ICE INTELLIGENT COMMUNITY ENERGY

Interreg France (Channel Manche) England

EUROPEAN UNION

ICE REPORT 2.4.3

ICE GENERAL METHODOLOGY VALIDATION STUDY: LUNDY

16/12/22

Calum Harvey-Scholes, Nick Treneary, Victor Kouloumpis, Peter Connor, Oscar Fitch-Roy, Jiangjiao Xu, Sreeram Valsalakumar, Essam Hussain, Mohammad Abusara, Jon Hardwick, Helen C M Smith, Jonathan Williams, Senthilarasu Sundaram

BRETAGNE DÉVELOPPEMENT INNOVATION

EXETER

PLYMOUTH UNIVERSITY

UEA

marine

About ICE

Supported by Interreg VA France (Channel) England, the Intelligent Community Energy (ICE) project, aims to design and implement innovative smart energy solutions for isolated territories in the Channel area. Islands and isolated communities face unique energy challenges. Many islands have no connection to wider electricity distribution systems and are dependent on imported energy supplies, typically fossil fuel driven. The energy systems that isolated communities depend on tend to be less reliable, more expensive and have more associated greenhouse gas (GHG) emissions than mainland grid systems. In response to these problems, the ICE project considers the entire energy cycle, from production to consumption, and integrates new and established technologies in order to deliver innovative energy system solutions. These solutions will be implemented and tested at our unique pilot demonstration sites (Ushant island and the University of East Anglia's campus), to demonstrate their feasibility and to develop a general model for isolated smart energy systems elsewhere. The ICE consortium brings together researcher and business support organisations in France and the UK, and engagement with SMEs will support project rollout and promote European cooperation.

1 Introduction: purpose of this report

This report contributes to fulfilment of task 2.4 of the ICE project. The objective is to provide empirical validation of the 'ICE General Methodology' developed in task 2.1 and presented in report T.2.1.2 through application to four alternative sites. The objective of the task is to consider how the application of the methodology may be affected by local considerations and to suggest refinements to the general methodology where required.

The sites are:

- Chausey, France (report 2.4.1)
- Molène, France (this report 2.4.2)
- Lundy, UK (report 2.4.3)
- Isles of Scilly, UK (report 2.4.4)

Contents

2 Smart energy transition on Lundy island

2.1 Island overview

Lundy is a unique case of a privately managed island, overseen by a UK charity, the Landmark Trust, with a focus on the protection of the island's wildlife and heritage. Lundy is situated 12 miles off the North Devon coast of the UK and is less than 5 km long and 1 km wide. For the protection of wildlife, there are no roads or streetlights and it was gifted to the National Trust in 1969. The word Lundy is Norse and means 'Puffin Island'; it is the South West UK's largest seabird colony after surviving a breeding pairs crisis in the 1990s, mainly arising from predatory rats feeding from bird nests. The combined efforts of the National Trust, the RSPB, Natural England (then English Nature) and the Landmark Trust within the 'Seabird Recovery Project' to make the island rat-free have led to a tripling in the total seabird numbers on the island (Lundy Field Society, 2016). Additionally, the sea around Lundy was designated as the UK's first Marine Conservation Zone (MCZ) in 2010.

2.2 Reasons for selection

Lundy has challenges in common with many small islands when it comes to its sustainable energy transition; the small scale of energy demand, large seasonal variations in demand, the lack of a conventional supply chain and heritage restrictions on development. Lundy differs from the other sites in this validation study in that the island is privately owned, belonging to the Landmark Trust, which presents unique stakeholder and implementation challenges. Additionally, the environmental protections on the island restrict the type and scale of interventions. The island's electricity needs are fulfilled by a small power station comprising three Cummins B and C series diesel engines with capacities of 140kW, 140kW and 80kW.

2.3 Demographics and location

Located off the north coast of Devon, UK, Lundy is considered to be part of the district of Torridge. In 2007 the resident population was 28 people. These are the people who are necessary for the running and maintenance of the island as an environmental, touristic destination and comprises a warden, a ranger, an island manager, a farmer, bar and house-keeping staff, and volunteers. Their residences are at or near the village at the south of the island. There are also 23 holiday properties and a camp site for over-night visitors. According to the 2017 Annual Report of the Lundy Field Society Archive "over 18,000 people visit the island each year on holiday or on a day trip, sailing on the island's passenger and supply ship, MS Oldenburg, or flying out and back by helicopter during the winter months" (Lundy Field Society, 2016).

Lundy's links with the mainland where the visitors and suppliers of goods come from the UK mainland, including the diesel required for its generators. Connection via the sea is the main way, with 96 out of 100 scheduled sailings, (11 to full capacity) taking place in a typical year and carrying about 16,870 passengers over the year. During the winter there is a helicopter service realising 33 out of the 36 scheduled flights in a typical year and carrying 1283 passengers rising the total attendance for both ship and helicopter to 18,153.

Lundy needs to protect and monitor its rare plant and animal life. It has long term goals of becoming more self-sufficient in its water supplies, waste management and energy. The impact of the weather is direct as Lundy is exposed to the elements and as such, the potential impacts that will arise from climate change should be taken into account when planning.

2.4 Economic status

Due to the special environmental importance and character of the island, Lundy depends on tourism. The Landmark Trust offers rental of a wide range of buildings, including a 13th century castle, a late Georgian gentlemen's villa, a lighthouse, an Admiralty lookout and a fishermen's chalet. The majority of the buildings are constructed from the light-coloured granite that can be found on-site. The facilities include heating and some open fires and stoves, baths or showers, running hot and cold water, mains drainage and gas and electricity (except the admiralty lookout). There are no telephones in the properties and there is limited mobile phone network coverage across the island.

2.5 Policy and regulatory overview

The following subsections summarise relevant policy and regulatory information from ICE report T1.1.2 (Fitch-Roy and Connor, 2018) covering renewable energy routes to market, network and grid access and social and environmental permitting.

2.5.1 Routes to market: RE production, offtake and remuneration

Renewable energy output remuneration policies

Following the staged closure to new projects of the renewables obligation (RO) quota system in March 2017, and the closing of the Feed-In Tariff to new entrants in April 2019, there is only one principle financial support mechanisms for renewable electricity in the UK: Contracts for Difference.

Contracts for Difference

Conceived in 2011 as an element of electricity market reform (EMR), the contracts for difference (CfD) mechanism is the UK's main financial support instrument for large-scale 'low carbon' generation, including renewable energy (DECC, 2011). The instrument is a form of sliding premium, designed to offer a payment in addition to wholesale electricity market revenues up to a fixed 'strike price'. The strike price is set through competitive tenders (Fitch-Roy and Woodman, 2016). The CfD auctions held to date have allowed participation of a range of renewable energy technologies divided into two categories of more and less mature technologies. Onshore wind was excluded from the second and third auction due to a political commitment from the governing political party. The auctions have resulted in the contracting of a large volume of renewable energy, mostly offshore wind (DECC, 2015; BEIS, 2017). It is unlikely that a project scaled for use on Lundy would be economuically viable within the CFD.

2.5.2 Network access and grid connection

Generators gain access to the GB electricity networks through contracts with either the TSO, in the case of large, transmission-connected plant or one of 14 distribution network owners (DNOs). Concerning these small generators in particular, the cost, time involved, transparency and difficulty of obtaining a grid connection offer – and then securing a functioning connection – from DNOs has posed some challenges for some generators, especially small renewable generators. Efforts have been made by the regulator, however, to make the process more efficient, which to-date have proved largely unsuccessful, leading the regulator to explore punitive measures (Ofgem, 2014, 2017).

2.5.3 Social and environmental permits, licences and land-use planning

Under the Town and Country Planning Act (1990), local planning authorities are responsible for issuing permits to developments with installed capacity of less than 50MW. The level of local engagement required to gain permission to build new renewable installations means that planning policy in the UK tends to favour projects that are either wholly or partly owned by community initiatives. Since 2015, the necessity of local involvement in approving areas for wind energy in particular, has been explicit, making wind energy development very challenging in many areas, setting a clear division between onshore wind energy and other renewable energy technologies (DCLG, 2015a; Smith, 2016). However, some opportunities for very small installations on existing buildings remain under what are known as 'permitted development rights' (Smith, 2016). For projects larger than 50MW, the Planning Act (2008) allows decisions to be taken by the responsible minister with local planning authorities contributing through formal consultation (DCLG, 2015b).

2.5.4 'Smart grids' policy

The UK has implemented or is in the process of implementing a number of policy and regulatory changes with the goal of fostering a 'smart and flexible' energy system (BEIS, 2021). Enabling smarter grids is seen by government, regulators and other stakeholders as essential to facilitating increasing volumes of intermittent and distributed low carbon technologies by allowing system wide adoption of new 'smart' technologies, more active network management and opening markets to services and technologies that will increasingly include demand side action (Jenkins, Long and Wu, 2015). The UK Government has taken a number of actions already to facilitate change in the UK's regulation of markets and networks to meet the needs of the low carbon transition and many of these will have implications for opportunities for increased network smartness. The Government, in partnership with energy markets regulator, Ofgem, established the Smart Grid Forum (SGF) in 2014. The SGF has worked closely with electricity sector stakeholders to devise actions to identify all areas requiring action to facilitate smart grid evolution.

2.5.5 Policy for Future Smart Networks

Significant actions already undertaken include a change in incentive structures for the transmission and distribution companies, to try to drive greater network innovation and to allow greater flexibility in terms of investment and return on smart network management approaches rather than simply expanding physical networks. Ofgem also permits network companies to commit additional spending to network innovation through various programmes, including the Low Carbon Network Fund, the Electricity Network Innovation Competition (ENIC) and the Network Innovation Allowance (NIA). Essentially, their aim is to allow the network companies to explore smarter solutions to integrating large volumes of low carbon technology, while minimising cost and maintaining reliability (Connor *et al.*, 2014; Jenkins, Long and Wu, 2015).

The Government has recently announced changes that will have significant further implications for distribution networks. with the announcement that the current, largely passive, distribution network owner (DNO) model will switch to a more active 'distribution system operator' (DSO) model (Ofgem, 2019; BEIS, 2021). The Open Networks Project is an initiative of the energy sector aiming to determine what changes are needed, including the changing interaction between transmission and distribution, impact on consumers, and charging issues, as well as the DNO to DSO transition (Energy Networks

Association, 2020). The DSO model is common across Europe and the changing role of the DNOs is seem as essential to enabling many of the features likely to be essential to smart grids in the UK (Xenias *et al.*, 2014; BEIS, 2021). Essentially, the shift would see DNOs maintain their current responsibilities but have access to a wider range of active network management approaches and be expected to work more closely with the System Operator and Transmission Owners. The UK is engaged in a nationwide effort to replace all domestic and small business electricity and gas meters with smart meters by 2020. The goal is to bring down systemic costs by reducing supplier costs, driving energy efficiency and by enabling new and innovative approaches to network management such as aggregation, time-of-use tariffs. There are substantive hurdles to maximising benefits however, since some rely on behaviour change and some on access to smart meter generated data by companies which do not currently enjoy access. The rollout of smart meters has also been subject to delays and there is thus some way to go to enabling some key smart energy initiatives deriving from smart meters. There are additional barriers to the coming to fruition of some of the potential smart grid services. Further planned actions include (BEIS, 2021):

- Facilitating flexibility from consumers by
    - Enabling smart buildings
    - Enabling smart electric vehicles
    - Enabling smart local energy solutions
- Removing barriers to flexibility on the grid through electricity storage and interconnection
- Reforming markets to reward flexibility
    - By 2025, the ESO will be net zero ready, ensuring it has the markets and tools in place to safely operate a zero carbon system.
    - The government and Ofgem will ensure that appropriate governance is in place to deliver coordinated and effective flexibility markets.
    - Ensure that flexibility technologies can compete effectively in market structures that drive investment in low carbon technologies and ensure capacity adequacy.
    - A standardised approach to carbon monitoring and reporting will be implemented.
    - Network users will receive better price signals through network access and charging arrangements about where to locate on the network.

It is likely that the need for additional actions beyond this list will emerge as experience with improving systemic smartness grows and as some options prove themselves or are rejected by the various stakeholder groups. This wide selection of overarching policy and regulatory changes are relevant in the case of many sites, though not all will be relevant to Lundy. Potential for demand side initiatives is likely to be limited beyond improvements in energy efficiency, there is potential for the Landmark Trust to act as a producer from different technologies, or via a 'private wires' agreement, to use storage systems to maximise gain from renewable generation, to become a mini-grid operator or to manage its own consumption more cost-effectively. Decisions regarding all of these actions would typically be impacted by the options that the market allows, but this may not apply due to the Landmark Trust's ownership of structures on the island. The wider regulatory architecture, licensing costs, the availability of new market opportunities and the emergence of new actors or divergence of established actors in exploiting them should still be considered however.

2.5.6 Smarter Energy Markets

Ofgem announced a new programme – Smarter Energy Markets (SEM) – in 2013, with the goal of delivering reform in the wider electricity market and enabling smart approaches that would improve competition and enhance consumer protection (Ofgem, 2013). Enhanced DSR and new products and services fall into this category but are likely to be less relevant to Lundy, which is effectively a private wires system of energy provision.

2.6 Key data on energy production and use

Lundy power system

Electricity generation on Lundy is provided by a diesel-fuelled combined heat and power generator station on the island; there is no interconnection with the mainland. The three primary generators were installed in 2000 by an external contractor in capacities 140kW, 140kW and 80kW. Typically only one or two run at any one time with the third engine acting as a standby in the event of an unplanned shutdown of the other engine/s. The engines are run for an average of 18 hours per day, 6am – 12am, with an enforced shutdown overnight partly due to the noise of the engines, partly to save fuel and as part of the way of life the island offers to its guests; redolent of a time when electricity was not readily available. The electricity network on Lundy is owned by the National Trust who own the island and managed by the Landmark Trust who lease the island. The network is generally three-phase, 400 Volt with some two-phase spurs in parts.

Due to the small number of residents and the special nature of the island, it has not been possible to access statistics for the energy production and use. These will have to be obtained from a field trip and special site visits, something rendered not possible by the Covid-19 pandemic. The main and most important information concerning Lundy is that the island is not connected to the national grid, it has its own electricity generation, a small power station comprising three Cummins B and C series diesel engines, offering an approximately 150 kVA 3-phase supply to most of the island buildings. Waste heat from the engine jackets is used for a district heating pipe and there are also plans to collect the waste heat from the engine exhaust heat gases to feed into the district heat network to improve its usefulness further (Green, 2005). The power is normally switched off between 00:00 and 06:30 (Landmark Trust, 2016). As far as the stoves and open fires mentioned in the previous section, fuel is available from the only local shop.

There is some limited experience with renewables on Lundy. A publication (Infield and Puddy, 1984) from 1984 describes the installation of a 55kW Windmatic wind turbine in 1982 which resulted in reducing the diesel usage from 60 gallons to 5 gallons during a two week period around Christmas. Of course this information is outdated but it is useful to know about the previous efforts of using renewables on the island. As far as greater scale of renewable energy projects are concerned, it can be noted that the 1.2 GW capacity Atlantic Array proposed offshore wind farm in the Bristol Channel, a development by RWE Npower Renewables was cancelled in November 2013.

3 Implications for the ICE General Methodology

This section examines the applicability, relevance of, and possible challenges to, the seven key elements of the ICE general methodology (GM) developed in ICE report T2.1.2 (Matthew *et al.*, 2018).

3.1 Stakeholder engagement

The ICE GM identifies two area of importance for stakeholder engagement. The first is the purpose of the engagement and the second is an outline of some broad guidelines for engagement practices.

The purpose of stakeholder engagement is sometimes seen in purely instrumental terms. i.e., a means of obtaining public consent for a particular technological or organisation change. However, change on the scale implied by smart energy transition on an isolated island requires a deeper, and more participatory, deliberative approach in which both the goals of the transition and decisions about the means by which goals are achieved, are the result of open and inclusive discussion among all interested or affected parties. Consideration of approaches tailored to different constituencies is essential to create such meaningful engagement.

The ICE GM strongly suggests that the further 'upstream', or earlier in the decision-making process engagement can occur, the greater the trust between project promoters and the community and, ultimately, the more constructive the engagement. The ICE GM views local communities not as an obstacle to be overcome, but rather a source of knowledge and legitimacy. Engagement is an ongoing relationship that does not stop once a project is completed.

3.1.1 Overview of key principles of GM

The GM therefore:

1. Acknowledges diversity of rationales for both support and opposition to a variety of renewable energy technology options
2. Seeks to ensure that communities have the greatest freedom possible in defining the sustainability challenge at hand, and identifying locally desirable actions
3. Prioritises co-production approaches, where (local) experts (e.g., policymakers, technology and project developers) and publics are brought together to jointly define the problems and potential solutions
4. Considers the needs of various constituencies, with the aim of achieving inclusive and holistic public engagement over the course of energy infrastructure siting
5. Continually engages with stakeholders throughout and beyond the timescale of the project(s)

3.1.2 Limitations to this study

Stakeholder engagement was not possible within this study due to time and resource constraints and severely complicated by the Covid-19 pandemic from February 2020. We were able to integrate some objectives from publicly available documents and through limited communication with the island general manager.

3.1.3 Guiding Principles and Considerations

There is no single recommended approach to public engagement on energy issues and case evidence suggests that public engagement exercises tend to be most effective when they reflect the characteristics of both the project and the local area (Alexander, Wilding and Jacomina Heymans, 2013; de Groot and Bailey, 2016; Dwyer and Bidwell, 2019). Specifically, there are at least five areas of consideration:

- Awareness of and attention to local energy and public engagement history
- Understanding and appropriate inclusion of diversity and difference
- Tailoring participation approaches for the whole community and specific groups
- Ensuring a two-way flow of information and integration of stakeholder input
- Flexibility, transparency and good-faith negotiation in discussing and the determination of community benefits

One important consideration is whether the island has had any previous experiences with engagement processes and energy projects, and how these might influence perceptions of new projects (Alexander, Wilding and Jacomina Heymans, 2013; Papazu, 2016). For example, an unsuccessful wind turbine project on Ushant led to local scepticism towards wind energy on the island. Engagement processes also need to consider the wider issues island communities see as important so that, as far as possible, energy projects enhance the economic, social and cultural fabric of islands and limit any negative effects (Devine-Wright, 2009; de Groot and Bailey, 2016). Wider issues that engagement processes might consider include: employment opportunities; reducing out-migration among younger residents; protecting existing economic sectors like tourism; and ensuring projects respect the local natural and cultural environments (Gross, 2007; de Groot and Bailey, 2016). Understanding people's energy needs is also essential for ensuring that energy projects contribute positively to residents' well-being and energy security and access.

Engagement processes also need to reflect the diverse character of island communities and the potential for differences in opinion between permanent and part-time residents, visitors, and between different economic sectors, such as fishing, agriculture and tourism (Colvin, Witt and Lacey, 2016; Dwyer and Bidwell, 2019). Different engagement strategies and methods may also be needed to engage with groups who, for various reasons, may be unwilling or unable to participate in certain types of engagement activity. Issues of representativeness should also be considered in order, for example, to come to reasoned judgements on how, for example, to consider the views of second homeowners compared with those of lifelong or other permanent residents. Understanding local social structures, power relations, and differences in values is often critical in gaining the trust and cooperation of local communities. Engagement strategies additionally need to incorporate mechanisms that allow groups to express disparate views and manage disagreements. These challenges may be especially pronounced in island communities because some groups (such as part-time residents) may be hard to contact, and because of an aggravated risk of divisions if engagement processes do not pay careful attention to the social dynamics of small communities (Colvin, Witt and Lacey, 2016).

Participation strategies should encourage equitable involvement; however, the techniques used must consider both island community as a whole and the needs and preferences of specific groups. Previous research indicates that more intense engagement processes are not always popular or successful. Sometimes individuals lack the time, confidence, or skills to take a more active role in debating and decision-making on proposals and not everyone will want to be involved. Engagement techniques therefore need to be flexible, pragmatic, and tailored to the needs of each community, and to avoid over-consultation, which can be a particular risk in islands and remote areas with small populations (Haggett, 2011; Aitken, Haggett and Rudolph, 2016; Rudolph, Haggett and Aitken, 2017). Case study evidence shows some preference for workshops (Kerr *et al.*, 2014; Heaslip and Fahy, 2018) and science fairs (Sperling, 2017; Dwyer and Bidwell, 2019) that create relaxed atmospheres for discussions without being onerous for participants.

Wherever possible, engagement processes should involve two-way flows of information (Reed, 2008; Devine-Wright, 2011) that allow dialogue on information provided by engagement organisers (Aitken, Haggett and Rudolph, 2016). Two-way exchanges encourage trust by providing platforms for sharing local knowledge about the physical, economic, political, social, and cultural characteristics of areas that may be unknown to developers and decision-makers, and can then be combined with scientific and technical information to produce more informed decisions (Haggett, 2008; Reed, 2008). Attempts should also be made to act on public and stakeholder concerns, or at least for developers and decision-makers to respond so that residents feel valued in the decision-making process (Sorensen *et al.*, 2002; Gross, 2007; Haggett, 2008; Aitken, Haggett and Rudolph, 2016; Sperling, 2017; Dwyer and Bidwell, 2019). It is important that developers communicate their decisions and rationales for particular courses of action, so that communities feel they are being kept informed, rather than being marginalised once initial consultations have taken place. Developers of the Triton Knoll offshore wind farm shared feedback from pre-application consultations with local stakeholders via a report summarising how consultees' views had been considered in the final application (Aitken, Haggett and Rudolph, 2014). Another way to facilitate information sharing is to use trusted community intermediaries (Klain *et al.*, 2017; Sperling, 2017; Dwyer and Bidwell, 2019). Experience suggests that the context in which information is shared and the person presenting information can be as important as the information itself in shaping the dynamics of engagement (Klain *et al.*, 2017).

Careful consideration is needed as to the forms of any community benefits offered as part of the energy project. The types of benefit made available are likely to vary between locations but flexible and transparent processes, with active negotiation with local representatives on their design and distribution, can help to address perceived imbalances between the impacts and benefits of projects. Benefits can include community funds, community ownership, apprenticeships and studentships, educational programmes, and electricity discounts, while indirect benefits, such as enhanced tourism, should also be discussed (Firestone, Kempton and Krueger, 2009; Rudolph, Haggett and Aitken, 2014, 2017). Energy projects can also bring community benefits in their own right, e.g. by lowering energy costs and/or improving reliability of connections, though it should not be assumed that these alone are sufficient. A recurring theme in work on community benefits is that benefit schemes should be tailored to the needs of individual areas, sites and projects (Rudolph, Haggett and Aitken, 2017). For example, Devine-Wright and Sherry-Brennan's (2019) analysis of a community benefit fund for a high-voltage power line in Ireland highlights the need for iterative dialogue with local stakeholders when determining the boundaries of benefit schemes. Negotiated approaches were seen as preferable to more formulaic approaches to 'boundary drawing' in securing acceptance that eligibility for benefits had been determined fairly and reflected local knowledge and interests.

