Interreg France (Channel Manche) England

European Union

ICE Intelligent Community Energy

ICE REPORT 2.4.1

ICE GENERAL METHODOLOGY VALIDATION STUDY: CHAUSEY

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

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2 Smart energy transition on Chausey

2.1 Island overview

Chausey is a cluster of small islands and islets to the South of the Channel Islands in the Norman/Breton gulf in Northern France. Grande-Île (45 hectares) is the only inhabited island of the French-administered archipelago. The exposed area of the islands varies greatly between high and low tide with the number of island and islets increasing from 52 to more than 300.

2.2 Reasons for selection

Among the many challenges facing sustainable energy transition on small islands, the small scale of demand, large seasonal variations in demand, lack of available energy resources and heritage restrictions on development, are particularly significant. Chausey, where demand can be as low as zero in the winter months, is an extreme example.

2.3 Demographics and location

The permanent population of the island is around a dozen, but the island receives large numbers of visitors, and the island has many seasonally occupied residences.

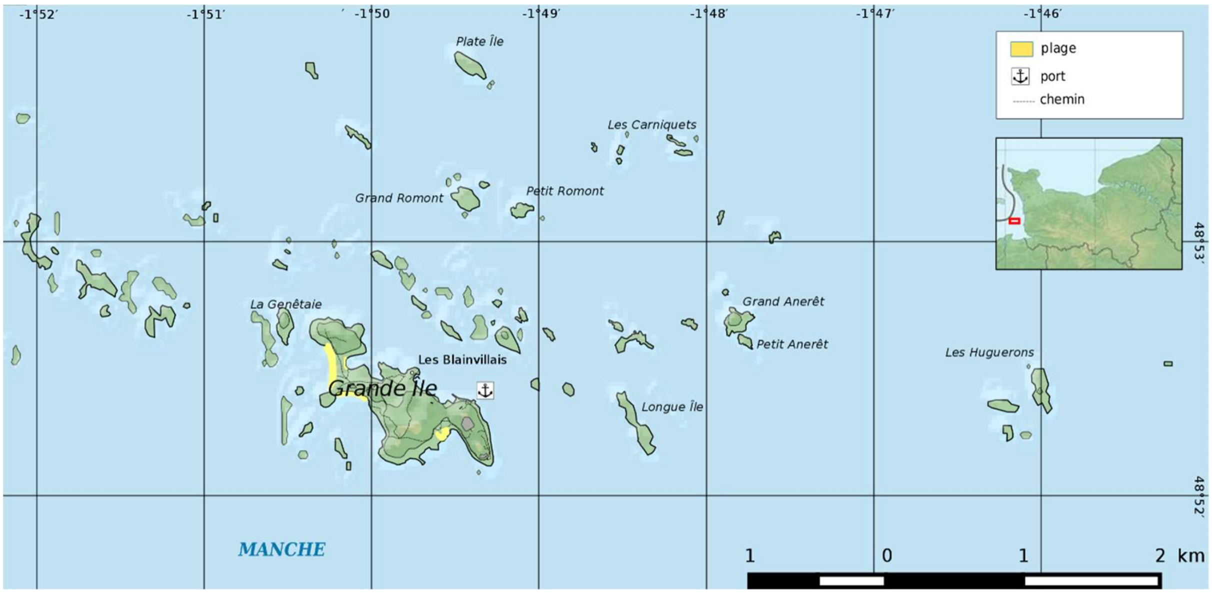

Figure 1: The Chausey archipelago[1]

2.4 Economic status

Chausey's primary economic activity is associated with tourism but there is also significant fishing activity in the surrounding waters. The only commercial activity permanently operating on the islands of Chausey is a hotel, restaurant and a grocery store on Grande-Île.

[1] By Soisyc Croisic - Own work, DEM from NASA SRTM V3.0 - 1 arcsec, coasts and roads from Opentreetmap, island names from Les îles Chausey sur la carte du diocèse de Coutances de Mariette de la Pagerie, 1689 and Les îles Chausey sur la carte de Herman van Loon, 1753., situation map from File:France relief location map.jpg (author: User:Sting), symbols from File:Maps template-fr.svg, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=46443251

2.5 Policy and regulatory overview

The following subsections summarise relevant policy and regulatory information from ICE report T1.1.2 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

Offtake and RES obligation

As discussed above, the French electricity system, including the development and integration of renewable energy technologies, has been traditionally dominated by the state-owned utilities company, Electricité de France (EDF), which either owned or acted as offtaker and counterparty[2] for nearly all independent renewable energy projects. Although EDF (or one of its local subsidiaries) remains the primary route to market for independent generators, recent changes make the participation of other offtakers more likely. However, if renewable energy projects are unable to access an offtake contract on commercial terms, EDF will act as an 'offtaker of last resort', letting a contract for a maximum of 80% of the electricity's market value.

Output remuneration policies

France has two primary output-based support mechanisms for renewable energy: a premium sliding tariff for large-scale installations, allocated through competitive auctions, and a feed-in tariff for smaller projects.

Premium tariff (Complément de rémunération par guichet ouvert)

The feed-in tariff has been the main instrument for encouraging deployment of renewables in France to-date. However, the European State aid guidelines updated in 2014 require a major re-design of RES support systems in France.

To this end, the Act on Energy Transition for Green Growth in August 2015 introduced a sliding premium tariff known as the "compensation mechanism" (mécanisme de compensation). This instrument consists in allocating a premium tariff to renewable electricity producers on top of the price they can achieve in the electricity market, in order to cover the costs of their installations and ensure their profitability (art. 104, loi n°2015-992). Depending on the technology, location and size of the installation, the premium tariff is allocated to generators either administratively through first-come, first-served 'open' contracts ("guichet ouvert") or through a competitive auction process. The value of the premium is calculated by the French electricity market regulator, CRE, using a formula that considers the market price, estimated administrative costs, the cost profile of a reference installation and revenues from capacity guarantees. The tariff payable reduces (towards the wholesale market price) once a threshold volume has been generated by the generating plant.

Importantly for non-interconnected zones (ZNI), the move to the sliding premium system is only applicable in the continental French electricity system where there is a liquid wholesale electricity market to provide a reference price for these contracts. In electrically isolated territories, a fixed-price contract will remain the primary revenue support structure. Whether the tariff is sliding or fixed, the contract duration is twenty years.

Renewable energy auctions (tenders)

As discussed above, in common with all other EU members, France has moved to a tendering or auction system for allocating all renewable energy support with some exemptions such as installation with less than 1MW installed capacity or fewer than six wind turbines. For mature

[2] EDF contracted with generators to both fulfil the physical and financial elements of taking production

technologies such as onshore and offshore wind and solar PV, France has been experimenting with the use of tenders for some years. Recently, the government launched a series of tenders for a wide range of types of renewable energy support.

In 2016, the government launched a programme of six tenders to be held between 2016 and 2019 to support a total of 3GW of solar PV. At the time of writing, one of these tenders saw 79 projects take contracts for support at an average price of €62.5/MWh. In parallel, a similar series of six tenders was held between 2017 and 2020 for all onshore wind installations with more than six turbines, also letting contracts for up to 3GW[3]. A tender was also opened for 50MW of self-consumption installations, with qualified bidders required to consume at least half of the project's output on-site.

Solar plus storage tenders

In 2015, the French government launched a tender specifically targeting the country's island territories. The 'solar-plus-storage' tender for 25MW of ground mount and 25MW of rooftop solar PV systems over 100kW requires the integration of electrical energy storage. Altogether, the first round of this type of tender fulfilled its 50MW goal with 33 projects on islands in France and her overseas territories in June 2016 (Ministère de l'Environnement de l'Énergie et de la Mer, 2016). In March 2017, the government announced that it would launch a tender for tidal energy projects between 50 and 100MW in designated zones in Normandy and Brittany (OEE, 2017). France has run two successful tenders for offshore wind in 2012 and 2013 and plans to contract up to 3GW by 2023.

In addition to the regular tenders, the scale of which may not lend themselves to projects on ZNIs, CRE also allows renewable capacity to be procured on an ad-hoc basis in these territories. These 'over the counter contracts' are "*subject to analysis by CRE and allow the determination of a level of support tailored to the specificities of the project and the territory it is connected to*" (CRE, 2016, p. 29).

Feed-in tariff (Tarif d´achat)

Although the sliding premium is being expanded progressively, a role remains in France for the 'classic' fixed-price feed-in tariff as a support instrument for smaller installations and less mature renewable energy technologies including solar PV plants of up to 100kW capacity.

Other financial elements

Homeowners in France can benefit from a tax credit (crédit d´impôt pour la transition énergétique, CITE) aimed at encouraging energy saving and renewable energy production. The tax credit can be claimed for 30% of qualified works up to a limit of €8,000. There are also value added tax (VAT) concessions for building renovation work that improves energy performance (IEA, 2016).

2.5.2 Network access and grid connection

Renewable energy installations in France must meet the same obligations as any other form of generation when connecting to electricity networks and while they are not given priority, neither can they be discriminated against. Plant owners seeking electricity export to the public distribution system apply directly to transmission system owner, Réseau de Transport d'Electricité (RTE), or the local distribution company, almost invariably Enedis.

Agreements must be held for access to the grid (*Contrat d'accès au réseau public*), connection to the grid (*Contrat de raccordement*) and use of grid connection equipment (*Contrat d'exploitation des ouvrages de raccordement*) (Boekhoudt and Behrendt, 2015). Recent changes introduce strict

[3] http://www.cre.fr/documents/appels-d-offres

deadlines for connection. From the point at which a signed contract is accepted, connections of more than 3kVA must be made available within 18 months. As before, smaller connections must be prepared in two months or less.

