energy by 2035. In 2014 50% of all district heat was produced from renewable sources.
- No specific EV target, but a target of 70% reduction in transport emissions.

Network Context

- Mains supply @ 230VAC / 50Hz
- DSO invest 2bn DKK/year in electricity infrastructure.
- 73 inhabited islands.
- Denmark has taken part in 22% of all smart grid projects in the EU and has a demonstration budget of EUR 1 billion.
- Denmark has 225 Smart Energy Projects.
- Smart meter penetration rate of 80% of all households. Aims for 100% by 2020.

Smart Local Energy Systems

- Denmark leading in the smart grid sector in the EU, with 80 smart grid projects.
- Large supplier base (174 companies)
- 2 Smart City projects: Frederikshavn aims to be 100% renewable and Aarhus plans to be carbon-neutral by 2030.
- 3 example Island Energy Systems: Samsø (100% electricity and 70% heat supplied by renewables), Faroe Islands (aim to become independent from fossil fuel in 2030) and Bornholm (goal to become 100% renewable through integration of wind turbines, biomass and district heating).

Estonia

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- By 2030, Renewable Energy at 50% of domestic electricity and 80% of the heat generated in Estonia.
- FITs – 0.0537 €/kWh for 12 years.
- No specific target for EV but aims that share of renewable fuel increases in the transport sector.

Network Context

- Mains supply @ 230VAC / 50Hz
- Depends on Russian Grid until 2025: relies on energy imports from Russia, aims to transition to European grid post 2025.
- Major programme of network strengthening underway, implemented by Elektrilevi - Estonia's largest network company - who are investing €40 million.
- There are around 20 inhabited islands.

Smart Local Energy Systems

- Estonia has many on-going R&D smart grid projects, including smart street lighting, a cross-border smart city demo lab and smart house competence test centre.
- Manufacturing base: ABB Diesel / Wind Generators.
- Energy trading (blockchain) project underway. First of its kind in Europe and will connect renewable energy producers to the Estonian Smart Grid.
- 1 Smart City project: SmartEnCity project in Tartu, the goal is to make the city environment smart and sustainable and make the project replicable in other European cities.
- 3 example Island Energy Systems: Saaremaa (led by industry investments €3.5 million in solar) Hiiumaa (plans to develop a 700-1,100 MW offshore wind farm) and Muhu (utilises biomass district heating systems)

Finland

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- Increase RE from 40% (current level) to 50% by 2030.
- FITs – Finland is replacing its tariff scheme with an energy tender for 1.4TWh of wind, solar, biomass, biogas and wave power, the government will support the wining schemes for 12 years at EUR 30/MWh.
- Finland has the target of 47% of heating and cooling supplied by renewables by 2020. Currently 20% of all primary energy comes from biomass.
- EV target of 250,000 by 2030, current number around 2,500.

Network Context

- Mains supply @ 230VAC / 50Hz.
- Fingrid is investing €1.2 billion/year 2017-2027.
- 25,000+ island communities although many connected via roads.
- Finland has over 3.5 million smart meter points.

Smart Local Energy Systems

- Smart Grids and Energy Markets R&D programme – Finland promotes itself as a test bed for smart grid technologies.
- Manufacturing base: 24 companies (CleanTech Finland – provide solutions to environmental and energy-efficiency problems specialising in renewables and smart grid integration)
- 2 Smart City projects in Marjamaki and Tampere; 1 Smart Green Campus at LUT university; 5 Eco-Industrial Parks - Kolenkulma, Rantasalmi, Harjavalta, Jyväskylä and Uimaharju; 3 Green Towns – Henna, Bromarf and Eco-Viikki.
- 1 example Island Energy System: Aland an island with a target to become carbon-neutral by 2051, by introducing wind, smart grids, 40% of heat supply already is delivered through DH.
- Many smart energy projects, such as the LEMENE smart energy system in the city of Tampere. The project has set up a medium voltage network and electrical storage system for an industrial district of 300 companies.

Japan

Policy Drivers

- GHG reduction targets: 25.4 % reduction by 2030 compared to FY 2005, 22-24% RE (Currently 10% RE-E)
- FITs – The Japanese Government supports solar, wind, geothermal, hydro and biomass FiTs.
- No specific heating target but a consensus to increase the renewable share of heating supply.
- EV share of new car sales of 50 ~70% by 2030 (currently ~1% market share).

Network Context

- Mains supply @ 100VAC - split between 50Hz & 60Hz.
- Major grid investment projects underway. Small transmission network.
- 430 inhabited islands
- Ministry of Environment has a budget of $7 million USD per year to develop microgrids that will improve overall system reliability, enhance RE and energy storage integration and incorporate EVs.
- 35.3% target for smart meter coverage by 2030.

Smart Local Energy Systems

- Equipment suppliers: Hitachi and Mitsubishi.
- 2 example Smart City projects –Kitakyushu – commercial and residential smart grid using DH, wind, solar, and hydrogen. Fujisawa – smart grid servicing 600 houses and 400 apartments using solar, heat pumps and hydrogen generator.
- 3 example Island Energy Systems; Yokohama and Nii-jima – demonstration project using battery storage supplied by solar PV and wind and also utilises heat pumps; Okinawa – Uses mix of solar (3 ‘mega’ solar fields), wind and waste heat generators (6 generators across Okinawa).
- “Dozens of Towns go off grid” (microgrids) after 2011 Earthquake/Tsunami – plan to develop microgrids within cities to decentralise power supply.
- APEC an R&D company to facilitate and increase the use of new and renewable energy technologies in the Asia-Pacific area. Supports the Energy Smart Communities Initiative and aims to double the share of renewables in the energy mix by 2030.

Latvia

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- RE 40% by 2020 (37.2% in 2016) – 60% RE-E by 2020 (RE-E 54.7% in 2016)
- FITs – Scheme is currently ‘suspended’ until the end of 2019.
- By 2020 53% of total heat consumption met by renewable sources.
- 150 EV charging stations to be installed by 2020.

Network Context

- Mains supply @ 230VAC / 50Hz
- Depends on Russian Grid until 2025: relies on energy imports from Russia, aims to transition to European grid post 2025.
- Major programme of network strengthening underway. The programme encompasses the reinforcement of current grid and the establishment of new connections wit neighbouring countries.

Smart Local Energy Systems

- Government aims to equip 80% of consumers with smart meters by 2020 and 100% by 2023.
- Smart Grid and Renewables Technological Park (limited info).
- 1 Smart City project (Riga) aims to increase use of DH, use smart grids and increase consumption of renewable energy.
- No Island Energy System identified (20 islands listed).

Lithuania

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- 80% of its total energy demand with renewables by 2050 (27% now), 45% by 2030.
- FiTs – new programmes to be introduced in July 2019, introducing a fixed feed-in premium.
- 90% of DH to be supplied by RES by 2030 and 80% of household heat consumption supplied by RE by 2030. Currently 46.1% of heat is supplied by RE.
- Plans to install 4,000 publicly accessible EV charging stations by 2020.

Network Context

- Mains supply @ 230VAC / 50Hz
- Depends on Russian Grid for main interconnectors until 2025
- Relies on energy imports from Russia, focusing on transition to European grid post 2025
- Major programme of network strengthening underway.
- €3 billion investment 2014-2020 – to enhance functions of the grid – distributed generation, monitoring, control, energy storage and electric vehicles.
- Lithuanian Governments national plan to increase the country's energy independence by increasing share of RE.

Smart Local Energy Systems

- Smart Specialisation Strategy (S3) – strategy to bring together national companies to develop and implement smart grid technologies.
- €200 million Smart meter tender due being installing smart meters in 2020.
- 3 Smart City projects – Vilnius, Kaunas, and Klaipeda – this projects are focused upon giving up-to-date data of the city, such as waste management and air pollution.
- No Island Energy System identified (26 islands listed).

New Zealand

Policy Drivers

- GHG reduction targets: GHG Target 30% below 2005 levels by 2030.
- RE: 90% of electricity supply by 2025
- 55% electricity generated from Hydro in 2013 (98% on the South Island).
- No FITs
- Government program ‘Warm Up New Zealand’ provides a subsidy to homeowners to install insulation and clean heating devices in their homes (invested NZ$340 million)
- Target to have 64,000 electric vehicles on the road by 2021 (currently 12,000).

Network Context

- Mains supply @ 230VAC / 50Hz
- Around $1.6bn/$5bn savings available by 2030/2050 though Smart Grid Technology
- Number of isolated islands, microgrid deployed on the Cook Islands.
- Over 1.75 million smart meters have been installed across New Zealand (covering 70% of homes).

Smart Local Energy Systems

- Green Grids Research Programme, a six-year programme completed in late 2018 – trialling Demand Response, P2P trading and low voltage networks using bi-directional power flows.
- Established supplier base (links to Australia/Japan)
- Auckland and Wellington whose electricity was sourced 80% from RES (60% hydro and ~20% geothermal)
- 3 smart city projects: Auckland – installed sensors to monitor water quality and evaluate traffic;, Wellington – Monitoring congestion; Oamaru Water Treatment Plant.
- 3 example Island Energy Systems; Cook Islands - aims to become 100% renewable by 2020, currently uses solar PV coupled with battery and diesel backup; Tokelau - Large solar production into grid and storage in 60 batteries, part of the Pacific Islands Renewable Energy Project; Niue – Government investing NZ$5 million into solar energy to meet its target 0f 80% by 2025. Biomass account for 68% of energy production, 30% solar PV and solar water heater systems at 2% - however still relies heavily on fuel imports.

Norway

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- 67.5% RE by 2020, 100% RE-E by 2030 (96% RE-E in 2016)
- Hydro accounted for 97.9% of electricity demand in 2015.
- No FITs
- Target to generate 43% of heating and cooling consumption from renewable sources in 2020.
- All new cars by 2025 will be zero emission (currently 200,000 EVs in Norway and plug-in hybrids have 50% market share).

Network Context

- Mains supply @ 230VAC / 50Hz
- 81 Islands (3 populated and isolated)
- 100% smart meter deployment.
- Planned grid investments of ~$17 billion between 2016 and 2025.
- 6 Smart Grid demonstrator projects so far - offering R&D on P2P trading- such as SmartNEM, EYDE innovation centre and E-REGIO.

Smart Local Energy Systems

- E-REGIO – project will analyse, test and validate a new way to implement local energy markets. New markets will be based on energy storage units and flexible assets (funded through horizon 2020).
- Suppliers: Smart Innovation Norway AS (cluster - 70 Companies – export focus)
- Identified 1 Smart City project - Oslo Airport City ‘designing an energy efficient city from scratch’.
- Green Town example – Skarpnes, a development of 20 housing units that utilise wind and solar PV.
- 3 examples of island energy projects; Utsira I and II – 15MW wind farm with hydrogen storage system provides energy for 10 households; Hvaler – smart grid operating on cluster of islands covering 4,300 cottages; Froan – isolated micro-grid using hybrid solar PV and wind generators, supports P2Psystem and funded by horizon 2020.