3.2 Assessing energy demand outlook and identifying options

A key determinant of decisions about the future of an isolated or peripheral electricity system is an informed view of demand for electricity, the factors that drive changes in demand, and how these may evolve over time. The first stage in a demand assessment is the gathering of appropriate information. Secondly, consideration needs to be given to how changes in consumers' behaviour can impact energy demand.

3.2.1 Overview of key principles of GM

The GM therefore considers:

- Aggregate demand data across electricity, heat and transport
- Historical demand by sector and geography
- Granular data on domestic energy usage patterns
- Economic and demographic drivers of energy demand
- The interaction of policy and behaviour change, particularly with regard to increasing levels of energy 'prosumption'
- Anticipated changes to energy demand or production

Load profile

The load profile of Lundy is shown in Figure 1 for a year from March 2019 to February 2020. Power demand peaks during the winter and is lowest during summer.

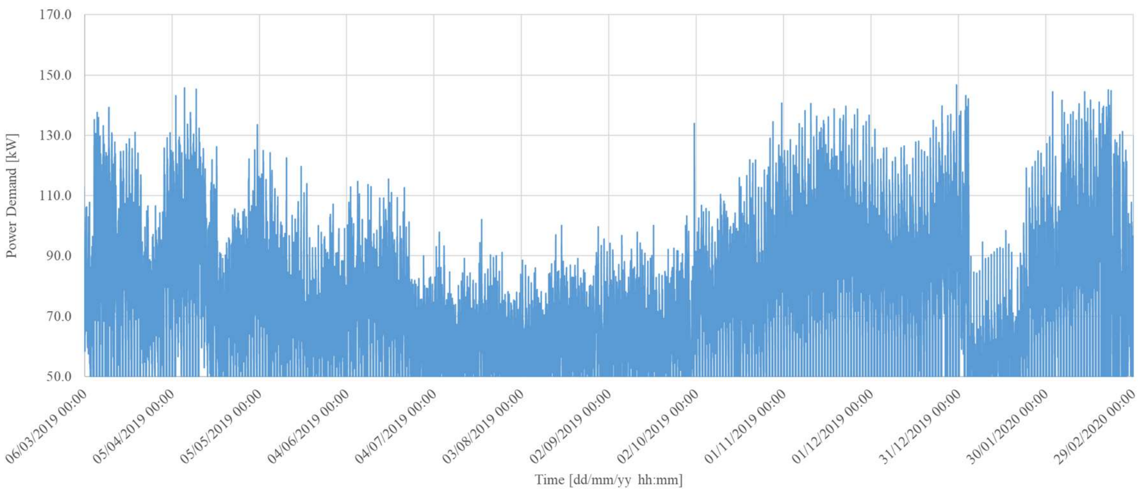


Figure 1: Lundy power demand from March 2019 to February 2020

The load demand profile during the day is shown in Figure 2. The power is available only from 6 am to 12 am. The peak load demand is during the morning (7 am to 8 am) and during the evening (5 pm to 6 pm).

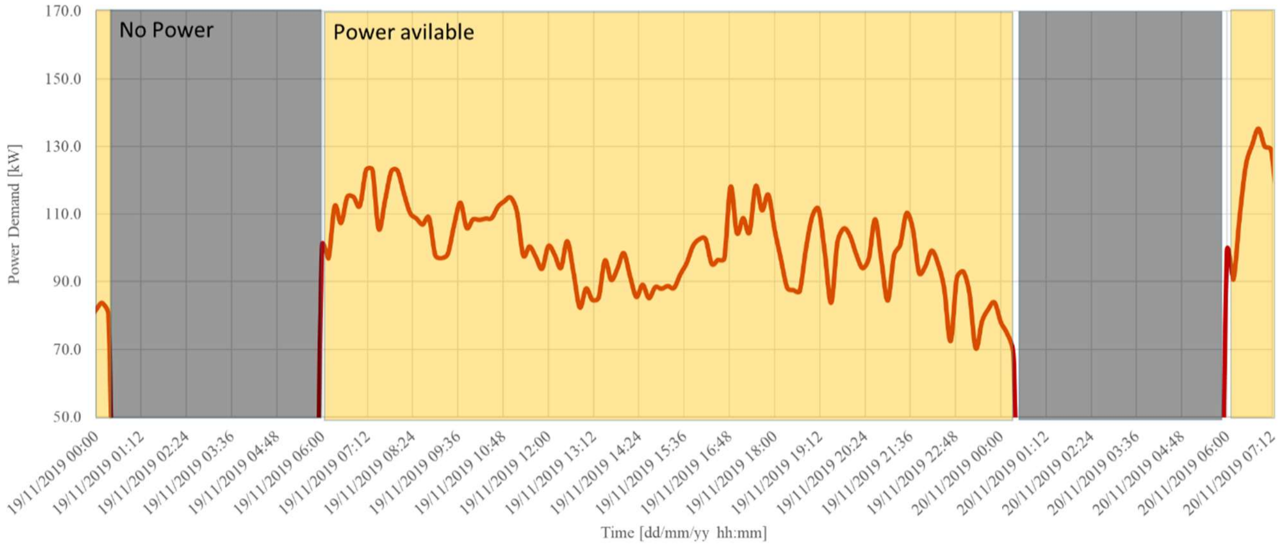


Figure 2: Lundy power demand during the day

The network and the power loads on the island are a mixture of three and single-phase. This results in an imbalance between phase currents as shown in Figure 3.

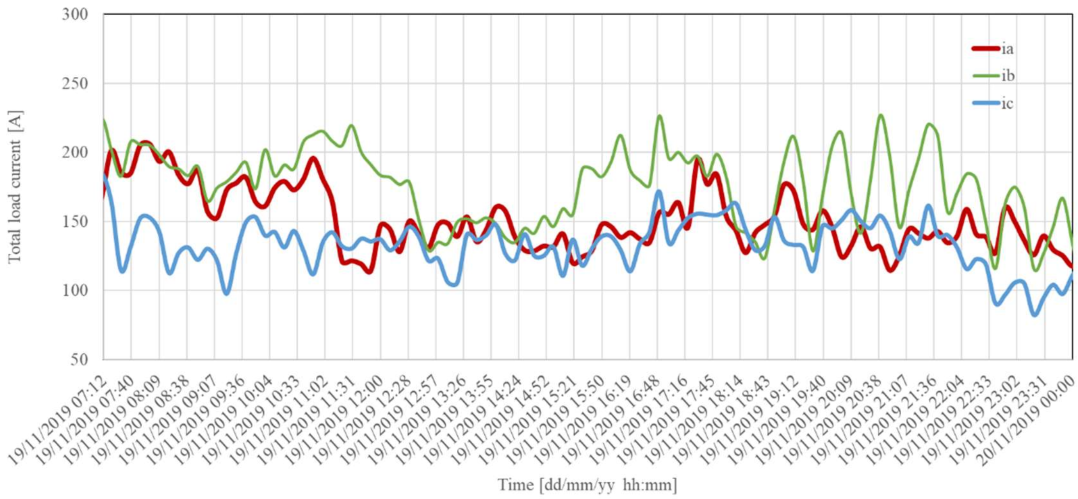


Figure 3: Total load phases currents

3.2.2 Potential future changes to energy demand.

Reduced demand

Installing insulation measures as well as more efficient heating technologies (e.g. heat pumps) are both ways to reduce the demand for energy for heat. The use of more efficient electricity devices (e.g. light bulbs and appliances) will directly reduce electricity consumption. In this study, the future energy scenarios will assess the potential savings from installing a heat pump to serve the heat network in the village.

Smart technologies

The increasing deployment of smart technologies for storing energy and flexing electricity demand will help alter the energy load profile to match variable generation. This will enable the community to make maximum use of the cheaper renewable energy. There are plans to install a small number of domestic battery systems on the IoS. Our modelling of future energy scenarions will determine an optimal storage capacity.

3.3 Energy supply outlook

Developing an understanding of the current and future potential of available energy sources is a key step in the ICE Methodology.

3.3.1 Overview of key principles of GM taken from T2.1.2 (repeated across all four documents)

There are two main components to this activity:

1. *Evaluating current energy supply:* A comprehensive review of the current energy supply options with its related infrastructures, attributes and options is a good first step in gauging the supply options for the system
2. *Assessing renewable energy potential*: Once the initial data on the current supply options is assessed, the current and potential supply options must be evaluated to gain insights into which of the supply option can be useful. The choice of supply option is intertwined into the stakeholder goals and objectives for the type of energy system pursued. Resource assessments carried out for the renewable generation technologies can provide a basis for their use as a supply option. This enables the quantification of the amount of energy available at a site or sites and to estimate the amount of electricity or heat that is be extracted. Included in the resource quantification can be the estimated power that could be exported to the local grid as a unit commitment with the demand. An assessment on the correlation of generation times with consumption is also needed. Consideration of the technical, environmental and social constraints to deploying the potential technologies should be included.

3.3.2 Current Energy Supply

Electricity

The three primary diesel electricity generators on the island were installed in 2000 by an external contractor and comprise two 140kW units and one of 80kW. Typically one or two engines run at any operational time with the third engine acting as a standby in the event of an outage or unplanned shutdown. The engines typically run for 18 hours per day from 6 am to 12 am.

Heat

Space and water heating on Lundy is primarily provided by the diesel-fuelled combined heat and power (CHP) unit. The unit supplies heat to a small heat network in the village whilst the other buildings rely on direct electric heating as their primary heat source. A small amount of gas is used for heating and cooking, this is estimated to be less than 4% of the island's total energy demand. The presence of a district heating system is relatively rare for a UK location, and in addition, this may impact the economics of energy supply on the island in comparison to other ICE island sites. A solar thermal system is also installed to provide hot water to the most recently added staff accommodation with an estimated capacity of 750 Watts.

Alongside the CHP unit, a 100 kW boiler supplements the heat supply. The heat network supplies heat for the pub and much of the staff accommodation. The heat delivered is not metered so the additional energy load must be estimated.

Transport

Passenger transport ferries visitors to and from the island. Transport on the island is limited to staff activity. Transport was not analysed in this study.

3.3.3 Renewable Energy Potential

Solar Resource Assessment

Resource Constraints

The available solar resource on Lundy has been estimated through PVGIS, using the database PVGIS-COSMO. PVGIS uses combined satellite data to estimate the irradiance received at a location at a spatial resolution of roughly 6km squares.

PVGIS-COSMO provides average monthly and hourly data for the specific latitude (51.165°) and longitude (- 4.666°) of the island. The direct normal irradiation (DNI) received is expected to be 1049 $KWh/m^2/year$, the global horizontal irradiation (GHI) is 1032 $KWh/m^2/year$ and on a plane of 39° 1230 $KWh/m^2/year$. Monthly irradiance is presented in Figure 4. The optimum tilt angle for the PV panels is estimated at 39° facing directly south. See the Appendix for more information.

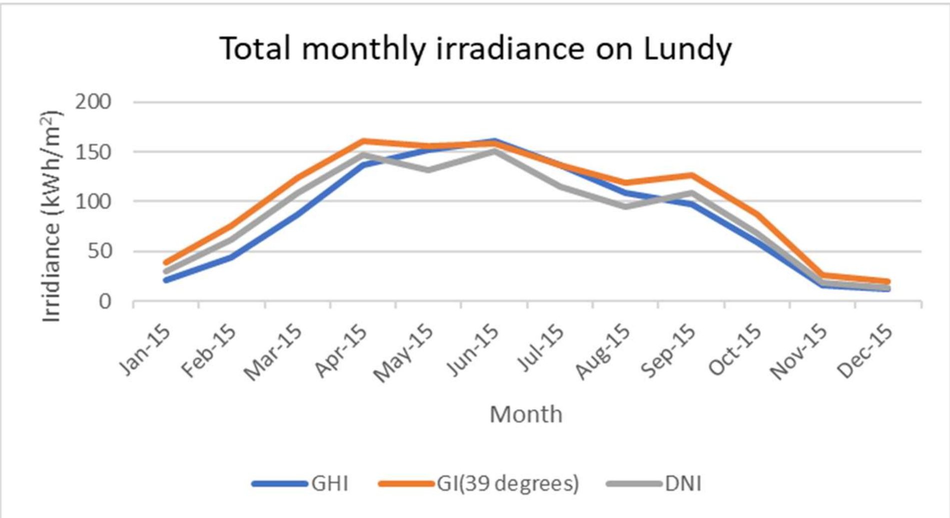


Figure 4 - Irradiance values for Lundy, generated using the PVGIS- COSMO database.

The latitude of the island of Lundy results in high levels of seasonal variability in solar irradiance with a considerably reduced solar resource during winter months due to both reduced irradiance intensity and fewer daylight hours – $842kWh/m^2/month$ G(39°) over the summer and $380kWh/m^2$ /month G(39°) in winter. More information can be found in the Appendix.

Technical Constraints

Rooftop solar PV panels have been deployed widely across the UK and can be installed on the roofs of most buildings. To generate the most electricity, the panels should be located on a south-facing, sloped roof. Panels facing East and West are also viable and mounting systems for flat roofs are also available. The volume of PV which can be introduced to the grid is also limited by Lundy's electrical network.

Typically in the UK, output of less than 3.68KW does not need any permission (Energy Saving Trust, 2020), but Lundy's private ownership, the nature of the owner's mission and the management of intermittent on its grid, all add grounds for further consideration.

Several of the island's buildings are grade II listed and the majority are at least 100 years old. Should rooftop solar be installed, it is essential to perform necessary strength calculations to ensure the buildings can take the added weight of the panels.

Equipment used in typical solar installations is readily available on the UK mainland and there are numerous solar installers on the mainland that could travel to Lundy via the ferry relatively easily with few special considerations, although the ferry only runs in March-October (The Landmark Trust, 2020).

Ground-mounted solar farms are subject to similar grid constraints to roof-mounted solar, and any installation in Lundy would be subject to the capacity of the grid to cope with the increased generational load. While some amount of ground mounted capacity could be brone by the grid, the Landmark Trust, as owners would have to decide whether additions are within an aceeptable change to the aesthetic of the island and its visitors.

Environmental, Social and Political Constraints

Lundy is both a conservation area and a Site of Special Scientific Interest that has numerous listed and scheduled areas, detailed in Figure 33 in the Appendix. Permission from the local planning authority will be required. Torridge District Council has published a Local Plan which is expresses support for renewable energy developments which do not substantially impact the landscape or biodiversity.

The island of Lundy has eighteen Grade II listed buildings, thirteen of which are holiday houses, one is a church and four (the Battery Cottages) are uninhabitable (Historic England, 2020) – all would need listed building consent to install roof-top solar. There are 46 scheduled monument sites on Lundy that total 0.35km^2, just over 8% of the island. The entire coastline and northern half of the island of Lundy is classified as a Site of Specific Scientific Interest (SSSI) which is less appropriate for development including renewables. A list of the graded buildings, information on scheduled monuments, and a map of the SSSI is presented in the Appendix.

Site Selection and Power Production

Based on the constraints described above and consultation with the Landmark Trust, the most likely viable sites have been selected and are detailed in Figure 5. These areas will be used within the following energy production calculations for both ground and roof mounted solar.

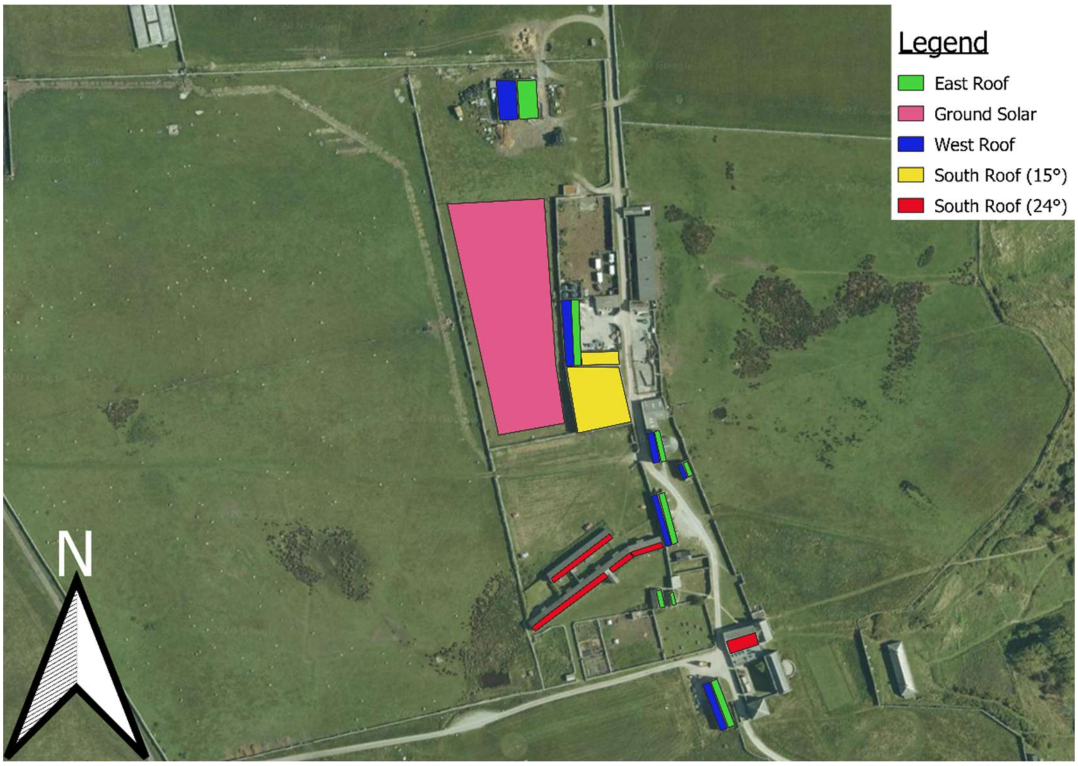


Figure 5 - A map showing the solar sites identified

Roof mounted Solar Power Production

The buildings that have been identified have roof areas of 352m^2 South-facing (24°), 482m^2 East-facing, 477m^2 West-facing and 801m^2 South-facing (15°). These areas were scaled and the modelled generation capacity and annual electricity production is laid out in Tables 1-4. Table 4 breaks down the generation and electricity demand into summer and winter to compare seasonal performance.

Table 1 – Solar rooftop power production

Orientation	Inverter Size (kW)	Number of Panels	Generation capacity	Power Production MWh/year	% of demand
South (24°)	30	162	48.6 kWp	51.22	9.6
East	4.2	221	66.3 kWp	52.09	9.8
West	3.0	219	65.7 kWp	59.28	11.1
South (15°)	12	154	46.2 kWp	47.98	9.0
Total	N/A	565	169.5 kWp	210.58	39.5

Table 2 – Solar rooftop seasonal generation (Summer = April-September, Winter = October-March)

Orientation	Summer: Winter Generation (MWh)	Summer: Winter Demand (MWh)	Summer: Winter Generation (%)	Summer: Winter Demand (%)
South (24°)	36.6 - 14.7	241.7:292.5	71.4 - 28.6	45.2-54.8
East	40.3 - 11.8	241.7:292.5	77.4 - 22.6	45.2-54.8
West	44.8 - 14.5	241.7:292.5	75.6 - 24.4	45.2-54.8
South (15°)	35.0 - 13.0	241.7:292.5	73.0 - 27.0	45.2-54.8
Total	156.7:53.9	241.7:292.5	74.4-25.6	45.2-54.8

Ground-Mounted Solar Power Production

The potential for ground-mounted solar PV on the available 3,969m^2 using 300 Watt panels was modelled using Helioscope and the results are presented below in Table 3. More information on the model assumptions can be found in the Appendix.

Table 3 - The ground mounted solar specifications and energy generation

Specification	Row Spacing (m)	Panel Number	Generation capacity	Energy (MWh/year)	Energy/Panel MWh/Year/Panel	% of total demand
1	6 (Portrait)	882	264.9 kWp	264.9	0.30	49.6
2	6 (Landscape)	594	178.2 kWp	182.3	0.31	34.1

Table 4 - The seasonal energy generation from the proposed arrays.

Specification	Summer: Winter Generation (MWh)	Summer: Winter Demand (MWh)	Summer: Winter Generation (%)	Summer: Winter Demand (%)
1	184 - 80.9	241.7:292.5	69.5 - 30.5	45.2-54.8
2	125 - 57.3	241.7:292.5	68.6 - 31.4	45.2-54.8

The generation expected from each of the four different layouts of the site is detailed in Table 6 andTable 7. There is a potential to meet a large portion of the energy demand on the Island, although as with the rooftop solar the generational profiles is heavily weighted towards the summer and does not match the demand profile on the island. In contrst, the daily generation curve is a better fit to the demand than wind energy, generating nothing between 12pm - 6am when the grid is shut down.

Wind Resource Assessment

Wind generation is the leading renewable technology in the UK, producing 20% of the UK's electrical power in Q3 2019 (Evans, 2019). A 55kW Windmatic wind turbine was previously operational on the island at the location marked in Figure 6, providing up to 89% of the island's power demand in the 1980s (Infield and Puddy, 1984). It has long been decommissioned.

Figure 6 - A map of Lundy showing the historic location of the 55kW wind turbine installed in 1982. (Infield and Puddy, 1984)

Resource Constraint

Data collected on the site of the previous turbine shows that Lundy has a considerable wind resource; an average wind speed of 8.17ms^{-1} at a height of 8m. To model larger turbines we upscaled the wind speeds to heights of 25m, 50m, 75m and 100m, these wind speed profiles are presented in Figure 7 & 8. More information for our upscaling methods can be found in the Appendix.