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

Formerly complex, onerous and seen as a drag on development, the planning permits required to build renewable energy projects in France have recently been significantly simplified. Until 2017, many permits were required and gaining permission to build a 12MW wind farm took an average of 7-8 years (Lazerges, Gölz and Sauzay, 2016). A single environmental permit issued by the departmental prefect, and covering all requirements was introduced in June 2017. The key elements of the new system are:

- Special authorization for national nature reserves and nature reserves that are Government-listed in Corsica;
- Special authorization for registered sites or those pending registration;
- Exemption from measures protecting wild fauna and flora;
- Non-opposition procedure for Natura 2000 sites;
- Authorisation to operate an electricity production installation;
- Approval of private electricity structures using public land;
- Land clearance authorisation; and
- For onshore wind turbines, various authorisations under defence national heritage

(Fornacciari and Verrier, 2017; Martor and Harada, 2017)

Electricity generating plants in France are required to obtain an electricity generation license. Smaller renewable energy generation stations are exempt, however. The exemption threshold was raised in 2017 from 12MW for solar and 30MW for wind farms to 50MW for both, as well as for ocean renewables.

2.6 Key data on energy production and use

Chausey has no electrical connection to the mainland. In common with France’s other non-interconnected zones (ZNI), Chausey’s electricity is produced and supplied by EDF-SEI, a division of the French national utility, Électricité de France (EDF). Prices in Chausey, as in the other ZNIs are regulated in line with those experienced by consumers on the mainland. Four diesel generators produce around 532 MWh per year, consuming approximately 180,000 litres of diesel fuel, with weekly deliveries from the mainland.

2.7 Network status

The island has a distribution network with two voltage levels, assumptions about this are made in the model, as set out later in this document.

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 'Manche 50' government objectives based on a review of publicly available strategies and plans, including the national multiannual energy programme (Le Ministère de la Transition Énergetique, 2019).

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

Chausey is not connected to the mainland grid, and all its electricity is produced on-site. As on all the islands, and unlike the mainland, EDF-SEI operates, maintains the production facility and markets the electricity. In most cases, EDF-SEI is also the owner of the production plant. The tariff is therefore regulated there, there is no additional cost for the purchase of energy. The schematic diagram for the power grid is shown in Figure 2. There are only two HV load nodes and most of the cables are underground cable. We will consider only the HV grid for power flow and reliability assessment.

Assumptions:

1- The power flow analysis considers the maximum power
2- The system is a balanced system.
3- The power factor of the load is 0.9 and it is same at each load node.
4- The grid voltage is 5.5kV

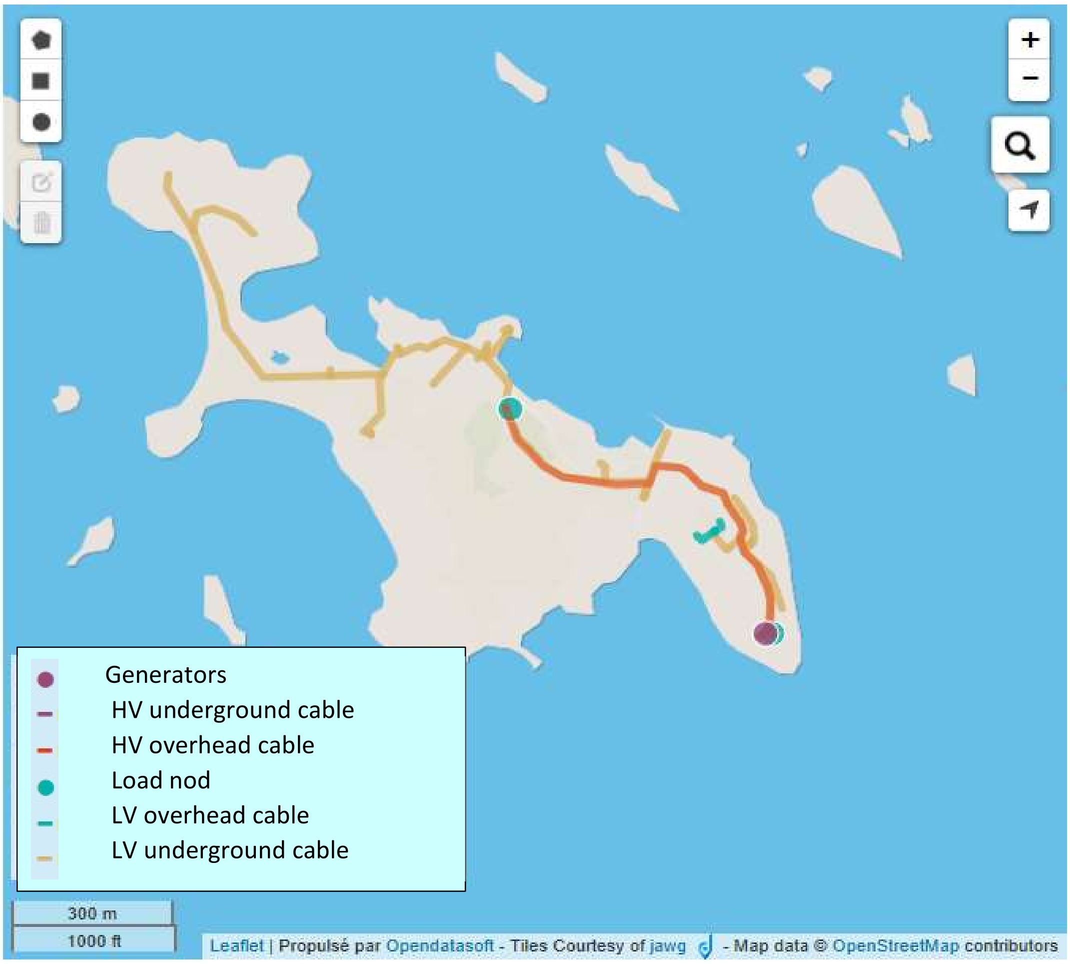

Figure 1 - Chausey power grid

We were unable to obtain high resolution energy data for the island. The only available data for electricity demand is the annual total: approximately 532 MWh per year. Both Ushant and Molène show a similar demand profile. Using the annual electricity consumption for Chausey, we modelled the hourly consumption using the profile from the Ushant network, this profile is presented in Figure 3. Given its extremely low number of winter residents, it is possible that in reality Chausey's electricity profile has more pronounced seasonal differences and that we are overestimating winter demand. If this is the case, then our analysis might turn out conservative in terms of the utility of renewable generation.

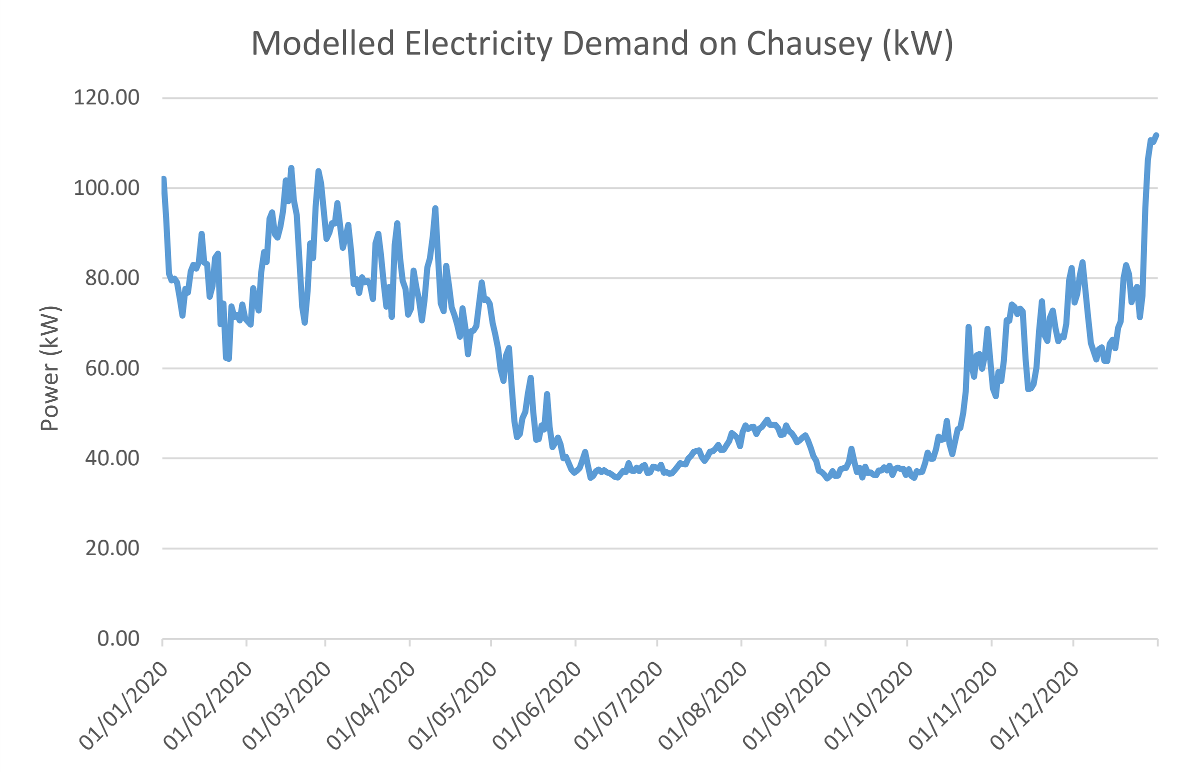

Figure 2 – Modelled power demand on Chausey over the year

For the power flow assessment, we need to know the highest power demand. The load profile on Chausey is assumed to be similar to the nearby French islands of Ushant and Molène. On Ushant and Molène, the highest energy consumption month is about 1.6 times the average consumption for the whole year and the maximum power during the day is about 1.3 times the average daily power. Applying his assumption as in (1), the maximum power demand of Chausey can be estimated.

$$Maximum\ power\ demand = 1.6 \times 1.3 \times average\ power\ demand \qquad (1)$$

The maximum power demand for the island is 128kW and this figure will be used for power flow analysis.

3.2.2 Potential future changes to energy demand.

Reduced demand

Chausey's energy strategy outlines a 100 MWh target for demand reduction by 2028 which equates to just under a 20% cut from current consumption. So far, enhancing energy efficiency has involved distributing LED light bulbs and water economy measures, the latter reducing the need for energy-intensive water treatment. Though the winter population on Chausey is low (around 10 people), ensuring high levels of insulation and deploying heat pumps would nonetheless dramatically reduce the energy demand for heating during these months.