Russia

Policy Drivers

- GHG reduction targets: 25% by 2020 relative to 1990, 30% by 2030.
- 4.5% RE by 2020, 5% by 2030 (16.9% RE-E in 2016)
- FITs – set at €0.12 per kWh may be increased by 2022 (Government investments of ~ USD 900 million).
- District heating – accounts for 70% of distributed heat, annual investments of US$1-1.5 billion in the modernisation of DH in Russia.
- Aims to increase EV sales to 100,000 units by 2025, 4-5% of overall vehicle sales.

Network Context

- Mains supply @ 230VAC / 50Hz
- 40 sub power systems eastern regions of Russia (microgrids).
- No information on isolated island communities, but 60 islands >30 sq km.
- 300,000 smart meters deployed (Echelon).

Smart Local Energy Systems

- Joint smart grids R&D initiative - Rossetti, Russia and Enel, Italy. Enel will provide expertise in network digitisation with Rossetti whose strategy is to optimise the reliability and network efficiency of 2.3 million km of transmission lines and 496,000 substations.
- Skolkovo Science Park (Smart City) - large number of multinational companies here.
- Increasing demand for electricity generation and storage for off-grid communities, such as Ust-Kamchatski using wind power and microgrid system.
- Smart City project (Moscow) up-to-date information on traffic, public transport and lighting powered by solar.
- Example Island Energy System: The Bering Island – stand alone 550 kW wind-diesel hybrid energy system. Using two Vergnet GEV-MP turbines with automated equipment control and monitoring system.

Sweden

Policy Drivers

- GHG reduction targets: 40% by 2030, 80-95% GHG reduction by 2050 compared with 1990 levels.
- 100% Renewables by 2040. 51.7% RE-E (2016).
- No FITs
- Aims to become free of fossil fuel vehicles by 2030 (currently EVs have 12% market share).
- District heat accounts for 50% of heat demand, renewable supply to increase but market to decline due to increased efficiency of technology and buildings.

Network Context

- Mains supply @ 230VAC / 50Hz
- Nordic Grid: €15 billion until 2025, Sweden SEK 9 billion 2016 and 2019.
- 81 inhabited islands
- Replacement of all smart meters to second generation technology by 2025.
- Government has a smart grid strategy over 2015-2030 for the R&D and implementation of smart grid technologies.

Smart Local Energy Systems

- 6 Smart Grid demonstrator projects so far. R&D on P2P trading
- Suppliers: Smart Innovation Norway AS (cluster - 70 Companies – export focus)
- Major Suppliers: Ventryx (ABB), Schneider Electric
- 3 Smart City projects: Smart City Sweden – national project introducing smart grids, smart mobility, biogas, waste to energy and biomass fuels; Stockholm Lighthouse – aim for the city to become fossil-fuel free by 2040 through smart grids and renewable energy delivery.
- Green Town example: Simris an off grid village running off wind turbine – battery storage system.
- Eco-industrial: Handelo – waste incineration plant sends steam to fuel a grain based ethanol production plant where residuals go back to agriculture for fodder.
- 2 example Island Energy Systems: Gotland, aims to gave a climate-neutral energy supply by 2025, wind meets 45-50% of electrical demand and biofuels supply domestic heating. Oland, a member of the Pact of Islands scheme, has 68 wind turbines with an annual production of 133 GWh. The island aims to become fully renewable in 2020.

United States of America

Policy Drivers

- GHG reduction targets: Was 17–24% below 2005 levels in 2025.
- National Target 20% RE by 2020 (not enforced) (14.7% in 2016)
- US mayors pass resolution to target 100% renewable energy by 2035 – 250 cities passed resolutions to support vehicles electrification, energy efficiency grants and city-driven plans to increase the use of renewable energy.
- No FITs
- Aims for 30% car sales to be EVs by 2030.
- No renewable heat targets at national level

Network Context

- Mains supply @ 110VAC / 60Hz
- Smart Grid: $8bn per year, $1.5 trillion will be required between 2010 and 2030, this includes the installation and distribution of two-way smart meters in homes and the necessary improvements to the distribution grid.
- 95 inhabited islands.
- Around 70 million smart meters installed in US households (~50%of households).

Smart Local Energy Systems

- Recovery Act: provided the Department of Energy with $4.5 billion to modernise the electrical power grid. This focuses on smart grid technologies and energy storage systems. Grant programme, Smart Grid Investment Grant and Smart Grid Demonstration Programme.
- 10 large international suppliers including: ABB, Emerson, GE, Siemens, Schneider Electric, Toshiba …
- 2 Smart City projects: Brooklyn (Microgrid P2P trading) and Burlington.
- 12 Eco-Industrial Parks - Berks County, Pennsylvania - $117 million ceramic tile plant that utilises the gas produced by land fill as fuel.
- 3 example Island Energy Systems: Hawaii – aims for 100% renewable by 2045, already uses DSM with renewable energy and creating a tariff scheme for microgrid owners; Tau (American Samoa) – Tesla installed a microgrid of solar energy panels and batteries to supply nearly 100% of energy for the island’s 600 residents; Kodiak, Alaska - a microgrid with the installed capacity of 75,000 kW, uses combination of wind (16.9%) hydro (82.8%) and diesels (0.3%).

Policy implementation

Country Name	Renewable energy integration into the grid	Carbon Targets	Smart grid strategy/ policy	Low Carbon Heat	Smart Grid R&D	Liberalised electricity market	Electric vehicle integration
New Zealand	✓✓✓	✓✓	✓	✓	✓✓✓	✓✓	✓
Denmark	✓✓	✓✓✓	✓	✓✓	✓✓✓	✓✓✓	✓✓
United States	✓	✓	✓✓	✓	✓✓✓	✓✓✓	✓
Norway	✓✓	✓✓✓	✓	✓✓✓	✓✓	✓✓✓	✓✓✓
Sweden	✓✓	✓✓✓	✓	✓✓✓	✓✓✓	✓✓✓	✓✓
Estonia	✓	✓✓✓	✓✓	✓	✓	✓✓	✓
Finland	✓✓	✓	✓	✓✓✓	✓✓	✓✓✓	✓✓
Lithuania	✓✓✓	✓	✓	✓✓✓	✓	✓✓✓	✓✓
Ireland	✓✓	✓✓	✓	✓✓	✓	✓✓✓	✓
Canada	No Target	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓	✓✓
Latvia	✓✓	✓	✓	✓	✓	✓✓✓	✓
Japan	✓	✓	✓	✓	✓✓✓	✓✓✓	✓✓
Russian Federation	✓	✓	✓	✓	✓	✓✓	✓
Chile	✓✓	✓✓	✓	✓	✓✓✓	✓✓	✓
China	✓	✓	✓✓	✓	✓✓✓	✓✓	✓

Marker	Renewable energy integration into the grid	Carbon Targets	Smart grid strategy/ policy	Low Carbon Heat	Smart Grid R&D	Liberalised electricity market	Electric vehicle integration
✓	25%	25%	Market Driven	Market Driven	<1bn	None/ Early Stage	Low/Early Stage Uptake
✓✓	25-75%	25-75%	Government Led	Government Led	<2-5bn	Partly	Medium Market Penetration
✓✓✓	75%+	75%+	Government Funded	Government Funded	6bn+	Fully	Good Market Penetration

Policy implementation

- In assessing the policies implemented in different countries, we used a grading to determine the level of policy support in the different technology areas.
- The number of ✓ reflects a high level assessment of the potential for the Scottish local energy system supply chain. The IEA database of policies has been used. A detailed assessment of every policy has not been completed to determine whether the level of support makes a particular technology economically viable, however it is assumed that that the presence of government funding in addition to the policy represents an opportunity.
- Where government funded, government led or market led, is an indication of whether smart grid/ low carbon heat are currently funded through implementation grants or tariffs (not including innovation funding), there is a policy driver with no funding, such as emissions trading, or it is left for the market to determine whether a technology is implemented. Funding through grants of tariffs offers opportunities for the Scottish supply chain, if government led, then a relevant policy is in place or market led, then less opportunity.
- ✓✓✓ for renewable penetration and carbon targets, indicates the country has significant targets for decarbonisation and renewables, which potentially links to local energy system suppliers.
- It is the combination of these policies, coupled with the local supply chain, standards that are in place and ease of doing business.
- It is recognised that in China, the level of government support is not necessarily as transparent as in other jurisdictions

Market assessment: relative ranking of market potential: High

RICARDO

Country Name	Opportunities	Threats
Canada	• A global leader in smart grids, with a market lead on implementing standards • A high number of microgrid opportunities • Significant renewable resources (wind, hydro, solar) • Liberalised electricity market • High level of investment in grid infrastructure forecast	• Lots of market competition, especially from US and Canada companies • Local academic, network operator and technology supplier partnerships proposed • Large number of case studies using local supply chain
United States	• Lots of microgrid potential • Significant renewable potential • Liberalised electricity market • Multiple DNOs • Smart grid strategies in place and high smart meter penetration • High levels of grid infrastructure investment required	• Lots of competition (US and Canada) • Lots of case studies • Many different grid standards • Low renewable energy policy targets at Federal level, although strong in some states and cities

These countries, were considered to be those with the highest potential for Scottish companies, considering a range of criteria that were considered on a relative ranking across all countries. The criteria include: policy support (such as RE targets, smart metering, EVs), ease of doing business, competition from local contractors and grid standards. The bandings of the market potential is High (highlighted in Green), Medium (highlighted in Orange) and Low (highlighted in Red).

