


# Energy Infrastructure Plan for the Isles of Scilly

## Smart Islands




**Report for the Council of the Isles of Scilly**
**Funded by the Local Enterprise Partnership**
**Submitted by Hitachi Europe Ltd**

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# Executive Summary

The Council of the Isles of Scilly (IoS) commissioned a technical survey to evaluate the energy infrastructure and propose practical solutions to increasing renewables and making the IoS more resilient. This study contract was awarded to Hitachi Europe Ltd. The study complements the work currently being undertaken by the Environment Agency and the Drinking Water Inspectorate to map all the private water supplies and sewerage systems.

Two major framing assumptions were made for the work. Firstly, there is no expectation that IoS energy demands will not dramatically increase or decrease. Secondly, it will not be possible to net export (backfeed) electricity from the IoS to Cornwall some of the time.

Development on IoS is often challenging (a combination of statutory designations, conservation zones and increased costs) and renewable energy proposals will be heavily scrutinised. Nevertheless, development of a more sustainable energy infrastructure will bring environmental and economic benefits that should outweigh the costs.

The IoS current situation can be summarised as follows:

- Energy on IoS is completely imported, save a small amount of photovoltaics (PV), currently 270 kilowatt peak (kWp), generating around 1.6% of the IoS total electricity demand of 18,500 megawatt hours per annum (MWh/a).
- IoS is connected to the mainland electricity system via a single 33 kilovolt (kV) cable, which was installed in 1989 by Western Power Distribution (WPD).
- As a backup for a cable fault and to facilitate planned maintenance and network improvements, the power station which was originally used for all island supplies is maintained in an operational condition.
- This power station was initially commissioned in 1932, taken over by South West Electricity Board (now WPD) in 1957 and reduced to its current standby arrangement in 1989. To fully modernise the power station would require substantial investment.
- Even though the power station runs for less than 100 hours per year a full programme of inspection, maintenance and building maintenance is required. WPD have employees based at the power station to facilitate this.
- IoS energy challenges – the high societal cost of providing energy to IoS, reliance on diesel fuel and electricity, a high share of fuel poverty (22.4% against the national average of 10.4%).
- Sewage treatment is limited and the existing solution for Hugh Town via an offshore pipe disposal is not fit for purpose and requires urgent investment.
- There is no on-island solution for green waste, waste wood and food waste, which is either composted (green waste only) or sent to mainland at huge cost.
- St Mary's desalination plant suffers from nuisance shutdowns due to power supply quality on the end of the line.

The IoS electricity system has evolved from a non-interconnected system to being connected to Cornwall and so is fairly robust with currently good redundancy.

The solutions for IoS need to be integrated and holistic to work. The IoS is too small to treat each item in isolation and so the traditional silo approach will not work effectively. For example, there is a need to tackle sewage, a wish to understand and contribute to the plans WPD has for the power station, green waste, wood waste and food waste issues as an integrated set of items to achieve the right balance for the new energy infrastructure.

The types and amount of renewable generation have to be balanced and focusing on a single generation type, e.g. PV will be sub-optimal and will be limited in impact. Integrated with the renewable energy generation will be flexible loads, demand response and intelligence in the IoS's energy system.

The Energy Infrastructure Plan (EIP) focuses on an initial stage to meet the targets of 40% renewables, 40% EVs (Electric Vehicles), 20% reduction in energy bills and implementation of energy efficiency measures. As such these targets could be considered starting points rather than end points with respect to renewable energy development on the islands.

The EIP has a timeframe of the next five years. It deals with infrastructure projects, such as sewage treatment, district heating and also sees opportunities to build a fully integrated energy hub with WPD taking an option to relocate the power station as part of this integrated island project. All the technologies proposed are proven and integration issues are well understood.

A variety of generation options have been evaluated, including their impacts on the electricity network. The total generation capacity is 3.1 megawatt (MW) and this is expected to generate around 7,500 MWh/a of electricity or 40.5% of the IoS electricity consumption.

The central case comprises:

- PV – 1.5 megawatt peak (MWp), which includes the current installed capacity of 270 kWp. Up to 2 MWp is possible, but any more is difficult to integrate due to over-generation compared to IoS loads. There is no shortage of sites for PV and its impact will be minimal visually.
- One of or a mixture
  - Wind – around 1 MW – cheapest generation option available
  - Tidal Stream – 1.2 MW – still pre-commercial and expensive
- Anaerobic digestion (AD) for sewage/food waste/green waste – around 100-200 kilowatts (kW)
- Gasifier for the sewage cake/waste wood and woody green waste – around 500 kW
- New power station – relocated, greater flexibility and modular
- Demand response (DR) and energy storage in the range 1.5 megawatt hours (MWh) to 2.5 MWh

The table below summarises this case, together with estimated annual generation and indicative capital investment costs totalling roughly £8 million (not including WPD connection costs). Please note that in the case of wind, the cost assumes 2 * 250 kW and 5 * 100 kW turbines as this affords lower visual impact, whilst a much taller single 1 MWe turbine could be deployed for approximately half the cost and deliver a similar amount of generation.

| Renewable Energy | Capacity (kW) | Annual Generation (MWh) | Share of IoS Demand | Capital Investment (£) |
|---|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% | £ 0 |
| New PV | 1,230 | 1,353 | 7.31% | £ 1,552,320 |
| Wind | 1,000 | 3,942 | 21.31% | £ 4,080,000 |
| Tidal Stream | 0 | 0 | 0.00% | £ 0 |
| AD | 100 | 800 | 4.32% | £ 600,000 |
| Gasifier | 500 | 1,095 | 5.92% | £ 1,700,000 |
| **Total** | **3,100** | **7,487** | **40.47%** | **£ 7,932,320** |

There are a number of options for dispatchable loads that can be controlled as part of a smart grid solution. These loads are important to accommodating the levels of generation and to prevent the export of power through the 33 kV cable to Cornwall in particular during summer months, but also allow export during winter months when there is little or no grid constraints on the mainland.

As part of the energy infrastructure some new devices will need to be deployed. These will include heat pumps, controllable immersion heaters, controllable storage heaters, EV charging points and small house-scale battery energy storage. The precise number of each of these depends on the dispatchability of load required. With the generation resources proposed the DR and storage is expected to be in the range of 1.5 MWh to 2.5 MWh. There are multiple locations for these, though a significant part of the deployment will be on St Mary's.

Finally, the use of energy efficiency is an important option for IoS. Two key measures are appropriate for widespread deployment on the IoS. First, the use of LED light bulbs. Second, building insulation, in this latter case, both the Council and the Duchy are progressively refurbishing their housing stock in this respect. Cutting energy demand will enable the targets of both 40% renewables and 40% energy cost savings to be achieved much more easily.

A balanced mix of PV, wind, AD and gasification allows the IoS to reach its 40% target of electricity demand being supplied by renewable energy. The use of DR allows IoS to balance generation and load at peak generation periods whilst limiting the impact on the wider network (such as no backfeed of electricity to the mainland during those periods). In addition, with WPD facing challenges in the South West due to a high penetration of PV and wind, they have implemented a system-wide constraints system, based on a 'last in, first out' (LIFO) stack, which will curtail (reduce potentially to zero) excess generation to keep the network operating within limits.

Underpinning the EIP is the requirement to deploy an ICT platform plus a control system located in energy consumers' premises. This platform will enable the deployment of more renewables than would otherwise be possible, allowing a better balance between generation and demand.

# 1. Introduction

In 2012 the Council of the Isles of Scilly (IoS) undertook a high-level infrastructure plan that identified a range of challenges to the IoS infrastructure. Over the last 3 years the Council and partners have been working on plans for improving energy, waste, water and sewerage infrastructure.

As a consequence of the high-level infrastructure plan, the Council commissioned this technical survey to evaluate the energy infrastructure and propose practical solutions to increasing renewables and making the IoS more resilient. This study contract was awarded to Hitachi Europe Ltd. The study complements the work currently being undertaken by the Environment Agency and the Drinking Water Inspectorate to map all the private water supplies and sewerage systems.

As part of the work to deliver Smart Islands (island smart grid and associated energy enterprise, e-health, home and business energy management systems, renewable energy, electric vehicle (EV) charging, and EV car share schemes), the technical survey has developed an overarching understanding of the current infrastructure and planned infrastructure on the Islands and the implications for the energy system. The outcomes of this study are designed to inform the design of the Energy Enterprise, as well as the definition of requirements for the supporting information and communications technology (ICT) infrastructure.

This work has:

- Developed a holistic high level understanding of infrastructure needs and plans (water, sewerage and waste) and the implications for the energy infrastructure
- Identified potential suitable locations for new infrastructure components, considering the relationships between water, waste and energy infrastructures and network topology
- Identified suitable locations for renewable generation
- Performed an initial survey of representative buildings on the Isles to refine assumptions regarding distributed energy and smart technology potential
- Undertaken detailed discussions with Western Power Distribution (WPD) regarding the implications of the Infrastructure Plan on the network
- Engaged extensively with the Council, The Duchy of Cornwall and Tresco Estate, along with local stakeholders

Two major framing constraints were placed on the work. Firstly, there is no expectation that the net impact of changes in IoS energy demands will dramatically increase or decrease. This constraint takes into consideration the growth of population over time, electrification of heat, energy efficiency schemes as well as new infrastructure. Secondly, it will not be possible to net export (backfeed) electricity from the IoS to Cornwall, as it is assumed that there will be no major grid reinforcement in Cornwall to allow net exporting or backfeeding to the mainland. However, this constraint is seasonal, and although the grid will experience major constraints during summer months, mainly due to the abundance of photovoltaic (PV), there will be less constraints during winter months when there is less hours of sunshine and higher heating demands.

# 2. Context and Targets

The IoS are a group of many tens of islands of which five are inhabited. The whole area sits within an Area of Outstanding Natural Beauty (AONB), Conservation Area, a mix of Marine Conservation designations and much of the land surface is covered by designations of one type or another (Sites of Special Scientific Interest (SSSI), archaeological sites, scheduled monuments, etc.). In this context, development is often challenging and renewable energy options will be heavily scrutinised. Nevertheless, development of a more sustainable energy infrastructure will bring environmental benefits that should outweigh the environmental costs.

Most of the land is owned by the Duchy of Cornwall, with Tresco on leasehold of 999 years and other parts of the islands on shorter leases and shorthold tenancies. Aside from the Duchy, the other major "landowners" are the Council and Tresco Estate. The total land area is 14.43 $km^2$ and the land is a mix of farmland and wilderness area.

The IoS are outstandingly beautiful, uncrowded and unspoilt, and support a resilient and entrepreneurial community. Looking to the future the IoS face a wide range of challenges, but also have opportunities to be realised in equal measure.

A number of documents articulate this with the most recent and comprehensive being '*Island Futures*' and *'Infrastructure Plan'* (Ash Futures, 2014), and these have been taken up by the Smart Islands Partnership.

Regarding energy, the key headlines are:

<u>Renew the key primary and backup energy infrastructure</u>

Central to delivering this vision is a commitment to capitalise on the islands' unique environment and entrepreneurial community, ensuring any change embeds resilience, self-sufficiency and sustainability from the outset.

<u>Sustainability must be key around everything that we do</u>

Whilst there has been a great deal of progress recently on the islands to upgrade both physical and social infrastructure, there is still much to do. The islands are also dominated by a low wage economy and high living costs.

Smart Islands reflects the logical next step for the islands, through capitalising on a unique set of circumstances.