Smart technologies

The increasing deployment of smart technologies for metering and storing energy as well as flexing electricity demand will help alter the energy load profile to match variable generation. Chausey are also exploring the potential benefits of developing hydrogen electrolysis as a form of medium-term energy storage. Local authorities are currently studying the potential for improving the flexibility of energy demand on the island, such as running the electrolyser and water treatment system at times of high renewable generation.

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

A diesel generator provides all the electricity currently consumed on Chausey. The generator is reliant on regular fuel deliveries from the mainland which is a recurring system cost, an environmental impact, and a system security risk. We are not aware of any renewable energy generation technology currently installed on the archipelago.

No battery storage has yet been installed on the island, however, since 2016 Enedis have installed 'Linky' smart meters for all active electricity customers. This means that Enedis have high resolution consumption data and allows for the possibility of deploying time of use tariffs.

Heat

We do not have data from the island about the sources of space or water heating on Chausey. To the extent that the island is similar to Ushant (and France more widely), it is likely that properties on the island rely heavily on direct electrical heating (Hardwick et al., 2018). As at present this electricity is produced by a diesel generator and is thus carbon intensive. One advantage of electric heating is that decarbonising the electricity supply directly reduces carbon associated with heating. Installing heat pumps in the homes of permanent residents is an aspiration on Chausey (Ministère de la Transition, 2019). As heat pumps generally use one third to one quarter of the electricity compared to direct electric, this will reduce electricity demand. Potentially, the associated saving in operational cost may have benefits for human comfort. We did not account for installation of heat pumps in the study, since high capital cost of installation was an issue on the island and because it would require

Transport

Transport on Chausey was outside the scope of this study. While a shift to electric vehicles might offer some alternative to the need for installation of storage affordability of these vehicles seems likely to be prove to be an issue. Further, at time of writing there did not seem to be a mechanism in place for delivering grid services by household operators.

3.3.3 Renewable Energy Assessment

Solar Resource Assessment

Solar PV is one of the most cost-effective technologies to generate electricity in France. The map in **Error! Reference source not found.**. The Îles du Ponant, including Molène, have a relatively high potential for solar PV deployment – see Appendix Figure 15.

Resource Constraints

The solar resource on Chausey has been estimated using PVGIS which combines satellite data to calculate the irradiance at a specific location producing gridded data in roughly 6km squares. We used average monthly and hourly data from Caen, as the most appropriate nearby weather station, the specific latitude and longitude used were 49° 18’ and 0° 45’, respectively.

On Chausey, the global horizontal Radiation (GHI) is 1,129.7 kWh/m^2/year and this rises to 1,313 kWh/m^2/year on a 38^o plane. On Chausey, a 38^o plane was determined optimal, the higher pitch increasing generation during winter months compared to the horizontal irradiance – see Appendix for details. All panels were modelled facing due south. The irradiance is detailed in **Error! Reference source not found.** And illustrated over the year in Figure 4.

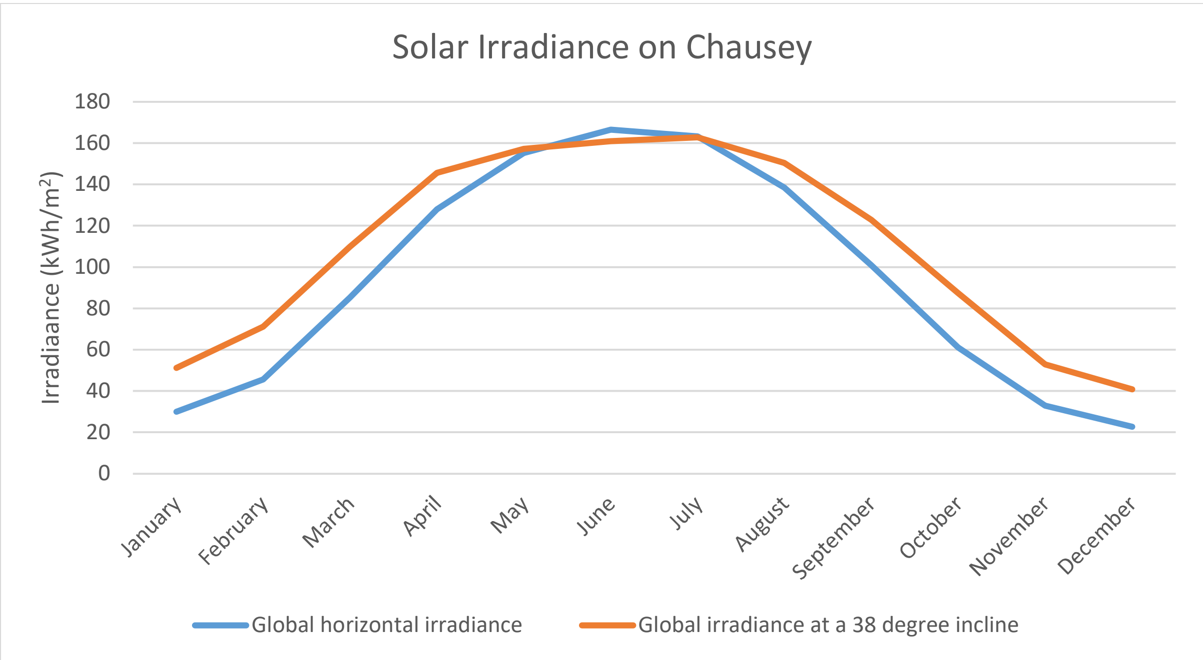

Figure 3 – Global irradiance for Chausey from PVGIS

Technical Constraints

Equipment used in typical solar installations is not especially large or complex and even the more specialised elements are readily available on the French mainland, if not on the island itself. There are numerous solar installers located in the region who could travel to the island with equipment via ferry without special transport requirements.

Independent solar farms may be installed away from existing grid connections, however, in this case permission to connect will be required and a connection to the network will need to be constructed. The installation route and methodology should be considered when planning a project. Proximity to existing infrastructure will be a key factor is deciding where to site a project. In this case, the analysis does not identify specific locations but models a generic solar farm on the island.

Environmental, Social and Political constraints

Chausey is entirely within at least two protected areas: a Site of Community Importance (under the EU Habitats Directive (European Council, 1992)) and a Special Protection Area (under the EU Birds Directive (European Parliament and Council, 2009)). In addition, the waters surrounding the archipelago as well as much of the southern tip of the Grande Île were acquired by the Conservatoire du Littoral (coastal conservancy) to ensure conservation – see Figure 5.

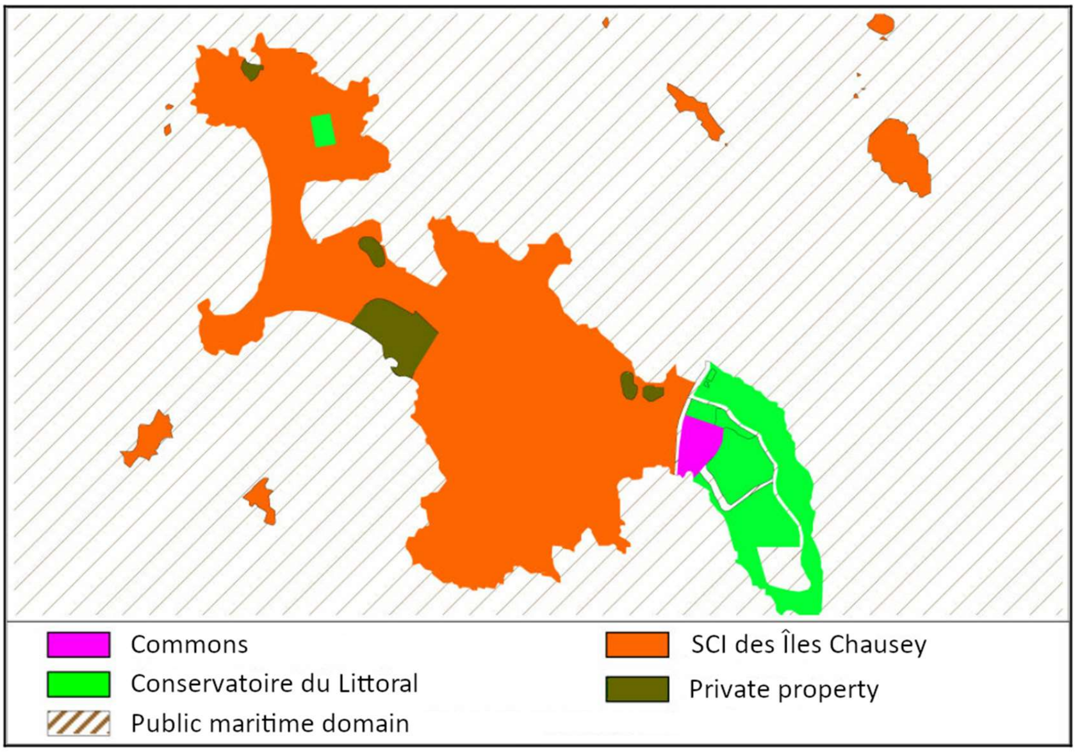

Figure 5 - Land ownership on Chausey Grande Île

Site Selection and Power Production

The energy strategy for Chausey does not identify any specific viable locations for solar on Grande Île though it mentions 'distributed solar PV' development. There are a limited number of buildings on Grand Île on which solar PV might be installed and, according to the island's energy strategy, their architectural suitability is being examined. Without this information, this study models notional ground-mounted solar PV systems to explore the size required to supply sufficient energy to the island to achieve 100% renewable energy. Viable sites for ground-mounted solar PV have not been identified in any publicly available planning documents. In our analysis we assumed that pasture could be repurposed to host a solar farm - Figure 6 shows pastureland on the island as classified by the Conservatoire du Littoral. This area measures more than 100,000 square metres.