Market assessment: relative ranking of market potential: Medium

Country Name	Opportunities	Threats
Finland	• Lots of microgrids • Strong low carbon heating and cooling targets	• Government support for smart grid and R&D programmes • Many examples of smart grid and smart city projects
Ireland	• Connected to UK electricity network • Limited local supply base • Strong business links • Strong community energy support	• Limited money available for grid upgrades/ smart grid projects • Lots of grid constraints holding back renewable development
Japan	• Lots of microgrids • Villages suffering blackouts • Strong EV targets	• Business culture • Lots of local competition • Strong political industrial support/ funding for local business • No heating/ cooling targets
Chile	• Liberalised markets • Multiple distribution networks • Relatively strong renewable targets • Strong EV penetration and targets • Developing hydrogen market	• Private sector needs to provide funding • Competitive market • Early stages of grid digitisation (smart metering, DSR)
China	• Large market demand across all technologies • Strong policy support • Feed in tariff • Strong renewable heat targets • Strong EV manufacturing targets	• IP • Difficulty in doing business due to language, cultural and political barriers • State owned distribution and transmission networks • China is taking a leading role in the deployment of renewables as a route to capturing the market for manufacturing

Market assessment: relative ranking of market potential: Medium

Country Name	Opportunities	Threats
New Zealand	• Large renewable penetration • Strong renewable targets • Developed market	• Local suppliers (linked to Australia) • Strong Australian capabilities • Developed smart grid
Denmark	• Large renewable energy penetration • Strong renewable energy targets • High district heating penetration	• Lots of trials of local supply/ smart grid projects • Low GHG reduction targets • Large local supplier base • Many domestic case studies
Norway	• Large renewable electricity penetration • Strong renewable energy targets, particularly renewable heat • Strong EV targets	• Strong R&D and demonstration experience • Large local supply chain • A number of case studies of LES projects with local suppliers
Sweden	• Strong policy focus on renewable heat • Smart grid strategy in place • Large number of islands • Strong EV target	• Strong interconnection with Baltic States • Strong local supply chain • Focus on energy efficiency reducing district heating demand • Lots of local case studies

Market assessment: relative ranking of market potential: Low

Country Name	Opportunities	Threats
Estonia	• Strong policy drivers (heat and power) • FiTs in place • First example of blockchain project in EU	• Reliant on Russian grid until 2025. Focus is on greater EU integration • No EV targets
Lithuania	• Tendering for large smart meter rollout • Isolated microgrid islands	• Reliant on Russian grid. Focus is on greater EU integration. • Limited market information available
Latvia	• Number of islands in Latvia although no island wide energy systems were identified • All households will be on smart meters by 2020, so smart local energy systems could be applied	• Reliant on Russian grid. Focus is on greater integration
Russian	• Although it does have a large district heating infrastructure, it is in need of significant upgrade to be fully operational and less suited to ASHP • Feed-in-tariff in place	• Limited targets for renewable generation • Low EV targets • Commercial agreement with Italian companies to deliver grid upgrades

- These countries all have limited potential for Local Energy System potential over the short to medium term, primarily as their current focus is on greater integration with the European network and away from a reliance of the Russian grid (with the obvious exception of Russia). In the short to medium term, the infrastructure upgrades required to facilitate this are expected to mean there will be limited investment in local energy system projects.

Conclusions

- Dependence on Russian Grid:
  - Estonia, Lithuania and Latvia all currently rely on imported energy from Russia. However, by 2025 these countries plan to consume more energy from the European market. While this offers a potential opportunity, these countries may focus on the development of grid infrastructure and not necessarily the immediate introduction of smart energy technologies.
- Opportunities in North America:
  - The North American market (Canada and the US) offers a large potential for smart technologies due to the ease of penetration into the liberalised electricity market and because of both public and private investment and funding to support renewable energy technologies. However, because of these factors it means that there is also a high amount of competition in the market.
- Chile:
  - Chile can be seen as a good opportunity due to its liberalised energy market and strong renewable targets. Although, there are also many barriers to entry such as high competition, infrastructure not yet capable of supporting new technologies, lack of funding opportunities and also the location and language of Chile itself.
- China:
  - Has potential market due to its large size and government investments in energy infrastructure. A drawback of China is that the majority of the Chinese energy market is controlled by two companies and therefore difficult to enter the market.

Methodology – Project screening

Following the initial screening of project status, consideration was made of:

- **Scottish supply chain content**: level of involvement of Scottish supply chain in the delivery of the project, with a focus on those inputs that would not always be delivered by a local contractor such as manufacturing or design. Local contractors will be involved in development and construction
- **Level of innovation:** in comparison to other countries reviewed.

Projects of interest

Following the assessment of the 261 projects in the list, the following projects met the criteria

- Orkney Smart Grid
- Accelerating Renewable Connections (ARC)
- Northern Isles New Energy Solution (NINES)
- Heat Smart Orkney / SMILE
- H2 Aberdeen (Hydrogen Bus Project)
- Levenmouth/ Big Hit
- Hillpark District Heating
- Queens Quay and Clydebank District Heating Network

Active Network Management

- **Orkney Smart Grid**
  - Using Automatic Network Management (ANM) to manage renewable generation
  - SSEN & Smarter Grid Solutions (SGS)
  - Enabled SSE Networks to add a further 26MW of renewable generation to a previously constrained network. Delivered £30m of savings, with the islands becoming a net exporter of renewable energy.
  - SGS is already exporting with offices in New York and London.

- **Accelerating Renewable Connections (ARC)**
  - Using Automatic Network Management (ANM) to match locally-produced energy with local energy demand.
  - Scottish Power Energy Networks, Smarter Grid Solutions (SGS), Community Energy Scotland & University of Strathclyde
  - More than 160MW of generation was connected over the four years that otherwise would have been put off until Transmission upgrades had been completed.
  - SGS is already exporting with offices in New York and London.

Related projects:

- Dalavich Improvement Group smart hydro
- Dumfries and Galloway
- All DNOs have ANM systems in place

Demand Side response

- **Northern Isles New Energy Solution (NINES)**
  - Using Automatic Network management to undertake Demand Side Management (DSM) in conjunction with Glen Dimplex smart electric heating system to provide space and water heating.
  - SSE, Shetland Islands Council, Hjaltland Housing Association and Shetland Heat Energy and Power, Glen Dimplex
  - Has been successful in meeting both the customer and the networks needs. Lots of issues resolved.
  - The main equipment supplier Glen Dimplex is based in England.

- **Heat Smart Orkney / SMILE**
  - Using Demand Side Response (DSR) to improve grid stability in severely constrained environments by providing intelligent control and aggregation of electric heating systems in homes, businesses and council buildings, as well as EV charging points and hydrogen electrolysers.
  - Sunamp, Routemonkey, Lithium Balance A/S & Vcharge
  - EU funded project – still ongoing. Integrated solution/ model is likely to be exportable.
  - Sunamp is exporting already heat batteries, Vcharge is now owned by Ovo Energy based in Bristol.

Other related projects:

- East Heat

Hydrogen

- **H2 Aberdeen (Hydrogen Bus Project)**
  - 10 Hydrogen buses supported by a hydrogen refuelling station
  - Aberdeen City Council, First group, Stagecoach, SSE, SGN, Hydrogenics, Van Hool, BOC
  - Establishing a state-of-the-art hydrogen refuelling station, Scotland's first commercial-scale hydrogen production and bus refuelling station that will include hydrogen production through electrolysis
  - Funded by 2 EU project (High Vlo City & HyTransit)
  - None of equipment suppliers is Scottish, but potential for Scottish supply chain is being explored.

- **Levenmouth Community Energy Project**: Constructed 2017.
  - Integrates wind, solar PV, hydrogen, refuse collection vehicles and council fleet. Two vehicle refuelling stations.
  - Partners include: Toshiba, Bright Green Hydrogen, Logan Energy, Bright Green Hydrogen, Fife Council, Toshiba, Hydrogenics, Ulemco, Logan Energy, Capstone ASG, Forster Energy, AECOM

- **Big HIT/ Orkney Surf and Turf**
  - BIG HIT uses two proton exchange membrane (PEM) electrolysers. The Shapinsay electrolyser is 1MW capacity and Eday electrolyser is 0.5MW capacity, both located close to the renewable generation assets.
  - Hydrogen as an energy-storage medium which can later be converted back into power for docked vessels (cold ironing) in Kirkwall harbour

Heat Pump District Heating

- **Hillpark District Heating**
  - Approx 400kW Hybrid air sourced heat pump (largest in UK) and gas boiler backup to replace electric storage heaters
  - 313 connected flats in 7 tower blocks.
  - Approximately £200,000 of energy cost savings per year for consumers by switching to district heating
  - Around 19,000 tonnes of CO_2 offset
  - 2,440 MWh heat per year
  - >86% supplied by heat pump
  - Star Renewables, Glasgow Housing Association, local contractors
  - Scottish company with projects in several EU locations
  - Designed and fabricated in Scotland, but heat pump manufactured elsewhere

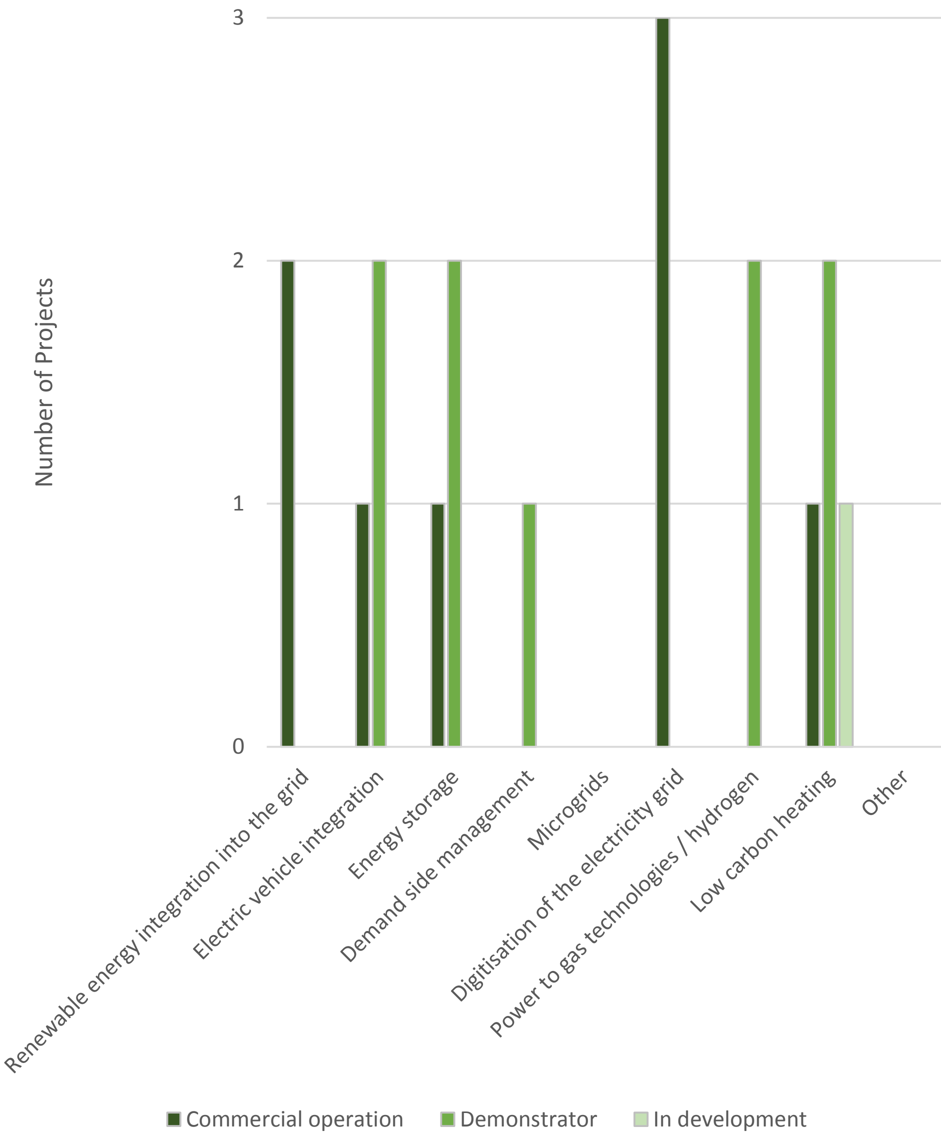
- **Queens Quay and Clydebank District Heating Network**
  - Water source heat pump to provide district heating to Golden Jubilee Hospital, care home, West College of Scotland, domestic properties
  - Star Renewables, Vital Energi