The Council has proposed a series of objectives for the Smart Islands programme that will be reviewed and refined by the Smart Islands Partnership:

- 20% reduction in energy bills by 2020, 40% by 2025
- Implement a full programme of energy efficiency measures by 2020
- 40% renewable energy production by 2025
- 40% of electric vehicles by 2025
- Internships, cultural exchanges and Science, Technology, Engineering and Mathematics (STEM) skill delivery for young people

Delivering these objectives will be a challenge and will require a collaborative and innovative approach, but has the potential to change the discourse on the islands from *'needing to leading'*.

Smart Islands offers the potential to not only develop an innovative, world-class social infrastructure. This investment could also deliver new social, economic and environmental outcomes for the community.

The IoS is currently a carbon intensive community with many outdated and inefficient social infrastructures, relying heavily on imported fossil fuels and electricity to meet the community's needs. This current situation is in contrast to the opportunity the islands' unique natural environment and engaged community presents.

Smart Islands will capitalise on this opportunity to demonstrate the potential to rapidly move from a carbon intensive to a low carbon community, and in doing so demonstrate a model that can be replicated across the European Union (EU).

Whilst the foundations for Smart Islands are based on developing a new integrated energy infrastructure it also has the potential to benefit many other aspects of people's lives, acting as a catalyst for change. This has been well articulated by the community and underpins the proposed approach to delivering Smart Islands.

The Energy Infrastructure Plan (EIP) builds on this work and these aspirations, considering the drivers and the practical implementation of the vision.

Finally, the IoS face a series of modernising challenges, which for each on its own is a challenge. However, tackling these in a more holistic and integrated fashion will bring cost benefits and a greater use of sustainable energy in an improved environment. These challenges include upgrading the Islands' sewerage, tackling the cost of waste disposal, improving the supply and quality of drinking water, modernising St Mary's power station and reducing household energy bills.

# 3. Current Situation

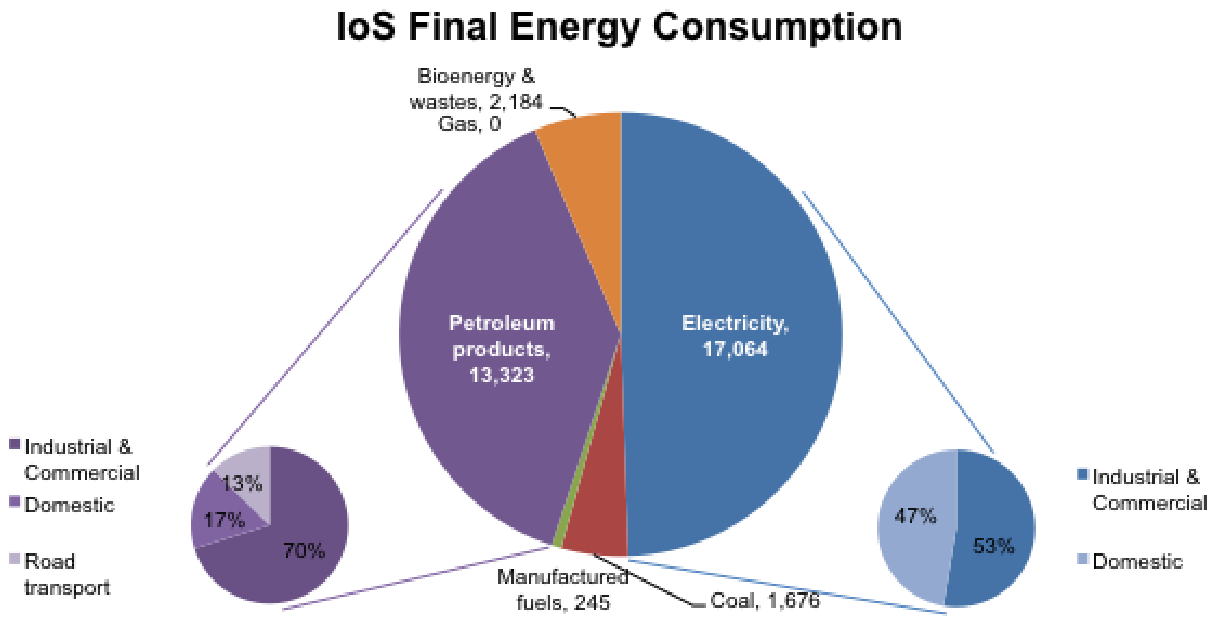
The population of the IoS is seasonal, reflecting the touristic nature of the economy. In the off-season the population is around 2,200 and this swells to as much as 6,000 in the peak of summer. Much of the population is based on the largest Island, St Mary's with around 1,720. The Off-Islands have smaller resident populations of Tresco 175, St Martin's 142, St Agnes 75 and Bryher 92. It should be stated that the residential population is probably slightly higher than this due to long-term housed labour, on flower farms for example. The IoS has one major town, Hugh Town.

The electricity distribution network operator (DNO), WPD, states that the number of customers on the system is 1,678 ("Network Management on the Isles of Scilly" LCNF closedown report, 2013). There are 989 housing units, of which 169 are social housing. That leaves 689 industrial, commercial and public buildings. The amount of industry is rather low and is concentrated around Porthmellon on St Mary's. The islands are major horticultural growers, especially cut flowers, and the farms also have small-scale industrial units to process the produce.

## 3.1 Energy Demand

Energy on the islands is completely imported, save a small amount of PV. The two major energy demands are for electricity and petroleum products, see Figure 3.1.1 below.

Figure 3.1.1: IoS final energy consumption



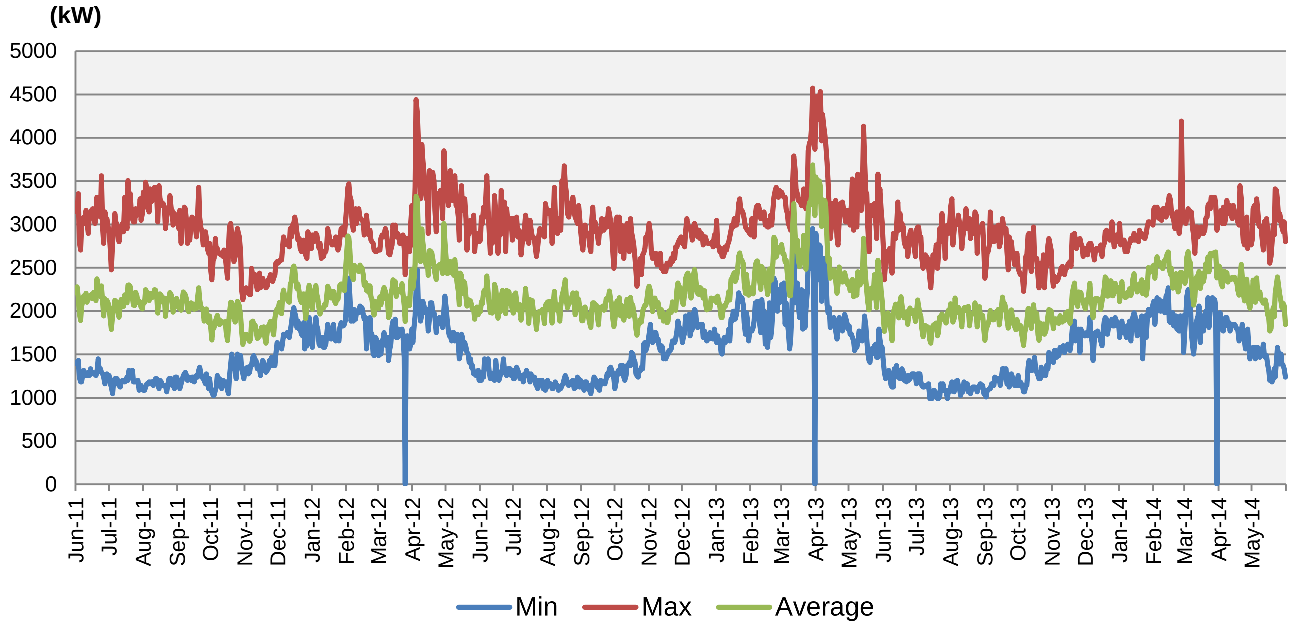

| Source: | Sub-national estimates of non-gas, non-electricity and non-road transport fuels in 2012 (DECC), Sub-national electricity sales and numbers of customers, 2012 (DECC) |
|---|---|

The level of import and especially the isolated nature of IoS results in energy supply being vulnerable to interruption, though historically this has been classified as reliable when considering Ofgem targets.

Most of the EIP focuses on the electricity sector as this is the predominant energy vector for both heating and power demands.

The electricity demand trends for IoS are shown in the next figure. Figure 3.1.2 shows the daily demands (maximum, minimum and average). It can be seen that the peak demand is around 4.5 megawatts (MW), though this only occurs for a few hours each year. The average demands are around 2 MW.

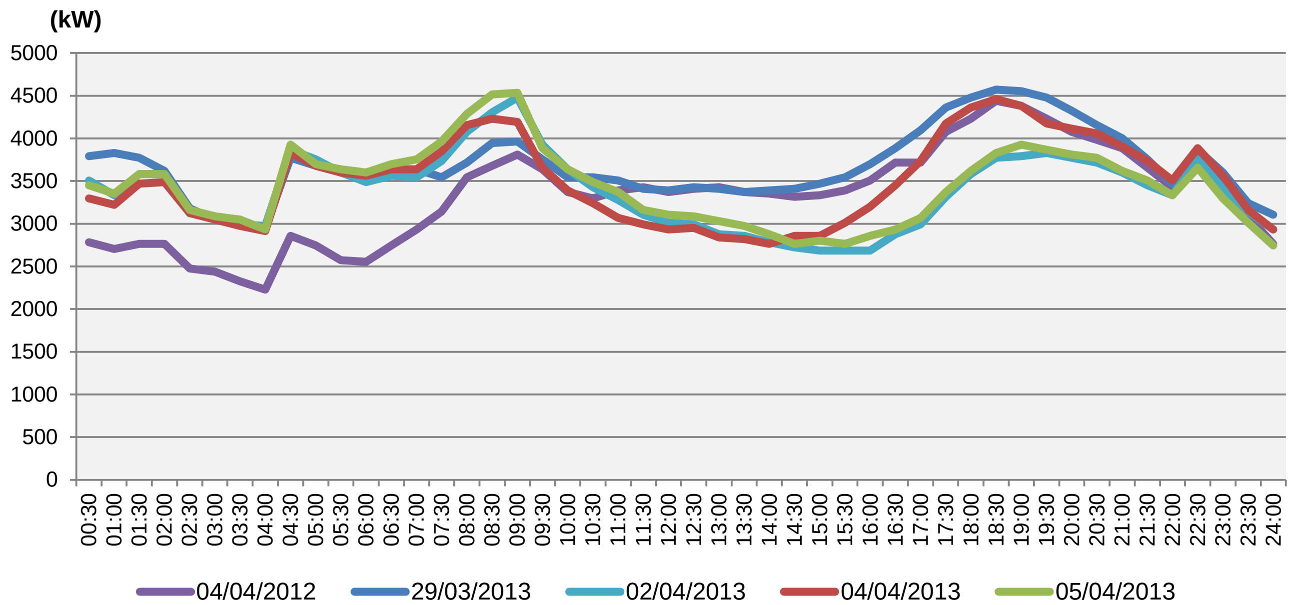
Figure 3.1.2: IoS electricity demands from 2011 to 2014




| Source: IoS annual power data from WPD |
|---|

Figure 3.13 below shows the days in 2012 and 2013 where the total demand exceeded 4.4MW.