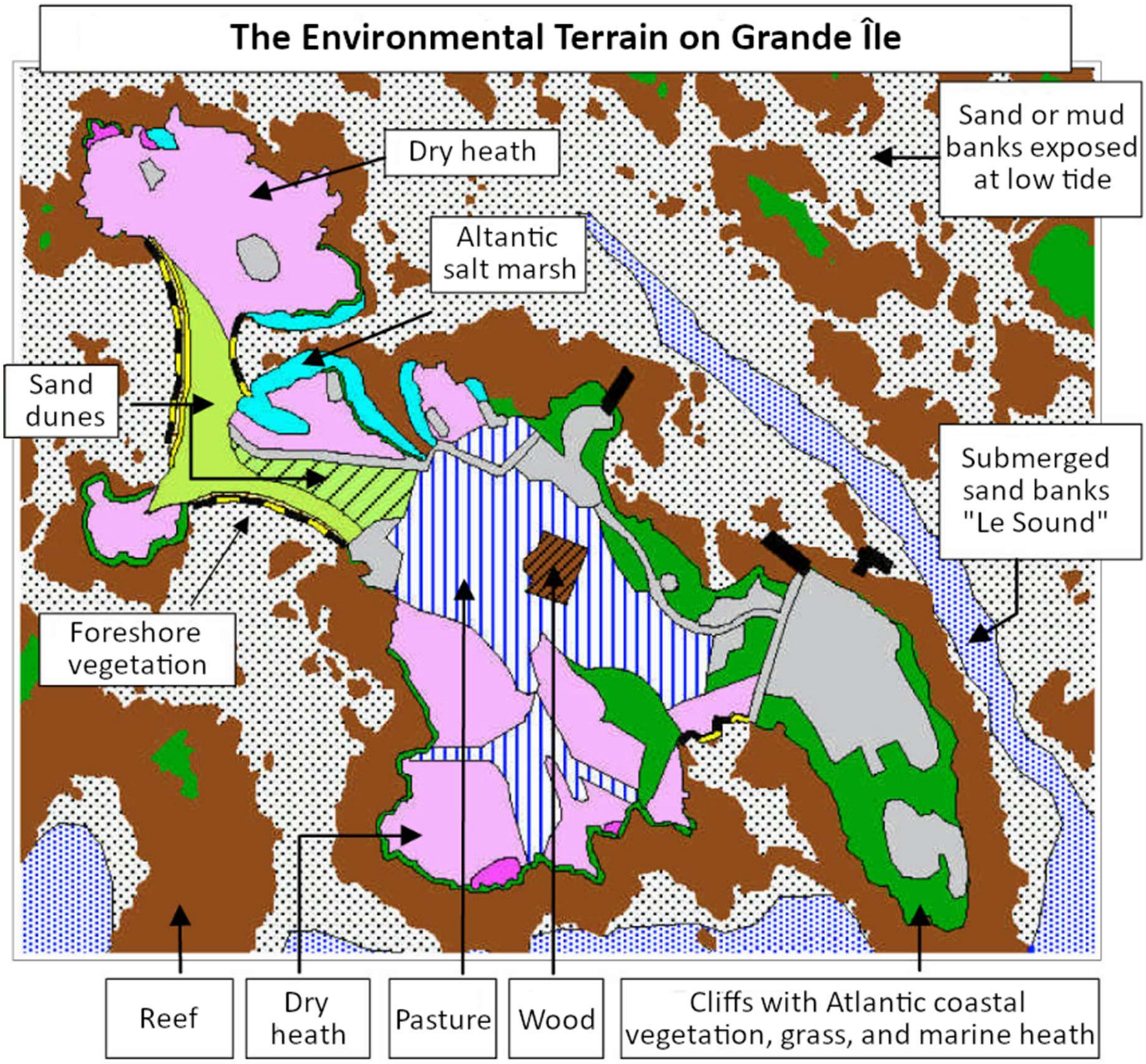

Figure 4 - A map of terrain on Chausey (Translated from Conservatoire du Littoral, 2000).

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 (Matthew *et al.*, 2018) outlines some of the considerations for accessing suitable data.

Since Chausey is not connected to the mainland grid, all the electricity is produced in-situ. As on all the French islands, and unlike the mainland, EDF-SEI operates, maintains the production facility and markets the electricity. In most cases, EDF-SEI is also the owner of the production plant. The tariff is regulated there, with no additional cost for the purchase of energy. The schematic diagram for the power grid is shown in Figure 7. There are only two HV load nodes and most of the cables are underground cable. We will consider only the HV grid for power flow and reliability assessment.

Assumption

1- The power flow analysis considers the maximum power
2- The system is a balanced system.
3- The power factor of the load is 0.9 and it is same at each load node.
4- The grid voltage is 5.5kV

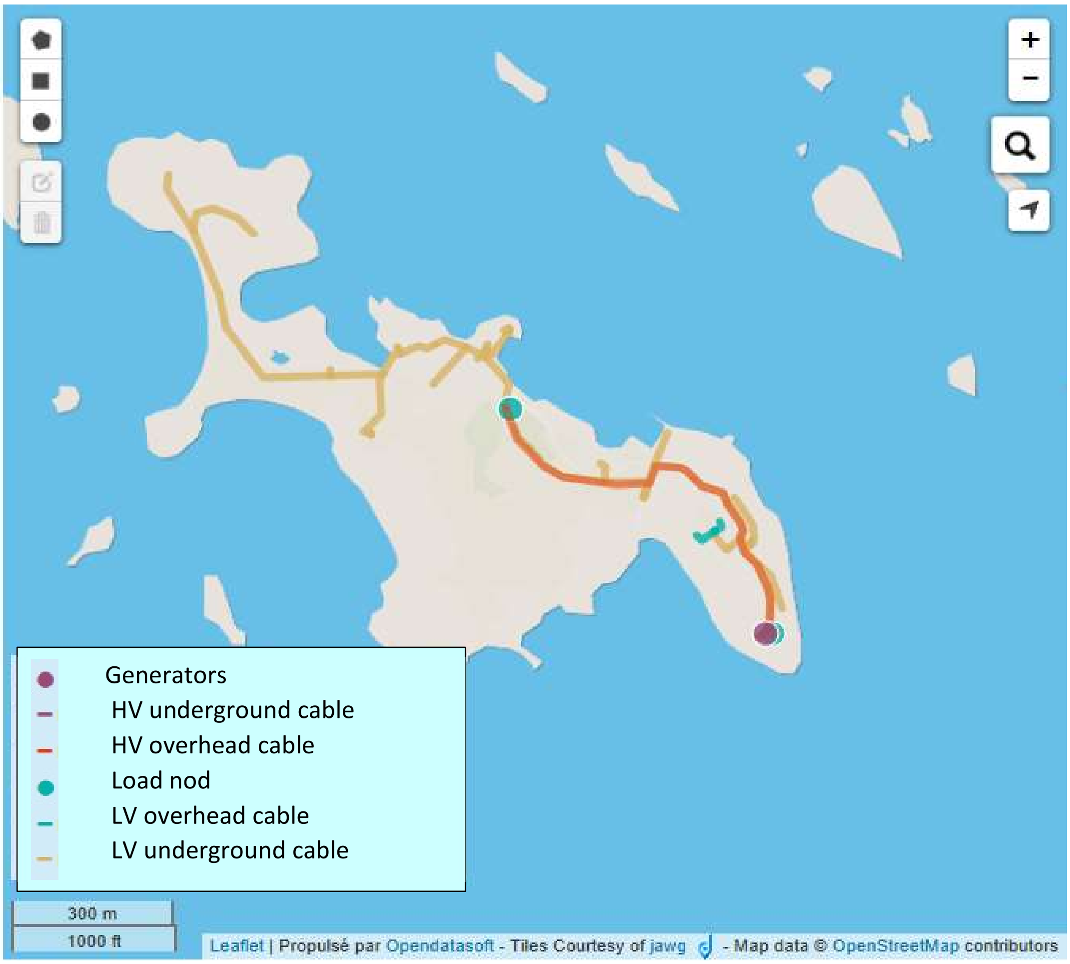

Figure 5: Chausey power grid

3.5 Load profile

The only available data for electricity consumption is the average energy per year and it is approximately 532 MWh per year. There is little information about the daily, monthly or yearly power demand. For the power flow assessment, we need to know the highest power demand. We are making the assumption that Chausey's load profile is similar to the nearby French islands of Ushant and Molène. Comparing to Ushant and Molène, the highest energy consumption month is about 1.6 times the average consumption for the whole year and the maximum power during the day is about 1.3 times the average daily power (Hardwick *et al.*, 2018; Harvey-Scholes *et al.*, 2022). According to this assumption, the maximum power demand of Chausey Island can be estimated as in (1).

$$Max\ power\ demand = 1.6 \times 1.3 \times average\ power\ demand \qquad (1)$$

The estimated maximum power demand for the island is 128kW and will be considered for power flow analysis.

Load at each node

Limited data concerning the Chausey island power grid layout was made available, only the schematic diagram of the Chausey shown in Figure 7. There are only two load nodes with a label for P01 and P02 shown in Figure 8. To get the power demand at each load node, a catchment area is drawn with the help of the LV network, Figure 8.