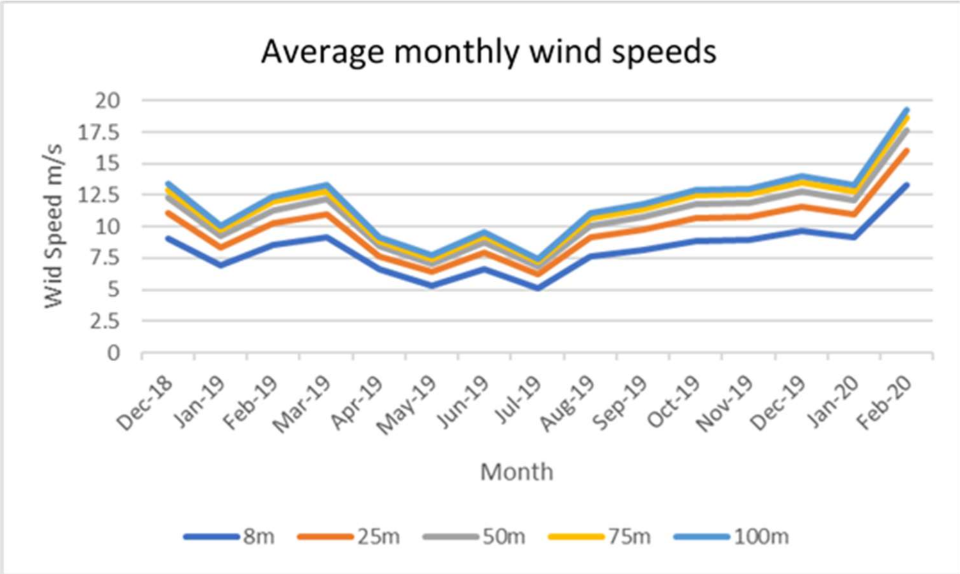


Figure 7 - Average monthly wind speeds at 8m, 25m, 50m, 75m and 100m

The distribution of wind speeds was matched to a Weibull curve, ensuring that the average wind power densities of each plot were the same. The generated Weibull curve allowed the shape (k) and scale (c) factor of the distribution to be determined, which were 1.5 and 9.05, respectively.

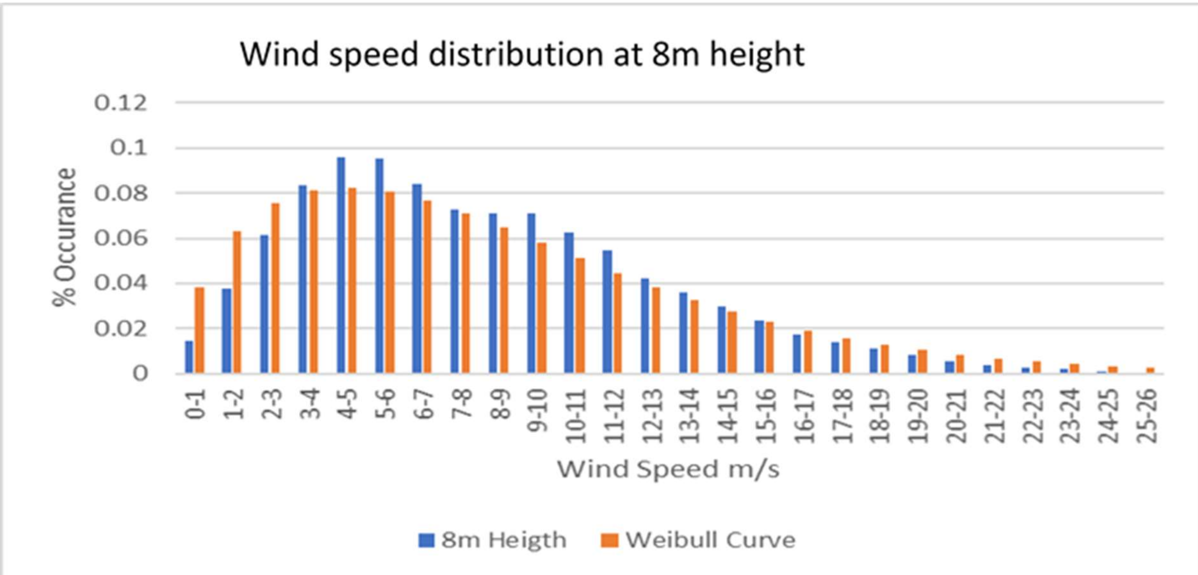


Figure 8 - A histogram of measured wind speeds at 8m and a fitted Weibull curve.

Technical Constraints.

To install single or multiple wind turbines on the island, a site with sufficient access for construction vehicles and a suitable port to allow shipping of the turbine's components are factors that need to be considered within the planning stage. Owing to the island's rural nature, and the existence of farm tracks, large vehicle access to the suggested site is not a concern but this will need to be assessed on-site to ensure access is possible.

Lundy has one port, in the South-East of the island, with a jetty installed in the year 2000. A ship, the MS Oldenburg, services the island's needs, transporting fuel, passengers, livestock and cars to and from the island, and sporting a 3-ton crane on the front deck (The Landmark Trust, 2020). Whether this would be sufficient for the turbine transport will depend on the size and type of turbine installed. The selected site will also need to be near existing electrical infrastructure to avoid the substantial costs associated with high voltage cabling. The historic location of the wind turbine has the concrete pad, connecting cables and interface with the control cabinet already installed (aardvark, 2017). The installed cables will need to have the suitable capacity to export the maximum power of the turbine.

The island's geology is primarily granite, apart from towards the far South-East of the island which consists of slate. The island is covered by a superficial deposit that is primarily made up of sand, gravel and soils (Dollar, 1941). The depth of the superficial deposit is unknown, and a ground survey would be needed when undertaking foundation design.

Environmental, Social and Political Constraints.

Local impacts of noise, flickering effects, visual impact and bird collisions will need to be measured, minimised and deemed tolerable in order to obtain planning permission from the local authority.

Onshore wind turbines that have a height exceeding 11m require planning permission from the Local Planning Authority, Torridge District Council. Whilst the historic turbine site on Lundy is not identified as a suitable site for wind development in the Local Plan, the clarification must be sought as to the implications of the historic permission for a turbine on the site. More information can be found in the Appendix.

Power Production.

The historic site shown in Figure 6 is the chosen site for the following power calculations for the WES50 (50 kW) and the NPS 60C (60 kW), both with a similar hub height to the installed historic turbine, as well as a larger nED100 (100 kW). More information can be found in the Appendix.

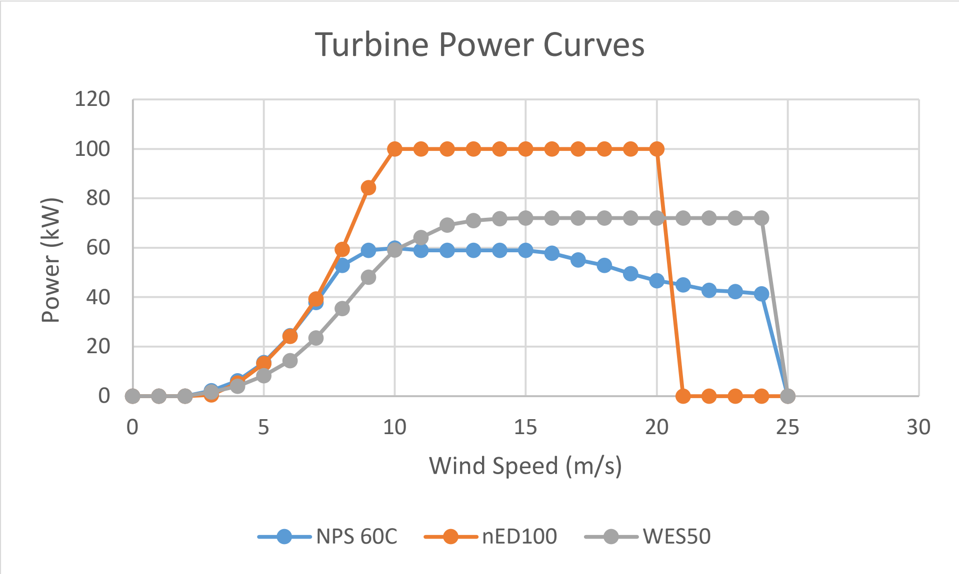


Figure 9 - The power curves of the 50 kW, 60 kW, and 100 kW turbines.

Annual power generation is estimated using the wind speed data presented above and is set out in Table 5.

Table 5 - Turbine power production

Turbine	Generation	Island Demand	Percentage of Island Demand
WES 50	0.295GWh	0.54GWh	55%
NPS 60C	0.311GWh	0.54GWh	58%
nED 100	0.454GWh	0.54GWh	86%

The generation periods of each turbine are highly variable, this variability in power production creates generational surplus and deficit hours compared to network demand, presented in Table 6.

Table 6 - Turbine deficit and surplus energy generation times.

Turbine	Generational Surplus (Hours)	Generational Deficit (Hours)	Generation = Demand (Hours)
WES 50	2369	6207	183
NPS 60C	2196	6386	177
nED 100	3984	4530	246

These data show a need for grid management and indicate the value of strategic planning for complementary generation as well as flexibility (such as demand response or battery storage). Over the year, there are both seasonal and hourly imbalances, as shown in Table 7.

Table 7 – Wind energy generation over summer and winter, compared with demand.

Turbine	Summer Generation (GWh)	Winter Generation (GWh)	Ratio Summer: Winter	Demand Ratio Summer: Winter
WES 50	0.716	1.055	40:60	45.2-54.8
NPS 60C	0.821	1.045	44:56	45.2-54.8
nED 100	1.204	1.522	44:56	45.2-54.8

The seasonal generation is consistent across all three turbines, each showing increased generation potential in the winter months, as would be expected given the wind climate. These outputs broadly match the demand profile on Lundy, although generation is marginally more weighted towards the winter months than is demand.

3.4 System reliability assessment

The ICE Methodology recommends rigorous reliability analysis of the electrical system to determine the envelope for action.

3.4.1 Overview of key principles of GM taken from T2.1.2

The main purpose of the reliability study is to establish the reliability of the current energy system to then assess the impact different generation/storage/smart energy options may have on the system reliability in the future. Parameters that will be used for this analysis include:

- Reliabilities of energy security and availability
- Target reliability/availability
- Potential for optimised supply and generation mix.

The analysis rests on two distinct studies:

1. *Reliability study of the network:* This is done by translating the physical electrical distribution network into a conceptual Reliability Block Diagram (RBD). Some software to facilitate this process and the subsequent analysis readily exists, e.g., ReliaSoft. The primary objectives of the reliability analysis are to obtain a life distribution that describes the times-to-failure of a component, subassembly, assembly or system. This analysis is based on the time of successful operation or time-to-failure data of the item (component);
2. *Power Flow Analysis:* In order to understand the power flow in the network. This is derived through a power flow analysis, analysing the voltage levels for each load node. Software such as Matlab Simulink will be employed for the power flow analysis;
3. *Options for smart system operation and innovative technologies:* Once the reliability and power flow of the current system is established, the information will be used to model and assess the different generation and supply portfolios. This will incorporate the renewable energy generation and the correct physical locations, i.e., connect to the correct geographical network nodes. Both types of analysis, the reliability study of the network and the power flow analysis, will be carried out for the range of generation/smart technology scenarios.

Accurate data on the following is a prerequisite for the most rigorous analysis:

A. Schematic diagram of the island power-system network and the network voltage.
B. The main components of the island network, such as power cables, transformers, circuit breakers and generator units.
C. Failure rate of the main components of the network or a record of the failure for each network components for 5 years or more.
D. The cables type, length and size.
E. The transformer parameters, terminals voltage, parameters and type.
F. The electrical generator parameters (power, type and impedance).
G. The load (active and reactive power) at each load connection node for a year at least in hourly time intervals.
H. The circuit breaker information, location and type.

However, data collection has proven to be a challenging issue in some contexts. The ICE methodology document T2.1.2 outlines some of the considerations for accessing suitable data (Matthew *et al.*, 2018).

3.5 The Lundy Electricity Network

Only the schematic diagram of the Lundy power system is available. A label for each load node (L1 to L15) is placed as shown in Figures 10 and 11 for the schematic diagram of the Lundy power grid.

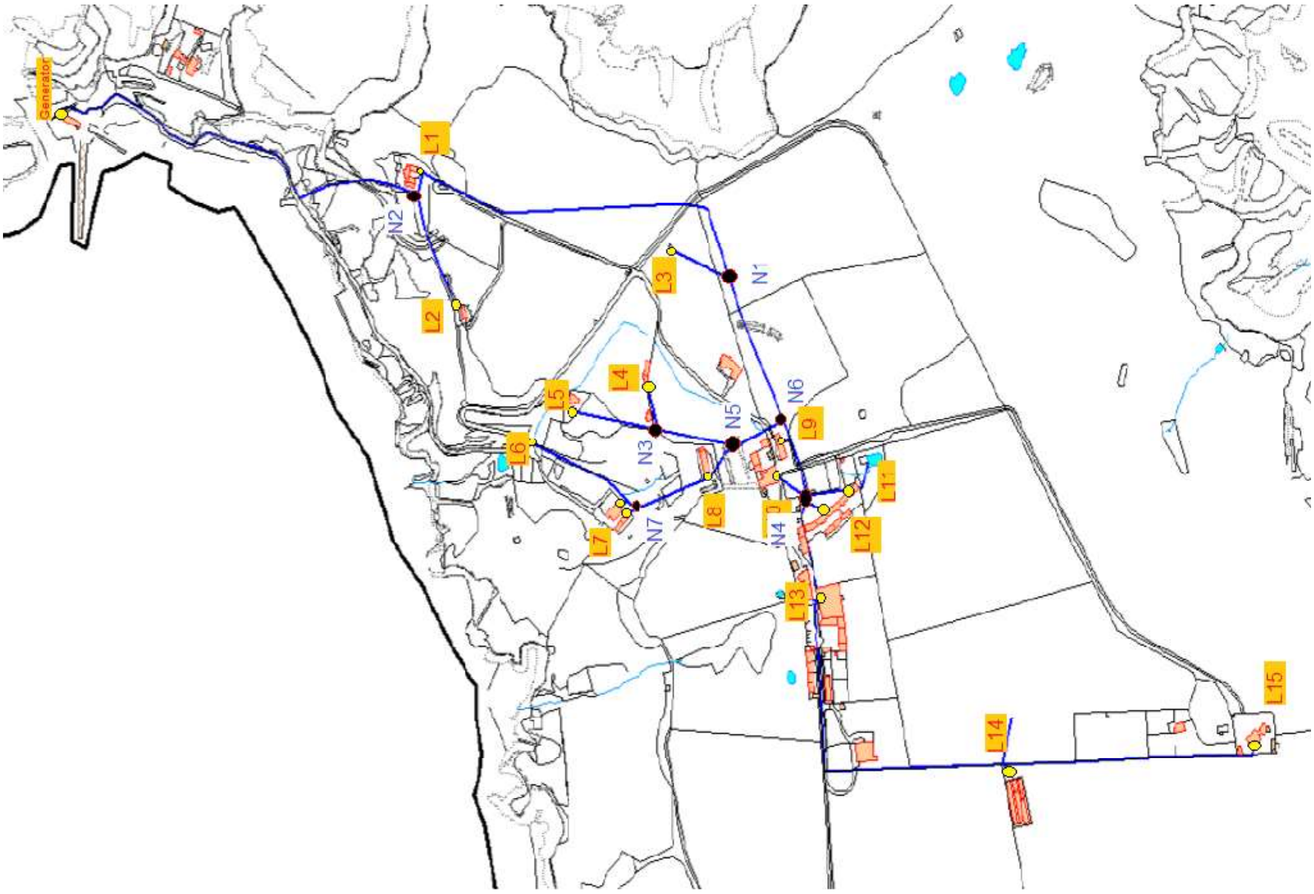


Figure 10: Lundy power grid and load node

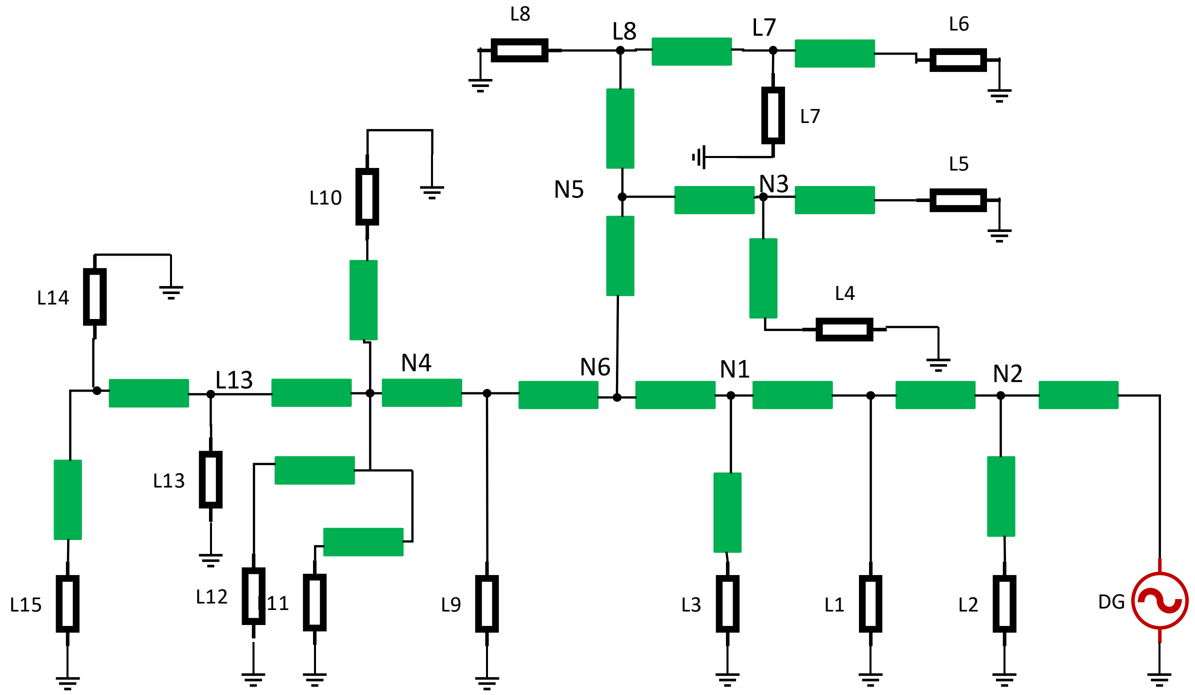


Figure 11: Lundy power grid schematic diagram

Power Flow Assessment and Reliability Study

Due to the limited available data, some assumptions are required to carry out the power flow assessment. These are listed below:

1- The power flow analysis considers the maximum power which is 148.3164kW (03/03/2020 at 08:00 am), see Table 15. In this case, the total load power for phase A is 51.566kW, for phase B is 47.882kW and for phase C is 48.569kW.
2- The unbalanced degree in the load power at each load node is the same.
3- The power factor of the load is 0.9 and is same at each load node.
4- The cable size is 120mm^2 which can handle up to 312A continuous current. This size is selected according to the island current profile where the maximum current is 278A (from the provided data).
5- The grid voltage is 240V/phase.

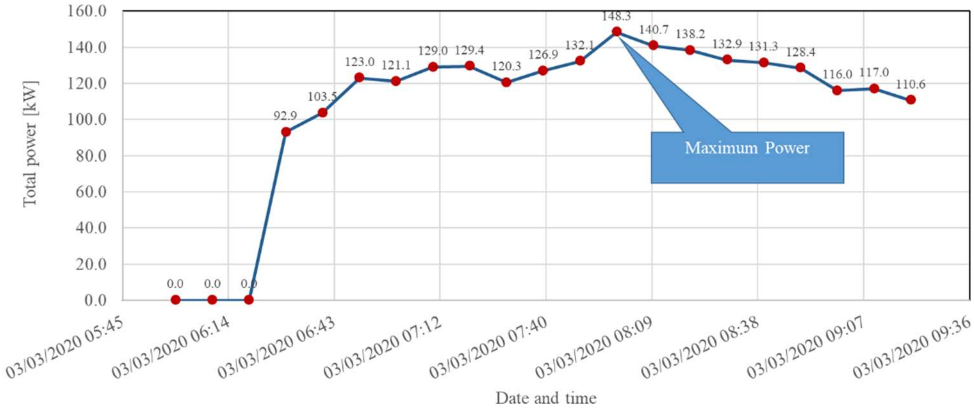


Figure 12: Lundy power grid and load node

The power demand at each load node is estimated based on the total power demand and the number of buildings at each load node. We estimated the cable parameters and built a grid model to test the network power flow. Overall, the cables are not heavily loaded (none exceeding 60% capacity) and the maximum voltage drop at each node in the model is 2.7% which is within the standard fluctuation range. The model also shows a low cable failure rate (<0.18/year) and a low node failure rate (up to 0.11/year). More information can be found in the Appendix.

3.6 Scenario analysis

Uncertainty about the future is an inherent component of decision making in energy systems. The many different possible futures, each with different social, technical, economic and political characteristics. Which future we arrive at is decided by innumerable decisions and events along the way (Schwartz, 1997), many of which will be beyond the control of individual stakeholders.

3.6.1 Overview of key principles of GM taken from T2.1.2

The ICE Methodology suggests the use of scenario analysis to make decisions about how best to:

- test or examine different plans and policy options, with the aim of exploring which combinations are likely to work more or less well in which scenario(s);
- provide the basis for developing new policies or actions;
- provide the basis of a strategic vision about an organisation's evolving role or opportunity; and
- act as a means of identifying signs of movement towards a particular kind of future

Scenario analysis can use both qualitative quantitative techniques to develop narratives/storylines that describe scenarios which describe how the world might look at some stage in the future. A set of different scenarios is often developed to reflect the range of different possible futures that might take place. In order to be useful, each scenario must be plausible, internally consistent, based on rigorous analysis and engaging (Foresight 2009). These different futures are shaped by different actions, trends and events. The ICE methodology advocates the use of scenarios across the scope of the transition. The scenarios can be developed from the outlook of the demand and supply options and will give insights into the preferred plan/s that will signal the smart energy transition of peripheral communities.

Figure 13 outlines the general scenario analysis process:

Figure 13 - Scenario development process

3.6.2 The Scenarios on Lundy

We developed two sets of future energy scenario for Lundy modelling hourly energy data, the first set aims to provide at least 50% of electricity from renewables and the second set looks to provide 100%. All of the scenarios use a combination of wind turbine and solar PV generation and the second set incorporates battery storage; these are summarised in Table 8.

Table 8 - Scenarios on Lundy

Scenario	Description	% Renewable Energy
1.1	One 50 kWp wind turbine	55%
1.2	280.5 kWp roof and ground-mounted solar PV	50%
2.1	One 55 kWp wind turbine, 264.9 kWp solar PV and energy storage	100%
2.2	A 100 kWp wind turbine with 111 kWp solar PV	100%

Scenario 1.1

The first scenario assesses the electricity generated from a single WES 50kW wind turbine at the site of the previous wind turbine. The wind turbine is estimated to produce 295MWh of electricity injected into the grid. A time-series comparison between the power generation and the power demand is shown in Figure 13. 2366 hours across the year see the power of the solar farm exceed the demand of the grid and for a total of 184.6 hours both the grid demand and generation drop to zero. The amount of time that the wind turbine is generating excess energy is sizable, thus the need for battery storage or the dumping of large amounts of power will be required, if the turbine is to be generating continuously. Table 9 summarises some key numbers from the scenario.