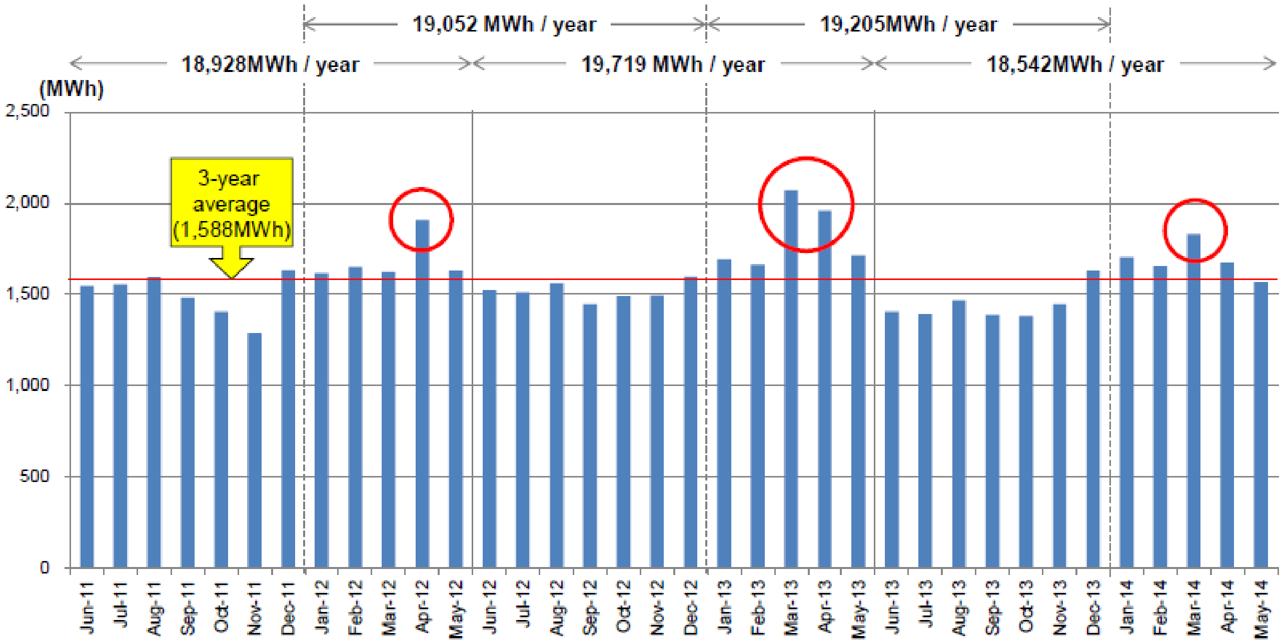
Figure 3.1.3: IoS example daily electricity demands




| Source: IoS annual power data from WPD |
|---|

Figure 3.1.4 shows the daily electricity consumption. It is estimated that the total electricity consumption on the IoS is approximately 18,500 megawatt-hours (MWh) per year, with the highest monthly consumption in April.

Figure 3.1.4: Daily and average electricity consumption




Source: Derived from WPD IoS annual power data

## 3.2 Existing PV

The IoS saw the first PV installation in November 2008 and most of the installations occurred in a period between November 2011 and March 2012. Most schemes are small, domestic roof projects, between 2 and 4 kilowatt-peak (kWp). There are some larger rooftop PV schemes on the schools and community centres. There are no ground mounted schemes.

There is a discrepancy between the schemes registered on the Feed-in-Tariff (FiT) register and those assessed by experts on the islands. This discrepancy can be explained by PV systems that either have not been registered, or are being registered. It should also be noted that WPD records rely on installers to send paper work, thus it can be seen that whilst paperwork is sent for the FiT register (to receive incentives), the same may not have been sent to WPD.

Table 3.2.1: Current PV installations (kWp)

| Island | FiT Register | IoS Analysis | WPD |
|---|---|---|---|
| St Mary's | 189.37 | 205.00 | |
| St Martin's | 18.72 | 21.00 | |
| St Agnes | 32.38 | 42.00 | |
| Tresco | 2.52 | 2.50 | |
| Bryher | 0.00 | 0.00 | |
| **Total** | **242.99** | **270.50** | **140.00** |

Note that the IoS analysis is based on a number of individuals collecting data on renewables. This is led by Jonathan Smith of Scilly Organics.

Generation from PV on IoS is excellent and better than anywhere else in the UK. Although it is not possible to collect generation data from the FiT register, anecdotal evidence was collected from a number of PV owners and the generation varies from 1,100 to 1,150 kilowatt-hours (kWh) per kilowatt-peak (kWp) of installed PV per year.

There is one ground-mount project on IoS that was approved, but could not secure a cost-effective grid connection. This was a 50 kWp project on St Martin's. In this case the grid connection cost was £50,000 and this was too expensive for the developer to bear. The main reason is this location was only supported by a small single-phase transformer, thus the 50 kWp connection would incur grid infrastructure upgrade costs. This project is well-known on IoS and shows that careful planned siting is important.

## 3.3 Power Station

Electrical power supply is provided to IoS by WPD through a 33 kilovolt (kV) sub-sea cable installed in 1989 with a capacity of 7.5 MW. This cable is the principal source of electricity.

The IoS has a diesel-fuelled power station on Hospital Lane on St Mary's which is operated by WPD Generation, a wholly-owned subsidiary of WPD. It acts as a back up to maintain supply if there is a problem with the cable supply from the mainland, to meet Engineering Recommendation P2/6 (security of supply). This power station provided the supply for the islands prior to the sub-sea cable. In addition, the power station is operated by WPD to supply power during Triad periods.

The 7 individual generation sets in the power station are all in good working order. They were installed as required, which has resulted in the fleet having three units commissioned in the 1960s, two in the 1970s and two in the 1980s. They are inspected and maintained in line with supplier recommendations and with the limited running the frequency of major overhaul is reduced but when trigger hours are reached then often, due to the age of some of the units, parts have to be specially made.

As they are used for less than 200 hours per year they are exempt from meeting current standards on NOx, SOx and particulates. However, should there be a problem with the 33 kV cable then the power station could run continuously and this will increase the maintenance frequency and also mean environmental monitoring will be required.

The power station therefore requires care and attention as it is an essential part of the electricity resilience for IoS. Our overall assessment of the power station:

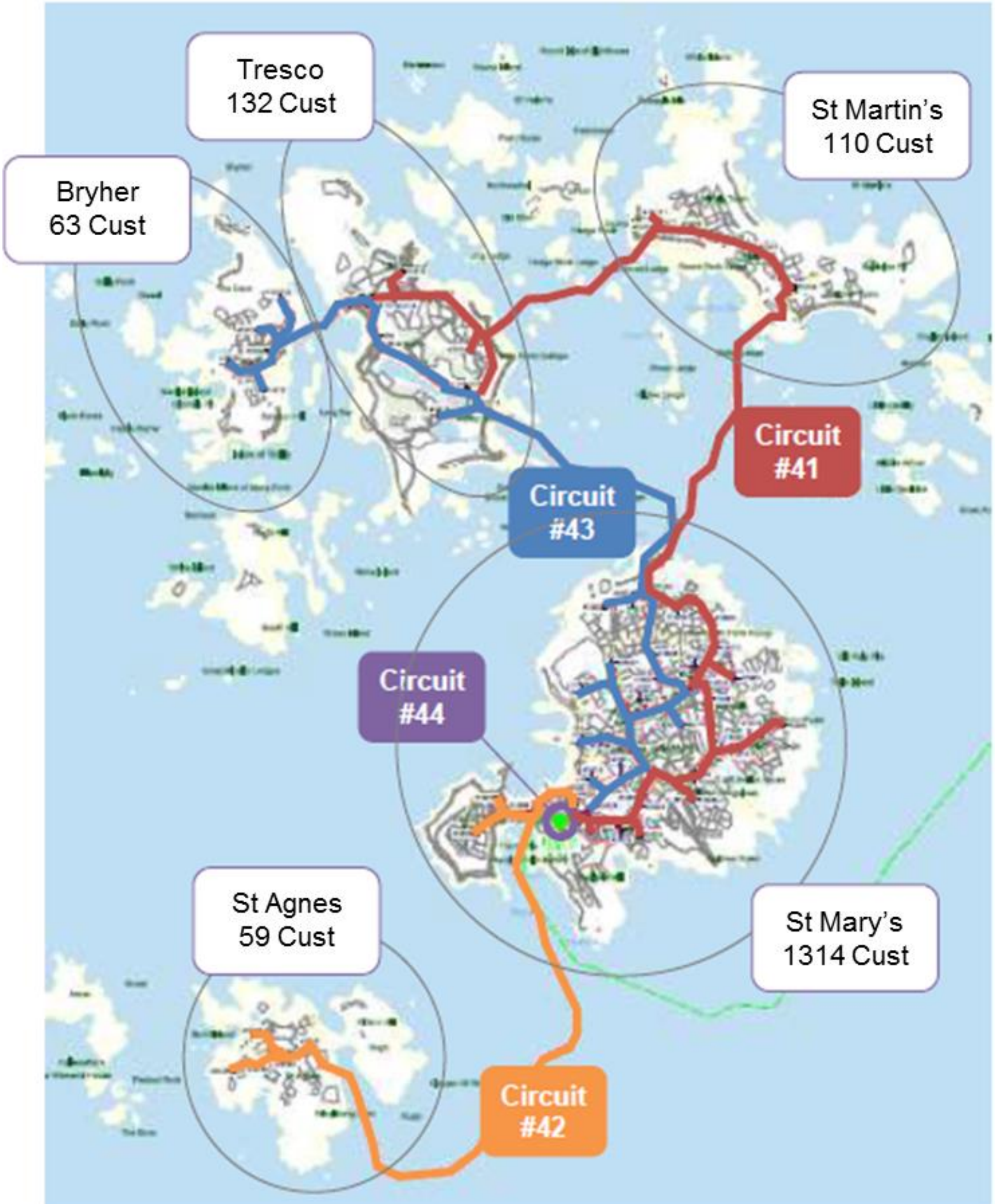
- Generators are in good working order
- Emissions will be high due to age
- Efficiency will be low due to age
- Power station is very visible and the stack is very high
- The stack height is a function of location and the age of the engines
- The station runs 25-30 times a year at 5 MW to hit Triads
- Assets are owned by WPD Generation and is a special dispensation due to the security of supply
- Site is very cramped

To fully modernise, WPD would need to invest a substantial amount of money. In addition to the power station on St Mary's, there are two emergency generation stations on Bryher and St Agnes respectively, each with two 200 kilovolt-ampere (kVA) diesel generators. Both stations are relatively new and operated remotely. These are at the end legs of the 11 kV system and are used if there are inter island cabling problems. The rest of the island network can be supplied from two directions and so the need for additional emergency generators is not required.

## 3.4 Electricity Network

The electricity network is owned, operated and maintained by WPD. The IoS is fed from Cornwall by a 33 kV sub-sea cable. This cable terminates at the St Mary's Power Station/33 kV primary substation which forms the main distribution point for the 11 kV network. There are four 11 kV feeders which supply power to the islands.

Figure 3.4.1: Sub-sea cable network and number of connected customers



The 33 kV cable was installed in 1989 and at the time of writing is therefore is now 27 years old. The cable is a single cable and has historically been reliable, however like any cable, is still vulnerable to damage. WPD has carried out some remedial works where the cable comes to shore to reduce this risk.

We have been told that the capacitance of the cable limits its power transfer capabilities, losing up to 3 MW of transferred power.