Secondary projects

- **Outer Hebrides Local Energy Hub:** Funded in 2016. Concluding 2019. Wholistic approach to island energy system linking wind generation, fish processing, hydrogen, AD, biogas, refuse collection. Innovation lies in the integration of multiple energy vectors. Project led by Community Energy Scotland. Final report expected by end of March 2019. Uncertainty about Scottish supply chain involvement. LECF funded
- **The Fair Isle Unified Low Carbon Electricity Storage and Generation Project:** constructed 2018, 3 x 60kW wind turbine, storage system, dump loads to provide heating, fly wheel and solar generation to help meet the island's energy needs. Provides 24 hour electricity supply. Project led by Arcus and SSE Contracting. Partners include Scottish Water, Shetland Island Council, National Trust for Scotland, Fair Isle Bird Observatory. Innovation is low, but strong example of collaboration across different sectors
- **Canna Renewable Energy and Electrification Project (CREE)** . Similar to Fair Isle, as an upgrade to the electricity system. Theoretically >80% of electricity from renewables (wind, solar, storage). Project led by Community Energy Scotland, turbines by SD Wind Energy. Inverters supplied by Wind and Sun. See also EIGG

Secondary projects

- **Smart Marine Energy Storage**: Funded in 2018. The project will install, commission, operate and demonstrate the REStore system at the Shetland Tidal Array. Integrating Nova Innovations tidal array on Shetland (3 x 100kW turbines) with a Tesla battery to timeshift electricity supply on Shetland. Innovation around integration of marine and storage and potential ability to provide base load to the island. Uncertainty around performance as project is in development.
- **East Heat**: Funded 2015. Solar PV and Sunamps phase change heat storage batteries installed in >600 properties. Theoretically lower cost heating and water, when charged by solar PV or low tariff electricity. Edison Energy and Sunamp primary contractors. Uncertainty around performance.
- **Levenmouth Community Energy Project**: Bright Green Hydrogen, Fife Council, Toshiba and Logan Energy implemented this project combining wind and solar generation on a campus to produce hydrogen to be used in transport. Hydrogen therefore provides a means of storage.
- **Shared Active Network Management**: This partnered two generators to be able to share grid capacity, relieving grid constraints, utilising Smarter Grid Solution’s technology. This could equally apply to partnering generation and demand across the same part of the distribution network


Number of Projects
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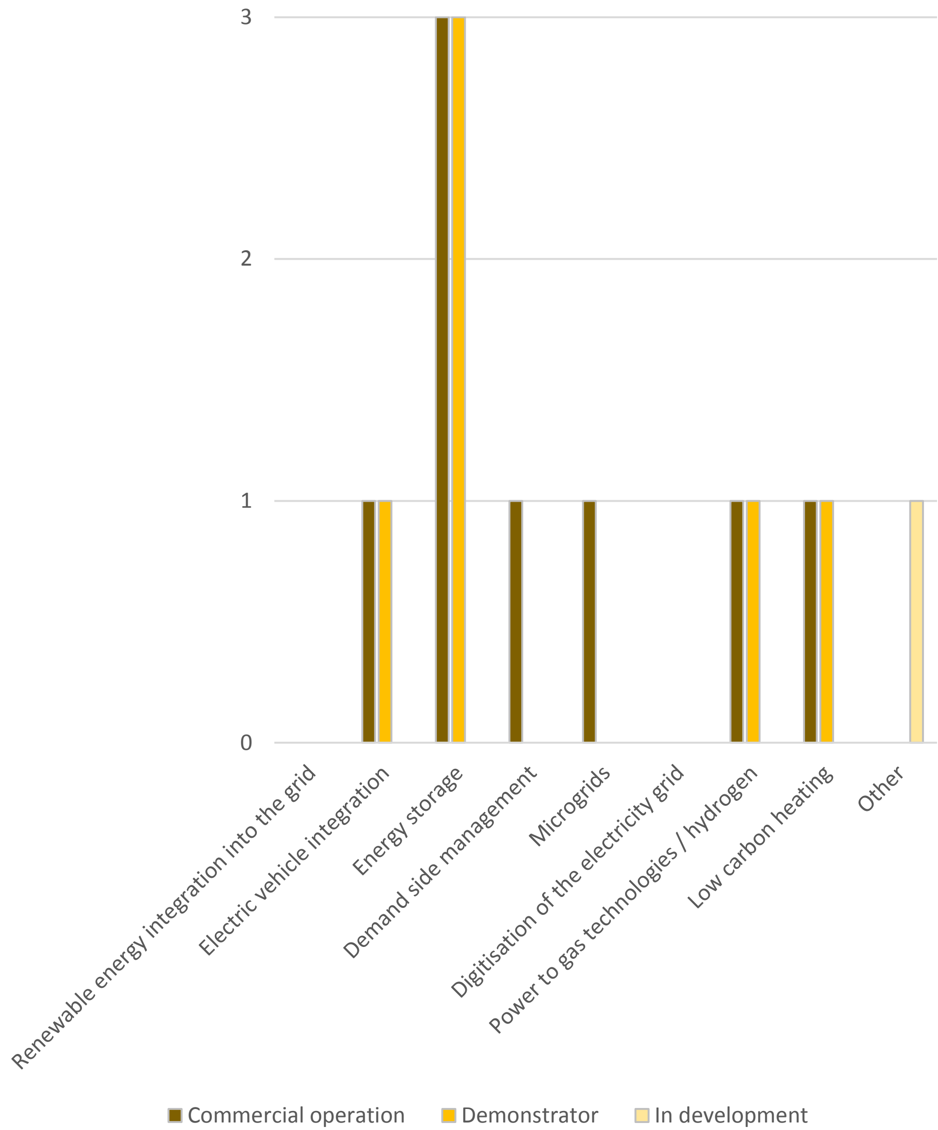
Renewable energy integration into the grid
Electric vehicle integration
Energy storage
Demand side management
Microgrids
Digitisation of the electricity grid
Power to gas technologies / hydrogen
Low carbon heating
Other
Commercial operation
Demonstrator
In development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Energy storage
Demand side management
Microgrids
Digitisation of the electricity grid
Power to gas technologies / hydrogen
Low carbon heating
Other
Commercial operation
Demonstrator
In development

Scottish Projects Typology mix

Country Name	Islanded rural community	Remote green village*	“Off grid” green town†	“On grid” commuter town	“On grid” industrial town	Large urban	Industrial Park/Campus
H2 Aberdeen (Hydrogen Bus Project)							
Accelerating Renewable Connections (ARC)							
Hillpark District Heating							
Orkney Smart Grid							
Heat Smart Orkney & SMILE							
Northern Isles New Energy Solution (NINES)							
Outer Hebrides Local Energy Hub (OHLEH)							
Fair Isle Unified Low Carbon Electricity Storage and Generation Project							
REStore Demonstrator							
Shared Active Network Management							
Canna Renewable Energy and Electrification Project (CREE)							
East Heat Project							
Levenmouth Community Energy project							
Eigg Electric							

Primary Projects that demonstrate most potential for Scottish supply chain

Secondary projects that have some potential for Scottish supply chain

Typologies that the project has been demonstrated in

Additional typologies that might be suitable for implementation

Scottish Projects Typology mix

- From the project list, it is clear that the largest proportion of projects appear across Scottish islands (8 out of the 15 demonstration projects). This is likely to be for a number of reasons:
  - The balance between energy generation and demand on an island is more critical, so this is a focus for communities on the island to identify ways to manage this and organisations supporting these communities
  - It can be easier for an island to agree to take action, as an urban area may need a council (or other agency) to act, where there might not be the same degree of focus
  - On these microgrids, some of the technologies that are implemented (such as demand side response) are relevant for other typologies, however others (such as fly wheel grid balancing are less relevant). As a SLES approach is being taken here, if the whole SLES is not applicable is has not been considered for other typologies
- For some technologies, the typology analysis does not apply well, as there is no direct link between the outputs from the technology and the typology. This might apply to ANM, where the technology is closely linked to the location of renewable resources
- For some projects, it is specific typology criteria that influence their suitability (for example district heating and heat/ population density)
- Some projects (such as hydrogen projects) require a more significant development in the market globally to be transferrable to other typologies than others (such as ANM/ ASHP, which are already commercial technologies) so there will be levels of innovation funding required in an market for them to be replicated in that typology.

Discussion on typology approach for market assessment

The following observations are made about the analysis using typologies:

- The original definition of a typology is very specific, across 14 different criteria. To use such a specific definition requires a significant amount of data analysis. For some of the criteria, this data is not easily available (in some countries it is unlikely to be available)
- Typologies are an easily recognisable description, however can have slightly different definitions for each audience if they are not familiar with the detail
- As typology analysis is not used widely across the markets assessed, then proxies were identified. These proxies are often technology focussed
- There are additional factors to consider when looking at the market. The PESTLE approach to market analysis includes Political, Economic, Social, Technological, Legal and Environmental factors. The typology approach overlaps in some of these factors, but does not cover all. Some of these factors have been included in this study
- Typologies take no account of the potential customer or funder for a project. This could be related to the Political or Economic factors which will influence the appropriateness of a project within a typology
- SLES require a number of different stakeholders, often across different sectors and demographics (communities/ businesses/ local authorities) which is not captured by typology analysis

Typology definition stakeholder discussions

Discussions were held with 3 companies to understand their views on the typology approach:

- Large multinational equipment supplier moving into new sectors: the typology approach was considered a useful tool for taking a holistic approach to the energy demands within an area. The equipment supplier might consider such an approach, although did consider the amount of resource required to complete analysis in this manner would be high
- Large environmental consultancy: would not complete any typology analysis themselves when looking at new markets as normally considers specific project opportunities by looking at resource, environmental and planning considerations
- Small environmental consultancy: most new business comes from repeat customers, or recommendations.