Table 9 – Summary of Scenario 1.1

Scenario 1.1	**Annual**	**Summer (Apr - Sep)**	**Winter (Oct - Mar)**
Generation (MWh)	295.2	119.3	175.9
Demand (MWh)	534.2	241.7	292.5
Surplus/Deficit (MWh)	239	122.4	-116.6
Surplus Hours	2366.2	1237	1129.2
Deficit Hours	6209	3040.5	3168.5
Peak Surplus (KW)		72	72

Peak Deficit (KW)		-128.62	-139.7
Usable Energy Generated (MWh -assuming no storage)	222.6	89.8	132.8

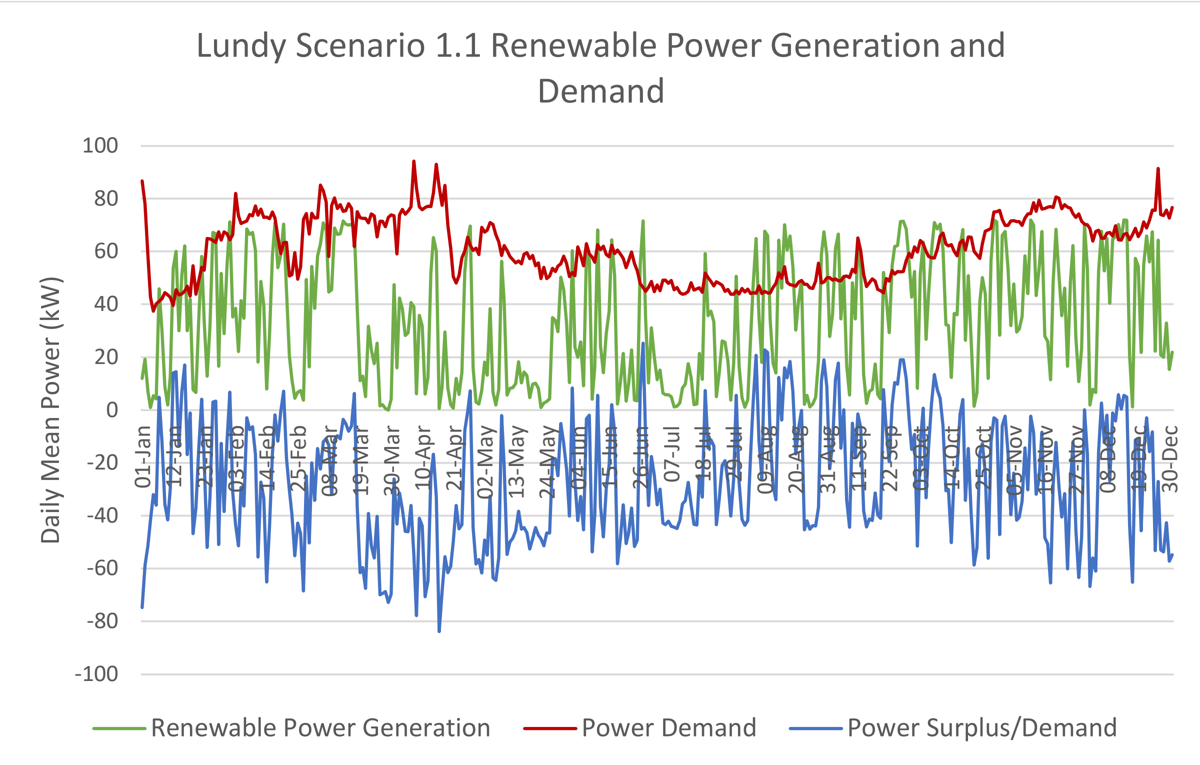


Figure 14 - The surplus and deficit generational trend of Scenario 1.1 over one year.

Scenario 1.2

The installation of a 178.2 kWp ground mounted solar array (Specification 2 decribed above), and the installation of 102 kWp of roof top solar PV (specifically, that on the East roof (66.3 kWp) and on the West roof (36 kWp)) could supply 50% of the island's electrical demand. This scenario is estimated to produce 266.9MWh of electricity injected into the grid, as summarised in Table 10. Figure 15 shows a time-series comparison between the power generation and the power demand, a total of 1,468 hours across the year sees the power of the solar farm exceed the demand of the grid and for a total of 1522 hours both the grid demand and generation drop to zero. The amount of time that the solar farm is generating excess energy is sizable, thus the need for battery storage or the dumping of large amounts of power will be required, if the farm is to be generating continuously.

Table 10 - Summary of Scenario 1.2

Scenario 1.2	**Annual**	**Summer (Apr - Sep)**	**Winter (Oct - Mar)**
Generation (MWh)	266.93	189.89	77.04
Demand (MWh)	534.2	241.7	292.5
Surplus/Deficit (MWh)	-267.27	-51.81	215.46
Surplus Hours	1468	1083	385
Deficit Hours	5770	2586	3184
Peak Surplus (KW)		152.87	116.43
Peak Deficit (KW)		-124.60	-135.14
Usable Energy Generated (MWh - assuming no Storage)	177.2	115.2	62.0

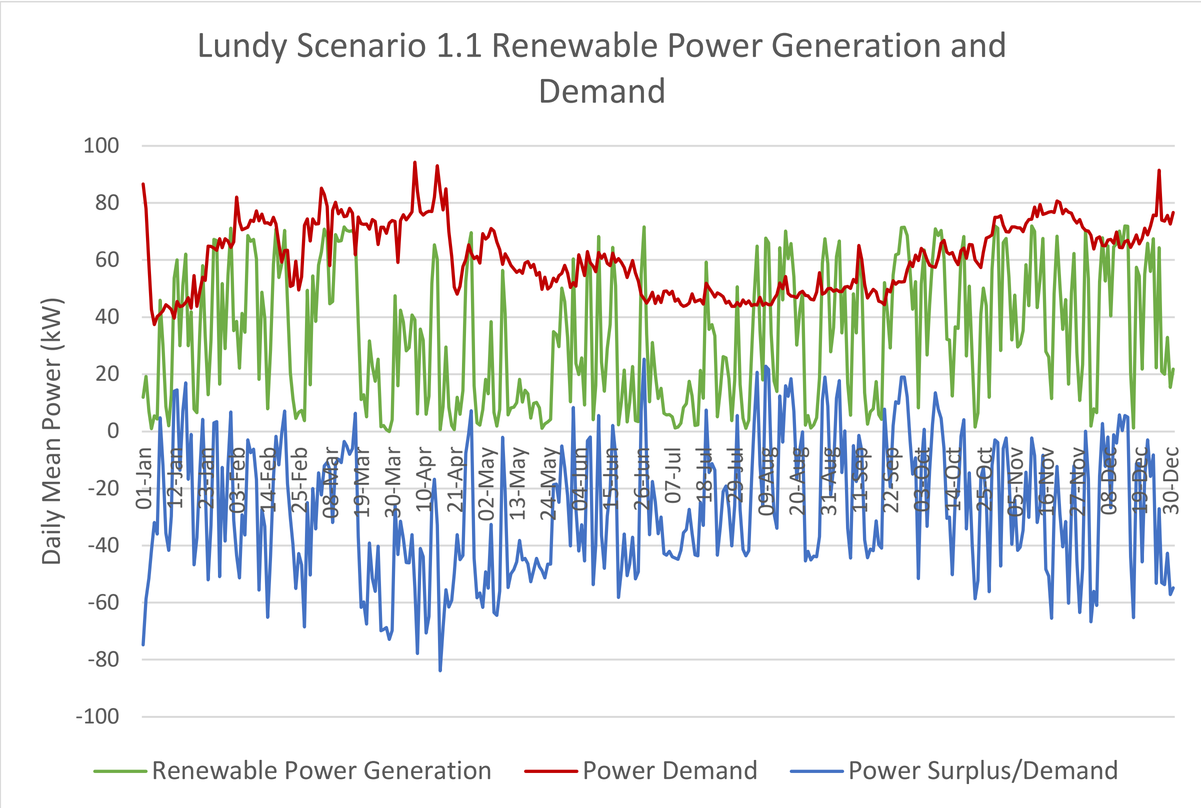


Figure 15 - The surplus and deficit generational trend of Scenario 1.2 over one year.

Scenario 2.1

The installation of a 264.9 kWp ground-mounted solar PV array (Specification 1 descirbed above) and the installation of the WES 50 turbine (50 kWp) would be sufficient to generate around 104% of the annual energy consumption for the island. In total, these systems would inject 560MWh of electricity into the grid. A summary of the data is presented in Table 11. The hourly power generation and demand model over a year shows that 4,160 hours see surplus generation and 4,509 hours have greater demand than generation. The daily mean power generation and demand is plotted in Figure 16.

Table 11 - A summary of scenario 2.1

Scenario 2.1	**Annual**	**Summer (Apr-Sep)**	**Winter (Oct-Mar)**
Generation (MWh)	559.95	303.17	256.78
Demand (MWh)	534.2	241.7	292.5
Surplus/Deficit (MWh)	+25.75	+61.47	-35.72
Surplus Hours	4160	2422	1738
Deficit Hours	5770	1910	2599
Peak Surplus (KW)		212.25	193.16
Peak Deficit (KW)		-110.37	-132.49
Usable Energy Generated (MWh - assuming no Storage)	337.09	165.7	171.4

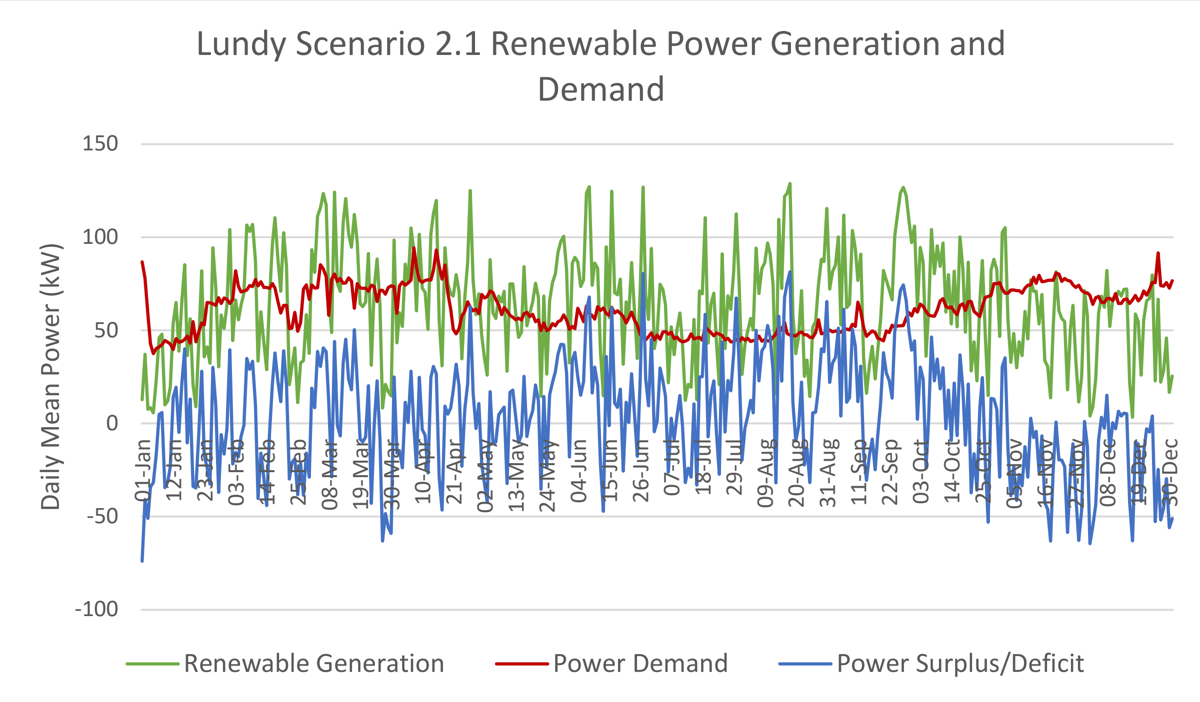


Figure 16 - The surplus and deficit generational trend of Scenario 2.1 over one year.

Scenario 2.2

The installation of a nED 100 turbine (100 kWp) alongside 111 kWp of solar PV – the West (65.7 kWp) and South (15°) (46.2 kWp) roof mounted arrays – could supply sufficient energy annually to equal the current electrical demand. The system would provide roughly 562kWh (455 kWh from wind and 107 kWh from the solar PV) which equates to 105% of the total demand, summarised below in Table 12. The power generated is modelled hourly, and over the year the system generates a surplus for 4709 hours and a deficit for 3912 hours. Figure 17 shows the daily mean generation and demand over twelve months.

Table 12 - A summary of Scenario 2.2

Scenario 2.2	**Annual**	**Summer (Apr-Sep)**	**Winter (Oct-Mar)**
Generation (MWh)	561.65	280.51	281.13
Demand (MWh)	534.2	241.7	292.5
Surplus/Deficit (MWh)	+27.45	+38.81	-11.37
Surplus Hours	4709	2517	2192
Deficit Hours	3912	1818	2094
Peak Surplus (KW)		130.72	142.52

Peak Deficit (KW)		-115.83	-132.50
Usable Energy Generated (MWh - assuming no Storage)	362.52	171.6	190.9

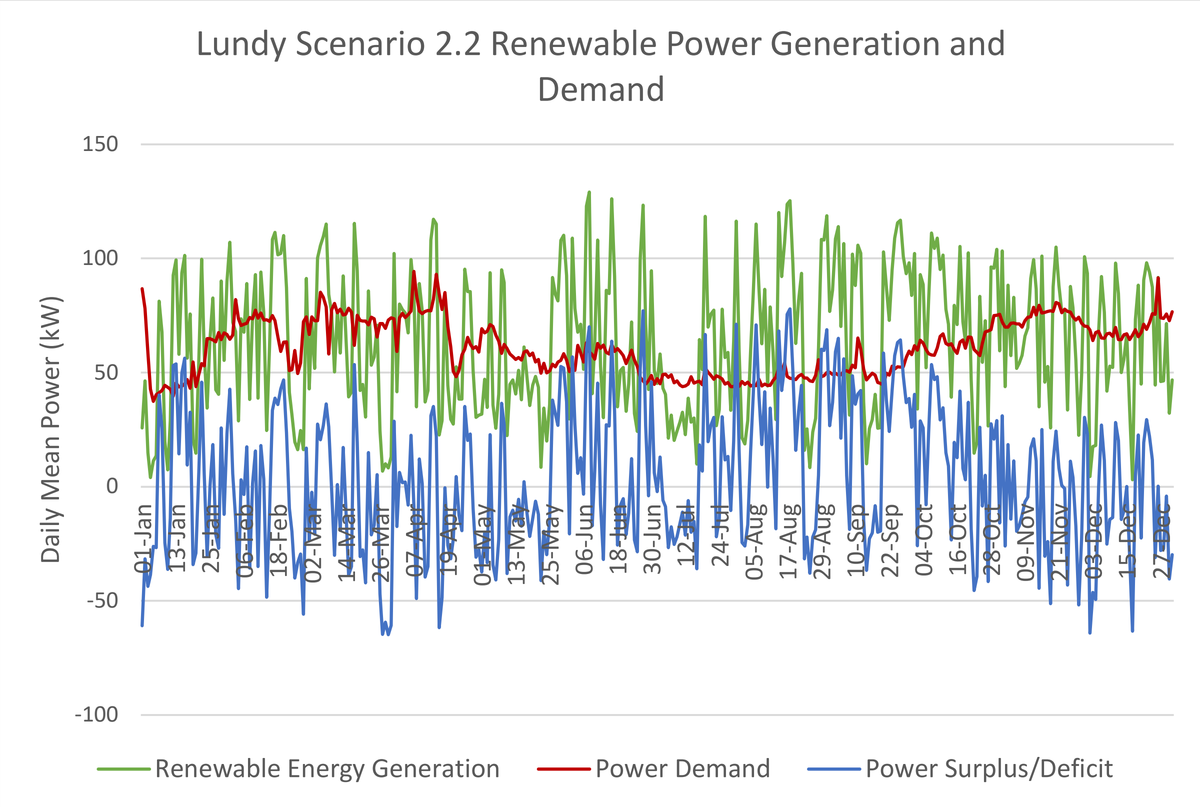


Figure 17 - The surplus and deficit generational trend of Scenario 2.2 over one year.

3.6.3 Evaluation of scenarios

Stakeholder Evaluation

Ideally, the creation of these scenarios would be informed by stakeholder priorities and objectives and these stakeholders would be revisited to understand their views of the modelled scenarios. In this case, it was not possible to carry out a stakeholder evaluation of the scenarios due to time constraints and the global Coronavirus pandemic.

Economic Analysis

We calculated the levelised cost of electricity (LCOE) for all scenarios on Lundy over 25 years as summarised in Table 13. A description of the data and calculations is available in the Appendix. The analysis revealed that for scenarios 1.1, 1.2 and 2.2 the lowest costs were with no battery storage. The addition of a small battery (0.5 MWh or less) only marginally increased the LCOE and larger batteries had a greater upward pressure on the overall cost of electricity. For scenario 2.1, the addition of a 0.2 MWh battery system alongside the wind and solar PV generation reduces the overall cost of electricity compared with the renewable generation alone.

Table 13 - Levelised cost of electricity on Lundy

	Scenario 1.1	Scenario 1.2	Scenario 2.1	Scenario 2.2
System LCOE (€/MWh) - no storage	€ 170.32	€ 211.56	€ 155.37	€ 145.68
System LCOE (€/MWh) - 0.2 MWh	€ 173.56	€ 215.71	€ 151.83	€ 146.70
System LCOE (€/MWh) - 0.5 MWh	€ 182.80	€ 222.86	€ 155.55	€ 155.15

Load Analysis

There are some assumptions considered in this analysis as follows:

1. Due to the mismatch between the load and the power generation, a battery unit able to store the surplus energy and compensate for the shortage in the power generation is located in the middle of the island.
2. Load unbalanced is considered in all cases and all the three-phase currents and voltages are shown in the figures.
3. For reliability, only the circuit breaker is considered due to the grid voltage being nominal load voltage (240V/phase), with no need to step down via transformer.
4. The reliability analysis considers each renewable energy source can supply the load when the diesel generator has a failure. This gives the maximum reliability of the system. Therefore, the provided failure rate in this report is the minimum value and in reality, these values can be less but they are more than the values if we considered diesel generation only. This is all dependent on how much power comes from renewable energy sources and when this generation occurs.

There are two main targets for renewable energy to supply the island as follows, (summarised in Table 14).

Scenario 1 - To meet 50% of the island's current energy demand from renewable technology, specifically using a 55kW wind turbine, solar panels, and a storage solution. The combination of renewable energy sources to meet this target can be arranged into three sub scenarios as follows:

Scenario 1.1: A single WES 50 turbine at the site would meet 55% of the current yearly demand on the island. The wind turbine is estimated to produce 295MWh of electricity injected into the grid.

Scenario 1.2: A ground-mounted solar farm would provide 49.6% of the island's total energy demand. This solar farm is estimated to produce 264.9MWh of electricity injected into the grid.

Scenario 1.3: The installation of ground-mounted solar, Specification 3 and the installation of all the East rooftop solar and 55% of the West rooftop solar would supply 50% of the island electrical demand. This Scenario is estimated to produce 266.9MWh of electricity injected into the grid.

Scenario 2 - To meet 100% of the islands current electrical demand using wind, solar, heat pumps and a storage solution. The following renewable energy combinations are suggested to meet this target

Scenario 2.1: Ground-mounted solar and the WES 50 turbine. This produces 559.9 MWh: 264.9 MWh from Ground-mounted solar and 295 MWh from the WES 50 turbine equating to 104% of the demand

Scenario 2.2: Ground-mounted solar, NPS 60 turbine and ½ of East and West facing roof-mounted solar. This combination produces 549 MWh: 182.3 MWh from the ground-mounted solar, 311 MWh from the NPS 60 turbine, and a combined 55.7 MWh from the East and West roof-mounted solar, equating to 103% of demand.

Table 14 - Renewable energy scenarios

Scenarios		**Aims**	**WT**	**PV**	**Heat Pump**
1	1.1	50%	WES 50	No	No available data
	1.2		No	Ground mount solar	No available data
	1.3		NO	• Ground mount • All east rooftop • 55% west rooftop	No available data
2	2.1	100%	WES 50	Ground mount	No available data
	2.2		NP60	• Ground mount • ½ of east and west-facing roof	No available data

To study the effect of integration the renewable energy sources into the power system grid, the maximum value of the load and renewable energy outputs should be known. This gives an idea about the ability of the present power system to handle the power between the loads and sources. The values of the maximum load and renewable energy sources for each scenario are shown in Table 15. The imbalance in the phases' currents are considered in this study, according to the provided data.

Table 15 - Maximum load and maximum renewable energy output at each scenario

Scenarios		**Maximum power generation**		**Maximum Load**	
		Renewable Energy	Load	Renewable Energy	Load
1	1.1	72kW	0.0 kW	72kW	148.3kW
	1.2	214.09kW	74.27kW	14.94kW	136.638kW
	1.3	211.12kW	73.35kW	1.65kW	136.64kW
2	2.1	324.7kW	104.17kW	146.2kW	136.64kW
	2.2	245.23kW	70.06kW	65.86kW	136..64kW

The location of the renewable energy sources and the point connected to the grid is shown in Figure 18 and Table 16.