WPD is considering installing a second cable in the next RIIO period (from 2023), subject to Ofgem approval. The decision for this investment would take place in 2016-2017. This new cable would cost a substantial sum of money. A similar project in Kangaroo Island, Australia (33 kV cable of around 70 km) cost £22.5 million to install. A smart island energy system would start to reduce and perhaps ultimately remove the need for such an investment.

**11kV Network**

The 11kV network distributes electricity to the IoS through a mixture of overhead and underground lines on land and sub-sea cables. The 11 kV is converted to a nominal 230 V and 415 V via a mixture of ground-mounted and pole-mounted substations. The only significant portion of the network that is underground is serving Hugh Town on St Mary's. In terms of overall route length, much of the network (+/- 75%) is overhead.

The sub-sea 11 kV cables are all around 30 years old and may need replacing at some stage in the next 10-20 years.

The four 11 kV feeders as shown in Figure 3.4.1 are:

- 76/41 St Mary's, St Martins and Tresco
- 76/42 St Mary's and St Agnes
- 76/43 St Mary's, Tresco and Bryher
- 76/44 Ring main unit (RMU) for 76/43

It should be noted that the cable configuration is complex and reflects the gradual development of the network.

**Power Carrying Capacity**

We were supplied with network diagrams from WPD for this analysis, though these are confidential. The WPD schematic diagrams indicate conductor sizes for the 11 kV network. From this it is possible to determine the power carrying capacity (for various operational conditions) for each of the four 11 kV circuits. This was done using a mix of cable/overhead conductor specifications from WPD as well as data from manufacturers (of cable).

Simple spreadsheets were constructed for each feeder with a given feeder broken down into section of conductors (overhead or underground). Data generated for each section of conductor including: length of that section, the rating in MVA (summer sustained, cyclic, distribution). An example is shown in Table 3.4.1.

Table 3.4.1: Carry capacity of feeder 41

| Conductor Type | 95 EPR u/g | 25 mm o/h | 95 CAS /Al u/g | 50 Cu s/s | 50 Al u/g | 50 Cu s/s | 50 Al u/g |
|---|---|---|---|---|---|---|---|
| Section Length | 200 m | 4,000 m | 100 m | 2,500 m | 2,000 m | 600 m | 500 m |
| Rating MVA (summer: sustained, cyclic, distribution) | 3.46<br>3.94<br>4.07 | 2.40<br>2.80<br>3.00 | 3.46<br>3.94<br>4.07 | 2.60<br>2.96<br>3.06 | 2.60<br>2.96<br>3.06 | 2.60<br>2.96<br>3.06 | 2.60<br>2.96<br>3.06 |
| Comments | Hugh Town | St Mary's | St Mary's – St Martin's | St Mary's – St Martin's | St Martin's | St Martin's – Tresco | Tresco |
| **Total Route Length (not including spurs)** | | | | | **10,500 m** | | |

This analysis has shown that all the 11 kV feeders have minimum ratings at any point on the line of between 2.4 to 2.6 MVA. Putting this into context, the maximum island load tends to occur in April (particularly if it is cold) and is roughly 4.5 MVA (spread, somewhat unevenly over the 4 feeders). Feeders 42 and 41 are the most heavily loaded with 1.6 MVA and 1.4 MVA respectively (occurring in April). This means that even the most heavily loaded circuits have the capacity to carry around 50% more load.

It has not been possible to develop load profiles for each circuit (i.e. where the load is located on each circuit). However, discussions with WPD suggest that physically, most load is located on St Mary's with some significant, but seasonal load on Tresco. The other islands are lightly loaded.

In terms of the ability of the network, i.e. the cables and overhead lines, to carry power generated by new renewable generation, some conclusions can be drawn:

- On any circuit, renewable generation will feed existing load and if the renewable power generated is greater than load on that circuit, it will feed back to the primary substation and then out to the other feeders;
- For renewables to overload the power carrying capacity of a given circuit it would need to be far greater than 2.4 MVA;
- The installation of new renewable systems on the IoS will be distributed across the network/across different feeders. Assuming around 3.5 MW of new generation is installed, this will not breach the carrying capacity of the current 11 kV network.

Apart from capacity adequacy, the location of new renewable generation vis-a-vis existing load is the other area of consideration. As already noted, most load is located on St Mary's. If significant new generation is located at the end of a given feeder or close to a split point there is the potential for this generation to cause a voltage rise. Semi-rural networks such as the IoS where there is minimal existing generation are "tapered" from a voltage point of view, i.e. higher 11kV voltage closer to the primary substation, with a voltage decrease further away (due to the resistance and reactance of the conductors). WPD and other UK DNOs have compensated for this voltage gradient using the fixed taps on distribution transformers. Given this reality, the introduction of generation at the end of a feeder (or close to a split point) may cause voltage issues.

The word "may" is used because at the moment WPD (in fact all UK DNOs) have limited data with respect to load distribution for most rural circuits. On the 11 kV network, WPD has feeder currents and uses aggregated load flows to calculate the impact of generation, whilst there is less information (if any) available for the low-voltage (LV) networks. WPD uses conservative assumptions and considers only worst case conditions when calculating the impact of a conventional connection, thus a "common sense" approach should be taken when selecting the location of generation on a given circuit, i.e. match generation amount and location to where load is estimated to be.

**Substations**

There are 63 substations on the IoS and are a mix of ground-mounted and pole-mounted. The ground-mounted tend to be 200 kVA or greater, with pole-mounted being less than 200 kVA. Most substations are 3-phase and serve multiple properties. The remainder are single-phase in the range 16 kVA to 50 kVA.

Substations may place a constraint on the amount of generation that can be installed at a given location. This is because, for example, a 50 kVA 3-phase transformer may supply a given location and have capacity for 100 kW of roof-top mounted PV. This can occur on farms that have some large sheds (which could carry PV) and are served by 50 kVA 3-phase transformers. It could also occur for multiple properties that have significant roof space. This illustrates the importance of site selection.

**LV Network Looping**

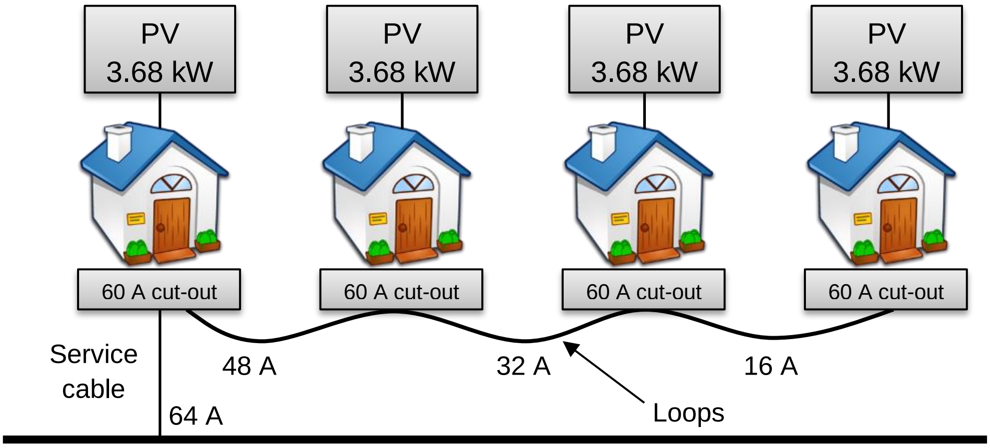
For underground networks, houses usually receive their (single phase) electricity supply via a service cable teed-off the 3-phase underground main. The service cable is terminated into a "cut-out" which carries the main 60 amperes (A) fuse. All cut-outs can support looping i.e. another cable can be run from that cut-out to the adjacent property. In some cases, multiple loops can be made. For houses that are heated by oil (or gas) such looping is not a problem. Problems will occur for:

- Multiple houses electrically heated (that are on a loop)
- Multiple houses with PV on the roof (that are on a loop)

The cut-out is "rated" at 60 A/14.4 kW, which means that it can safely carry a load of up to 14.4kW. But this also means that if there is a loop from one house to the next, the first cut out carries both the load for the first house and the load for the second house. Normally, the load on a given house rarely exceeds 3 kW (e.g. kettle and oven on at the same time) and so it is not a problem to have one or more loops. Some UK DNOs have up to 4 loops (which would mean that the cut-out on the first house would carry a load of 4 x 3 kW = 12 kW).

Figure 3.4.2 shows this rather extreme arrangement – with 3.68 kW of PV installed per house. In this arrangement if it was a bright sunny day, the output from the 4 houses (4 x 3.68 kW = 14.72 kW) would exceed the rating of the cut-out into which the service cable terminates, assuming minimal load. If the installations/cut-outs were old this could lead to problems.

Figure 3.4.2: Looping on the LV network – an extreme example




What the above means in terms of IoS and looping is that when site surveys take place this should include a review of how a property receives its electricity supply and condition of those assets.

On the IoS most detached properties have their own service cable (or own overhead services cable in the case of an overhead network). This can be seen from the WPD supplied high-resolution maps which show the route of cables and overhead lines as well as most services cables. In the case of some/many terraced houses fed from the underground network these may well be looped.

**LV Network**

Apart from the potential problem, there are some other considerations. Outside of Hugh Town, much of the LV network is overhead. Taking one example, the BBC substation transformer (300 kVA) feeds around 22 properties using 0.3 square inch aluminium conductors. This has a rating of 258 kVA, which is very adequate for the load it serves.

LV networks originating from different transformers (appear) to interconnect although with split points. Presumably this is to cater for a transformer failure that would allow the back feeding of customers (on the LV circuit) from an alternative transformer whilst the failed transformer or LV cable is replaced or repaired, and while maintenance is being carried out for ground-mounted transformers. Examination of the high resolution WPD maps suggest that this occurs for Signal Station and BBC Station as well as Porthloo, Porthloo Lane, Rocky Hill and Porth Mellon. In the case of the Porth Mellon substation, the LV network appears to extend into Hugh Town.

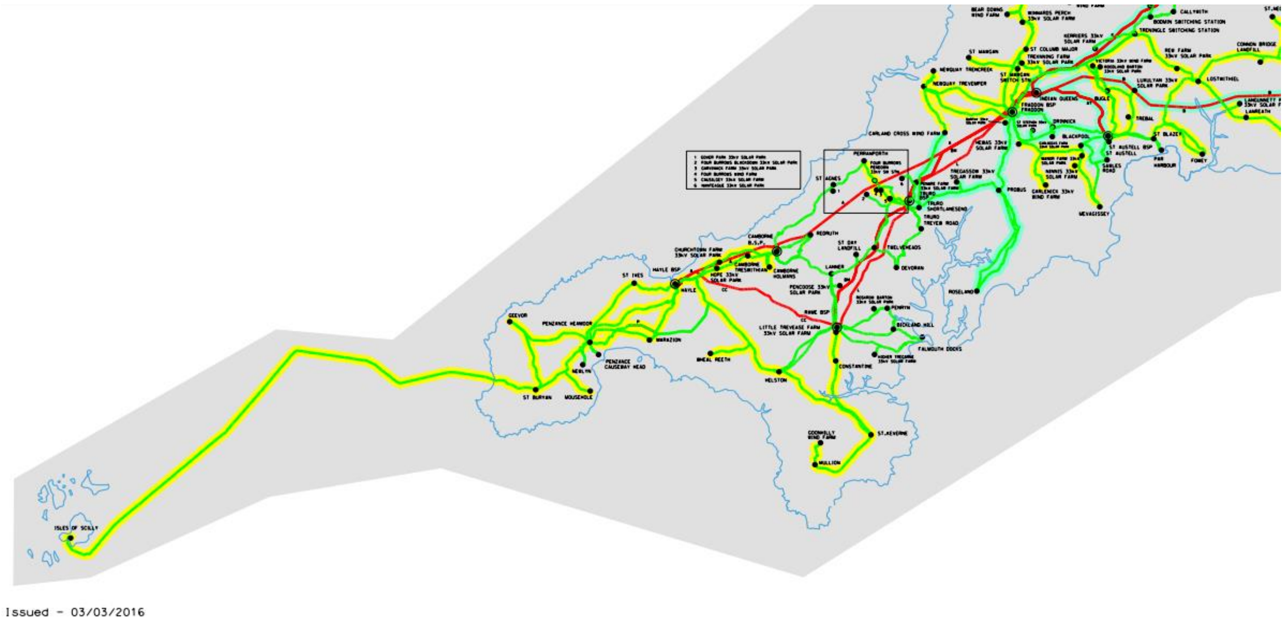
The other location where multiple substations are connected at LV is the Old Town, Old Town Lane and Old Town Pump nexus. Link boxes are indicated on the map suggesting a reconfigurable LV network.