This feedback is obtained from short discussions about the typology approach. The main conclusion that could be drawn from this is that different companies have very different approaches to identifying new business opportunities, using a more focussed approach suited to their own requirements.

Smart Local Energy Systems case studies

Scottish Enterprise requested examples of case studies of smart local energy systems from the selection of countries reviewed as part of this study. Given the large number of case studies across different technologies and typologies, the subset shown presented here include an example from each of the typologies, covering some of the technologies that have been demonstrated in Scotland.

In the Appendix, we include a long list of additional case studies that are of relevance.

Okinawa, Japan – Smart Energy Island Projects

A programme to support and diversify energy supply, improve energy self-sufficiency and reduce dependency on fossil fuels. Okinawa are collaborating with Hawaii to implement microgrids, EVs, biofuels and energy recovery technologies onto the Islands. Okinawa also provide supply chain support across the Pacific and SE Asia.

- **Typology:** Islanded rural community
- **Technology:**
  - Three 'mega' solar fields; Fukuzato, Miyakojima (4,000kW) Okinawa Electric Power Co; Abu, Nago (1,000kW) Okinawa Electric Co; Ikehara, Okinawa (2,000kW) EcoLumiere LLC. The solar arrays are integrated with wind turbines.
  - 6 waste heat generators; Naha-Haebaru Clean Centre (8,000kW, stoker and melting furnace); Ecotopia Ikehara (6,000kW, fluidised-bed gasification melting furnace); Mishima Clean Centre (3,000kW, direct gasification melting furnace).
  - Micro grid system in Miyako island that is 100% self-sufficient through integrated smart grid.
- **Cost and funding:** A pilot project for micro-grid systems on small islands began in 2009. The project aims to improve grid stability and install battery systems. Project budget was $60 million and was funded publicly and privately by the Ministry of Economy, Trade and Industry and private electricity companies Kyushu Electric Power Company and Okinawa Electric Power Company.
- **Objectives:**
  - Objectives set for sourcing 22-24% of power from renewable technologies by 2030.
- **Companies involved:**
  - Hawaii-Okinawa Project Team for Environmental Energy
  - Kyushu Electric Power Company
  - Okinawa Electric Power Company

Isles of Scilly, UK – Smart Energy Islands Programme

The Isles of Scilly has integrated a central IoT Platform to enable the ongoing deployment of energy infrastructure by balancing local energy generation and consumption.

- **Typology:** Islanded rural community
- **Technology:** 450kW of solar PV and Home Energy Management Systems devices deployed on 100 social houses. 10 Smart Homes with a mixture of Air Source Heat Pumps and batteries have been constructed.
- **Cost and funding:** Partly EU-funded through the European Regional Development Fund and the Business Energy Efficiency Scheme financed by HM Government. Overall investment cost around £10.8 million.
- **Objectives:**
  - Cut electricity bills by 40%, meet 40% of energy demand through renewables and see 40% of vehicles be low carbon or electric by 2025.
- **Companies involved:**
  - Moixa, UK (smart battery company)
  - PassivSystems, UK (home energy management system)
  - Hitachi Europe Ltd, Japan (consultancy and lead company)
  - The Duchy of Cornwall, UK
  - Tresco Estate, UK
  - Council of the Isles of Scilly
  - Islands Partership (Scilly)
  - Isles of Scilly Community Venture

Marstal, Denmark – SUNSTORE 4

Marstal is a town in Denmark located on the island of Ærø. This project looked at integrating a 100% renewable district heating system to supply 1,420 users.

- **Typology:** Islanded rural community
- **Technology:** Solar thermal system, thermal storage , heat pump and CHP plant connected to district heating.
- **Cost and funding:** The total budget of the project was €15,102,351 this was partly funded by the EU through the FP7 programme which awarded the project €6,127,548 the rest of the project was self financed and from loans.
- **Objectives:**
  - To demonstrate a technical reliable energy system with 100% RES and a heat production price of 50-55 €/MWh.
  - Individual components shall include ORC (0.75 MW), an electrical driven heat pump (1MW), pit heat storage (75, 000 m^3), innovative solar system (15,000 m^2) and biomass CHP (4MW).
- **Companies involved:**
  - Marstal Fjernvarme (Denmark),
  - Advansor (Denmark),
  - Ambiente Italia (Italy),
  - Bios Bioenergisysteme (Austria),
  - AF-CityPlan (Czech Republic),
  - Energy Management (Sweden),
  - Euroheat & Power (Belgium),
  - Euro Therm A/S (Denmark),
  - PlanEnergi (Denmark)
  - Solites (Germany).

Simris, Sweden

A small village in Sweden has become 100% renewable and off-grid through the development of a microgrid to supply the 150 houses in the community.

- **Typology:** Remote Green Village
- **Technology:** The village has hybrid 400 kW ground mounted solar array and 500 kW wind installation that are part of a microgrid. The grid uses smart controls allowing excess generation to be stored locally in an 800 kW battery. The system also gas a back-up generator that runs on hydrated vegetable oil.
- **Cost and funding:** The project has been part funded by the EU's Horizon 2020 InterFlex programme and E.ON whom have both funded 50% of the €3.36 million (SEK 35 million) total project cost.
- **Objectives:**
  - To build and demonstrate capability (technical and commercial) of microgrids.
  - Understand the business of LES, cost drivers, barriers and possibilities.
  - Develop business cases and business models as well as identifying potential customers.
- **Companies involved:**
  - E.ON (Germany)
  - CellCube (Canada)
  - Holtab (Sweden)
  - Coromatic (Sweden)

Kitakyushu Smart Community Creation Project, Japan

Kitakyushu has converted a city district into a smart technology initiative project, covering 120 hectares of brownfield site. The project involves 12 commercial organisations, 5 factories, 26 office buildings, 218 apartment complexes and 6 hydrogen demo-houses.

- **Typology:** Large Urban
- **Technology:** Natural gas CHP (33,000 kW), roof mounted solar power (816 kW), small scale wind turbines (6kW), hydrogen - used for storage, vehicle fuel and electricity production - (113 kW), solar heat (equivalent to 153 kW) and battery storage (565 kW). An energy management system monitors the whole system as a microgrid which is then used for dynamic pricing and incentive programs for consumers to use electricity efficiently.
- **Cost and funding:** The Japanese Government invested £110.5 million (16.3 billion YEN) over five years to develop the project as well as private contributions from various organisations (see below).
- **Objectives:**
  - Create a new energy system in which consumers are active participants and which utilises a Cluster/Community Energy Management System.
  - Aims at 15% peak cut for electricity demand in the area, and, by 2050, a 50% reduction in GHG emission. Housing showed a peak cut effect of around 20% and offices around 9%.
- **Companies involved:**
  - Fuki Electric System (Japan)
  - Fujitsu Electric (Japan)
  - General Electric (USA)
  - IBM (USA)
  - Nippon Steel (Japan)

Other smart-city projects:

- Songdo International Business District

Hayle Marine Renewables Business Park, Cornwall, UK

The Hayle MRBP was developed by the Cornwall Council to promote sustainable business development. The offices and industrial units are built on a brownfield site and for marine renewable companies to sell and develop technologies from**.**

- **Typology:** Industrial park/ campus
- **Technology:** PV array of 1560m^2 that generates over 200,000kWh/yr divided between offices and industrial buildings. Energy management system to distribute energy throughout the business park with maximum efficiency.
- **Cost and funding:** The Hayle HMRBP was developed through collaborative funding with £11.6 million of funding from the European Regional Development Fund, an £8 million investment by Cornwall Council and £4.25 million from the Department for Business Innovation and Skills. Total cost of the project is around £23.8 million.
- **Companies involved:**
  - Midas Group (UK)
  - Cornwall and Isles of Scilly Local Enterprise Partnership (UK)
  - SDS Engineering Consultants (UK)
  - Stride Treglown (UK)
  - Poynton Bradbury Wynter Cole Architects (UK)

Jyväskylä, Finland

Jyväskylä is a city located in central Finland, due to its location the city is not connected to Finland's national gas grid network. Jyväskylä Energy Group –a large electricity and heat supplier- uses biogas from waste pits in the production of electricity and heat delivered through district heating network.

- **Typology:** Off-grid green towns
- **Technology:** District heating network through two CHP production plants with the output of 460 MW, the main supply of energy is through peat, wood and biogas. Real-time monitoring controls to predict supply and temperature controls, to increase efficiency an reduce network losses.
- **Cost and funding:** Finnish Government can provide an investment grant for 15-40% of cost for the construction of biogas plants. Finland also supports feed-in-tariff scheme for bio gas at 83.5€/MWhe + 50€Mwhe heat bonus if 50% total efficiency is obtained.
- **Objectives:**
  - Finnish Government set target to produce 1TWh more biogas by 2020.
  - Finnish Biogas Association has a target to increase biogas production by 3TWh by 2020.
- **Companies involved:**
  - Valmet (Finland)
  - Jyväskylä Energy Group (Finland)
  - Jyväskylä Energiantuotanto Oy (Finland)

Stockholm Royal SeaPort

Stockholm Royal SeaPort is the largest urban development area is Sweden, upon its completion the site will contain 35,000 workplaces as well as 12,000 new homes. Work commenced on the brownfield site in early 2000s and will be fully developed by 2030 covering a 236 hectare site. The project has received an award for best urban development project in 2015 from the C40 Cities Climate Leadership Group.

- **Typology:** On grid industrial town
- **Technology:**
  - Demand side participation and building automation, residential areas accommodate distributed energy systems (solar PV and wind turbines), biogas production and waste management systems are linked into an integrated smart grid system.
  - CHP plant KVV8 in Stockholm supplies 90% of district heating supply – 1,700 GWh of heat and 750 GWh of electricity annually. The CHP unit is powered by biomass which is shipped into the city.
  - Public transport in the area utilises metro, biogas and electric-hybrid buses and commuter boats to the area, as well as electric car charging devices. Industrial waste is removed from the area via boats.
- **Cost and funding:**
  - £2 billion of total investment has been received, City of Stockholm are investing around £116 million.

- **Objectives:**
  - Energy use of 55kWh per m^2,1.5 tCO^2e per person by 2020 and fossil fuel free by 2030
- **Companies involved:**
  - Collaborations of private sector, academia, and local government: Fortum (Finland), Ericsson (Sweden), HSB, Interactive Institute, ByggVesta.