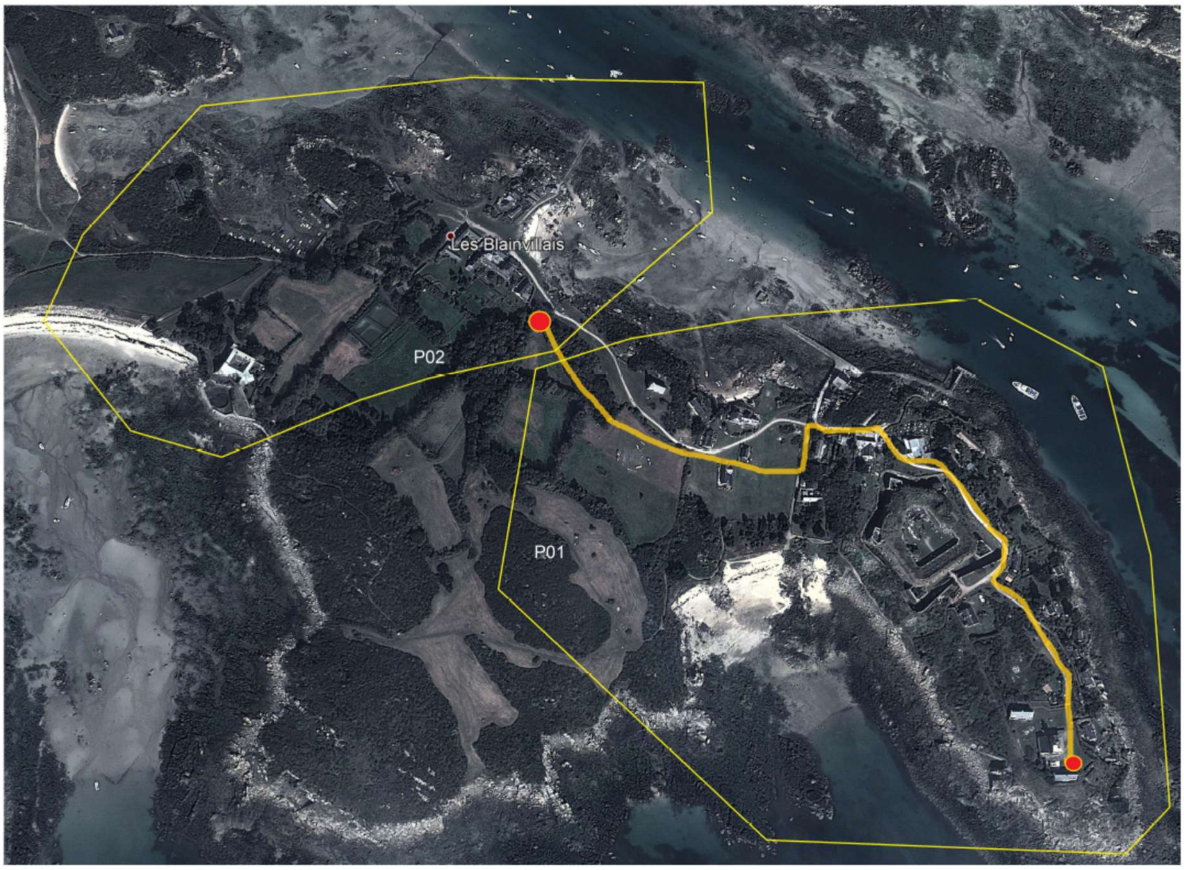

Figure 6: Load node and catchment area for Chausey Island

The number of houses is employed to estimate the power demand at each node as shown in Table 1. The two load nodes have nearly the same power demand.

Table 1 - Load node power

Load node	Number of houses	Load
P01	48	61.44kW
P02	42	53.76kW

The cable parameters can be estimated according to the cable length. Due to the load nodes are at the generator side and the other at the end of the HV grid, there is only one cable segment with a length of 862m. There is not much information about the cable size publicly available. Due to the island power demand is not high, 25m^2 cable is considered (rating 92A). In this case, the cable parameters are R=0.222Ω, L=0.83mH and C=0.19µF and it is reliability is 0.9666 and summarized in Table 2.

Table 2 - Cable parameters

Cable segment	Length	Resistance	Inductance	Capacitance
FromP01 to P02	862 m	0.222 Ω	0.83 mH	0.19 µF

3.6 Power Flow and reliability assessment

Based on the grid schematic diagram, load at each node and cable parameters, a power flow by Matlab Simulink and reliability assessment by ReliaSoft can be done. The power flow will consider only the maximum load demand and the reliability study steps in T1.2 will be repeated here.

The outcomes from the power flow and reliability assessment for load node voltage and reliability are shown in Table 3.

Table 3 - Load node voltage and reliability

	Voltage	Voltage drop	Reliability	Failure rate/year
P01	5500	0%	0.928	0.072
P02	5497	0.06%	0.897	0.103

The cable current and its capacity usage are shown in Table 4

Table 4 - Cable current and capacity usage

Cable segment	Current [A]	Capacity usage
From P01 to P02	5.71 A	6.2%

3.7 Conclusions

Chausey's power system has two grids, LV grid and HV grid. There is little information about the HV network voltage and cable size but assuming similarity to the other French islands such as Ushant, we take the HV voltage as 5.5kV with a 25mm^2 cable size due to the low load demand of the island. Due to the simplicity of the power network, it appears that there is no problem in the grid in terms of voltage drop, cable capacity usage and load node reliability. Again, this conclusion is based on some assumptions for the missing data.

3.8 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.

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

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 Horizon Scanning Centre, 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 9 outlines the general scenario analysis process:

Figure 7 - Scenario development process

3.8.2 Scenarios on Chausey

Chausey has renewable electricity generation targets of 50% by 2023, 65% by 2028 and 100% renewable generation by 2030. We used the two final targets to develop an initial scenario using solar PV to generate at least 65% of the island's energy consumption and then a set of scenarios to deliver 100% in 2030. Our modelled future scenarios also incorporate the island's target for reducing demand by 100 MWh by 2028. Demand in our future scenarios is based on reducing the baseline for consumption by 100 MWh (18.9%) – future hourly demand is calculated by reducing the modelled hourly values by 18.9%. These scenarios are summarised in Table 5. All scenarios are modelled using hourly generation and demand data over a year.

Table 5 - Future Renewable Energy Scenarios on Chausey

Scenario	Description	Renewable energy generated as % of future demand
1	240 kWp Solar PV generation	66%
2	372 kWp Solar PV generation	102%

Scenario 1

Our first scenario was scaled to generate energy equal to 65% or more of the island's future electricity demand using solar PV. This required 800 solar modules each with a 300 Wp capacity totalling 240 kWp, connected to seven 30 kW DC/AC inverters. This system was assumed to be installed on an area of pasture near the centre of the island. The modules would be mounted on the ground at a 38^{o} degree tilt facing due south. In total the system would generate 282 MWh of electricity a year which represents 66% of the projected 432 MWh future consumption. Whilst this technically generates around two thirds of the island's electricity demand, our modelling suggests that a far lower fraction could be used there and then – both battery storage and behaviour change to shift demand could help increase this level of consumption. The scenario is summarised in Table 6 and average daily power is presented in Figure 10.

Table 6 - Summary of hourly data from scenario 1

Scenario 1	**Annual**	**Summer (Apr - Sep)**	**Winter (Oct - Mar)**
Generation (MWh)	283	191 (68%)	92 (32%)
Demand (MWh)	432	171 (40%)	261 (60%)
Surplus/Deficit (MWh)	-149	21	-170
Surplus Generation Hours	2299	1646	653
Deficit Hours	6461	2746	3715
Peak Surplus (KW)		165	165
Peak Deficit (KW)		-101	-108
Usable Energy Generated (MWh -assuming no storage)	136	78	57

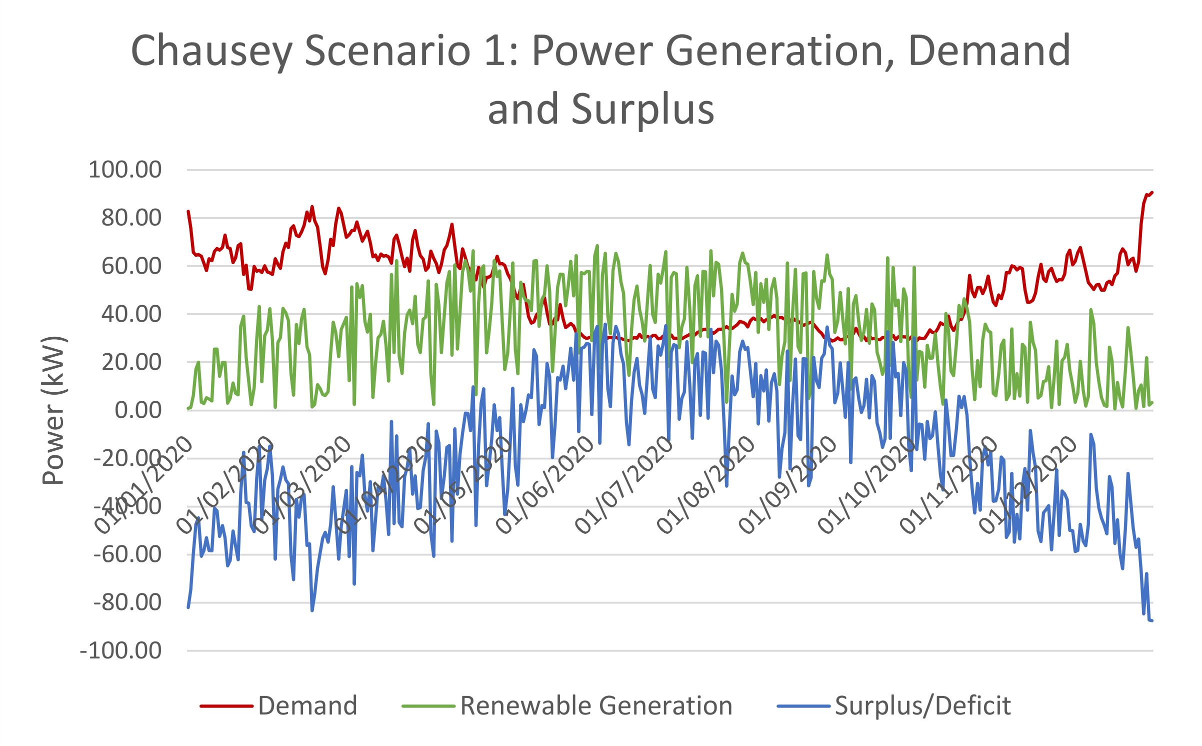

Figure 8 - Daily mean power surplus/deficit modelled over a year based on demand and renewable generation.