LV network topology and the WPD approach towards fault situations such as the one mentioned above, may need to be considered when making decisions on the location of rooftop PV.

**Network Constraints**

It has been widely publicised that UK's electricity grid is unable to cope with connecting new large renewable energy projects, in particular regions where there is already an abundance of renewable generation connected. For example, the constraint map dated 03/03/2016 and published by WPD for the South West of UK (below) shows that if a generator connects to the 33 kV undersea cable to the IoS then it will cause a voltage constraint in the form of voltage rise on the Penzance / IoS 33 kV ring. This means that any renewable generation planned on IoS that requires a connection offer from the DNO may incur reinforcement costs not only at the 11 kV level, but potentially at the 33 kV level on mainland UK as well.

Figure 3.4.3: WPD network constraint map of South West UK




Source: [https://www.westernpower.co.uk/docs/connections/Generation/Generation-capacity-map/Distributed-Generation-EHV-Constraint-Maps/South-West-Thermal-Map.aspx](https://www.westernpower.co.uk/docs/connections/Generation/Generation-capacity-map/Distributed-Generation-EHV-Constraint-Maps/South-West-Thermal-Map.aspx)

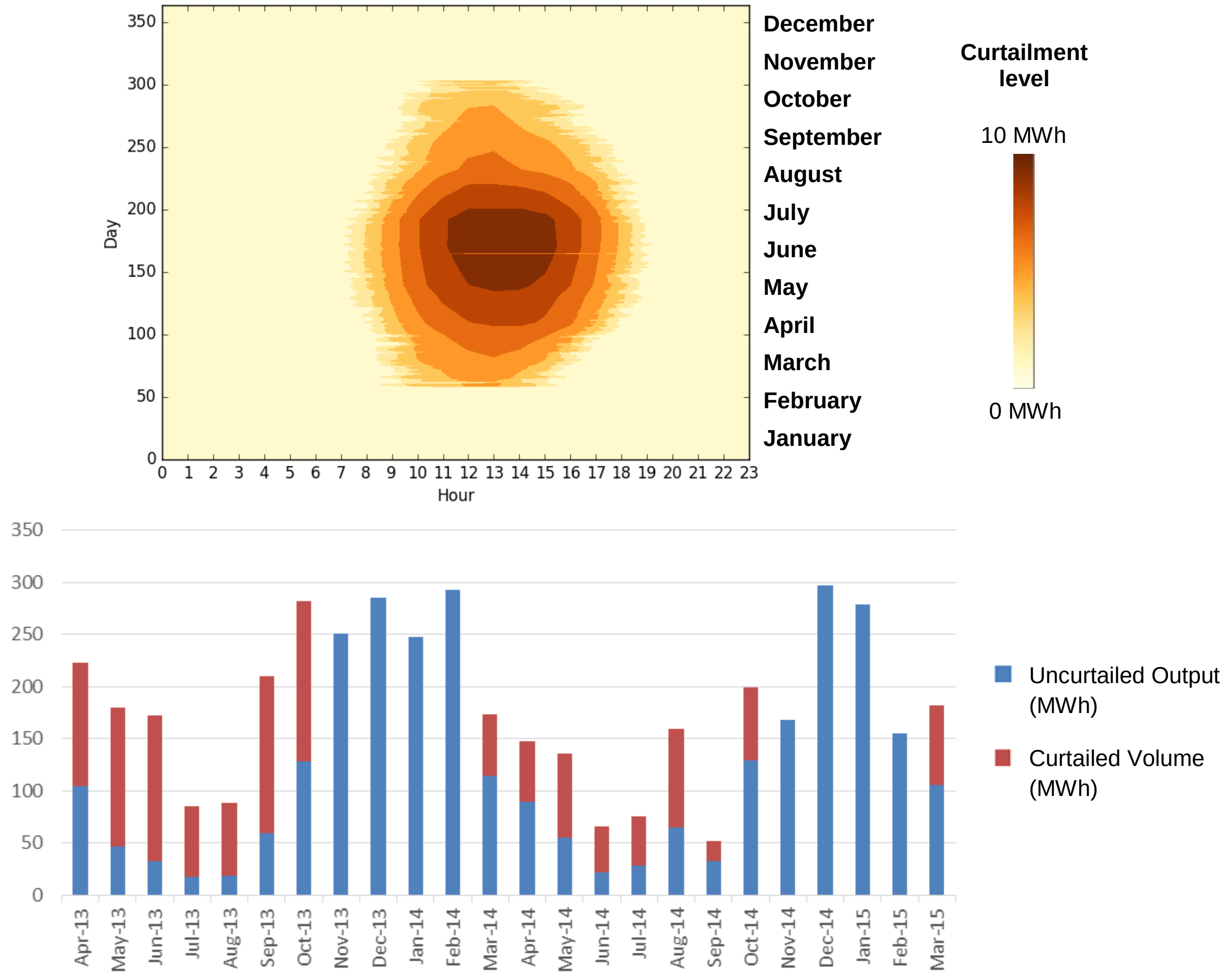
Traditionally all connection agreements have been in a single format (a conventional agreement), and generation connected under this agreement can generate at any given time up to the agreed limit. The cost of this agreement consists of:

- The full cost of assets that will be used solely by the connecting customer
- A proportion of the cost of network reinforcement where required, subject to a one voltage level above rule
- A rebate to the DNO or a previously connected customer under the Electricity (Connection Charges) Regulations 2002
- The cost of reinforcement in excess of £200/kW

Due to voltage or thermal constraints in certain areas of the distribution network, this type of agreement will now come at a very high cost, as demonstrated by the connection offered received by Johnathan Smith to connect 50 kW of PV. Recently, DNOs have developed new types of connection agreements that provide a lower cost of connection, but with reduced flexibility in generation from the connected assets. Some of these alternative connections utilise new sensors installed across the distribution network to actively monitor and analyse the network (e.g. Active Network Management or ANM), whilst other types may only monitor the network and curtail based on set conditions (e.g. specific hours of each day). ANM ensures that curtailment will be based on actual constraints rather than potential constraints and the methodology behind the order of curtailment is based on “last in, first out” (LIFO), whereby generators are curtailed in the reverse-order that the connection offers were accepted. Curtailment could mean a simple cut-off (reduction to zero) or it can be a reduction in generation (e.g. reducing the output of a wind turbine or farm) to a preset limit, or a dynamic limit informed by the DNO at the time, where applicable. Both systems can trip the G59/3 breaker but this only happens if the generator is non-compliant with signals or when the transient on the constraint is faster than the control system and the generator ramp rates need to respond more quickly. The issue with this method is that it is a commercial methodology that follows the order in which the generator is connected, although consideration is also given to the geographic location of the generator through the calculation of sensitivity factors to ensure generators which do not contribute to the constraint are not curtailed. The version of ANM that WPD is installing between Alverdiscott bulk supply point (BSP) and Indian Queens BSP calculates sensitivity factors dynamically, although this is the first time that WPD has implemented it. The LIFO methodology is exercised by all DNOs and is deemed by Ofgem to be fair and impartial, though not the most technically effective.

A curtailment assessment is usually provided at the time of the connection offer which shows an estimated level of curtailment that the connection may experience. This assessment uses historical load data (previous 2 years) and idealised generation profiles on the DNO's network models to estimate curtailment levels. Recent example assessments by WPD in the Cornwall region have estimated high capacity factors, and though this is changing all the time, it further strengthens the need to consider a mix of different types of renewables for the IoS.

Figure 3.4.4: Examples of graph information provided in a typical WPD curtailment assessment




Source : Provided by WPD Innovation Team

WPD has already begun their deployment of an Active Network Management (ANM) scheme in the South West of UK, named the Alverdiscott/Indian Queen ANM zone, with an expected completion in November 2016. This scheme will monitor and manage the 33kV and 132kV levels, whilst the 11kV level will be traditionally reinforced. As the IoS is included in this scheme, alternative connection offers in IoS may be susceptible to reinforcement charges at the 11kV level. In a recent meeting with WPD, we were informed that a large number of alternative connection offers have already been requested in this region, with numbers steadily growing. This puts an emphasis on early deployment of renewables on IoS to secure a more favourable position in the LIFO stack.

## 3.5 Waste

Municipal waste management services are provided by the Council on St Mary's, Bryher, St Agnes and St Martin's including, at the present time, household, commercial and industrial waste. Tresco Estates provides household waste management services on Tresco with commercial waste managed by the Council through Moorwell.

From January 2012 to July 2013 the average total waste per household on the IoS was estimated to be around 2.5 tonnes, which is considerably more than the 1.5 tonnes per household collected in Cornwall. On average, 14% of the total waste on the IoS is recycled, composted or reused, compared to 34% in Cornwall (http://www.scilly.gov.uk/news/improving-recycling-and-waste-management-isles-scilly). This is one of the lowest recycling rates in the UK, but reflects the unique position of the IoS with its distance from markets for recycling and seasonal nature of waste. Due to the lack of accurate historical data, the Council has recently invested in a modern weighbridge facility in order that it can start to generate better statistics in relation to waste generation.

Kerbside collection is used as the principle means of collecting waste on St Mary's and St Martin's, while on Bryher and St Agnes islanders take waste to designated locations, similar to mainland Household Waste Recycling Centres (HWRC) for collection and shipment to St Mary's. The off-island sites have recently been allocated small amounts of Council funding in order to improve waste handling at these sites.

Until recently the Council operated a 2,500 tonnes-a-year incinerator. The incinerator was old and unable to deal with the growing waste volumes. In recent times, the facility has also struggled to maintain compliance with tightened EU emission standards. The incinerator has now been dismantled and the site is being re-planned to be a Household waste and Recycling Centre and waste transfer station.

On Tresco, waste is managed by Tresco Estates, with different elements separated and incineration only of non-recyclable material such as dirty cardboard. Incineration on Tresco is in a burning pit.

The cost of waste disposal is huge. On average waste disposal costs are around £300/tonne and much more on the off-islands.

Total waste produced on the islands is estimated at 3,100 tonnes per year, of which 2,000 tonnes is household waste. This data is based on national estimates provided by RPS consultants and through the weighbridge for 2014/2015. Until the Council has undertaken a waste composition analysis this data is an estimate only and the best information available.. Table 4 presents the estimates of the waste composition. The discrepancy in the volume between the table and the number at the top of this paragraph is the waste dealt with on Tresco.