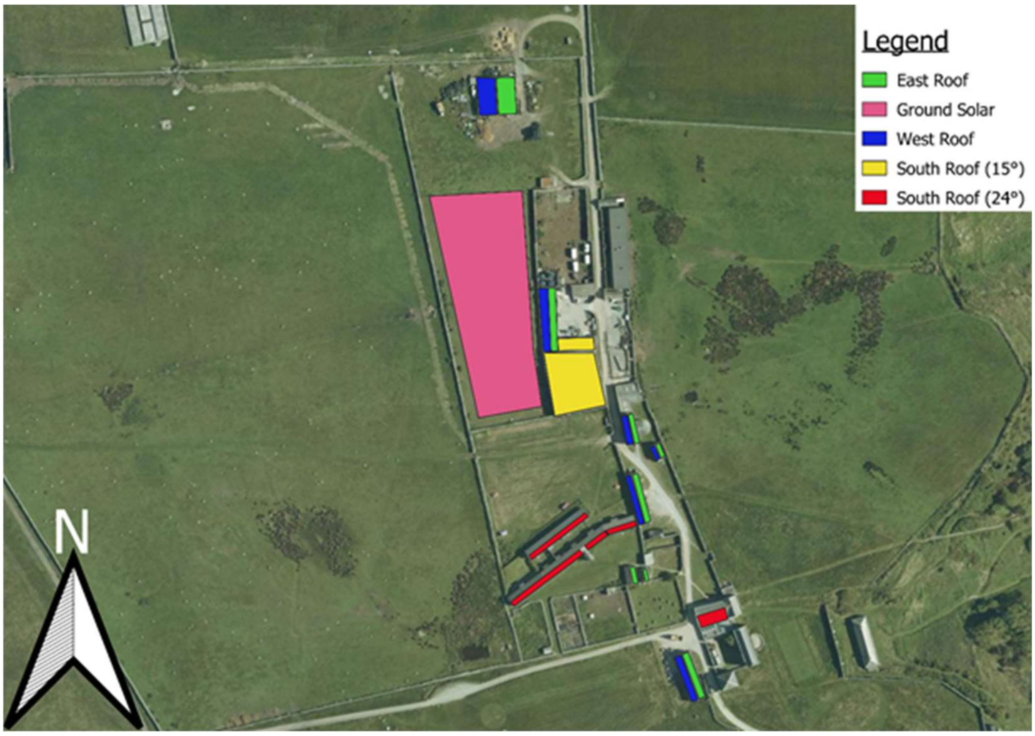


Figure 18 - Renewable energy sources locations

Table 16 - Renewable energy sources connected points

RE type	Connection point
Ground mount solar	L13
East rooftop	L9, L10, L13
West rooftop	L9, L10, L13
South rooftop	L11 and L12
Wind Turbine	L14

Power Flow assessment

Scenario 1: 50% load supplied from renewable energy

The main aim of scenario 1 is to supply 50% of the load from renewable energy. Based on Table 14 and the Simulink model, the voltage drop of the load node for scenario 1 compared with the diesel generator operation is shown in Figure 19 for maximum load conditions and Figure 20 for maximum renewable energy generation. The integration of renewable energy into the power system reduces the voltage drop by around 0.5%. It should be noted that each node has three bars (for the three phases due to the unbalanced load currents).

The cable usage capacity compared with the DG is shown in Figure 21 for maximum load and Figure 22 for maximum renewable energy. It is noticed there is a 2% to 5% drop in the cable usage capacity that the effect of renewable energy. For the maximum renewable energy generation, the cable capacity usage is quite high at the point of the renewable energy and battery connections points (80%) which indicates the attention of replacing the cable or increasing the cable size.

For the reliability assessments, the failure rates for the load nodes are shown in Figure 23 compared with the DG condition. The failure rate has been reduced (up to due to 75%) due to the effect of renewable energy integration.

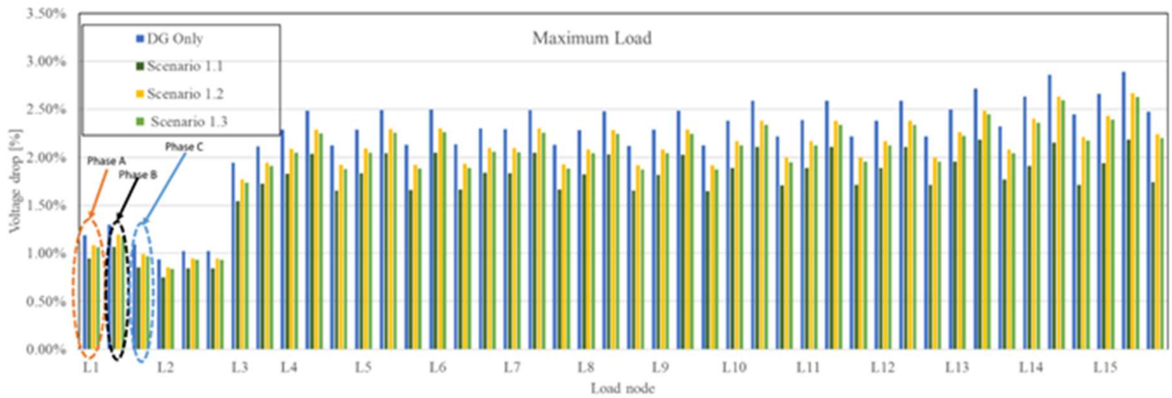


Figure 19 - Load node voltage drop with renewable energy sources and DG for scenario 1 at maximum load condition.

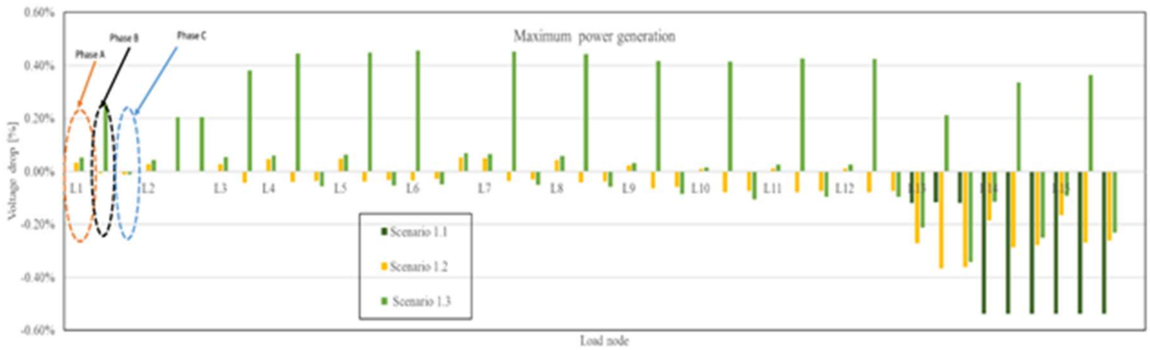


Figure 20 - Load node voltage drop with renewable energy sources and DG for scenario 1 at maximum renewable energy generation.

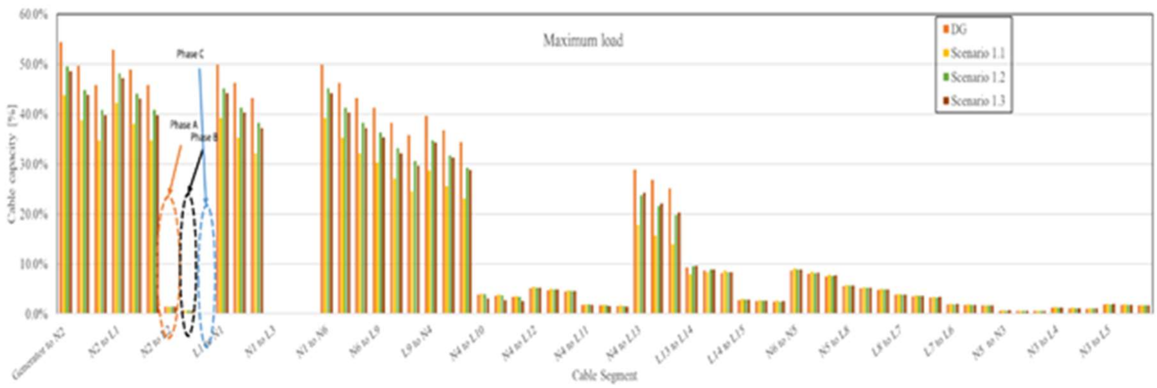


Figure 21 - Cable usage capacity with renewable energy sources and DG for scenario 1 at maximum load condition.

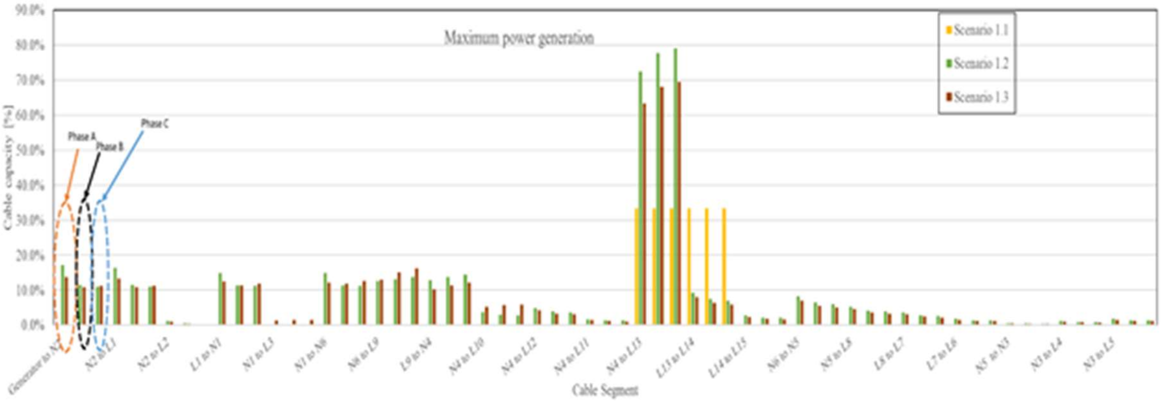


Figure 22 - Cable usage capacity with renewable energy sources and DG for scenario 1 at maximum renewable energy generation.

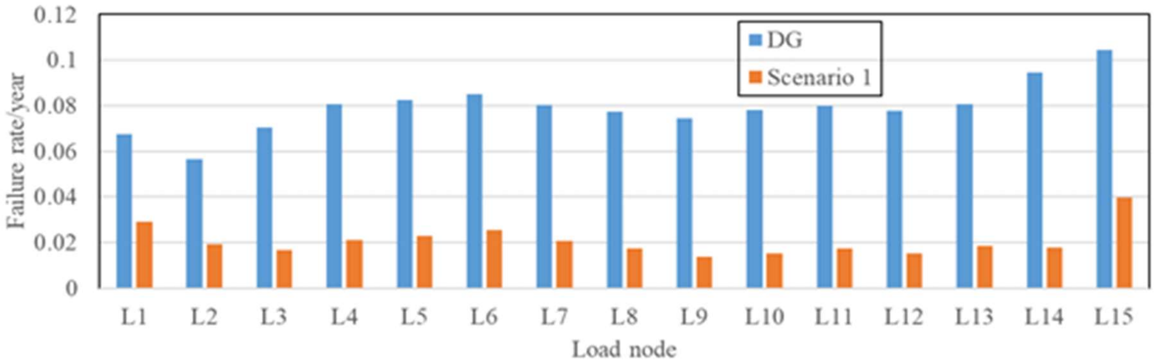


Figure 23 - Failure rate for the load node with renewable energy sources and DG for scenario 1.

Scenario 2: 100% load supplied from renewable energy

The main aim of scenario 2 is to supply 100% of the load from renewable energy. The cable usage capacity compared with the DG is shown in Figure 24 for maximum load and Figure 25 for maximum renewable energy. It is noticed there is a 50% drop in the cable usage capacity in some cable segments and a 50% increase in other cable segments connected to the renewable energy sources but the maximum cable usage capacity is still around 55%. For the maximum renewable energy generation, the cable capacity usage is quite high at the point of the renewable energy and battery connections points (120%) which indicates the attention of replacing the cable or increasing the cable size.

The voltage drop of the load node for scenario 2 is shown in Figure 26 for maximum load conditions and Figure 27 for maximum renewable energy generation. The integration of renewable energy into the power system reduces the voltage drop to be less than 1%.

For the reliability assessments, the failure rates for the load nodes are shown in Figure 28 compared with the DG condition. The failure rate has been reduced (up to due to 75%) due to the effect of the distributed renewable energy units.

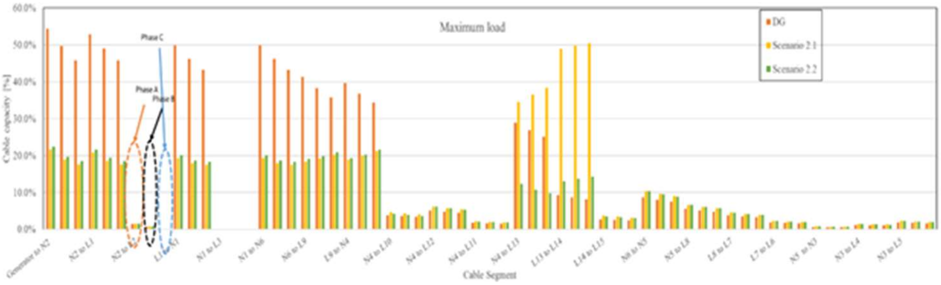


Figure 24 - Cable usage capacity with renewable sources and DG for scenario 2 at max load condition.

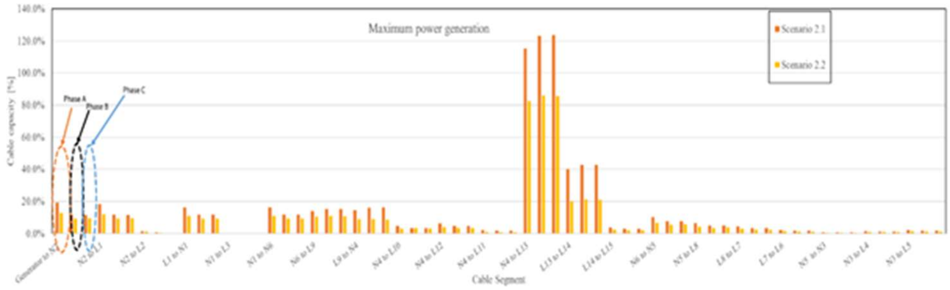


Figure 25 - Cable usage capacity with renewable sources and DG for scenario 2 at max renewable energy generation.

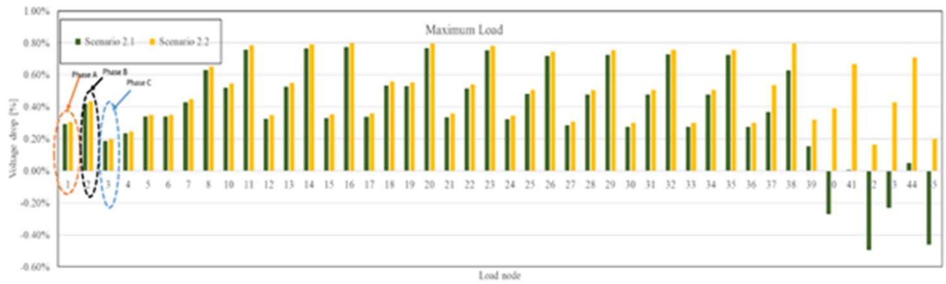


Figure 26 - Load node voltage drop with renewable sources and DG for scenario 2 at max load condition.

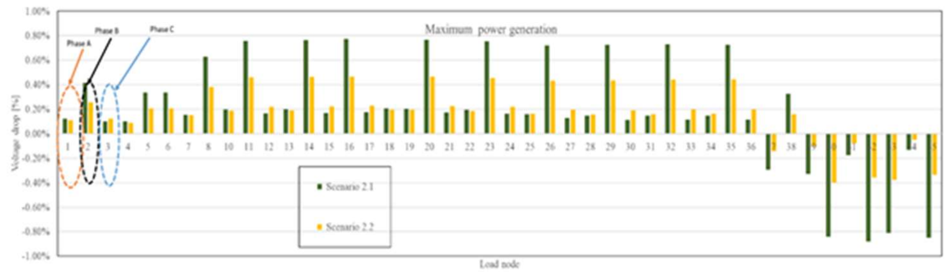


Figure 27 - Load node voltage drop with renewable sources and DG for scenario 2 at max renewable energy generation.

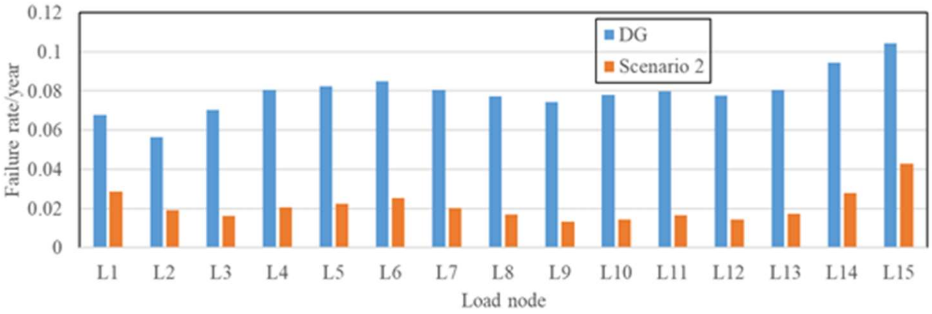


Figure 28 - Renewable energy sources locations.

3.7 Implementation challenges

The ICE Methodology recognises that an energy transition is an ongoing process, rather than a discrete event. It is likely that the ideal situation for each island considered within ICE will change over time. Obvious factors which will change are the relative costs of the wind, solar and storage technologies which form the foundation for our scenarios, but the same will also be true for other technologies, such as tidal energy. Improvements in energy efficiency, and the technologies that help deliver it, are also likely to change over time in terms of both cost and usefulness. Smart energy applications are coming to market in increasing volume, and it is likely that one or more of these will have application on some, or potentially all, of the islands in our study. Significant barriers to adoption of these technologies includes:

- overall cost;
- upfront capital expenditure;
- Perception of the usefulness of emerging technologies;
- Sophistication of grid management and the ability to integrate new grid technologies.

Attitudes to technology may also change but they may also stay the same, even as technologies improve in performance and costs. We found examples of several islands where technologies have been tried or considered once and where this has led to islanders having developed either very positive or very negative attitudes to them. This can lead to rejection of technologies which might otherwise seem appropriate or can mean an attachment to some options even where this does not seem likely to be economically favourable. Both may require work to get citizens to buy into a technology or may mean that a technology is ruled out. The topic is itself of interest for further study since it may impact the options available to islands and other communities.

While both Molène and Chausey have sufficient available potential to achieve a target of 100% renewable electricity, other locations may need to aim lower initially. This may be due to limited potential, relative economics of renewable costs compared with fossil fuels, or other reasons specific to the island under consideration. The ICE GM makes it clear there is a need for regular reconsideration of goals as regards island energy policy, as well as routes to achieving those goals. Both need to be reappraised on a regular basis. This reappraisal should also consider the evolving needs and wishes of the island citizenry and potentially also of other stakeholders.

The GM also makes it clear that state and private stakeholders need to practice transparency with the citizens impacted by changes to the energy system. This means openness about the technologies to be applied, the likely impacts on system performance, impacts on local emissions and the contribution to wider problems such as climate change, but also other potential routes to making changes. Utilities should assume that ordinary members of the public will not be aware of the options as the utilities themselves and make efforts to give fair and balanced information to the public. Real data on effective operation of the technologies, and any impacts on costs should also be as transparent as possible.

3.7.1 Challenges specific to Chausey

There may be some limits on siting of the selected renewable energy technologies on Chausey, but there are sufficient sites that this should not pose a problem to the levels of development outlined in the scenarios which could deliver 100% renewables for island electricity.

As also noted in the Molène study and elsewhere in this study, the French system of regulation for island electricity supply, along with the socialisation of costs across French consumers throws up some complicating factors for adopting large volumes of renewables. While the socialisation of costs is welcomed on the island, it removes a key incentive for consumers to pursue low carbon preferences for adoption. Since real cost savings and real carbon savings may arise from a shift from diesel to renewables in whole or in part, then a regulatory system which allows capture of cost and carbon savings is necessary. This is beyond the control of the citizens of Chausey, however.

Further work is likely to be necessary to ensure that the concerns of citizens of Chausey is properly considered in adopting any systemic changes or as regards technology selection - this was an intention of the ICE project, but interaction was limited by the Covid lockdown. A co-creation approach to new initiatives is essential.

3.8 Fostering local enterprise

As well as the varying technical nature of the products and services required in a smart energy transition, local factors mean that 'who does what' is likely to vary widely between settings. For example, the precise range of services providers and their contracting arrangements depend on a wide range of contextual factors such as access to capital, risk perception, legal environment, experience of contractors etc. For this reason, it is inappropriate to specify here the scope of particular contract packages. Instead, we draw from the literature that underpins these guidelines to outline the types of products and services that are likely to be needed and present a framework that communities and other stakeholders can use and adapt to map against their specific requirements.

3.8.1 Overview of key principles of the ICE General Methodology taken from T2.1.2

In general, a smart energy transition will present commercial opportunities spanning four broad domains of commercial opportunity (See Figure 29):

- **Renewable energy supply -** In most (but not necessarily all) smart energy transitions in peripheral territories, an important goal is increasing the provision of energy from renewable sources.
- **Smart technologies and practices -** Better or 'smarter' management of electricity systems through the adoption of new technologies and practices is a crucial component of a smart energy isolated system.
- **Stakeholder engagement -** Establishing the goals of the energy system, establishing support for action and realising the benefits of action are all crucial parts of a successful transition.
- **Oversight and management -** Planning, guiding and measuring the success of the system transition as a whole.

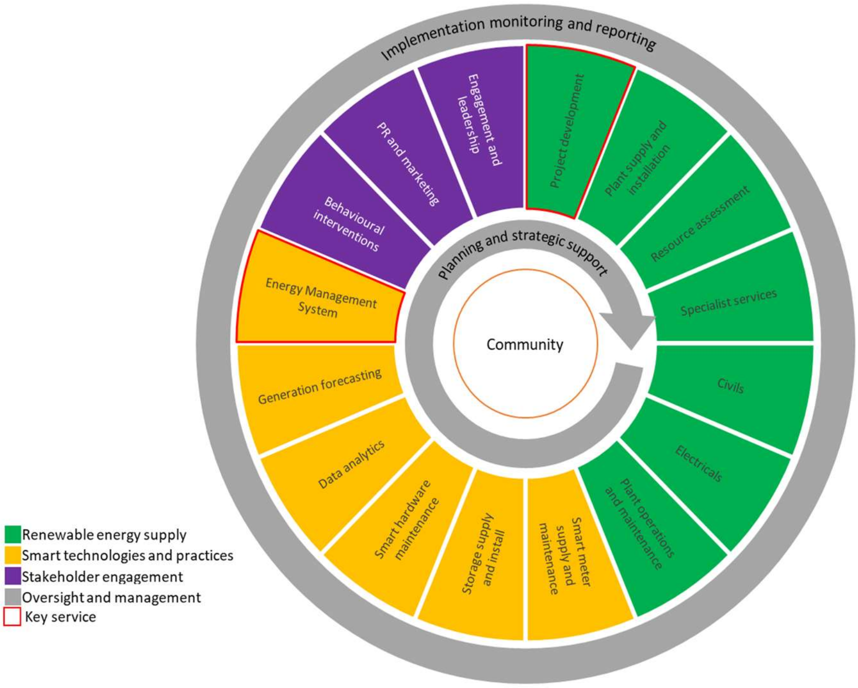


Figure 29 - Domains of opportunity and the likely types of product and service for the transition.

The ICE GM also seeks to build capacity in local businesses by providing advice on topics such as:

- Access to finance
- Innovation funding

Finally, a system of business support based on the creation of a network of businesses invited to participate in a network for collaboration and interaction

3.8.2 Local Supply Chain Analysis

Analysis of the capacities of local enterprise to service the demands of developing and maintaining the future energy system was carried out as follows: Key characteristics of the future energy system and stakeholders were identified in order to determine the opportunities for services and stakeholder engagement and populate the value chain. These characteristics were then mapped to nearby businesses and organisations in Torridge and wider Devon with relevant expertise to produce a picture of local capacity to inform an approach to supporting or engaging local enterprise.