Summary of Case Studies

There a vast amounts of projects worldwide that are deploying sustainable technologies across all typologies. One of the main drivers in implementing these projects is government backing through support, funding and implementing policies that drive the projects to take place.

The larger scale or more advanced implementation of these examples demonstrate that some countries are further progressed than in Scotland.

A theme across most projects is an aim to deliver the sustainable projects efficiently, reliably and low cost to the end consumer, so less focus on the innovation and demonstration.

Projects are delivered from multiple companies from different countries, for instance the SUNSTORE 4 project in Denmark used companies from 7 different European countries.

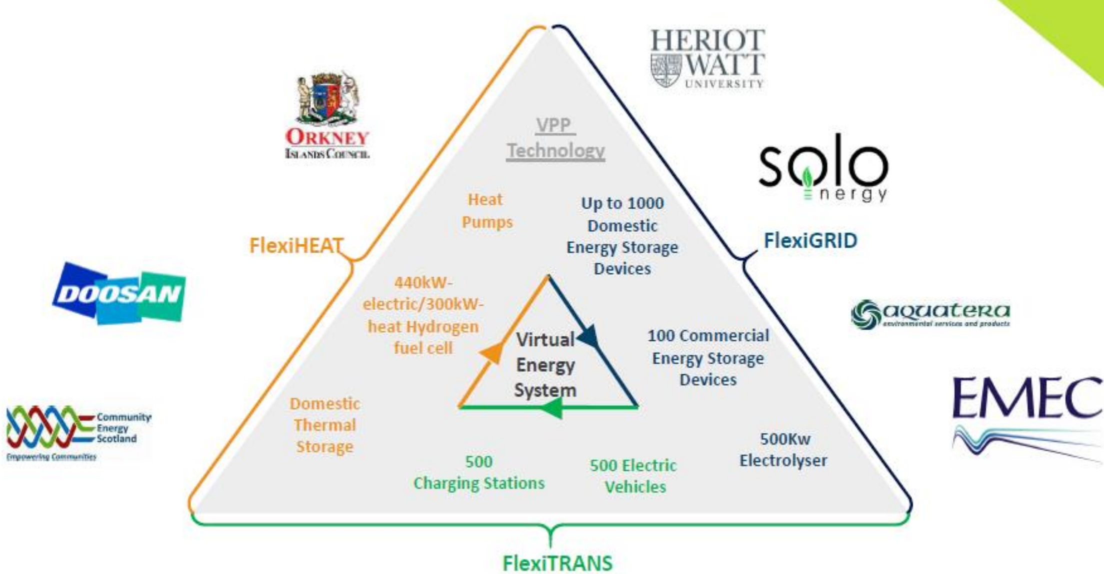
GO100%:

- A project that studies the global transition to renewable energy. The website has a library of information concerning sustainable energy projects around the world: http://www.go100percent.org/cms/

REflex

On Orkney, there is a significant penetration of renewables often generating more than 130% of the electricity used across the archipelago. However there are significant grid constraints, which mean the full renewable generation potential cannot be realised. ReFLEX is currently under early stages of development, so not yet in operation.

- **Typology:** Islanded rural community
- **Technology:** Demand side flexibility assets such as batteries, vehicle to grid chargers, electric vehicles and flexible heating systems will be installed. A FlexiGrid will be developed which will charge flexible assets during periods of peak local generation, which will be released during periods of peak demand. Ultimately a peer-to-peer trading service will be developed
- **Cost and funding:** £28.5 million of which 50% is government funded (Industrial Strategy Challenge Fund) and 50% is private sector funding
- **Objectives:**
  - Development of a “smart energy island”
  - Maximise renewable generation on the islands
- **Companies involved:**
  - European Marine Energy Centre
  - Aquatera
  - Community Energy Scotland
  - Solo Energy
  - Heriot Watt University
  - Orkney Island Council



Phase 2: Smart Local Energy Systems market size

Project to Export Market Mapping

Technology	Scottish Projects	Potential Exports
1. Smart Grids		
1.1 Active Network Management (ANM) Systems	Orkney Smart Grid, Accelerating Renewable Connections (ARC)	Software, Consultancy
1.2 Demand Side Management / Response	Northern Isles New Energy Solution (NINES), Heat Smart Orkney	Software, Consultancy
1.3. Smart Microgrids (Renewable mini-grids)	Fair Isle, Canna, Foula & Eigg projects (+ other island projects)	Consultancy, Equipment??
2. Renewable Power to Hydrogen		
2.1 Hydrogen fuelled buses	H2 Aberdeen (Hydrogen Bus Project), Dundee JIVE project	Consultancy, Equipment?
2.2 Fuel Cell Electric Vehicles (FCEV)	PURE project, Levenmouth Community Energy Project	Consultancy, Equipment??
2.3 Hydrogen refuelling stations	H2 Aberdeen (Hydrogen Bus Project), PURE project	Consultancy, Equipment?
3. Renewable Power to Heat		
3.1 Heat pump based District Heating	Hillpark District Heating, Queens Quay and Clydebank District Heating	Equipment
3.2 Thermal storage batteries	East Heat, Orkney SMart IsLands Energy system (SMILE)	Equipment

Notes:

- ? A potential Scottish supplier was identified
- ?? Scottish companies are or have been active in this area, but likely manufacturing will be undertaken outside Scotland.

Project to Export Market Mapping

- Eight technologies that had been successfully demonstrated in Scottish Smart Local Energy Systems projects were selected for the market size assessment exercise.
  - The main types of goods or services that potentially could be exported from Scotland is indicated in the right hand column: consultancy, equipment or software.
  - There may also be options for generating income from technology licensing, and through provision of specialist project management and financial services.
- These broadly feed into three categories of application:
  - Smart Grid solutions
  - Renewable power to hydrogen
  - Renewable power to heat
- The focus of these market size assessments was on equipment sales (including software) which is easier to model than consultancy or professional services.
- It should be noted that Scottish equipment suppliers are already active in some of these export markets (ANM, renewable heat) and in selling consultancy over the deployment of hydrogen technologies sourced from other countries in less developed countries.
- Scottish equipment suppliers are also playing an active part on EU RTD projects which are expected to develop the next generation of European SLES systems and solutions.

Market sizing data availability

Technology	UK	EU	Global
1. Smart Grids			
1.1 Active Network Management (ANM) Systems	√	√	√
1.2 Demand Side Management / Demand Response	√√	√	?
1.3. Smart Microgrids (Renewable mini-grids)	?	√	√
2. Renewable Power to Hydrogen			
2.1 Hydrogen fuelled buses	√√√	√√	√√
2.2 Fuel Cell Electric Vehicles (FCEV) (hydrogen fuelled cars)	√√√	√√	√√
2.3 Hydrogen refuelling stations	√√√	√√	√?
3. Renewable Power to Heat			
3.1 Heat pump based District Heating	√√√	√	√
3.2 Thermal storage batteries	√√	√	?

To determine the market size out to 2030 for technologies at different stages of development is very uncertain. To reduce this uncertainty a number of data sets were used and cross referenced. As data is not specifically collected across these technology areas, proxy data sets were used. The table shows the number of different data sets that were used to determine the market size.

√ = 1 estimate used for economic modelling
√√ = 2 estimates used for economic modelling
√√√ = 3 estimates used for economic modelling
? = no direct technology estimates available on this, so discussion papers or proxy technologies where used

Data Availability

- UK
  - Lack of transparency on investment in smart grid technologies
  - Uncertainty over EV deployment rates – limits technology rollout
  - Ofgem funding innovation projects – seeking lower cost solutions.
  - DNO focus on planning transition to DSOs – SLES post 2030.
- EU
  - Limited modelling work done on EU SLES market
- Global
  - Regional smart grid investment progressing at different speeds
  - Multiple drivers for SLES/microgrids
    - Electricity access for all (Africa/India/SE Asia)
    - Electricity generation capacity limits (USA / Japan / China)
    - Need to upgrade/decarbonise isolated island systems (Pacific/EU)
    - Maximising use of Distributed Energy Resources (DER)
    - Managing transmission & distribution network constraints
  - Market sizes mostly estimated by a equipment sales analysts.

Modelling Approach

- Estimate number of installations per year for base year (2015-2018), 2025 & 2030
  - From forecasts of installed base, % sales, heat output etc.
  - Identify high, central and low scenarios in policy/market assessments
  - Fill gaps in scenarios by applying high/central/low in UK to EU and/or EU to Global.

- Use estimated unit costs used within UK (or EU) scenarios
  - Adjust for cost reduction by 2030 due to technology learning / manufacturing volume
  - Use same unit costs across all geographical areas (Scotland, UK, EU, Global)
  - Rebase costs to 2019 prices using GDP deflators (HMT, USDA)
  - Convert currency from Euros and US Dollars to GB Pounds

- Estimate market share by LES typology
  - Focus on 2030 central market size estimates
  - Identify relevant typologies for each technology area
  - Sub-divide market size based on analysts' estimates (where available)
  - Pro-rata allocation based on EU population statistics and spatial analysis.

Primary data sources

- UK
  - CCC 5th Carbon Budget scenarios and supporting research
  - UKH2Mobility (HRS/FCEV)
- EU
  - EU funded Heat Map Europe
  - 2050 Hydrogen Roadmap
- Global
  - IEA 2DS / Irena ReMap scenarios
  - Hydrogen Council vision
- Scotland/rUK split
  - Based on ratios of population, peak demand, passenger miles, vehicles, heat density
- Exceptions:
  - ANM based on market analysts Global/EU estimates, UK based on innovation project rollout plans
  - Microgrids based on analysts Global/EU estimates with pro-rata allocation to UK.