Table 3.5.1: Estimated Waste Composition 2014/15

| Waste Category | tonnes per annum | Composition 2014/15 |
|---|---|---|
| Food waste | 395.3 | 14% |
| Garden waste | 358.6 | 13% |
| Other organic | 59.9 | 2% |
| Paper | 316.5 | 11% |
| Card | 101.1 | 4% |
| Glass | 291.9 | 11% |
| Metals | 178.5 | 6% |
| Plastics | 223.5 | 8% |
| Textiles | 48.6 | 2% |
| Wood | 79.3 | 3% |
| WEEE | 46.9 | 2% |
| Hazardous | 9.6 | 0% |
| Sanitary | 76.5 | 3% |
| Furniture | 236.8 | 9% |
| Mattresses | 0.0 | 0% |
| Misc. combustible | 41.4 | 2% |
| Misc. non-combustible | 204.2 | 7% |
| Soil | 14.1 | 1% |
| Other wastes | 29.5 | 1% |
| Fines | 34.6 | 1% |
| Sewage sludge | 1.8 | 0% |
| Waste oils | 3.0 | 0% |
| Tyres | 2.2 | 0% |
| **Total** | **2,753.7** | **100%** |

On the basis of £300/tonne disposal, this has a cost of around £1 million a year. Of this around 50% could be treated through energy plants, which should result in significant Council savings.

Finally, these values probably underestimate the tonnage of green waste and food waste. A portion of each is either composted or disposed of in the corner of fields, etc.

## 3.6 Sewage

In St Mary's, only Hugh Town and Old Town and some of Telegraph have a formal piped foul drainage systems. All other properties and smallholdings rely on private septic tanks, which are not currently subject to independent assessment. The Hugh Town system drains to a pumping station in Porthcressa View (Little Porth), and from there the effluent is discharged at Morning Point on the south east corner of the Garrison. A bio-bubble treatment plant serves Old Town and discharges final effluent into the leat and to Old Town Beach. From this bio-bubble treatment plant, excess effluent is also pumped via a rising main to the Hugh Town foul sewerage system before being pumped to the discharge point at Morning Point.

The sewage discharge pipe at Morning Point is broken and needs replacing. The sewage issue of Hugh Town is an urgent issue to resolve. In addition, Natural England and the IoS Wildlife Trust have concerns on silting problems in the leat at Old Town. A comprehensive solution to the sewerage of both Hugh Town and Old Town would be a benefit to IoS, but significant investment will be required to upgrade the systems.

On St Mary's, Hugh Town has a surface water drainage system with numerous storm drain outfalls on Town and Porthcressa Beaches, and there is a storm drain outfall at Old Town beach.

Tresco is served by a sewage treatment works which was installed in 1989 by Tresco Estates. This treats 98% of the properties, with the balance served by sceptic tanks.

On Bryher and St Martin's private septic tanks are used. On St Agnes a central bio-bubble is used at St Agnes Island Hall.

There are concerns that the septic tanks may in places contaminate the drinking water boreholes. This has recently been subject to investigation by the Environment Agency.

## 3.7 Water

Water supply on the IoS is a mixture of borehole sources and desalination. The off-islands are all supplied almost exclusively by borehole water with a small amount of rainwater harvesting. The water supply for St Mary's comes from the groundwater abstraction wells at Higher Moor and Lower Moor, which is supplemented by a desalination plant at Mount Todden.

The new desalination plant was introduced in 2013 at a cost of £723,000, using funding from Defra as part of a wider project. This new unit uses less power and has a greater capacity than the previous unit.

The desalination plant is sensitive to voltage fluctuations and power outages. In these cases it will go through a sequence to safely shutdown. This is expensive and reduces the life of parts of the plant. This is partly caused by the end of grid line connection and also the nature of the island network.

Use of the desalination plant during the off-season allows the groundwater levels to re-charge and reduces the risk of saline intrusion. There are three reservoirs on St Mary's all in the form of above or below ground storage tanks. Water extracted from groundwater boreholes or seawater treated at the desalination plant is all treated and distributed via the pumping station above Higher Moor.

There are three water abstraction boreholes on Bryher supplying fresh water to the island. These are all located just to the north east of Great Pool. Two replacement tanks and sampling facilities have been installed on Bryher to improve the water facilities on the island. Two new boreholes have also been drilled for sustainability of the supply and to ensure continuity of the water supply. Water supply on St Agnes uses the Big Pool SSSI in the north-west corner of the island, protected from the north and west by formal defences. The island depends on the aquifer for its fresh water supplies via borehole abstraction. The water supply on St Martins and on Tresco is drawn from private borehole supplies, supplemented with rainwater collection tanks.

Borehole water supplies are vulnerable to pollution from agricultural chemicals and septic tank seepage, potential contamination from the Moorwell landfill site and saline intrusion from coastal flooding and over-extraction.

Although not within the remit of this report, annex A3 profiles two approaches to addressing the water issues on the islands.

## 3.8 Challenges

The key challenges on the IoS relate to the size of the islands and the environment.

- As the islands are small and remote, projects cost more to implement. Typically, a project will cost between 20% and 50% more to implement on the IoS than in Cornwall. Individual domestic PV roofs would be cost prohibitive and, thus, a planned approach is the most cost effective way forward.
- There is a lack of appropriate skills on the islands to implement major projects. This is both in terms of the necessary technical skills and the numbers of people required. Thus for infrastructure projects the personnel would need to be imported from the mainland. It is vital that maintenance for systems is provided by people based on the islands. In turn this means that the skills to undertake this are developed on the IoS. This is especially true for items such as heat pumps.
- Because of the size, traditional silo solutions will not work and innovative approaches will be needed. In a major town, such as Truro, it is possible to deal with waste treatment, sewage treatment and water treatment entirely separately. This approach will not work on the IoS. Firstly, the volumes of material each on their own make technology solutions too small to be viable. Secondly, the IoS does not have the space nor personnel to run separate facilities, thus a more integrated approach is called for. However, this means crossing business boundaries and getting separate authorities to work together.
- The costs of infrastructure projects are high in comparison with size of the IoS economy and cannot be borne by the Islanders alone.

All of these challenges have been central to thinking through the EIP and is a key aspect of the Smart Islands Partnership.

Beyond the challenges above, the issue around electricity network constraints in South West England mean that it is not possible to export electricity to Cornwall using the 33 kV cable, typically at peak generation periods such as mid-day in the summer. This means that the IoS renewables developments need to be undertaken in a smart way, otherwise the amount of renewable generation on IoS will be limited to a very small fraction of what is possible.

- A certain penetration of renewables is possible on the IoS without a smart solution involving dispatchable loads and an ICT platform to manage both generation and demand, and without any constraints from WPD. This could involve projects such as rooftop PV that are below 16 Amps per phase (G83/2 connected generation, 3.68 kWp on a single phase), which are not subjected to LIFO stack.
- The existing renewable capacity on the islands is 270 kWp, this is fully absorbed by the IoS loads.
- It is assumed that WPD will design the network using their system model in power flow analysis software before approving any generation connections. As with all DNOs, WPD will be conservative and it is unlikely that generation capacity could increase beyond 1,000 kW. This will be a small fraction of what is possible or needed to get to the IoS target of 40%.

WPD will not overload any assets and will stay within voltage limits for the worst case scenario on all voltage levels, which translates into a high-level assumption that renewable generation must not exceed island load, though this is seasonal and particularly during mid-day peak generation times. When generation exceeds load, this is effectively the point at which generation would back-feed across the 33kV subsea cable to the mainland. However, even if this assumption is met, generation may still be constrained as part of the LIFO stack operated by WPD, thus a control system is required to ensure that the IoS can operate in as much of an unconstrained way as possible.

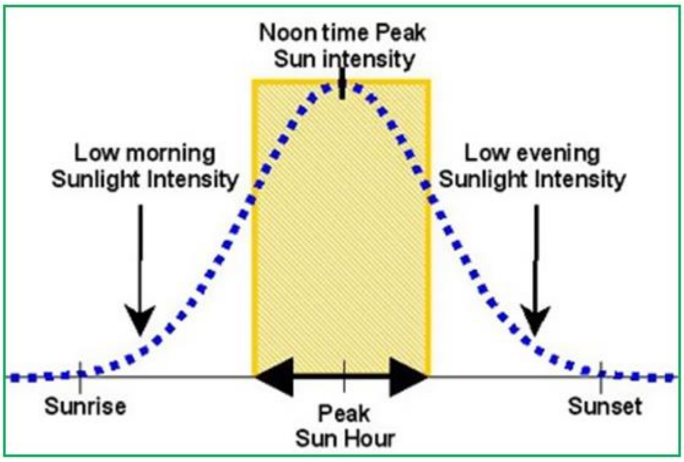
# 4. Opportunities for Renewables

The evaluation work for the EIP has considered all possible generation options for the IoS. In this work we have consulted widely, built up on previous studies and have been cognisant of the sensitivities of development in and around the Isles. The main avenues of evaluation have been solar, wind, biogas and ocean energy options, each explored in turn below.

## 4.1 PV

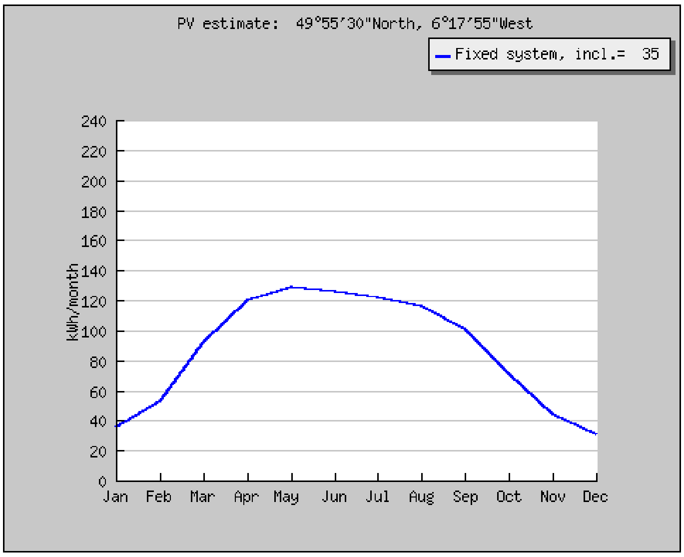
PV is a well-established generation technology with tens of thousands of schemes across the UK. On the IoS there is already a limited experience with roof-top PV, with around 270 kWp installed. There is no experience with ground-mounted PV. PV generation is predictable, but of limited duration each day. A typical daily curve is shown in Figure 4.1.1.

Figure 4.1.1: Daily PV generation




The PV system also generates the majority of the electricity during the summer months. For Cornwall and IoS around 60% of the generation will be in the months March to August. This can be seen in Figure 4.1.2.

Figure 4.1.2: Annual PV generation curve for St Mary's



PV generation in IoS is high in comparison with the rest of the UK and better even than Cornwall. This is due to the clear, unpolluted skies and high sunshine hours. Using the Photovoltaic Geographical Information System (PVGIS) database designed by the Joint Research Centre of the European Commission (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php), the predicted generation is around 1,000 kWh/kWp/year. However, experience of installed PV on IoS suggests that the PVGIS database underestimates PV generation by around 10%. Existing PV generate at least 1,100 kWh/kWp/year.

PV systems have reduced in price considerably over the last 10 years and this trend is continuing. This price reduction is driven by volume production and increasing efficiency of PV modules. For example, in 2010 each module had a capacity of around 220 W. Today modules are available with capacities up to 330 W, though the top end of this range has yet to reach market acceptance, bankable capacities of 285 W/module are readily available.