Scenario 2

This scenario was designed to deliver enough energy to match 100% of projected demand on the island of Chausey in 2030 using solar PV. This solar PV system comprises 1,240 solar PV modules with a combined generation capacity of 372 kWp. Connected to 10 inverters with a cumulative capacity of 300 kW and installed on pastureland, our model shows that this system would generate 437 MWh annually, 102% of future demand. Due to its reliance on solar PV the generation profile does not match the modelled demand on the island over the year, with excess generation in summer and a generation deficit compared to demand during the winter. The scenario is summarised in Table 7, while Figure 11 shows daily mean power.

Table 7 - Summary of hourly data from scenario 2

Scenario 2	**Annual**	**Summer (Apr - Sep)**	**Winter (Oct - Mar)**
Generation (MWh)	437	295	142
Demand (MWh)	432	171	261
Surplus/Deficit (MWh)	5	124	-119
Surplus Generation Hours	2735	1882	853
Deficit Hours	6025	2510	3515
Peak Surplus (KW)		264	263
Peak Deficit (KW)		-102	-109
Usable Energy Generated (MWh -assuming no storage)	152	85	67

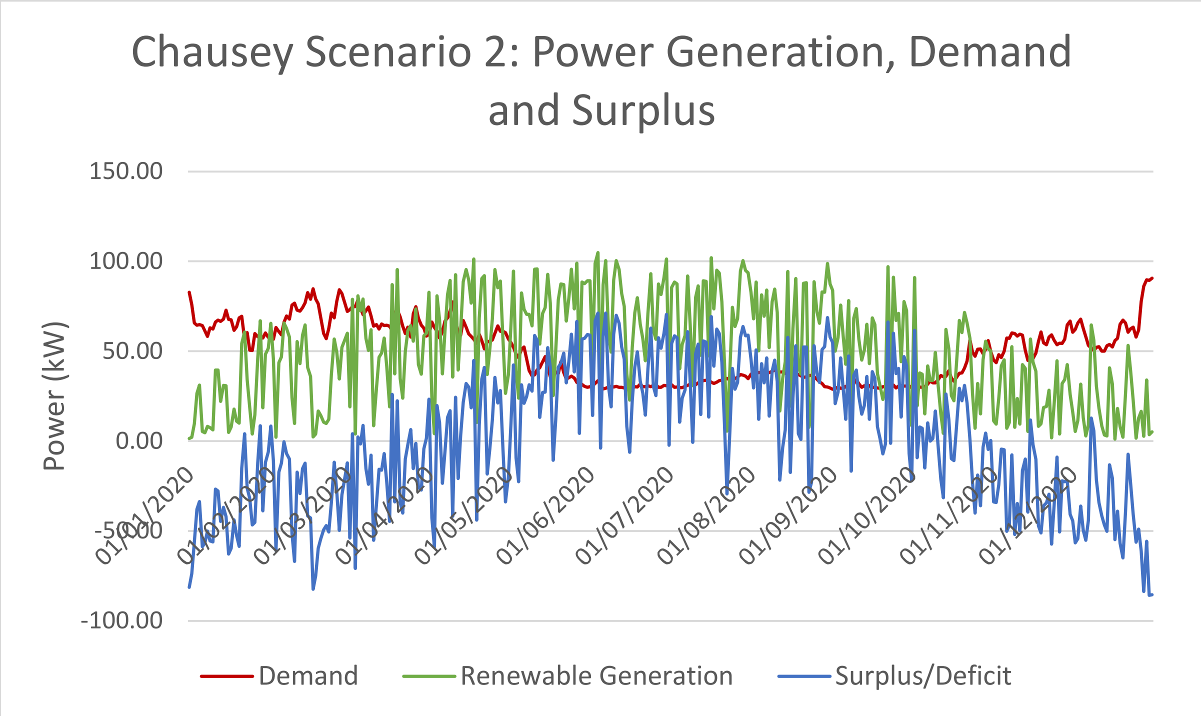

Figure 9 - Daily mean power surplus/deficit modelled over a year based on demand and renewable generation.

3.8.3 Scenario Evaluation

Stakeholder Evaluation

Ideally, the creation of 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.

Summary of Load and Reliability Analysis

The main renewable energy source to be employed on the island is PV. The location of the PV is proposed to be in the middle of the island as shown in Figure 12. The main reasons for selecting this location are:

It is at the middle of the island and the current power system network, allowing it to increase system stability and reliability.

- The is a large area in this location which allows a large capacity of the PV to be installed.

Figure 10 Proposed PV location

In this case, the island power grid is modified as shown in Figure 13. P01 and P02 are the loads. It is assumed that the PV station consists of PV panels and a battery.

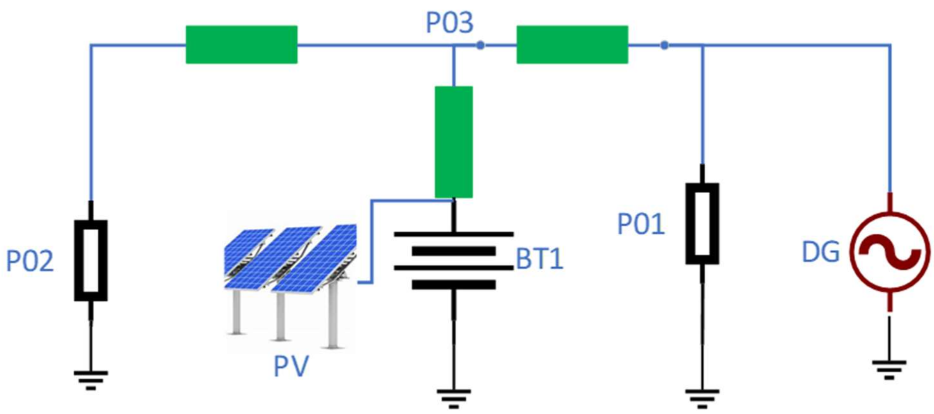

Figure 11 Island power system including the PV station

Scenario 1

Battery Storage Modelling

Based on the hourly demand and renewable energy generation, different battery sizes are tested to find the suitable size to achieve the 66% target. Figure 14 shows the uncovered energy demand and excess generation at different battery sizes. A 30MWh battery size is suitable to support achieving 66% of the load supplied from renewable energy. This battery size is quite high. The 30MWh battery energy state is shown in Figure 15. Most of the time the battery is undercharged or overcharged. This is due to the mismatching between the load demand and the PV output. To avoid using a high-volume battery size, other renewable energy sources need to be added to the mix, with a wind turbine being the most obvious recommendation.

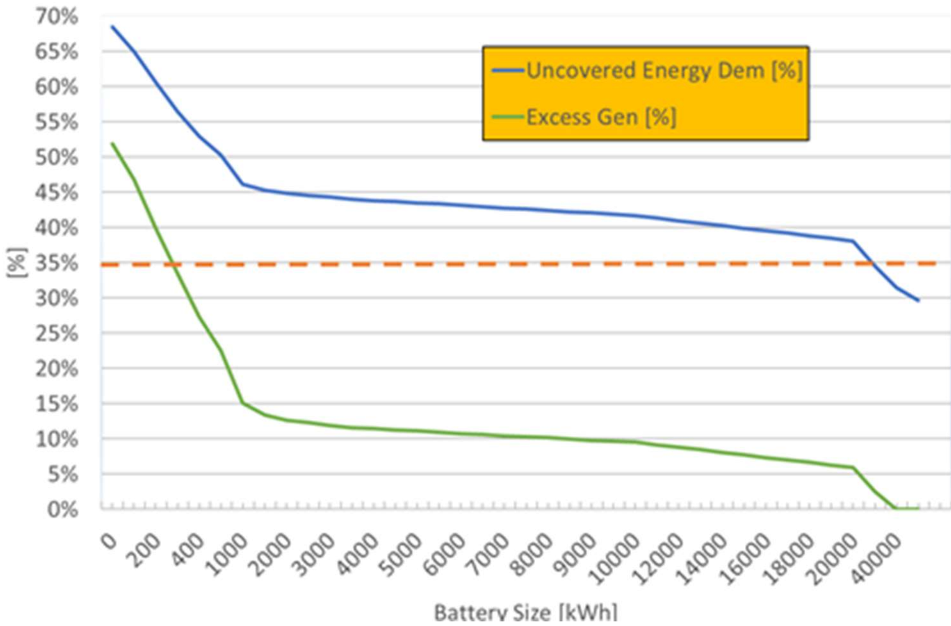

Figure 12 - Uncovered energy demand and excess generation at different battery sizes

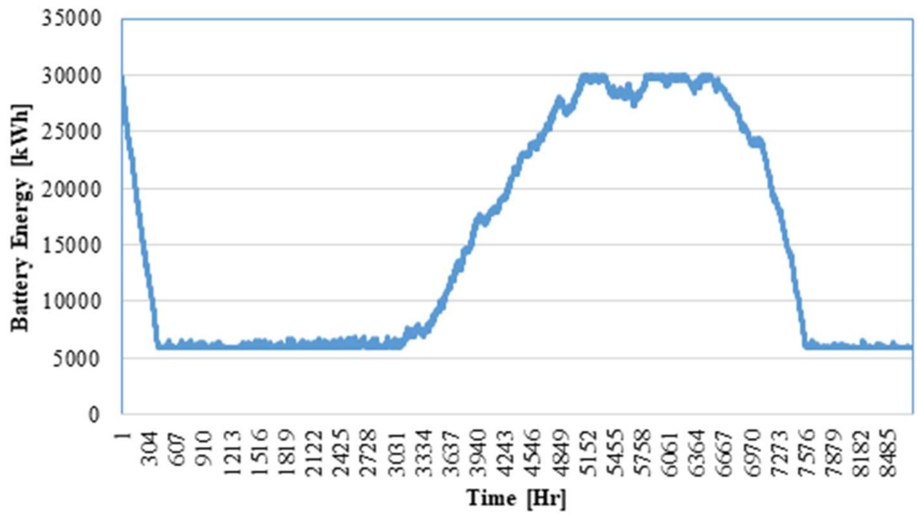

Figure 13 - Battery energy (30MWh)

Load Analysis

It is assumed that the battery storage system is large enough to store all the surplus power from the renewable energy sources and support the system to achieve the power scenario target when the output power from RE sources is not sufficient.