Characterise the energy system and stakeholders

The proposed energy system on Lundy involves a single wind turbine with some centralised solar PV generation. These generation technologies will be sited in two locations. The wind turbine will be installed on the site of a previous wind turbine, which may reduce planning and other permission requirements (though the island is a seabird conservation area, which in turn may add complications). Going beyond the act of obtaining planning permission, acceptability to stakeholders may be a concern to the Landmark Trust as a matter of relationship management.

The solar panels will be located in the vicinity of the barn housing the existing generator set and a workshop – either on the roof of the building of the adjacent field. The field is a site of archaeological value, requiring permission from Historic England for any development, but the panel mounting system would be secured with ballast to avoid any ground penetration. The proposed generation technologies are mature and familiar and would be centralised in the two locations most conducive to such development.

Energy efficiency has not been explicitly incorporated into our scenarios, though it is likely that it could be improved. Again, modifying historic builsings may raise complications and add costs. Our modelling does include a battery energy storage system and there is an existing demand response system on the island.

There are a limited range of stakeholders relevant to energy related decisions on Lundy, mainly organisations including the National Trust, the Landmark Trust, the Torridge District Council (as the local planning authority), Historic England and Natural England. Tourist visitors to the island are also considered to have an interest as the customers who provide the major revenue stream, they are also users of the island's energy system. Given this relatively small group of stakeholders, the engagement process may be suited to a fairly simple facilitation approach.

Capacity mapping

The characterisation process revealed potential commercial opportunities in the three areas of renewable energy supply, smart technologies and practices, and oversight and management. With regard to stakeholder engagement, the island has a unique set of organisational stakeholders with ownership or legal rights to the island, which means that a broad resident engagement process is not required, whilst some mediation may be helpful to strategy development. There may be some need for careful relationship management with regular visitors to Lundy.

Our analysis found good availability of expertise for many of the stages of renewable energy supply, such as solar energy specialists, electrical expertise, planning and environmental consultants, as well as ground workers and civil engineers. The installation of wind turbines themselves is generally carried out by the manufacturers and as such is unlikely to be local. Our analysis did not identify local high voltage grid specialists, but the island's network is maintained locally at present. External (non-local) engineers may be needed to carry out any upgrades that are required; it is unclear whether local providers could continue to maintain the future system.

With regard to smart technologies, small-scale technologies (e.g. batteries, insulation) could be installed by accredited builders or electricians, and examples of which were identified locally. The expertise required for smart-grid management systems, installers of large commercial battery storage or retrofit specialists were not identified in the immediate vicinity and it is likely that therewould be a need to source them from further afield if needed.

Oversight and management could be provided or supported by existing local organisations with capacity for administration and storage, as well as construction trades. A small number of renewable energy system asset managers were identified locally who could potentially provide a more comprehensive set of services.

The greater source of value may lie with the potential to make the island more appealing to visitors with a preference for greener tourism.

3.8.3 Available Funding

Grant funding

National Funding

Innovate UK offer grant support for commercial innovation, research and development. For example, as of 18th August 2020, Innovate UK is running a competition for its Sustainable Innovation Fund: round 2 (de minimis) which will fund innovative projects by businesses impacted by the Coronavirus pandemic.

Following the coronavirus pandemic, the Government's 'Getting Building' fund is supporting 'shovel-ready' building projects through Local Enterprise Partnerships.

The Department for Business, Energy, and Industrial Strategy has been running an Energy Innovation programme funding a series of projects focused particularly on renewable heating and energy efficiency.

Loan funding

National Funding

Innovate UK have provided innovation loans since 2017. Following the coronavirus pandemic, Innovate Uk announced 'innovation continuity loans' to support small and medium enterprises and 3rd sector organisations suddenly short on funds for a live project as a result of the pandemic.

The market for private loan funding is still challenging.

Equity finance

Equity finance options will depend on the incorporated nature of the organisation responsible for delivering the energy system. As registered charities, the National Trust and Landmark Trust could not themselves raise equity finance.

For example, if a community interest company were formed to deliver the new energy system, equity finance could be raised through process similar to a community share offer. Given the national profile of the National Trust and Landmark Trust, it may be appropriate to publicise such a share offer at a wider than community scale.

4 Conclusion

The ICE model suggests credible routes to Lundy achieving scenarios where either 50% or 100% of its power comes from renewable electricity sources. Transport was excluded from the assessment, since options for transport are relevaitly limited on the island, in keeping with its rural aesthetic. There may be some limited potential for a shift to electric vehicles for the island’s few working vehicles, this might offer some limited scope for storage other than in stationary batteries.

A mix of wind and solar was more useful in meeting demand than either technology alone. Wind sshows a good fit with demand on Lundy which can then be balanced via storage. The 100% scenarios include a recommendation for a substantial amount of storage capacity to enable the shift to renewables. The economic effectiveness of the move to 100% renewables will to some extent be dependent on the cost of storage, as well as the cost of solar and wind energy. While the latter pair have shown continuous downward costs in the period from 2008 to 2022, becoming, according to key industry assessors, the cheapest form of new electrical generating capacity, storage remains relatively expensive. It should be noted that our scenarios show an economic advantage for an approach with both a mix of solar PV generation and wind generation, LCOE increases somewhat with the addition of storage, but this may still be justified in enabling system balancing and in reducing the need for excess generating capacity . Our economic analysis showed substantially advantageous LCOE in the 100% scenarios, and the LCOE remains appealing even with the additional storage costs. This leads us to recommend this course of action.

While there are a more limited set of stakeholders regarding this island energy system, even in cmparison with the relatively low number for most of our case studies, the Landmark Trust will need to account for the impact on its sponsors and customers concerning any change in conditions on Lundy as regards landscape and its alteration. There is a need to consider how a wider set of viewpoints of island visitors can be take into account as to any substantive change to operations and island aesthetics. The prior existence of an operational wind turbine on the island may make it easier to consider a new wind turbine, something which can be controversial in protected landscapes and where public opinion can impact donations. This may help with both planning and with acceptance, but also help with site selection.

The UK regulatory system offers more limited support for new capacity than it did at the start of this project, with the termination of new entrants to the Feed-in Tariff (FiT) in 2019, and it is unlikely that Lundy could secure public subsidy. Despte this, the high cost of current fossil fuel supply may still allow justification purely on comparison with diesel generation. As with our French island case studies, there is potential for heat pumps on Lundy, particularly since an alternative to the current heat network will be needed. While there are releatively fewer opportunities on Lundy the Landmark Trust may find it easier to access the capital for such investment than the households of either Chausey or Molène. This may also present less non-tangible benefits to the Trust since dcrbonising energy supply may present some opportunities for marketing as green tourism.

4.1 Assessment of validity – does the General Methodology apply in this context?

We consider the application of the ICE General Methodology (GM), and any issues arising from the approach, in an addendum to the GM, which is available as a standalone document “Lessons from application of the ICE General Methodology” from the ICE website.

5 References

aardvark (2017) ‘Lundy Island Energy Assessment Report’, (February).

Aitken, M., Haggett, C. and Rudolph, D. (2014) *Wind Farms Community Engagement Good Practice Review*. Available at: www.climatexchange.org.uk (Accessed: 7 December 2022).

Aitken, M., Haggett, C. and Rudolph, D. (2016) ‘Practices and rationales of community engagement with wind farms: awareness raising, consultation, empowerment.’, *Planning Theory & Practice*, 17(4), pp. 557–576.

Alexander, K.A., Wilding, T.A. and Jacomina Heymans, J. (2013) ‘Attitudes of Scottish fishers towards marine renewable energy’, *Social and cultural impacts of marine fisheries*, 37, pp. 239–244. Available at: https://doi.org/10.1016/j.marpol.2012.05.005.

Bat Conservation Trust (2013) *Wind farms and wind turbines - Threats to bats*. Available at: https://www.bats.org.uk/about-bats/threats-to-bats/wind-farms-and-wind-turbines (Accessed: 7 May 2020).

BEIS (2017) ‘Contracts for Difference Second Allocation Round Results.’ Available at: https://www.gov.uk/government/publications/contracts-for-difference-cfd-second-allocation-round-results (Accessed: 16 December 2022).

BEIS (2021) ‘Transitioning to a net zero energy system: smart systems and flexibility plan 2021’. Available at: https://www.gov.uk/government/publications/transitioning-to-a-net-zero-energy-system-smart-systems-and-flexibility-plan-2021 (Accessed: 16 December 2022).

Burton, T. *et al.* (2011) *Wind Energy Handbook, 2nd Edition*. 2nd Editio. Wiley.

Colvin, R.M., Witt, G.B. and Lacey, J. (2016) ‘How wind became a four-letter word: Lessons for community engagement from a wind energy conflict in King Island, Australia’, *Energy Policy*, 98, pp. 483–494. Available at: https://doi.org/10.1016/j.enpol.2016.09.022.

Connor, P.M. *et al.* (2014) ‘Policy and regulation for smart grids in the United Kingdom’, *Renewable and Sustainable Energy Reviews*, 40, pp. 269–286. Available at: https://doi.org/10.1016/j.rser.2014.07.065.

DCLG (2015a) ‘House of Commons: Written Statement: Local planning, 18 June, 2015.’ Available at: https://publications.parliament.uk/pa/cm201516/cmhansrd/cm150618/wmstext/150618m0001.htm (Accessed: 16 December 2022).

DCLG (2015b) ‘Planning practice guidance for renewable and low carbon energy.’ Available at: https://www.gov.uk/guidance/renewable-and-low-carbon-energy (Accessed: 16 December 2022).

DECC (2011) ‘Planning our electric future: a White Paper for secure, affordable and low-carbon electricity’. Available at: https://www.gov.uk/government/publications/planning-our-electric-future-a-white-paper-for-secure-affordable-and-low-carbon-energy (Accessed: 16 December 2022).

DECC (2015) ‘CFD Auction Allocation Round One - a breakdown of the outcome by technology, year and clearing price.’ Available at: https://www.gov.uk/government/publications/cfd-auction-allocation-round-one-a-breakdown-of-the-outcome-by-technology-year-and-clearing-price (Accessed: 16 December 2022).

Department for Transport (2013) ‘The Strategic Road Network and the Delivery of Sustainable Development’, (September), pp. 1–23.

Devine-Wright, P. (2009) ‘Rethinking NIMBYism: The role of place attachment and place identity in explaining place-protective action’, *Journal of Community & Applied Social Psychology*, 19(6), pp. 426–441. Available at: https://doi.org/10.1002/casp.1004.

Devine-Wright, P. (2011) ‘Public engagement with large-scale renewable energy technologies: breaking the cycle of NIMBYism’, *WIREs Climate Change*, 2(1), pp. 19–26. Available at: https://doi.org/10.1002/wcc.89.

Devine-Wright, P. and Sherry-Brennan, F. (2019) ‘Where do you draw the line? Legitimacy and fairness in constructing community benefit fund boundaries for energy infrastructure projects’, *Energy Research & Social Science*, 54, pp. 166–175. Available at: https://doi.org/10.1016/j.erss.2019.04.002.

Dollar, A.T.J. (1941) ‘The Lundy Complex: Its petrology and tectonics’, *Quarterly Journal of the Geological Society*, 97(1–4), pp. 39–77. Available at: https://doi.org/10.1144/GSL.JGS.1941.097.01-04.03.

Dwyer, J. and Bidwell, D. (2019) ‘Chains of trust: Energy justice, public engagement, and the first offshore wind farm in the United States’, *Energy Research & Social Science*, 47, pp. 166–176. Available at: https://doi.org/10.1016/j.erss.2018.08.019.

Energy Networks Association (2020) *Open Networks fact sheets*, *Energy Networks Association*. Available at: https://www.energynetworks.org/newsroom/open-networks-fact-sheets (Accessed: 16 December 2022).

Energy Saving Trust (2020) *Solar PV connection to the grid*.

England, N. (1987) *SITE NOTIFIED TO THE SECRETARY OF STATE*.

Evans, S. (2019) *Analysis: UK renewables generate more electricity than fossil fuels for first time | Carbon Brief*, *Carbon Brief*. Available at: https://www.carbonbrief.org/analysis-uk-renewables-generate-more-electricity-than-fossil-fuels-for-first-time (Accessed: 17 April 2020).

Firestone, J., Kempton, W. and Krueger, A. (2009) ‘Public acceptance of offshore wind power projects in the USA’, *Wind Energy*, 12(2), pp. 183–202. Available at: https://doi.org/10.1002/we.316.

Fitch-Roy, O. and Connor, P. (2018) ‘ICE report 1.1.2 Policy Issues - An overview of renewable energy policy and regulatory considerations in Ouessant and the UEA campus’. Available at: https://www.ice-interreg.eu/public-deliverables.

Fitch-Roy, O. and Woodman, B. (2016) *Auctions for Renewable Energy Support in the United Kingdom: Instruments and lessons learnt.*, pp. 715–730.

Goverment Planning Portal (2000) ‘Draft PPS18: Renewable Energy | Annex 1 Wind Energy Planning Issues: Noise’.

Green, D. (2005) *Lundy General Managers Report for 2005*. Landmark Trust.

Greenage (2014) *How many solar panels can I fit on my roof? - TheGreenAge*. Available at: https://www.thegreenage.co.uk/how-many-solar-panels-can-i-fit-on-my-roof/ (Accessed: 16 April 2020).

de Groot, J. and Bailey, I. (2016) 'What drives attitudes towards marine renewable energy development in island communities in the UK?', *International Journal of Marine Energy*, 13, pp. 80–95. Available at: https://doi.org/10.1016/j.ijome.2016.01.007.

Gross, C. (2007) 'Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance', *Energy Policy*, 35(5), pp. 2727–2736. Available at: https://doi.org/10.1016/j.enpol.2006.12.013.

Haggett, C. (2008) 'Over the Sea and Far Away? A Consideration of the Planning, Politics and Public Perception of Offshore Wind Farms', *Journal of Environmental Policy & Planning*, 10(3), pp. 289–306. Available at: https://doi.org/10.1080/15239080802242787.

Haggett, C. (2011) 'Understanding public responses to offshore wind power', *Energy Policy*, 39(2), pp. 503–510. Available at: https://doi.org/10.1016/j.enpol.2010.10.014.

Heaslip, E. and Fahy, F. (2018) 'Developing transdisciplinary approaches to community energy transitions: An island case study', *Energy Research & Social Science*, 45, pp. 153–163. Available at: https://doi.org/10.1016/j.erss.2018.07.013.

Historic England (2020) *Living in a Grade I, Grade II* or Grade II Listed Building | Historic England*. Available at: https://historicengland.org.uk/advice/your-home/owning-historic-property/listed-building/ (Accessed: 15 April 2020).

Infield, D.G. and Puddy, J. (1984) 'Wind-powered Electricity Generation on Lundy Island', in J. Twidell, F. Riddoch, and B. Grainger (eds) *Energy for Rural and Island Communities*. Pergamon, pp. 137–144. Available at: https://doi.org/10.1016/B978-0-08-030580-6.50021-8.

Jenkins, N., Long, C. and Wu, J. (2015) 'An Overview of the Smart Grid in Great Britain', *Engineering*, 1(4), pp. 413–421. Available at: https://doi.org/10.15302/J-ENG-2015112.

Kerr, S. *et al.* (2014) 'Establishing an agenda for social studies research in marine renewable energy', *Energy Policy*, 67, pp. 694–702. Available at: https://doi.org/10.1016/j.enpol.2013.11.063.

Klain, S.C. *et al.* (2017) 'Will communities "open-up" to offshore wind? Lessons learned from New England islands in the United States', *Energy Research & Social Science*, 34, pp. 13–26. Available at: https://doi.org/10.1016/j.erss.2017.05.009.

Landmark Trust (2016) 'Lundy Island Before You Depart Guide 2016'. Available at: https://web.archive.org/web/20160224155740/http:/www.landmarktrust.org.uk/Documents/lundy/Before you depart guide - sailing 2016.pdf (Accessed: 16 December 2022).

Local Goverment Association (2020) *Benefits and potential impacts of wind energy*. Available at: https://www.local.gov.uk/benefits-and-potential-impacts-wind-energy (Accessed: 7 May 2020).

Lundy Field Society (2016) *Annual Report of the Lundy Field Society*. Available at: http://www.lundy.org.uk/index.php/resources/annual-report-archive?volume=68 (Accessed: 16 December 2022).

Matthew, G. *et al.* (2018) *ICE Report 2.1.2: General Methodology*. ICE Project, p. 52.

Mcpherson, S., Bolton, J. and Walker, H. (2019) *East Anglia TWO Offshore Windfarm Chapter 15 Civil and Military Aviation and Radar*.

Natural England (2009) *Bats and Onshore Wind Turbines: Interim Gidance*, *Technical Information Note*.

North Devon and Torridge Council (2011) *North Devon and Torridge Local Plan 2011-2031*. Available at: https://consult.torridge.gov.uk/portal/planning/localplan/adoption/interactive?pointId=5051463#document-5051463 (Accessed: 7 May 2020).

Ofgem (2013) *Creating the right environment for demand-side response: Next steps.* Available at: https://www.ofgem.gov.uk/publications/creating-right-environment-demand-side-response-next-steps (Accessed: 16 December 2022).

Ofgem (2014) 'A guide to electricity distribution connections policy.' Available at: https://www.ofgem.gov.uk/sites/default/files/docs/2014/04/guide_electricity_distribution_connections_policy_0.pdf (Accessed: 16 December 2022).

Ofgem (2017) 'Consultation on penalties for the distribution network operators under the Incentive on Connections Engagement.' Available at: https://www.ofgem.gov.uk/publications/consultation-penalties-distribution-network-operators-under-incentive-connections-engagement (Accessed: 16 December 2022).

Ofgem (2019) *Position paper on Distribution System Operation: our approach and regulatory priorities*, p. 40. Available at: https://www.ofgem.gov.uk/publications/ofgem-position-paper-distribution-system-operation-our-approach-and-regulatory-priorities (Accessed: 16 December 2022).

Papazu, I. (2016) 'Management through hope: an ethnography of Denmark's Renewable Energy Island', *Journal of Organizational Ethnography*, 5(2), pp. 184–200. Available at: https://doi.org/10.1108/JOE-11-2015-0025.

'Planning Act 2008' (2008). Available at: https://www.legislation.gov.uk/ukpga/2008/29/contents (Accessed: 16 December 2022).

Reed, M.S. (2008) 'Stakeholder participation for environmental management: A literature review', *Biological Conservation*, 141(10), pp. 2417–2431. Available at: https://doi.org/10.1016/j.biocon.2008.07.014.

Rudolph, D., Haggett, C. and Aitken, M. (2014) *Community Benefits from Offshore Renewables: Good Practice Review.* Available at: www.climatexchange.org.uk (Accessed: 7 December 2022).

Rudolph, D., Haggett, C. and Aitken, M. (2017) 'Community benefits from offshore renewables: The relationship between different understandings of impact, community, and benefit', *Environment and*

Planning C: Politics and Space, 36(1), pp. 92–117. Available at: https://doi.org/10.1177/2399654417699206.

Schwartz, P. (1997) *The Art of the Long View: Planning for the Future in an Uncertain World*. John Wiley & Sons.

Smith, L. (2016) 'Planning for onshore wind'. House of Commons Library. Available at: https://commonslibrary.parliament.uk/research-briefings/sn04370/ (Accessed: 16 December 2022).

Sorensen, H.C. *et al.* (2002) 'Experience with and strategies for public involvement in offshore wind projects', *International Journal of Environment and Sustainable Development*, 1(4), pp. 327–336. Available at: https://doi.org/10.1504/IJESD.2002.002353.

Sperling, K. (2017) 'How does a pioneer community energy project succeed in practice? The case of the Samsø Renewable Energy Island', *Renewable and Sustainable Energy Reviews*, 71, pp. 884–897. Available at: https://doi.org/10.1016/j.rser.2016.12.116.

The Landmark Trust (2020) *MS Oldenburg History*. Available at: https://www.landmarktrust.org.uk/lundyisland/ms-oldenburg/history/ (Accessed: 28 April 2020).

UK GOV (2020) *Scheduled monument consent (England, Scotland and Wales) - GOV.UK*. Available at: https://www.gov.uk/scheduled-monument-consent-england-scotland-wales (Accessed: 4 May 2020).

Xenias, D. *et al.* (2014) *Scenarios for the development of smart grids in the UK: literature review*. London: UKERC: London. Available at: http://www.ukerc.ac.uk/support/tiki-download_file.php?fileId=3510 (Accessed: 16 December 2022).

6 Lundy Appendix 1

6.1 Solar resource Assessment

Resource constraints

The map in Figure 30 shows that the South west of the UK has a relatively high potential for solar PV.