Installed prices for PV in the UK are approximately £900/kWp for large rooftop systems and £800/kWp for ground-mounted systems. This includes the equipment, installation and grid connection, though the grid connection cost varies depending on connection type and the surrounding network. For domestic rooftop systems this rises to £1,200 to £1,300/kWp. Costs for domestic installations can be reduced where there is a planned installation programme and the same installation team goes house-to-house. Here the costs would fall to around £1,100/kWp. Table 4.1.1 shows the estimated price for PV systems. Note that we have applied a 20% IoS mark up on all planned systems and a 50% mark up on an individual system, due to travelling and shipping costs.

Table 4.1.1: PV installed costs

| | Size (kWp) | Price (£/kWp) | Total (UK) | Total (IoS) | IoS £/kW |
|---|---|---|---|---|---|
| Individual installation | 4 | £1,300 | £5,200 | £7,800 | £1,950 |
| Planned programme of installation | 4 | £1,100 | £4,400 | £5,280 | £1,320 |
| Planned programme of installation | 10 | £1,000 | £10,000 | £12,000 | £1,200 |
| Ground | 50 | £900 | £45,000 | £54,000 | £1,080 |

PV systems require space to be installed. This is dependent on the angle of the roof or land, shading and orientation. A typical 4 kWp roof system on a pitched roof requires around 26-30 $m^2$ and will use 14-16 panels. A system mounted on a flat roof requires around 25% more space to install. For ground mounted systems, as they are orientated to an ideal angle the land space is around 3 times that of a pitched roof for the same capacity. This also takes account of fencing, access for maintaining the land (mowing or grazing) and shading from hedges etc.

The exact proportions of ground-mount, flat roof and pitched roof systems has not been identified, but our work suggests that 25% will be ground-mounted solar gardens, 75% will be roof top, of which around 20% are on flat roofs. Thus using these ratios the surface area required for PV is presented in Table 4.1.2.

Table 4.1.2: PV space requirements

| Type of PV | Capacity Share | 1,500 kWp Area ($m^2$) | 2,000 kWp Area ($m^2$) | 2,500 kWp Area ($m^2$) |
|---|---|---|---|---|
| Pitched Roof | 60% | 6,120 | 8,160 | 10,200 |
| Flat Roof | 15% | 1,868 | 2,490 | 3,113 |
| Solar Garden | 25% | 8,250 | 11,000 | 13,750 |
| **Total** | **100%** | **16,238** | **21,650** | **27,063** |

To maximise PV generation it is possible to vary the orientation of the PV systems deployed, i.e. choosing a variety of roof orientations from east-facing, though south-facing to west-facing. Clearly the better the orientation of the PV the better the economic returns as the generation is maximised. However, there are benefits to having a part facing west and a part facing south. Generation on a roof facing due east or due west will be 80% of a south-facing roof. However, the generation curve will be shifted, so an east-facing roof will generate more in the morning and less in the afternoon and a west-facing one vice-verse. Careful deployment on the IoS will enable approximately 10% more PV to be installed when a variety of installation orientations are used.

The final sizing of the PV for the IoS will be discussed in Section 6 of the EIP and will be a balance with other generation options, demand response (DR) and energy efficiency measures. However, PV can only supply a part of the generation and will never get to the target of 40% due to the constraints on the IoS electricity system. To achieve this level of penetration around 6,750 kWp of solar would need to be installed, this would generate excess electricity on the IoS network for most days of the year. Given that the average electricity demand on the islands is around 2 MW on a summer's day this would mean for most of the sunshine hours there would be a surplus of generation needing to be backfed to Cornwall and with non-G83/2 systems most likely being curtailed.

WPD has no possibility to constrain PV connected using G83/2 codes. This is a code for "fit and inform" and applies to all micro-generation than is less than 16 A/phase. So effectively any PV system that is less than 3.68 kWp is exempt from constraint. However, this is an installation of a planned number of domestic rooftop PV systems this would need to be announced to WPD and may then suffer from constraint. WPD has indicated that the constraint would come in the form of a delay in installation, to wait for LV network reinforcement, and costs forwarded to installers if 11kV reinforcement is required, before proceeding with the programme of installations.

## 4.2 Wind

Wind power is the most established of the renewable technologies and generation is at or around grid parity in terms of wholesale prices. Wind power is a variable generation source and in a small system like the IoS, will require careful integration. We have looked at the combination of PV, wind and electricity storage on a number of islands. Two examples are given below.

**King Island**

The first is King Island which is non-interconnected and located off the coast of Tasmania. There is a mix of wind, PV, battery storage and diesels used and data can be seen in real-time for the island (http://www.kingislandrenewableenergy.com.au/). This particular project aims to supply 65% of electricity from renewables.

### Kangaroo Island

Kangaroo Island, also off the south coast of Australia is very similar to the situation on the IoS. It is supplied by an ageing sub-sea cable and is looking at renewables as an alternative way of generating electricity. At the moment, the islanders plan to install 2 * 2 MWe wind turbines (http://kangarooislandenergy.com/) and the project is at the funding stage. There is also talk of PV and wave power systems to be installed in the future, funds permitting.

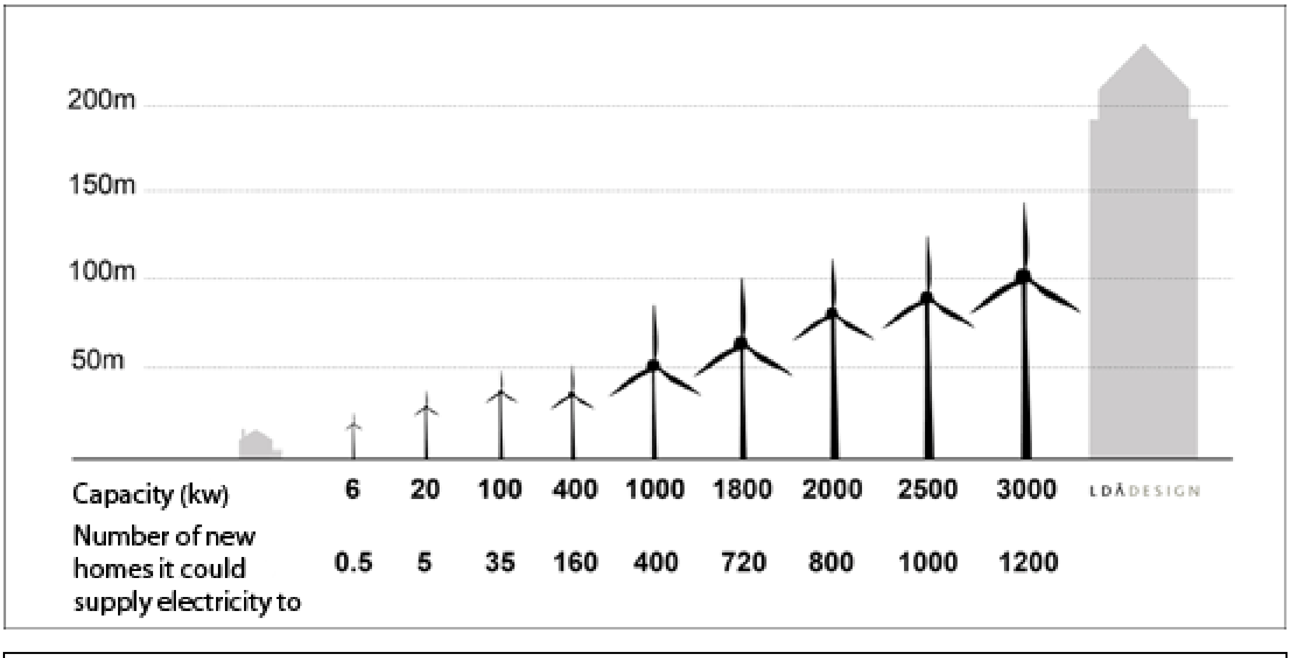
Wind power on the IoS has been discussed for years and during this project extensive discussions have been had with all parties. A combination of the natural environment, the landscape and opposition from some of the population and the Duchy would need to be overcome to deploy wind. The advantage of wind is that a relatively small amount of installed capacity will deliver substantial amounts of generated energy.

The EIP has considered three options for wind power. In each case we have consider a total capacity of 1 MW. More would be possible, but does not bring a substantially larger contribution to total electricity production due to increasing needs to constrain production. The three options are:

- A single 1 MW turbine, located away from areas of population and away from sensitive sites (bird sanctuaries, SSSIs, etc.), though it will be quite large and highly visible.
- A small number of distributed wind turbines: two 250 kW machines and five 100 kW machines. This would allow more diversity of generation than a single machine and could be placed around the islands in places where the location is practical and would not cause too much visual impact.
- A larger number of smaller turbines. This could be ten 100 kW or a larger number of smaller ones. The disadvantage of this approach is visual impact may be high and will also be more costly to install.

The heights of wind turbines vary depending on the supplier and the local circumstances. Some typical sizes are given in Figure 4.2.1.

Figure 4.2.1: Wind turbine sizes




Source: http://www.local.gov.uk/climate-change/-/journal_content/56/10180/3510953/ARTICLE

We have considered:

- 1 * 1,000 kW machine (height ground to rotor tip = 100 m)
- 2 * 250 kW machines (height ground to rotor tip = 45 m)
- 5 * 100 kW machines (height ground to rotor tip = 48 m)

For the 1,000 kW machine we have used the example of a three-bladed turbine. The blade length is 40 m and the tower height is 60 m. With a capacity factor of 45%, this machine could generate up to 3,950 MWh/a.

We estimate the capital costs to be almost £2 million per turbine installed. This price includes a 20% mark up for working on the IoS, but does not include any additional WPD reinforcement costs.

For the 250 kW machine, we have used a 3-blade up wind stall regulated rotor, with an improved overall efficiency. With a blade length of 13.4 m and a diameter of 30 m the rotor has a swept area of 707 $m^2$. The rotor speed is 40 rpm.

This machine will generate at a capacity factor of around 45% and so will generate 985 MWh/a.

We estimate the capital costs to be almost £1 million per turbine installed. As above, this price includes a 20% mark up for working on the IoS but does not include WPD reinforcement costs.

For the 100 kW machine, we have assumed a mast height of 36m and a blade diameter of 24m. At an average wind speed of 7m/s and a capacity factor of 44% it will generate 388 MWh/a.

We estimate the capital costs to be around £430,000 per turbine installed, assumptions as above.

Table 4.2.1 summarises the expected investment costs of the range of wind turbine sizes described above.

Table 4.2.1: Wind power investment costs

| Size (kW) | Total (UK) | Total (IoS) | IoS £/kW |
|---|---|---|---|
| 100 | £360,000 | £432,000 | £4,320 |
| 250 | £800,000 | £960,000 | £3,840 |
| 500 | £1,400,000 | £1,680,000 | £3,360 |
| 1000 | £1,600,000 | £1,920,000 | £1,920 |

## 4.3 Anaerobic Digestion and Gasification

**Anaerobic Digestion (AD)**

AD is well proven as a technology for processing biological materials into useful products by micro-organisms in the absence of air. The AD plant will convert the feedstock into biogas, which can then be used as a fuel for power (and heat) generation. The plant also produces a residual material, termed digestate. The digestate comprises a liquid fraction and a solid fraction.