Two cases are considered for power flow analysis; maximum load and maximum RE output power. The condition of the load and the RE output power are summarized in Table 9.

Table 9 – Load and RE values at the maximum load and maximum RE generation

	Load [Kw]	RE [kW]
Maximum Load	109	0
Maximum RE Generation	57	203

Based on the cable parameters, load and renewable energy output at different conditions, a SIMULINK model is built. The outcomes from the SIMULINK model are the node voltage and the current at each cable segment. The voltage and voltage drop at the load node is shown in Table 10.

Table 10 – Voltage at load node at maximum load and RE generation

Load node	Maximum load		Maximum RE generation	
	Voltage [V]	Voltage drop [%]	Voltage [V]	Voltage drop [%]
P01	5500	0%	5500	0%
P02	5499	0.018%	5500	0%
Battery	5500	0%	5501	-0.018%

The current at each cable segment and cable usage capacity are shown in Table 11.

Table 11 – Cable usage capacity at maximum load and RE generation

	Maximum load		Maximum RE Generation	
	Current [A]	Cable Capacity [%]	Current [A]	Cable Capacity [%]
P01 to P03	1.097	1.19%	3.28	3.57%
P03 to P02	5.933	6.45%	2.82	3.07%
P03 to Battery/PV	5.316	5.78%	6.067	6.59%

There is no problem with the voltage quality at each load node and the cables are not overloaded. Connecting PV to the island grid reduces the cable usage capacity to half (from 6% to 3%).

Scenario 2

Battery Storage Modelling

Load Analysis

As in scenario 1, two cases are considered for power flow analysis; maximum load and maximum RE output power. The conditions of the load and the RE output power are summarized in Table 12

Table 12 – Load and RE values at maximum load and maximum RE generation

	Load [kW]	RE [kW]
Maximum Load	109	0
Maximum RE Generation	57	300

It seems that scenario 2 is the same as scenario 1 for the load demand at maximum load and RE generation. The only difference is in the maximum RE generation case where the maximum RE is 300kW (higher than scenario 1).

The voltage at the load node is shown in Table 13.

Table 13 –Voltage drop at Load node for scenario 2

	Maximum load		Maximum RE Generation	
	Node voltage [V]	Voltage drop [%]	Node voltage [V]	Voltage drop [%]
P01	5500	0%	5500	0%
P02	5499	0.018%	5500	0%
Battery	5500	0%	5501	-0.018%

The cable usage capacity is shown in Table 14.

Table 14 –Current and cable usage capacity for scenario 2

	Maximum load		Maximum RE Generation	
	Current [A]	Cable usage Capacity [%]	Current [A]	Cable Capacity [%]
P01 to P03	1.097	1.19%	3.28	3.57%
P03 to Po2	5.933	6.45%	2.82	3.07%
P03 to Battery/PV	5.316	5.78%	9.18	10.59%

The size of the battery to achieve supplying the island with 100% RE is 80MWh as shown in Figure 16.

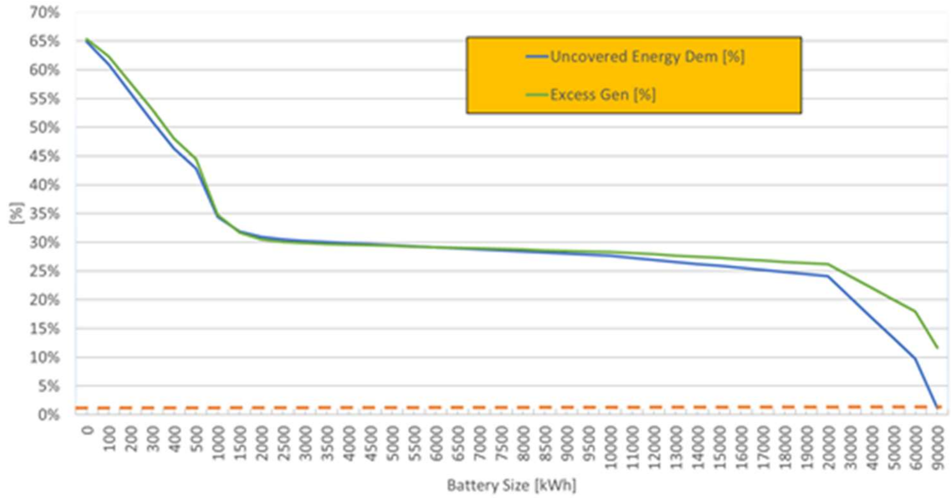

Figure 16 - Uncovered energy demand and excess generation at different battery sizes for scenario 2

Reliability Assessment

Both scenarios 1 and 2 employed PV only and based on the methodology, reliability data and the assumptions on Ushant Island deliverable (Hardwick *et al.*, 2018), the reliability of load nodes P01 and P02 are shown in Table 15

Table 15 - Load node reliability

	Scenario 1	Scenario 2
P01	0.9985	0.9757
P02	0.9868	0.9460

The reliability of scenario 2 is less than in scenario 1. This is due to only PV source in scenario 2 however, scenario 1 has a diesel generator and PV sources. Furthermore, the location of the battery is assumed to be at the PV location.

Introducing RE increases the reliability of the load node by at least 20% and reduce the cable usage capacity by 50% at one of the cable segment.

Economic Analysis

We calculated the levelised cost of electricity (LCOE) for the Chausey scenarios, see Table 16. A description of the data and calculations is available in the Appendix. The analysis shows that the cost of electricity on Chausey is relatively high using solar and storage, though still in most cases lower than the >€400 MWh cost of current diesel supply. As might be expected, Scenario 1 suggests that with less solar PV a smaller battery is optimal, 0.5 MWh in this case. Scenario 2 combines a high level of solar PV penetration with a 1 MWh battery storage system shows the lowest LCOE at just over €335/MWh.

Table 16 - System levelised cost of energy

	Scenario 1	Scenario 2
System LCOE (€/MWh) - no storage	€ 381.14	€ 396.73
System LCOE (€/MWh) - 0.2 MWh	€ 369.81	€ 381.31
System LCOE (€/MWh) - 0.5 MWh	€ 343.04	€ 342.36
System LCOE (€/MWh) - 1 MWh	€ 359.60	€ 335.67

3.9 Implementation challenges

The ICE Methodology recognises that an energy transition is an ongoing process, rather than a discrete event.

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.

3.9.1 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.

3.10 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.

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

In general, a smart energy transition will present commercial opportunities spanning four broad domains of commercial opportunity, as set out in Figure 17:

- **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.

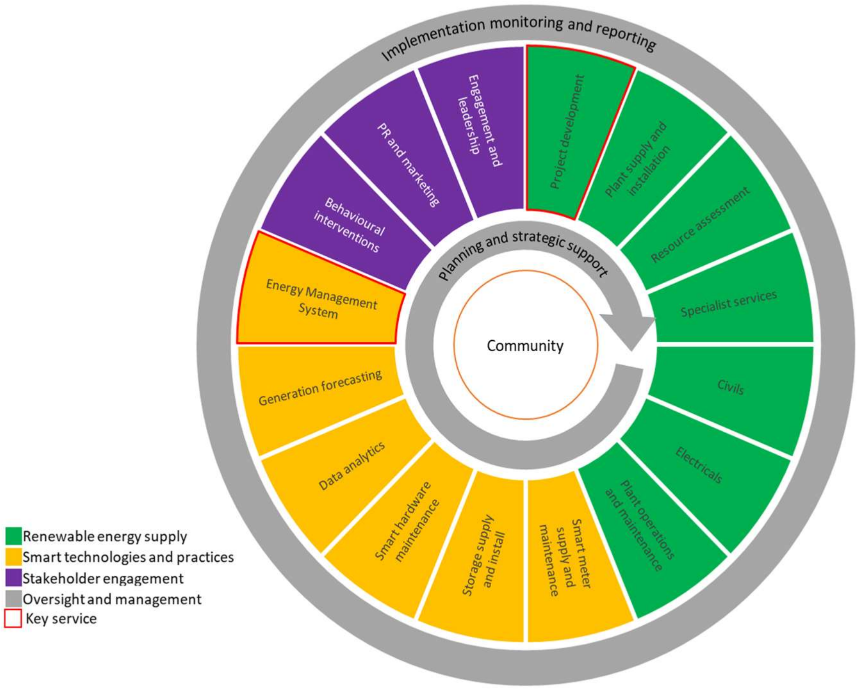

Figure 14 Domains of opportunity and the likely types of product and service for the transition

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. Opportunities for businesses form a major component of ICE Work Package 4.

3.10.2 Mapping Local Enterprise Capacity

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 Granville and the wider Manche area with relevant expertise produce an initial picture of local capacity to inform an approach to supporting or engaging local enterprise.

Characterisation of the future energy system and stakeholders

Chausey's future energy system will be reliant on solar PV generation, in our models this is centralised and ground-mounted. Solar PV is a mainstream technology but ensuring grid balancing in such a small system with a strong reliance on a single form of variable generation may be challenging and is likely to require expert support which may not be available in the immediate local area. We are not aware of the views of local stakeholders with regard to the potential new energy generation technologies.

The island has deployed Linky smart meters to all active customers with plans to implement differential time-of-use tariffs to incentivise consumption in off-peak times – this will be managed by EDF-SEI, but may involve external contractors. Centralised battery storage on the island will help balance supply and demand and is included in our model. Whilst distributed storage systems in properties could also help manage consumption patterns, these are not incorporated into our models as it is not yet clear that the economic environment is sufficiently favourable. A hydrogen storage system is mooted as a possibility for the island. This is not included in our scenarios and, in any case regarding local enterprise, as an emergent technology this would require specialist engineers who are perhaps unlikely to be found locally.