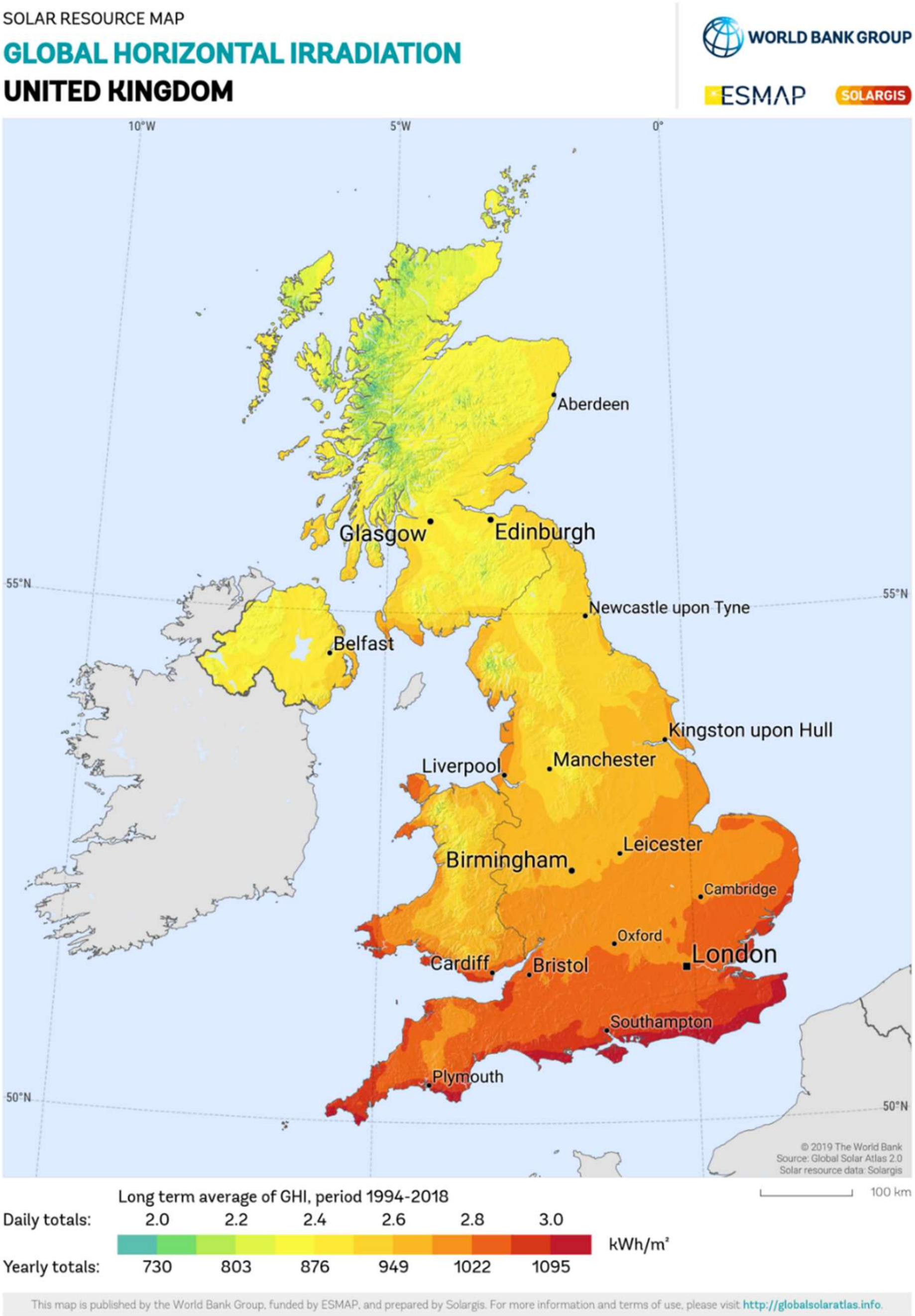


Figure 30 - Solar Geographical Information System Image of the UK

The latitude and longitude (51.165° - 4.666°) identify the location of the island's pub, situated in the most densely populated area on the island. The 6km spatial resolution of this software is large enough so that any variance in solar radiation around the island will be minimal. Average monthly irradiance is shown in Table 17. Average daily irradiance is shown in Figure 31.

Table 17 - Average monthly Irradiance

Month	**DNI (kWh/m^2)**	**GHI (kWh/m^2)**	**G(39°) (kWh/m^2)**
Jan-15	30.4	21.7	39.3
Feb-15	62.2	44.3	75.3
Mar-15	108.6	86.9	124.2
Apr-15	146.5	136.8	161.3
May-15	131.9	151.3	156.1
Jun-15	150.9	160.6	158.1
Jul-15	115.3	137.0	137.1
Aug-15	94.2	109.1	118.3
Sep-15	108.7	97.6	127.1
Oct-15	68.4	58.8	87.6
Nov-15	18.5	16.1	25.8
Dec-15	12.9	12.2	19.7
Total	*1049*	*1032*	*1230*

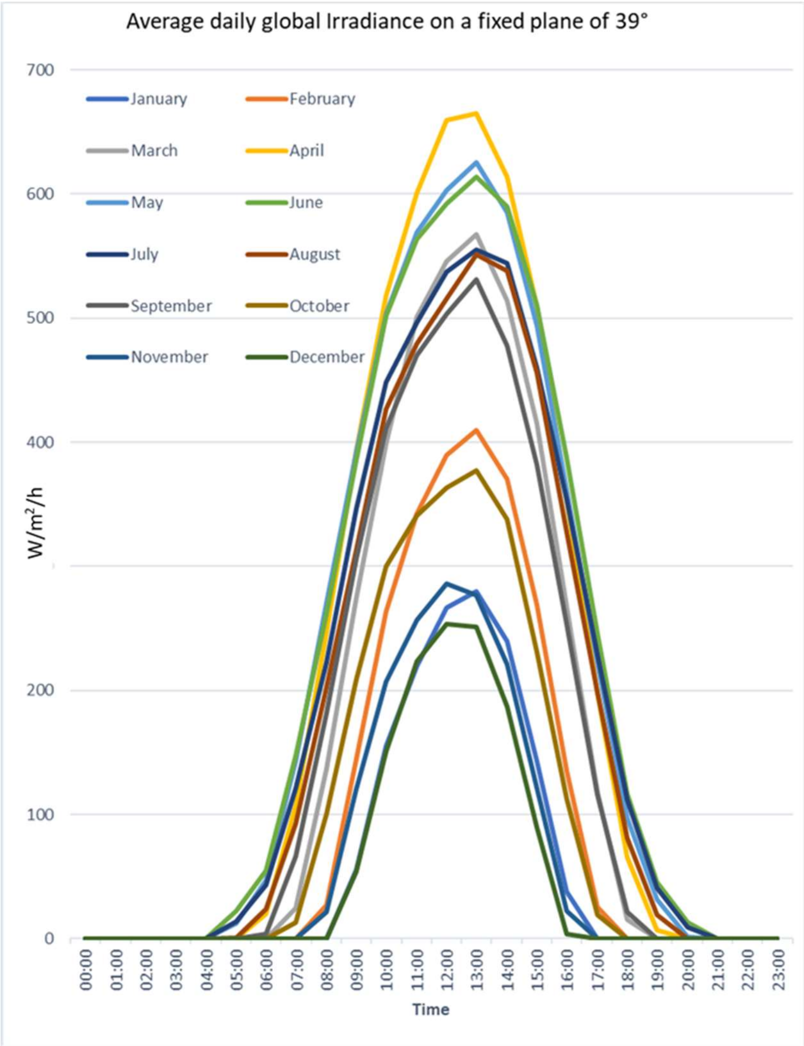


Figure 31 – The G(39°) average daily irradiance for each month in the year 2015.

Political constraints

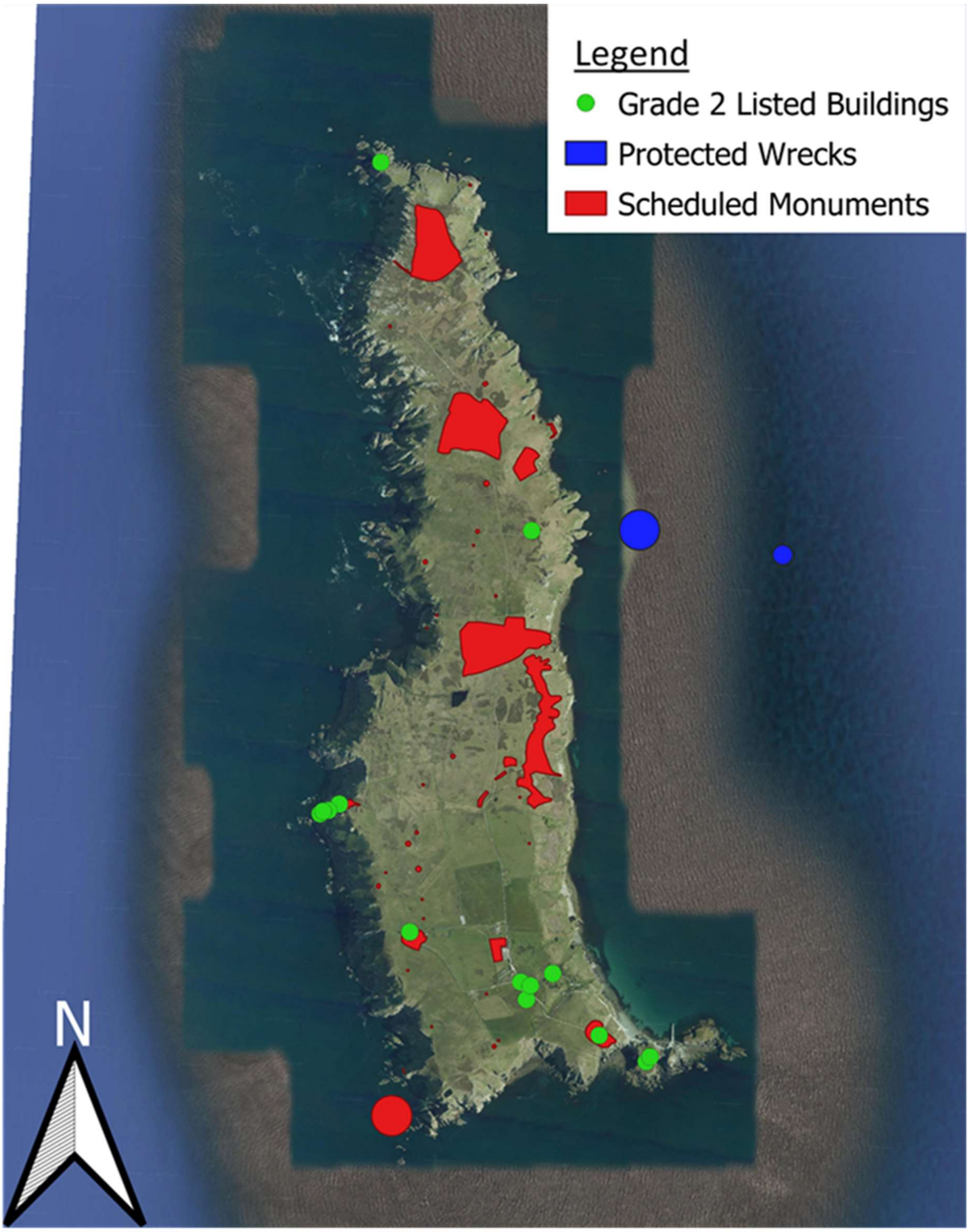


Figure 32 – A map of the Island of Lundy indicating classification of various areas that pose additional legislative challenges to the installation of renewables. Generated using QGIS 3.0 and data from (Natural England, 2020)

The Torridge District Local Plan outlines 4 points with respect to renewable energy and heat (North Devon and Torridge Council, 2011), which are:

1) Proposals for on-site provisions of renewable energy will be supported and encouraged.
2) Community-led schemes that off-set energy and heat demand will be supported and encouraged.
3) Developments where there is no significant local, environmental impacts and nationally important landscape and biodiversity are conserved, will be supported.
4) The project does not become the defining characteristic of the landscape.(North Devon and Torridge Council, 2011)

A listed building is a classification given out through Historic England to buildings that are of national importance. As such, listed buildings have extra legal protection within the planning system. A listed building is defined in three categories, listed by significance these are:

- Grade I, Grade II* and Grade II (with over 92% of classifications being the latter Grade II)

Table 18 below

Table 18 - All the Grade II listed buildings on the island of Lundy. Every building apart from 'Battery Cottage' is a holiday home (Historic England, 2020).

Property	Age
Battery Cottages (4 buildings)	1861
Castel Cottage	1243
Castel Keep South	1243
Castel Keep East	1243
Castel Keep North	1243
Church of St Helen	1896
Government House	1836
Millcombe House	1836
Old House North	1780
Old House South	1780
Old Light Cottage	1819
Old Light Lower	1819
Old Light Upper	1819

Stoneycroft	1819
Tibbetts	1909

The listing covers the whole building, including the interior unless stated otherwise and can also cover attached structures and fixtures, large additions and, on pre-1948 buildings, the land it sits on. Each building listed in Table 18 would need listed building consent before any additions are made (Historic England, 2020).

A scheduled monument is a classification given by Historic England on sites containing nationally important archaeological sites or historic buildings. Written permission is required for alterations from the UK Secretary of State for Digital, Culture, Media and Sport (DCMS). The Scheduled Monument Consent Act (1979) is enforced on activities that include: demolishing, destroying, damaging, repairing, altering, adding to the either above or below ground. Planning permission with the local authority is also required in addition to the requirements of the National Act (UK GOV, 2020).

The area was designated in 1987, due to the unique flora found on the island, it's importance to migratory and nesting birds and the presence of waved Calluna Heath which is only found in specific environmental conditions (England, 1987). There are laws in place that are designed to protect the area from development, damage and neglect and local authorities must consult with the appropriate conservation body over any planned changes to the area (England, 1987).

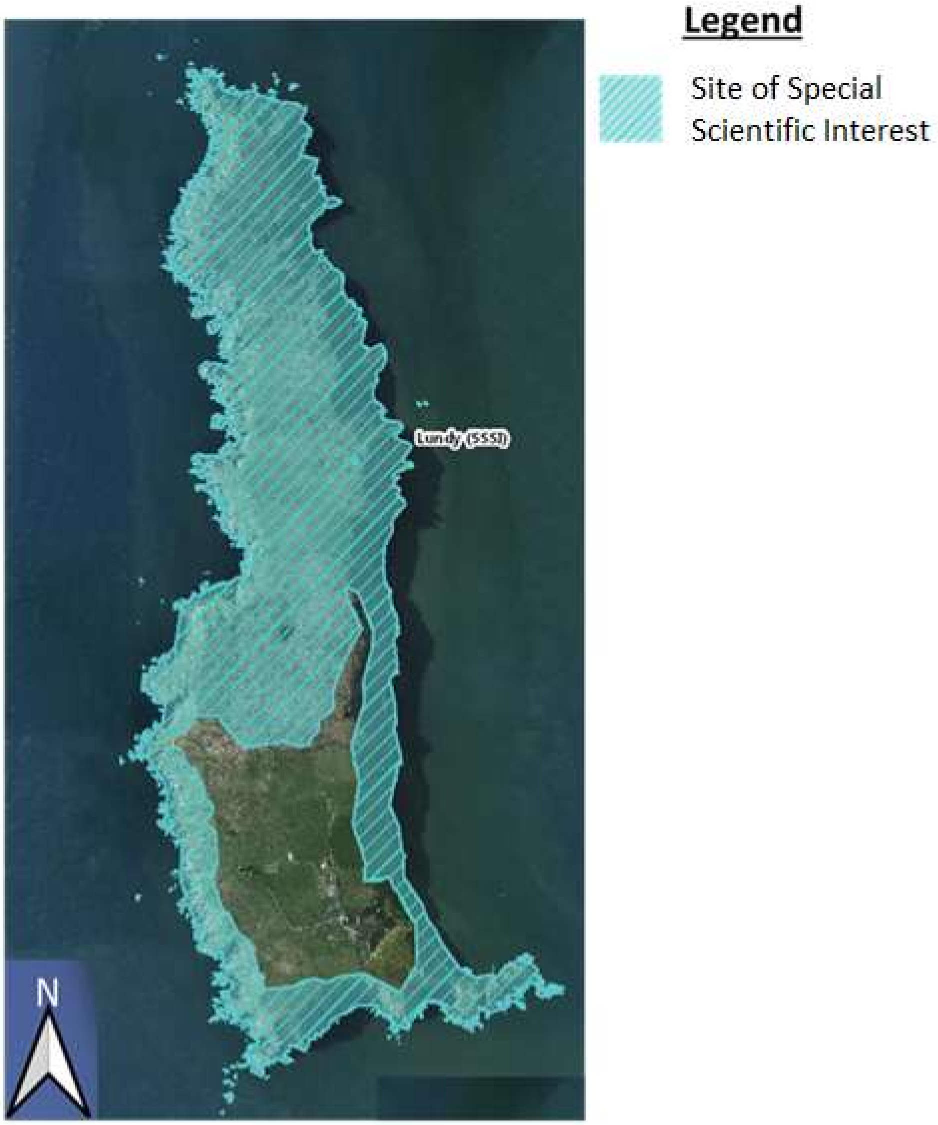


Figure 33 - The Site of Special Scientific Interest on Lundy (Magic Map, 2020)

Generation Modelling

These roof areas were scaled by 0.75 to estimate the useable area for solar PV panels (Greenage, 2014).Due to extremely limited information, regarding the slope and orientation as well as the size and location of skylights, we applied a cautious 0.5 scale to one section of south-facing roof area to minimise the likelihood of overestimating the potential energy production. The 0.5 scale is only applied to the larger of the two shallow sloping, South-facing roofs. Table 19 outlines the specifications for the rooftop sites.

Table 19 – Solar rooftop site specifications

Orientation	Total Area (m^2)	Multiplier (m^2)	Usable Area (m^2)
South (24°)	352	0.75	264

East	482	0.75	361
West	477	0.75	357
South (15°)	108 + 693	0.75/0.5	427

To produce theoretical power productions for each type of site, the software PVsyst is used in conjunction with HelioScope, along with several assumptions and variables which are listed below:

- A slope angel of 24° is assumed for all sloped roof tops unless stated otherwise. This angle is taken from the only known roof of 'the old light upper and lower buildings.
- An angle of 15° is used for the shallowly dipping south roof and a row spacing of 1.5m is assumed.
- South facing roofs have an azimuth of -20°.
- East facing roofs have an azimuth of -100°.
- West facing roofs have an azimuth of 80°.
- A generic 300Wp mono-crystalline panel as stated in PVsyst is used for all calculations.
- All sloped roof use 7.5kW inverters and the flat roof uses a 9kW inverter.
- All buildings are assumed to be unaffected by shading unless stated otherwise.
- PVGIS - COSMO 2015 solar file is used in all calculations

Ground-mounted solar PV

The potential site for ground-mounted solar shown in Figure 5 is 5,354m^2 before the application of any buffers. A 5 metre buffer is applied on the walls surrounding the filed to minimise shading, once applied the usable area measures 3,969m^2. The generation potential for ground-mounted solar PV was modelled in PVSyst using generic 300 Wp panels measuring 1 metre x 2 metres and 30 kW inverters. Using Helioscope, we calculated the total number of panels which could fit in the given area given that the mounting frame holds two rows of panels at the optimum 39^o tilt and the frames spaced 6 metres apart– the row spacing is defined as the distance between the back and front of two panels in adjacent rows.

Data comparison

To compare the power generation with the power demand, hourly values produced through PVsyst were compared to hourly demand data for the island. The islands generational data is measured on a 10-minute basic, so to transform the data, 6 values for each hour were summed and divided by 6 to produce an average for the hour. An example of this is as follows: the demand data for 9:00 - 9:50 is summed together and divided by 6 and assumed to be the demand for the 9:00 slot. The comparison of this with the same generational time slot was the basic for this analysis.

6.2 Wind Resource Assessment

The wind data was measured on site through a Logic Energy Ltd Wind turbine at a height of 8m. The data provided mean wind speed, gust speed, standard deviation, and wind direction at a resolution of 10 minutes. The values are recorded from 01/12/2018 – 01/03/2020 producing a total of 64,418 individual readings. The average wind speed is shown in Figure 34, calculated using the mean velocity recorded in each month.

Wind turbines are high structures usually having hub heights ranging from 20-200m. Therefore, the wind data needed to be upscaled to represent the wind speed at a given height. To upscale wind speeds, the aerodynamic roughness length of the environment needs to be defined (Z_0). The roughness length varies for different environments, city centres have values >2m, parklands and bushes have 0.5m, and open oceans have lengths of 0.0002m. A roughness of 0.03m is assumed for Lundy defined as open flat terrain with grassland and few isolated obstacles (Class II) (Burton *et al.*, 2011).

Equation 1 - Wind speed extrapolation to a particular height. (Burton et al., 2011)

$$v_2 = v_1 \frac{\ln\left(\frac{h_2}{z_0}\right)}{\ln\left(\frac{h_1}{z_0}\right)}$$

V_2 = New Velocity

V_1 = Reference Velocity

H_2 = New Height

H_1 = Reference Height

The distribution of wind speeds recorded over the 15 months of data collection at 8m is presented in Figure 34. The distribution will migrate right towards the larger wind speeds as height above the ground increases.

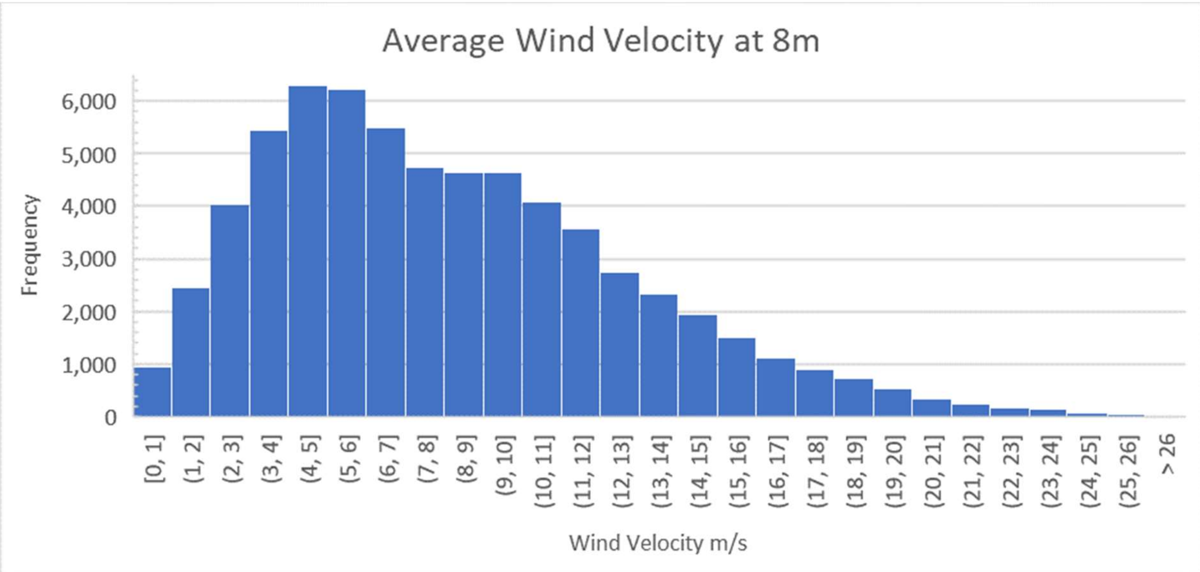


Figure 34 - A histogram of the recorded wind speeds at 8m height.

The wind direction was measured by a wind tracker, with an accuracy to the nearest 22.5°, hence the blocky appearance of the wind rose shown in Figure 35. Most of the points measured appear between, West North West and South, which will need to be accounted for if installing a fixed wind turbine.