Market size estimates (Low - High, £m in 2030)

Technology	Scotland	rUK	UK	EU	Global
1.1 Active Network Management (ANM) Systems	5 – 10	55 – 100	60 - 105	650 - 880	2,610 - 3,510
1.2 Demand Side Management / Response	70 – 110	630 - 1,000	700 - 1,110	7,800 - 13,000	157,560 - 261,530
1.3. Smart Microgrids (Renewable mini-grids)	5 - 20	30 - 166	35 - 184	265 - 1,430	19,260 - 104,800
2.1 Hydrogen fuelled buses	30 – 70	270 – 680	300 – 760	1,210 - 3,030	2,420 - 6,050
2.2 Fuel Cell Electric Vehicles (FCEV)	110 - 700	1,170 - 7,540	1,280 - 8,240	3,210 - 20,600	16,020 - 109,880
2.3 Hydrogen refuelling stations	10 – 20	110 – 240	120 - 260	400 – 660	1,590 - 2,380
3.1 Heat pump based District Heating	30 - 50	550 - 955	580 - 1,000	9,660 - 19,315	*2,170 - 4,345**
3.2 Thermal storage batteries	10 – 45	100 – 450	110 – 500	680 - 3,270	2,170 - 3,510
Total	**265 - 1,030**	**2,920 - 11,130**	**3,180 - 12,160**	**23,900 - 62,180**	**203,800 - 496,000**

- 2019 Prices
- Figures in red are based lower or older quality data
- Reflecting the uncertainty in the market analysis, figures have been rounded to nearest £5m
- The estimates are of the total market size, rather than accessible, so the accessible market may be smaller
- * note the Global Market size is smaller than the EU market. This is due to a difference in opinions on future of DH by the IEA and EU sources

Market size estimates

- Reasons for differences between high and low global estimates varies with technology:
  - ANM Systems :– differences between two market analysts' estimates for the growth in active network management systems (including next generation data analytics).
  - DSM/DSR :– IEA estimate of possible DSR demand taken as High. Low estimate derived using ratio of EU Low (BAU forecast) to EU High (Policy Options Analysis)
  - Microgrids :– the high and low values are based on market analyst's conservative and aggressive scenarios for growth rates around their current trends forecast.
  - Hydrogen Buses: - Hydrogen Council's estimate used as High. Ratio of UK High/Low used to derive global low. UK High based on CCC central scenario, UK Low was based on West Midland Buses' Low Emission Delivery Plan (modest scenario).
  - FCEVs: - Hydrogen Council's estimate used as High. Low based on market analyst's "midline estimate" based on infrastructure & manufacturing development plans.
  - HRS:- Hydrogen Council's estimate for 2030 taken as High. Low based on Hydrogen Council's analysis of investments in HRS projects already made and announced.
  - Heat pump based District Heating: - High based on Irena ReMap 2030 forecast. Low derived using ratio of CCC/Element Energy's barriers & high scenarios for UK.
  - Thermal storage batteries:- High based on Irena ReMap 2030 forecast. Low based on Irena ReMap reference scenario.

Details of the basis of UK & EU high-low estimates are in the accompanying workbook.

Market size estimates (Central, £m in 2030)

Technology	Scotland	rUK	UK	EU	Global
1.1 Active Network Management (ANM) Systems	7	77	84	765	3,061
1.2 Demand Side Management / Response	88	815	903	10,416	209,541
1.3. Smart Microgrids (Renewable mini-grids)	10	96	107	830	60,875
2.1 Hydrogen fuelled buses	58	546	604	2,421	4,838
2.2 Fuel Cell Electric Vehicles (FCEV)	422	4,522	4,944	12,360	63,179
2.3 Hydrogen refuelling stations	16	175	191	528	1,983
3.1 Heat pump based District Heating	39	733	772	14,484	3,259
3.2 Thermal storage batteries*	32	333	365	1,974	2,842
Total	**673**	**7,296**	**7,969**	**43,777**	**349,578**

- 2019 Prices
- Figures in red are inconsistent with EU estimates
- Rounding has caused some estimates of market across Scotland and rUK not to exactly total UK

Market size estimates (Central, £m in 2030)

- Central values were generally derived from the mid-point of low and high estimates in respect of EU and Global market size estimates, with a few exceptions:
  - Microgrids: Based on analyst's continuing trend estimate
  - FCEV: Based on IEA hydrogen and fuel cell scenarios
  - Hydrogen buses central is high scaled by ratio of UK(central) to UK(High)
- UK central values are based on CCC central scenarios where available, or derived from the mid-point of high and low estimates, with a few exceptions:
  - DSR central value is based on Carbon Trust/Imperial central scenarios
  - Hydrogen Buses central based on West Midland Buses' Low Emission Delivery Plan (ambitious scenario). NB. High is based on CCC's central scenario.
  - FCEV central based UK(high) multiplied by ratio of EU (central)/EU (High)
- The ratio of UK to EU and EU to Global market sizes were checked for consistency:
  - Heat pump based District Heating is likely to be inconsistent due to assumptions around whether this technology is likely to be most cost effective option to deploy. The Global market report details a wider range of potential technologies including gas CHP, biomass boiler, electric boiler, biomass CHP.
  - Demand Side Management / Response is probably inconsistent due to the inclusion of a wider range of flexibility options in the Global report – including smart appliances, and EV charging.

Technology to Typology Allocations

Technology	Islanded rural community	Remote green village	Off grid green town	On grid commuter town	On grid industrial town	Large urban	Industrial Park/Campus
1.1 Active Network Management (ANM) Systems	4.5%	23.5%	20%	9%	3%	40%	
1.2 Demand Side Management / Response	3.0%	15.8%	13%	6%	2%	27%	33%
1.3. Smart Microgrids (Renewable mini-grids)	1.3%	6.7%	8%	4%	1%	26%	53%
2.1 Hydrogen fuelled buses						100%	
2.2 Fuel Cell Electric Vehicles (FCEV)						100%	
2.3 Hydrogen refuelling stations (HRS)						100%	
3.1 Heat pump based District Heating						100%	
3.2 Thermal storage batteries*			21%	10%	4%	66%	

Technology to Typology Allocations

- Various approaches where used to allocate the estimated market sizes of the eight technology modelled onto the seven typologies. These were:
  - ANM systems were allocated across all urban areas using EU population statistics as a proxy for electricity demand, on the basis on academic papers that suggest the requirement for network reinforcement will be spread across the entire network.
  - DSR was first allocated on the basis of potential flexibility of industrial & commercial (I&C) vs residential identified in UK studies, then further split by EU population statistics. All I&C DSR potential is assumed to be on industrial parks/campus sites.
  - Microgrids are allocated firstly using NREL's estimates of market segmentation between remote systems, campus locations and others (based on 2 Analyst's databases), and then further split to different urban areas using Eu population.
  - Hydrogen fuelled buses, FCEV and HRS were 100% allocated to large urban areas as deployment up to 2030 is expected to be largely in high density populated areas.
  - Heat pump based District Heating was 100% allocated to large urban areas as deployment up to 2030 is expected to be mostly in high density populated areas although district heating is also expected to be deploy in large and medium towns.
  - Thermal Storage Batteries are allocated by EU population across towns & urban areas, on an assumption that up to 2030 heat pumps are most likely to be deployed in built up areas.

Typology Market Size Estimates (Global, Central, £m in 2030)

Technology	Islanded rural community	Remote green village	Off grid green town	On grid commuter town	On grid industrial town	Large urban	Industrial Park/Campus
1.1 Active Network Management (ANM) Systems	137	720	602	272	106	1,224	
1.2 Demand Side Management / Response (DSR)	6,284	33,025	27,609	12,462	4,855	56,157	69,149
1.3. Smart Microgrids (Renewable mini-grids)	779	4,091	5,010	2,261	881	15,589	32,264
2.1 Hydrogen fuelled buses						4,838	
2.2 Fuel Cell Electric Vehicles (FCEV)						63,179	
2.3 Hydrogen refuelling stations (HRS)						1,986	
3.1 Heat pump based District Heating						3,259	
3.2 Thermal storage batteries (TSB)			600	271	105	1,866	
Global Total	**7,200**	**37,837**	**33,821**	**15,266**	**5,947**	**148,098**	**101,412**

- Notes
  - Referring back to slide 10, the definitions used here for the different typologies are based on indicative population figures as the data is not available to use the full definition of the typology as shown in slides 85 – 87.

Typology Market Size Estimates (Global, Central, £m in 2030)

- This slide shows the breakdown of global market size by typology and technology for the central scenario. Breakdowns for other scenarios and geographies covered are provided in the accompanying workbook.
- The same percentage allocation has been used for all scenarios and geographies covered as data sources used for this market size analysis do not provide a technical basis for adjustment of the simplifying assumptions outlined in the previous slide.

Typology Market Size Estimates (Central, £m in 2030)

Technology	Islanded rural community	Remote green village	Off grid green town	On grid commuter town	On grid industrial town	Large urban	Industrial Park/Campus	Total
Global	7,200	37,837	33,821	15,266	5,947	148,098	101,412	349,581
EU	357	1,877	2,008	906	353	34,399	3,877	43,777
UK	32	169	221	100	39	7,053	355	7,969
rUK	29	153	201	91	35	5,909	320	6,737
Scotland	3	16	21	9	4	586	35	673

- The largest markets for LES technology seem likely to be located in larger urban centres and industrial parks/campus sites. The majority of the population and electricity/heat demand is located there, and the rapid uptake of Electric Vehicles are expected to drive the need for investment in LES systems in these typologies.
- However many Scottish projects have focussed on smaller rural sites as it is easier to demonstrate LES technologies on a small scale within grant funder projects. Whilst there are some Scottish District Heating projects in urban areas these are small scale.
- Conversely, small, medium and large towns may be the most accessible markets for demonstrating the scalability of LES technology, as the barriers to projects are lower.
- A substantial number of small scale demonstration projects are underway in remote communities (particularly islands) around the world, but it would be difficult for equipment suppliers to gain market traction without participation in large scale trial.