The electricity network on Chausey is owned by the local government, SDEM50, and operated under a recently renewed thirty-year contract by ENEDIS. ENEDIS will therefore be responsible for the network until 2050. Depending on the location of new generation and storage assets, the electricity network on the island may need upgrading for potentially higher generation output.

On Chausey, the key stakeholders include the 11 year-round residents, 123 seasonal residents, local businesses and the local government of Granville and the Manche region, as well as ENEDIS and EDF-SEI as utilities. There is a wider set of stakeholders which also includes local transport providers (ferry services), fishermen, conservation organisations, and the thousands of tourists who visit every year.

Capacity Mapping

Given the monopoly position of EDF-SEI and ENEDIS in France, a centralised approach to energy system change is likely, but there are nonetheless opportunities for much work to be carried out to local providers. A full breakdown of potential local capacities can be found in the appendix.

The set of stakeholders on Chausey includes a relatively small number of individuals and some organisations. No public engagement consultancies could be identified, although a number of local universities exist who may have the expertise to carry out an inclusive engagement or consultation exercise.

With regard to planning new renewable energy generation, a very small number of firms with expertise in solar PV energy advice was identified in Granville or Manche. A range of businesses providing ecological skills, environmental services, and more general renewable energy capabilities was found in the Manche area, with a few of those in Granville itself. There was a limited selection of companies who supply the material for solar PV systems in Manche, a larger, though still small, number of suppliers of general electrical material and batteries were identified. For the installation process, candidate building trades, ground workers and electricians were identified. A small number of high voltage distribution technicians were found, with a greater number of low voltage or generic electrical specialists.

Smart technologies and practices

No smart grid specialists could be identified local to the area – a quick search found only a handful across France. Conversely, a number of energy efficiency advisors operate in the Manche region and there are large numbers of building renovators including window fitters and cladding installers, as well as some heat pump installers.

The operation and maintenance of the future energy system could be supported by organisations in the local area. These include the electrical and solar PV technology experts identified above as well as transport and storage providers.

4 Conclusion

The ICE model suggests credible routes to Chausey achieving a scenario where 100% of its power comes from renewable electricity sources. Complications may arise should heat or transport move to electrified modes on the island. While a shift to electric vehicles might offer some alternative to the need for installation of storage and might mitigate its own impact on demand by contributing to demand shifting and the ability to peak lop, a shift to heat pumps might place further stress on the network and would likely impact the demand profile such that additional generation capacity and potentially additional storage is required.

There is 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 thus 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 (Lazard, 2022), storage remains relatively expensive. However, it should be noted that our scenarios show an economic advantage for an approach with both more solar PV generation and with the necessary storage to allow its use to be maximised.

There is a clear need for greater involvement of the island population to make the choice about the move to PV with storage, but other key stakeholders - most notably the state-owned actors – will tend to have a greater level of control in terms of making change happen. The incentives for them to do so remain somewhat opaque.

Access to information about the island electrical network and about the details of energy consumption on Chausey proved difficult. It is likely that access would have made the job of assessing installed renewable capacity and storage easier. We were able to develop a workaround to enable us to make better informed assumptions about the state of the island networks based on distance between nodes (Hussain *et al.*, 2021), but this does not provide the accuracy necessary to give a full picture of grid capability. Similarly, a full data set concerning consumption would have enabled more accuracy and more specific recommendations.

Similarly, there is also a clear need to better understand how the French regulatory system applies specifically to smaller French islands, and whether action is needed from policymakers to both incentivise change and to enable more rapid and more wide-ranging action. There appears to be clear economic and environmental justification for action to move electrical demand for heating over to heat pumps, to otherwise improve energy efficiency and that this may well lead to increased welfare benefits for islanders. Each of the French islands we examined had populations with income below their mainland compatriots and a roll out of heat pumps may have benefits in terms of addressing fuel poverty. However, assistance may well be needed to address how islanders can access the capital needed for heat pump installation.

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.

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6 Appendix 1

6.1 Power Flow Assessment

For the power flow assessment, we need to know the highest power demand and we do not have this data for Chausey, though we have the annual energy demand. We therefore used our experience from the islands of Ushant and Molène and drew some assumptions. Our reasoning was as follows:

- The load profile on Chausey is assumed to be similar to the nearby French islands of Ushant and Molène.
- On Ushant and Molène, the highest power consumption month is about 1.6 times the average consumption for the whole year and the maximum power during the day is about 1.3 times the average daily power.
- According to this assumption, the maximum power demand of Chausey can be estimated as in (1).

$$Maximum\ power\ demand = 1.6 \times 1.3 \times average\ power\ demand \quad (1)$$

6.2 Solar Resource Assessment

Figure 15 - Global Horizontal Irradiance in France

Table 17 shows the Global Horizontal Irradiance (GHI) and the Global incident irradiance at 30° and 38° values for Chausey.

Table 17 - Irradiance values for Chausey, generated using PVGIS data.

Month	**GHI (kWh/m^2)**	**G(38^o) (kWh/m^2)**
January	29.9	51.1
February	45.6	71.1
March	85.2	109.8
April	127.9	145.6
May	155.2	157.3
June	166.6	160.9
July	163.3	162.9
August	138.5	150.4
September	100.8	122.9
October	61.1	87.4
November	32.9	52.9
December	22.7	40.9
Total	*1,129.7*	*1,313.3*

6.3 Capacity Mapping

Using Kompass (fr.kompass.com)

Supplier opportunities	**Requirements/Organisations**	**Opportunities for Island**	**Example Businesses (Number)**
Planning			
- Project Rationale	SDEM50, EDF-SEI, ENEDIS		
- Public Consultation	Residents & stakeholders	Consultancy	Granville: Manche: Basse-Normandie: l'Université de Caen Normandie: l'Uni du Havre Bretagne: l'Uni de Rennes 1
- Surveying and Consenting	Environmental permit to Départment.	Renewable energy experts - 'energies renouvelables' 'Services techniques pour l'environnement (autres)' "Conseil en écologie et en environnement (autres)"	Granville: RE: 2 STE: 0 CEE: 3 Manche: RE: 38

			STE: 2 CEE: 99
Financing	EDF/SDEM50		
Grid Design and Engineering	Cable, connections and hardware upgrades.	(ENEDIS) Contracted engineers Electrical engineers - ‘Ingéniers électriciens’ Civil engineers: ‘‘Ingéniers civils’	Granville: EE: 0 CE: 3 Manche: EE: 10 CE: 22
Procurement			“SOCIETE DE NEGOCE DE NORMANDIE”
- Generation	PV panels, inverters, connections, mounting	Renewable suppliers - Local building trades suppliers ‘Matériel de production d'énergie solaire photovoltaïque, solaire thermale et héliothermique’ ‘Pièces et accessoires pour le matériel de production d'énergie solaire’	Granville: MPESP: 0 PAMPES: 0 Manche: MPESP: 1 PAMPES: 4 (all Engie)
- Storage	Battery systems, housing, connections, controls.	Local building trades/electrical suppliers	Granville: ACFLE: 2

		"Accessoires pour câbles et fils de lignes électriques" "Accumulateurs, batteries et piles électriques rechargeables" "Fils électriques isolés" "Commutateurs électriques" "Câbles électriques isolés par usage"	ABPER: 1 FEI: 1 CE: 2 CEIU: 1 Manche: ACFLE: 14 ABPER: 3 FEI: 11 CE: 11 CEIU: 11
- Interfaces & Services	Grid balancing – sensors & hardware; software.	Specialised N/A	Granville: Manche:
- Demand Management	Lightbulbs. Insulation, windows, Heat pumps	Electrical suppliers "Appareils électriques d'éclairage intérieur" Building suppliers	Granville: AEEI: 1 TIEB: 0

		"Travaux d'isolation et d'étanchéification des bâtiments"	Manche: AEEI: 7 TIEB: 61 TVB: 343
Installation			
- Generation	Solar PV – specialists Small-scale storage – generic electrician	Solar PV installers "panneaux solaires" 'Conseil en énergie solaire' Building trades: 'Metiers du batiment' 'BTP'	Granville: PV: 1 CES: 0 BTs: 1 BTP: 4 Manche: PV: 10 CES: 1 BTs: 20 BTP: 61
- Civils	Mounting system – ground workers	Ground workers – 'travaux publics'	Granville: TP: 0

			Manche: TP: 12
- Electricals	HV wires and connections – specialists LV wires and connections – Electrician	HV electrical engineers – ‘Installation de systèmes de distribution à haute tension’ Electrical contractors/engineers – ‘Travaux d’installation électrique’ ‘Installation de systèmes basse tension’ ‘Installation de groupes électrogènes’ “Installation de postes et sous-stations de transformation et de distribution”	Granville: ISDHT: 1 TIE: 5 ISBT: 0 IGE: 0 IPSTD: Manche: ISDHT: 23 TIE: 396 ISBT: 15 IGE:5 IPSTD:
- Demand management	Insulation and windows Heat pumps	Heating engineers – ‘chauffage’ Builders, Window fitters	Granville: HEs: 1 Heat, refrigeration, ventilation: 6 TVB: 5

		"Travaux de vitrerie de bâtiment" 'Conseil en économie d'énergie' Cladding: "Travaux de couverture, de toiture, de zinguerie et de bardage" "Entreprises de rénovation de bâtiments"	CEE: 0 TCTZB: 3 ERB: 0 Manche: HEs: 18 Heat, refrigeration, ventilation: 142 TVB: 343 CEE: 11 TCTZB: 277 ERB: 37
Operation			
- Logistics	Spares and co-ordination – EDF/ENEDIS or 3rd party	Storage providers – 'stockage' Electrical suppliers	Granville: St: 0 Manche: St: 1
- Maintenance	Inspection and monitoring	[SEE ABOVE] Solar PV Electricians	Granville:

		Grid experts	Manche:
- Billing	EDF-SEI	N/A	
- Management	EDF-SEI/ENEDIS	N/A	
User benefits			