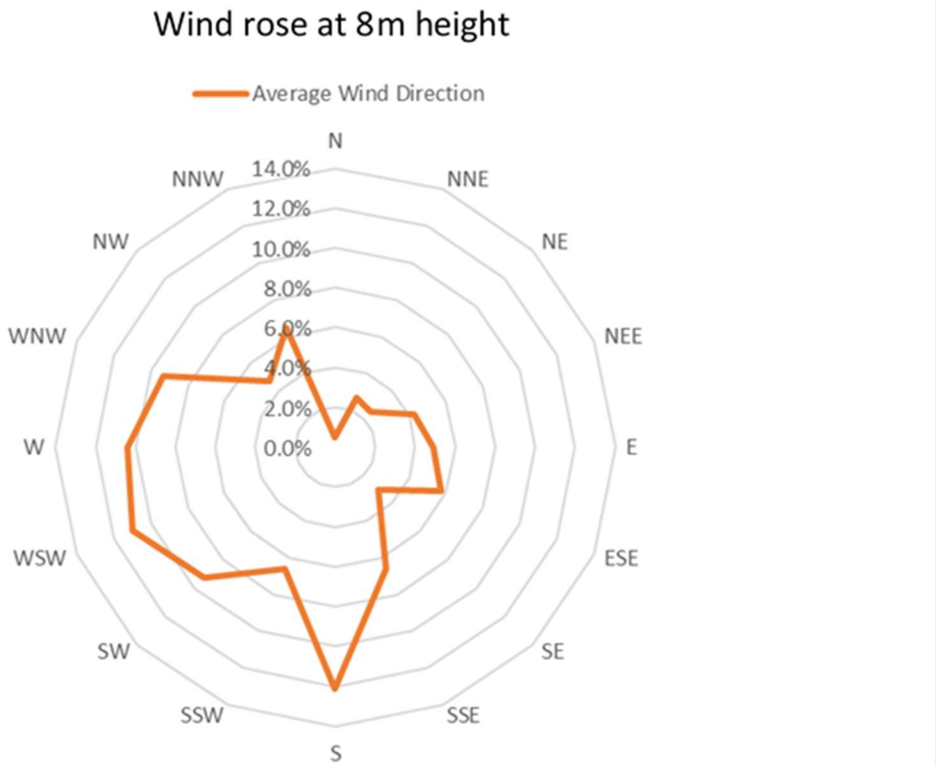


Figure 35 - A wind rose of the recorded wind direction at 8m height.

Environmental and political constraints

Several environmental impacts need to be considered before the installation of a wind turbine. These include flickering effects, rotor noise, radar interference, visual impact, and bird collisions. Each of these potential impacts will need to be mitigated and weighted against the energy generation benefits that the turbine would provide (Local Goverment Association, 2020).

The flickering effect occurs when sunlight is interrupted by a turbine's blades, creating intermittent shadows. However, the effect occurs only in properties within 130° of North at a distance of ten rotor diameters (Local Goverment Association, 2020).

Rotor noise is caused by mechanical components such as the gearbox and aerodynamically when the air interacts with the turbine's blades. Typically, at 350m from the source, the sound pressure level of a wind turbine is at or close to background noise at 35-45 dB(A) (Goverment Planning Portal, 2000). However, this varies dependant on turbine choice and background noise levels.

Radar interference is caused when a radar signal reflects off the structure of the turbine. The reflections can cause significant disruption to a radar system and any adverse impact of Lundy airfield would need to be quantified (Mcpherson, Bolton and Walker, 2019).

The visual impact of a wind turbine is entirely subjective and solely depends on inhabitants' views of the technology. For a turbine to generate electricity efficiently, it must be the tallest structure around, therefore, it will always be visible from certain perspectives. To ensure that visual impact is minimal viewpoints of where the turbine is visible need to be established, followed by a survey of the residents to ensure that any visual impact is deemed reasonable.

Bird and bat collision is a potential adverse impact of the wind turbine through direct collision, habitat loss and fragmentation - because of the disruption of the animals' communication- (Bat Conservation

Trust, 2013). To mitigate the impacts to fauna, extensive activity surveys should be undertaken to ascertain the type, magnitude, and behaviour of the species present. A 50m buffer from hedges is suggested by Natural England as mitigation minimum and is what is used in the site selection model below (Natural England, 2009).

Wind turbines should also be located a safe distance away from houses and roads. Highways England state that 50m + the height of the turbine is a minimum safe distance (Department for Transport, 2013).

Power Production – the turbines

The full details of each turbine are as follows:

1) WES50 - A 50kW direct drive permanent magnet turbine, with a rated windspeed of 9.5m/s, cut out wind speed of 25m/s and a survival windspeed of 52.5m/s. Available hub heights of 15/18/24/30 m.
2) NPS 60C - A 60kW direct dive permanent magnet turbine, with a rated wind speed of 11m/s, cut out windspeed of 25m/s and survival windspeed of 52.5m/s. Available hub heights of 22/29/37 m.
3) nED 100 - A 100kW direct drive permanent magnet turbine, with a rated wind speed of 7.5m/s, a cut-out wind speed of 20m/s and a survival windspeed of 52.5m/s. Available hub heights of 24.5/29.5/36m/

The energy calculations presented in the report make the following assumptions:

- The turbine is installed on the historic wind turbine site detailed in Figure 6.
- A single wind turbine is installed.
- The hub height for the WES50 is 18m, 22m for the NPS 60C and 29.5m for the nED100 turbine
- Wind data is taken from the recoded data and scaled up to match the hub height.
- The turbine is operational for 100% of the year.

System Reliability

Based on the total power demand and the number of buildings at each load node, the power demand at each load node is estimated in Table 20.

Table 20 - Load node power

Load node	Phase A power [kW]	Phase B power [kW]	Phase C power [kW]
L1	2.81	2.60	2.63
L2	0.72	0.66	0.67
L3	0.00	0.00	0.00

L4	1.31	1.21	1.23
L5	2.00	1.85	1.87
L6	0.66	0.61	0.62
L7	3.33	3.08	3.12
L8	1.86	1.72	1.75
L9	1.70	1.57	1.59
L10	4.14	3.82	3.88
L11	1.93	1.78	1.81
L12	5.48	5.06	5.13
L13	21.38	19.73	20.02
L14	7.23	6.68	6.77
L15	3.07	2.84	2.88

For the cable parameters, the length of the cable can be estimated by PlotDigitizer software as in Ushant Island. The cable parameters as shown in Table 21.

Table 21 - Cable parameters

Cable Segment	Length [m]	size	R (Ω)	C (μ F)	L (mH)
Generator to N2	453.88	120	0.100232	0.184126625	0.280202506
N2 to L1	34.4	120	0.007597	0.013955133	0.021236816
N2 to L2	125.7	120	0.027759	0.050993031	0.077600809
L1 to N1	398.3	120	0.087958	0.161579348	0.245890231
N1 to L3	72.439	120	0.015997	0.029386509	0.044720167
N1 to N6	165.327	120	0.03651	0.067068614	0.10206451
N6 to L9	21	120	0.004638	0.008519122	0.012964336
L9 to N4	61.166	120	0.013507	0.024813363	0.037760788
N4 to L10	34.87	120	0.0077	0.014145799	0.021526971
N4 to L12	28.572	120	0.00631	0.011590874	0.017638905

N4 to L11	87.113	120	0.019237	0.035339347	0.053779151
N4 to L13	110.44	120	0.024389	0.044802469	0.068180058
L13 to L14	384.244	120	0.084854	0.155877216	0.237212769
L14 to L15	277.814	120	0.061351	0.112701494	0.171508282
N6 to N5	62.58	120	0.01382	0.025386984	0.03863372
N5 to L8	38.699	120	0.008546	0.015699119	0.023890801
L8 to L7	83.793	120	0.018504	0.033992514	0.051729551
L7 to L6	128.96	120	0.028479	0.052315523	0.079613367
N5 to N3	82.53	120	0.018225	0.03348015	0.050949839
N3 to L4	48.337	120	0.010674	0.009117333	0.029840814
N3 to L5	93.502	120	0.020648	0.037931188	0.057723395

Using this data, a Simulink model for the Lundy was built as shown in Figure 36. Figure 37 shows the current in each cable segment. The cable capacity usage is shown in Figure 38; the cables are not heavily loaded where the maximum cable usage is about 60%. It should be aware that load power is the maximum load for the whole year.

Regarding the voltage drop at each load node, Figure 39 shows the percentage voltage drop at each node. Positive values indicate how far the node voltage is below the nominal voltage. The maximum voltage drop is 2.7% which is within the standard range of voltage fluctuation.

For reliability assessment, the technique employed for Ushant Island is repeated here. The operation procedure of the generators unit is that only one or two engines run at any one time with the third engine acting as a standby in the event of an unplanned shutdown. This means two out of three generators are running. According to the cable length, the failure rate of the cable segments is shown in Figure 40.

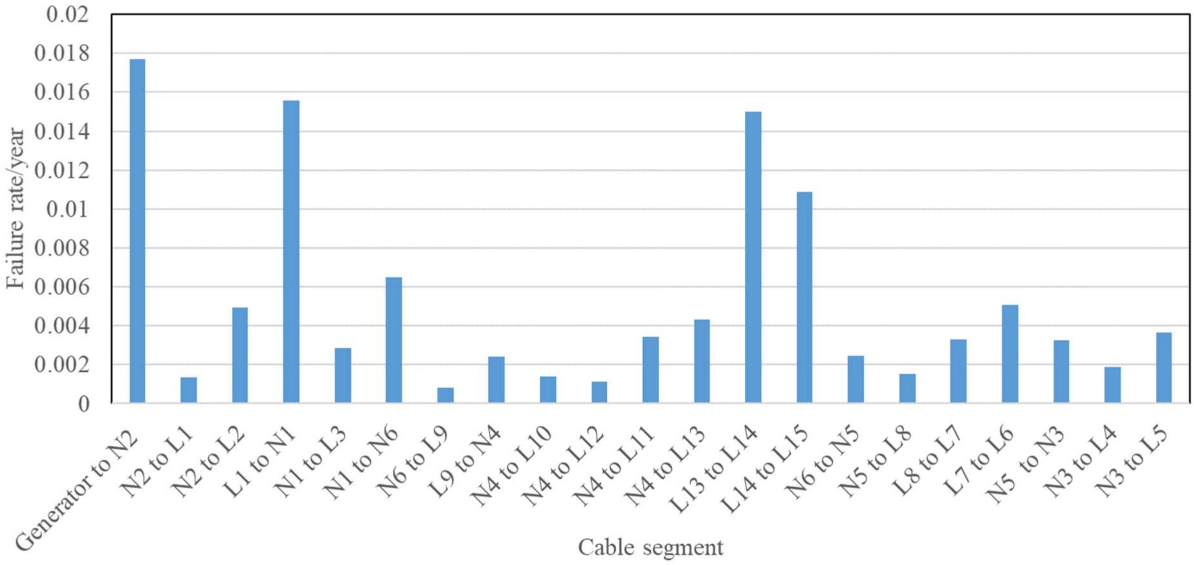
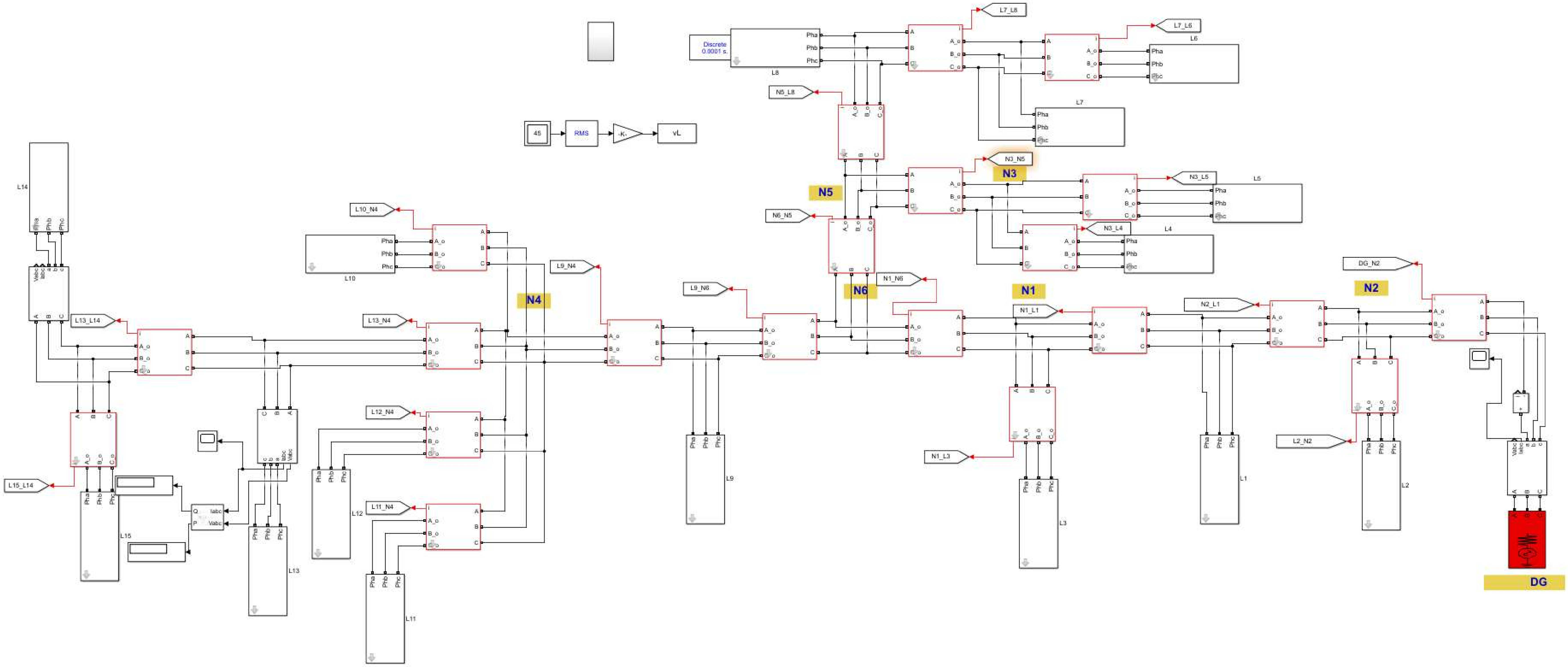


Figure 36: Lundy power grid and load node annual failure rate

Based on the grid schematic diagram, cable segment, generators and grid components reliability, the reliability block diagram for each load nod is built-in ReliaSoft software. The failure rate of the load node is shown in Figure 40. The failure rate of the grid increases with the distance from the generators unit. The highest failure rate is 0.11 per year of the farthest load node from the generators unit.


Discrete
0.0001 s.
L8
L7_L8
L7_L6
L6
L7
N5_L8
45
RMS
-K-
vL
N3_N5
N3
N3_L5
L5
N5
N6_N5
N3_L4
L4
L10_N4
L10
L9_N4
N4
L9_N6
N6
N1_N6
N1
N1_L1
N2_L1
N2
DG_N2
L14
L13_L14
L13_N4
L12_N4
L11_N4
L15_L14
L15
L13
L12
L11
L9
N1_L3
L3
L1
L2_N2
L2
DG

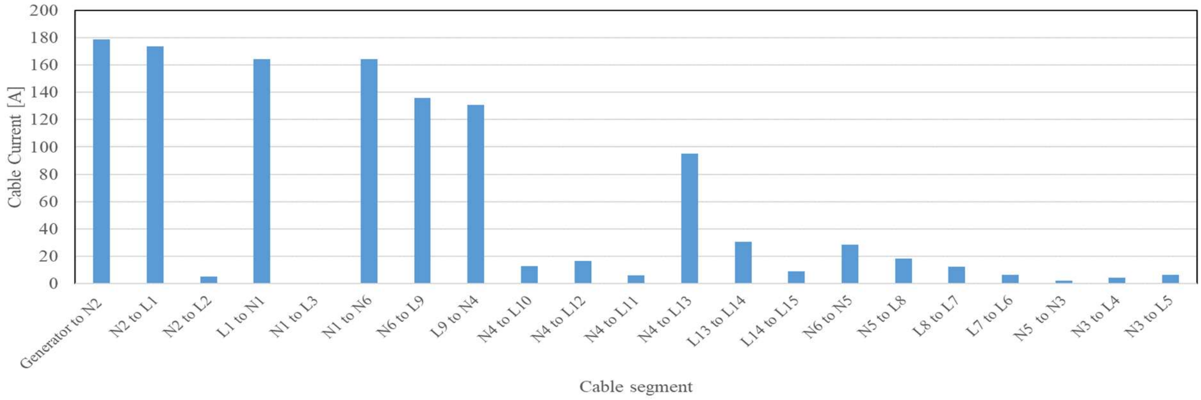


Figure 37: Cable segment current

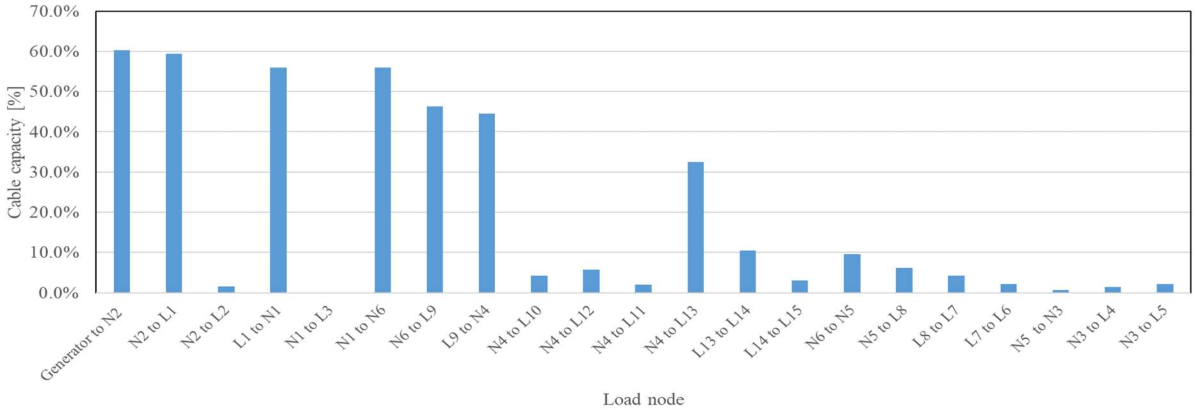


Figure 38: Cable capacity usage based on cable size of 120mm²

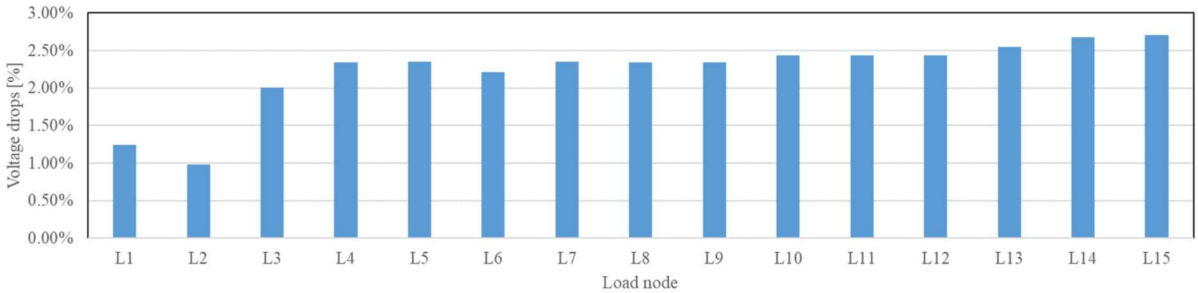


Figure 39: Load node voltage drop

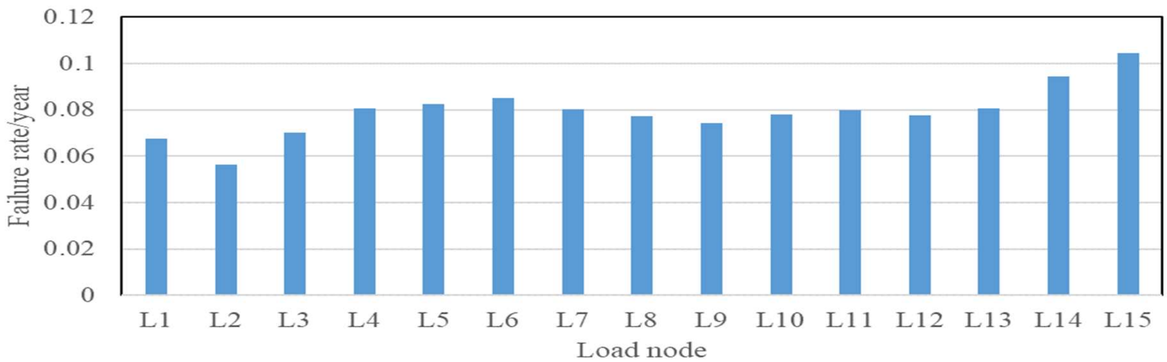


Figure 40: The failure rate of the load node

6.3 Fostering Local Enterprise

Capacity Mapping

Supplier opportunities		Opportunities for Island	Example Businesses
Planning			
- Project Rationale	Landmark Trust & NT		
- Public Consultation	LT & NT (+ some customers)	Consultancy	
- Surveying and Consenting	Planning application, ecological and archaeological surveying, and EIA	Local planning consultants, ecologists, archaeologists, and environmental consultants	ONS: 305 professional, scientific and technical businesses in Torridge, 4,625 in Devon. Yell: At least 15 planning consultants/architects within 7 miles. Yell: At least 3 Environmental consultants in Bideford Yell: 2 Archaeologists registered in Devon
Financing	Capital from Trusts or borrowed	Community share offer? Community energy finance for households/businesses	
Grid Design and Engineering	Integrating supply & Demand Upgrading island network design	M&E HV design specialists	ONS: 435 construction businesses in Torridge, 4,950 in Devon.
Procurement			
- Generation	Ground-mount solar PV + kit 50 kW wind turbine + kit	Via solar PV specialists and turbine manufacturer.	

- Storage	Battery		
- Interfaces & Services	Upgrading wires to full 3ph and transformers Voltage stabilisation		
- Demand Management	Balancing software Demand/supply forecasting DR hardware Comms relays		
Installation			ONS: 435 construction businesses in Torridge 4,950 in Devon
- Generation	Wind/solar PV – specialists Small-scale storage – generic (MCS) sparky	Solar PV & small-scale storage installation Wind by manufacturer	Yell: 6 Energy/PV installers within 12 miles
- Civils	Wind turbine base Storage location preparation	Engineering firms & builders	Yell: 60 'Builders' within 3 miles (Bideford) 11 ('Civil'/'Consulting') 'Engineers' in Bideford
- Electricals	HV Wires and connections – HV specialist LV wires & connections – generic sparky	Local electricians/M&E for LV work	Yell: 33 'Electricians' within 3 miles.
Operation			
- Logistics	Spares and co-ordination – LT or 3rd party	On-island storage Local storage Local business admin support	ONS: 100 *storage & transport* businesses in Torridge, 1,195 businesses in Devon. ONS: 195 *business administration* businesses in Torridge, 2,745 in Devon. Yell: 17 'removals and storage' providers within 10 miles

- Maintenance	Inspection and monitoring	Tradespeople – electricians Environmental consultants RE Asset managers	ONS: 435 construction businesses in Torridge, 4,950 in Devon. RE AM: Clean Earth Energy, Communities for Renewables
- Billing	N/A as single prosumer		
- Management	LT or 3rd party	Local business admin support	ONS: 195 *business administration* businesses in Torridge, 2,745 in Devon

“Yell” = Yell (2020), “ONS” = ONS (2019).