Scottish Content Analysis

Based on an analysis of the Scottish project costs

- Limited number of cost breakdowns
- Difficult to separate out internationally tradable goods and services:
  - Commonly traded: design consultancy, software, equipment, IPR/patents
  - Less often traded: PM & other professional services, installation, IT, O&M etc.
- Relatively low levels of unique Scottish tradeable content:
  - Many projects using “imported” equipment and expertise from rest of UK / EU
  - Many overseas competitors evidenced by similar demonstrators overseas
  - Exceptions: Sunamp heat battery, Smarter Grid Solutions ANM tools.
  - There are noticeable leading Scottish manufacturers of SLES technology that do not appear in these innovation projects such as Aggreko (diesel/ battery hybrid systems), SD Wind (small scale wind), Firefly (hybrid generator control system)
- Best estimates:
  - Scottish supply chain typically supplies 16-85% (Average: 50%) of goods and services
  - Unique Scottish content typically: 0-20% of goods and services (estimated)
- Quality of data insufficient to pin down export potential, but suggest:
  - Potential share of 2030 market: <=10% rUK, <=1% EU, <=0.1% Global
  - Increase share by focussing on developing of unique, tradable goods & services

Appendix: Original typologies definition

Typology	Scottish Examples	% of Scottish Population Represented (to be calculated)	% of Global Population Represented (to be calculated)	Criteria Bandings: Population	Population Density	Remoteness	Area Heat Density	Average Electricity Use Per Meter	Local grid Constraint	Heat Use Intensity	Waste Heat Availability	Gas Grid Availability	District Heating Network Coverage	Renewable Energy Resource Potential	Low Carbon Transport Infrastructure
Small Remote Island	Gigha, Fair Isle, Colonsay	0.36%	-	A	A	D	A	D	D	A	C	D	A	A	A
Large Island	Orkney, Shetland, Lewis & Harris	1.52%	-	**B**	A	D	A	D	D	A	C	D	A	A	B
Remote Rural Village	Tomintoul, Brora, Lochgilphead	3-5%	5%-15%	A	C	D	A	D	D	A	C	D	A	B	B
Rural Market Town	Oban, Stranraer, Keith	10-15%	30%-40%	B	D	C	B	C	D	B	C	C	A	B	C
Commuter Town	Kirkintilloch, Penicuik, Forfar	15-20%	2%-10%	C	D	B	B	B	B	B	D	C	A	C	D
Mid-sized Town	Kirkcaldy, Ayr, Stirling	20-25%	5%-15%	C	D	B	C	A	B	C	B	B	B	C	D
Large Town / City	Glasgow, Dundee, Livingston	32%	30%-45%	D	D	A	D	A	A	D	B	A	B	D	D
Industrial Park	Grangemouth, A1 industrial park	~2%	-	B	D	B	B	A	A	B	A	A	A	D	D

Appendix: Original typologies criterion

#	Criterion	A	B	C	D	Metrics
1	Population	0-2,999	3,000-9,999	10,000-49,999	50,000+	Number of occupants. Bands correspond to those used on www.usp.scot
2	Population Density (people/km2)	0-499	500-1,499	1,500-2,499	2,500+	Number of occupants/area info can be found at: http://www.citypopulation.de/UK-Scotland.html (need to confirm appropriate bands)
3	Remoteness	0	1-29	30-59	60+	Travel time (mins) to nearest settlement of over 50,000 people
4	Average Heat Use per Person (kWh/year)	0-7,999	8,000-11,999	12,000-16,999	17,000+	Average annual consumption in kWh of gas, heating oil, electrical heating or other. Bands correspond to Ofgem's 2017 recommendations for new Typical Domestic Consumption Values (TDCVs)
5	Average Electricity Use per Person (kWh/year)	0-1,899	1,900-3,099	3,100-4,599	4,600+	Average annual consumption in kWh of electricity (excluding electrical heating). Bands correspond to Ofgem's 2017 recommendations for new Typical Domestic Consumption Values (TDCVs)
6	Electricity Use Intensity (kW/10,000 people)	0-2,999	3,000-7,999	8,000-19,999	20,000+	Peak instantaneous electricity consumption for an area. This illustrates the maximum load that the local electrical infrastructure has to cope with (need to confirm appropriate bands)
7	Heat Use Intensity (kW/10,000 people)	0-14,999	15,000-49,999	50,000-99,000	100,000+	Peak instantaneous non-electrical heat consumption for an area. This illustrates the maximum load that the local heat infrastructure has to cope with (need to confirm appropriate bands)

Appendix: Original typologies criterion

#	Criterion	A	B	C	D	Metrics
8	Waste Heat Availability (GWh/10,000 people/year)	0-2,999	3,000-4,999	5,000-7,999	8,000+	Measure of waste heat available (i.e. technically and economically viable to extract) locally from any suitable source e.g. industry, waste water, data centres, large air-con systems, including low temperature heat that requires upgrading via heat pumps (need to confirm appropriate bands)
9	Gas Grid Availability	0%	1-69%	70-89%	90%+	Percentage of households with the option to connect to the gas grid (need to confirm appropriate bands)
10	District Heating Network Availability	0%	1-39%	40-79%	80%+	Percentage of households with the option to connect to a district heat network either available now or planned for deployment pre-2020 (need to confirm appropriate bands)
11	Electric Grid Strength	Very weak	Weak	Adequate	Strong	Ability of the local electricity network to cope with the addition of new variable renewables (need to define actual measurable scale)
12	Renewable Electricity Resource	0-49%	50-99%	100-150%	150%+	Realistic technical potential for local renewable electricity generation (primarily wind & solar) as a percentage of local electricity usage (need to confirm appropriate bands)
13	Public Transport Availability	Very weak	Weak	Adequate	Strong	Number of bus/boat routes servicing the settlement & Proximity to train station (need to define actual measurable scale)
14	Low Carbon Transport Infrastructure Availability	0-1	1-2	2-5	5+	Electric car charging stations or hydrogen refuelling stations per 10,000 people either available now or planned for deployment pre-2020. Electric charging points info on https://www.zap-map.com/ (need to confirm appropriate bands)

Country Distribution & Transmission Network voltages

Country	Distribution (kV)	Regional (kV)	Transmission (kV)
New Zealand	11/22/33/50/66	n/a	110/220/350/400
Denmark	10/20/30/50/60	n/a	110/132/400
United States	7.2/2.47/25/34.5	n/a	46/69/115/138/161/230/345/500/765
Norway	11/22	33-132	132/300/420
Sweden	10/20	110	220/275/400
Estonia	0.4-35	n/a	110/220/330
Finland	10/20	n/a	110/220/400
Lithuania	10/35	n/a	110/330
Ireland	10/20/38/110	n/a	220/400
Canada	2-35	44/49	115/230/500/713
Latvia	6/10/20	n/a	110/330
Japan	3/6/11/22/60	n/a	187/250/275/500
Russian Federation	6-35	n/a	110/220/330/500
Chile	12/13.2/13.4/15/23	n/a	66/110/154/220/500
China	35	n/a	220/330/500/750/800/1,000

Microgrid Suppliers

Canada
1. GE – large energy storage systems.
2. Pareto Energy Ltd
3. Power Analytics Corp
4. Viridity Energy
5. ABB Ltd
6. Chevron Energy
7. Echelon
8. Microgrid Energy LC / Pivot Energy
9. Siemens AG
10. Spirae

USA
1. Schweitzer Engineering Laboratories
2. Schneider Electric
3. Opus One Solutions
4. Encorp
5. Siemens
6. S&C Electric
7. PowerSecure
8. Spirae
9. Emerson Automation Solutions
10. CleanSpark

Global
1. ABB
2. GE
3. Echelon
4. S&C Electric Co
5. Siemens
6. General Microgrids
7. Microgrid Solar (Pivot Energy)
8. Raytheon
9. Surverge Energy
10. Toshiba
11. NEC
12. Aquion Energy
13. EnStorage
14. SGCC
15. Moixa
16. EnSync
17. Ampard
18. Green Energy Corp
19. Growing Energy Labs Inc
20. HOMER Energy
21. Spirae Inc

Companies listed in red are currently active in international markets; they are potentially the main competitors for Scottish companies active in the microgrid field.

Selection of case studies

	Country	Location	Title	Source
1	Croatia	Unije, Krk, Mljet	Smart Islands	http://smart-cities-centre.org/wp-content/uploads/agm18-gorankrajacic.pdf
2	UK	Cornwall, Isles of Scilly	Smart Energy Islands	http://www.cornwallislesofscillygrowthprogramme.org.uk/growth-story/smart-energy-islands/
3	UK / Scotland	Orkney Islands	SMart IsLand Energy systems (SMILE)	https://www.h2020smile.eu/
4	UK	FALKLAND ISLANDS	RE Microgrid	https://rmi.org/wp-content/uploads/2017/04/Islands_RenewableMicrogrids_Report_2015.pdf
5	Denmark	Samsø	SMart IsLand Energy systems (SMILE)	https://www.h2020smile.eu/
6	Portugal	Madeira	SMart IsLand Energy systems (SMILE)	https://www.h2020smile.eu/
7	Portugal	Porto Santo	Sustainable Porto Santo	https://www.engerati.com/smart-infrastructure/article/microgrids/sustainable-porto-santo-renault-creates-smart-island-project
8	Greece	Agios Efstratios	“Green Island” project	https://www.deddie.gr/Documents2/PAROUSIASEIS%202018/%CE%A0%CE%91%CE%A1%CE%9F%CE%A5%CE%A3%CE%99%CE%91%CE%A3%CE%97%20%CE%A3%CE%A4%CE%91%CE%A5%CE%A1%CE%9F%CE%A0%CE%9F%CE%A5%CE%9B%CE%9F%CE%A5%20%CE%93%CE%99%CE%91%20%CE%9D%CE%91%CE%9E%CE%9F%20290618.pdf
9	Greece	TILOS	TILOS project	https://www.deddie.gr/Documents2/PAROUSIASEIS%202018/%CE%A0%CE%91%CE%A1%CE%9F%CE%A5%CE%A3%CE%99%CE%91%CE%A3%CE%97%20%CE%A3%CE%A4%CE%91%CE%A5%CE%A1%CE%9F%CE%A0%CE%9F%CE%A5%CE%9B%CE%9F%CE%A5%20%CE%93%CE%99%CE%91%20%CE%9D%CE%91%CE%9E%CE%9F%20290618.pdf
10	Greece	Kythnos	Kythnos Microgrid in Gaidouromantra,	https://www.deddie.gr/Documents2/PAROUSIASEIS%202018/%CE%A0%CE%91%CE%A1%CE%9F%CE%A5%CE%A3%CE%99%CE%91%CE%A3%CE%97%20%CE%A3%CE%A4%CE%91%CE%A5%CE%A1%CE%9F%CE%A0%CE%9F%CE%A5%CE%9B%CE%9F%CE%A5%20%CE%93%CE%99%CE%91%20%CE%9D%CE%91%CE%9E%CE%9F%20290618.pdf
11	Greece	Sym, Astypalea, Megisti/Kastelorizo	Smart Island pilot projects	https://www.deddie.gr/Documents2/PAROUSIASEIS%202018/%CE%A0%CE%91%CE%A1%CE%9F%CE%A5%CE%A3%CE%99%CE%91%CE%A3%CE%97%20%CE%A3%CE%A4%CE%91%CE%A5%CE%A1%CE%9F%CE%A0%CE%9F%CE%A5%CE%9B%CE%9F%CE%A5%20%CE%93%CE%99%CE%91%20%CE%9D%CE%91%CE%9E%CE%9F%20290618.pdf
12	Finland	Åland Islands	SMART ENERGY PILOTING AND TESTING	https://www.businessfinland.fi/en/for-finnish-customers/services/build-your-network/bioeconomy-and-cleantech/aland-islands/
13	Japan	Okinawa	Okinawa’s efforts towards a Smart Energy Island	https://www.irena.org/-/media/Files/IRENA/Agency/Articles/2012/May/06_1_Katsuya-Furugen.pdf?la=en&hash=EBF0FFD96C034FF07A1753A30E1C6FCEC44989DF
			SARDINIA: RECORD-BREAKING LABORATORY FOR HIGH	