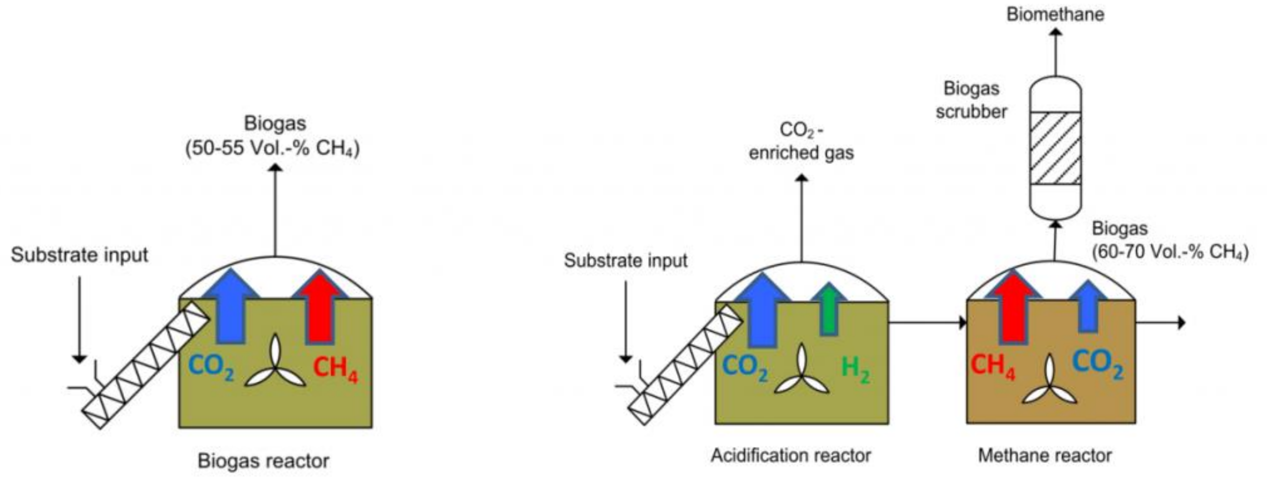
Within an AD plant the breakdown of the chemical chains of feedstock material is complex and involves 4 different bio-chemical processes: hydrolysis; acidification; acetification; and methanisation (the processes are explained in Annex 4).

The 4 AD processes are finely balanced and sensitive to each other; when not working well they can cause mutual inhibition. The digester can be designed to operate either within the mesophilic range (30°C-40°C) or within the thermophilic range (50°C-60°C). Whichever process is chosen, it is important to keep the temperature as even as possible.

There are two types of AD plants:

- Single-stage AD plant, operating mesophilically, which uses a single digester tank where the entire process takes place. This type of plant is used for most farm-based AD projects, but it is very sensitive to the feedstock make-up and is not suitable for a wide range of feedstocks.
- Two stage AD plant, operating both thermophilically and mesophilically, which uses a pre-processing in hydrolysis tanks, and the output of which is fed in batches to the digester tank, is a quicker process and can cope with a wider range of feedstock types and variations is proportions. All sewage treatment plants adopt the two stage process.

Figure 4.3.1: Comparison of a single-stage and 2-stage AD plant




Source: http://blogs.qub.ac.uk/atbest/2015/03/23/introduction-to-innovative-technology-of-biogas-production/

A 2-stage AD plant is sufficiently robust to utilise cheaper and more diverse feedstock (including slurry, litter and manure, and the fallow year rotation crop). This is well suited to the demands of IoS.

For the IoS the use of AD for sewage treatment, non-woody green waste, food waste, seaweed and bracken is a practice option. Mixing the feedstocks will give a scale of inputs that makes it viable.

It should be stressed that a full feasibility study has not been undertaken and so the following analysis is developed as a guide. Sizing an AD facility is complex and requires a reasonable level of resources to optimise the design. Thus, for this analysis we have erred on the safe side. The capacity of the project could be as much as 2-3 times larger.

Feedstock (tonnes per annum)

- Green Waste 150 [output based on 35% dry matter (DM) and biogas yield of 130 $m^3$ tonne]
- Foodwaste 1,000 [output based on 25% DM and biogas yield of 145 $m^3$ tonne]
- Sewage 2,000 [output based on 10% DM and biogas yield of 75 $m^3$ tonne]

We've erred on the side of caution with the above DM and biogas data and would strongly recommend sending samples for laboratory analysis.

Note, the waste arising in the waste section suggest that food waste is around 400 t/a, green waste 360 t/a and sewage is only available as pumping data (which would require deeper analysis). The waste arising may underestimate both food waste and green waste.

The plant would require up to 1,000m$^3$ of dirty water annually to bring the input material down to 12% DM for digestion. Once the plant is operational a significant proportion of this may be recycled from the liquor element of the digestate.

Sizing

- CHP capacity 100 kW
- Electricity Production 630 MWh/a
- Heat Production 850 MWh/a
- Hours of operation 8000 h/a

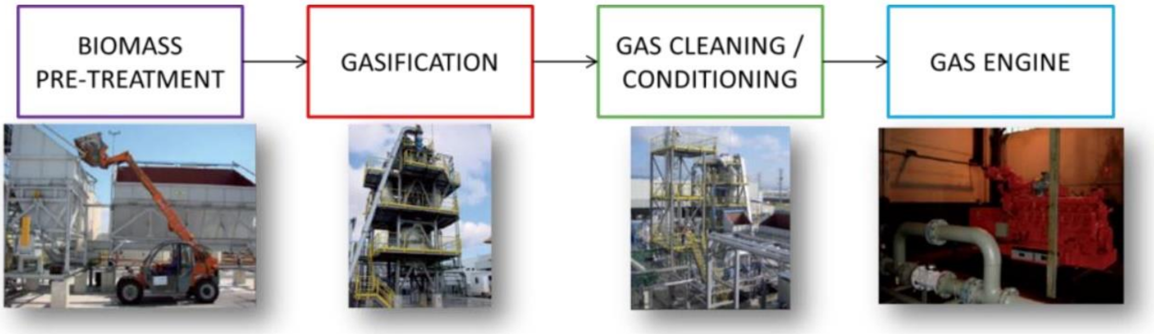
The approximate cost for this plant would be £600,000, before grid connection, foundations, civils for fuel storage, sewage dewatering plant and end treatment for water discharge. The estimated annual operating costs including full maintenance (CHP included), of £60,000 excluding people.

**Gasification**

Gasification is a high-temperature process in which a solid fuel (e.g. coal, biomass, wastes) is converted into a combustible gas, called producer gas or syngas. Gasification takes place at high temperatures (700 to 1,500°C), and heat or small amounts of air or oxygen are added to supply the energy needed for the gasification process.

70-80% of the energy contained in the initial solid fuel is transferred to the chemical energy of producer gas (remaining 20-30% accounts for heat and losses).

Figure 4.3.2: Configuration of a small-scale gasification plant




Source:
http://www.ieatask33.org/app/webroot/files/file/publications/Fact_sheets/IEA_What_is_gasification.pdf

A gasifier can be deployed to use the dry digestate from the AD plant, the wood garden waste, waste wood, paper and card, thus reducing the transport of waste off the IoS. In terms of volumes, the section on waste above gives the tonnages. In this case: wood is around 80 t/a, wood waste (furniture) 235 t/a, paper 315 t/a and card 100 t/a. Assuming the sewage feedstock discussed in the AD section of 2,000 t/a around 1/3 of this would form the dry digestate. This gives an approximate tonnage of 1,400 per year. Not all the paper and card would necessarily be acceptable to feed into the gasifier as this would need to be balanced with recycling rates.

There are a number of gasifier technologies available. We have considered a 500 kW unit which requires around 0.5 tonnes per hour of operating (this depends on moisture content and energy content of the fuel. This would imply the unit could run for up to 2,800 h/a. We have assumed that not all the waste is available and so it runs for 1,500 to 2,500 h/a. As this is dispatchable it could run for longer in the winter than in the summer to balance with other generation.

The capital costs for a system is around £1.7 million.

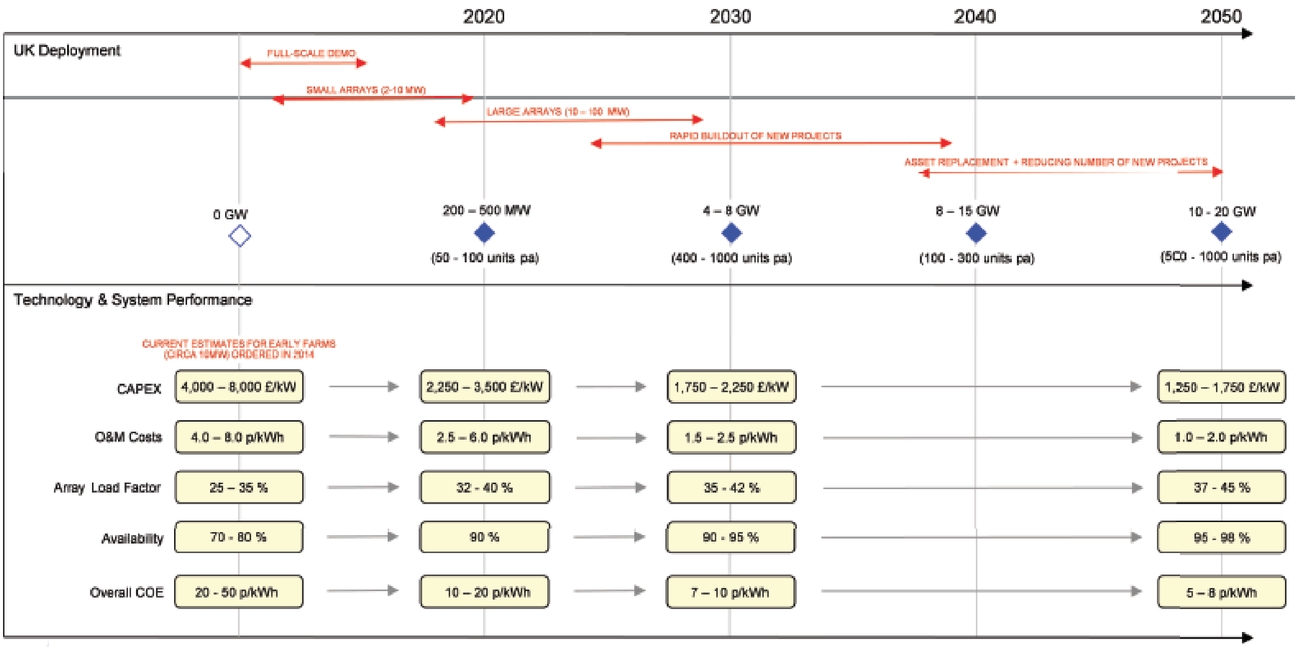
A location for both the AD plant and gasifier has been selected near the Carn Gwarvel Health and Wellbeing Centre on St Mary's. This will be discussed further in Section 6.

## 4.4 Tidal Energy

The marine environment can supply energy in three main forms – tidal stream, wave and tidal range/barrage. These provide significant potential since the UK has some of the world's best available tidal and wave resources. This section examines the option of tidal stream. Wave power is dealt with in Section 4.5 and tidal barrages are not applicable to the IoS.

Tidal stream energy is a reliable and predictable low-carbon energy source. There is sufficient energy resource in UK waters (if it can be economically exploited) to make a material contribution to future UK energy supply needs. Tidal stream energy has additional benefits such as low visual impact, economic activity and stimulus in remote areas of the UK. Some potential disadvantages are the environmental impact on wildlife and disruption to shipping navigation and other marine economic activities.

Figure 4.4.1: State of development of tidal energy




Source: http://www.eti.co.uk/wp-content/uploads/2015/02/Insights-into-Tidal-Stream-energy.pdf

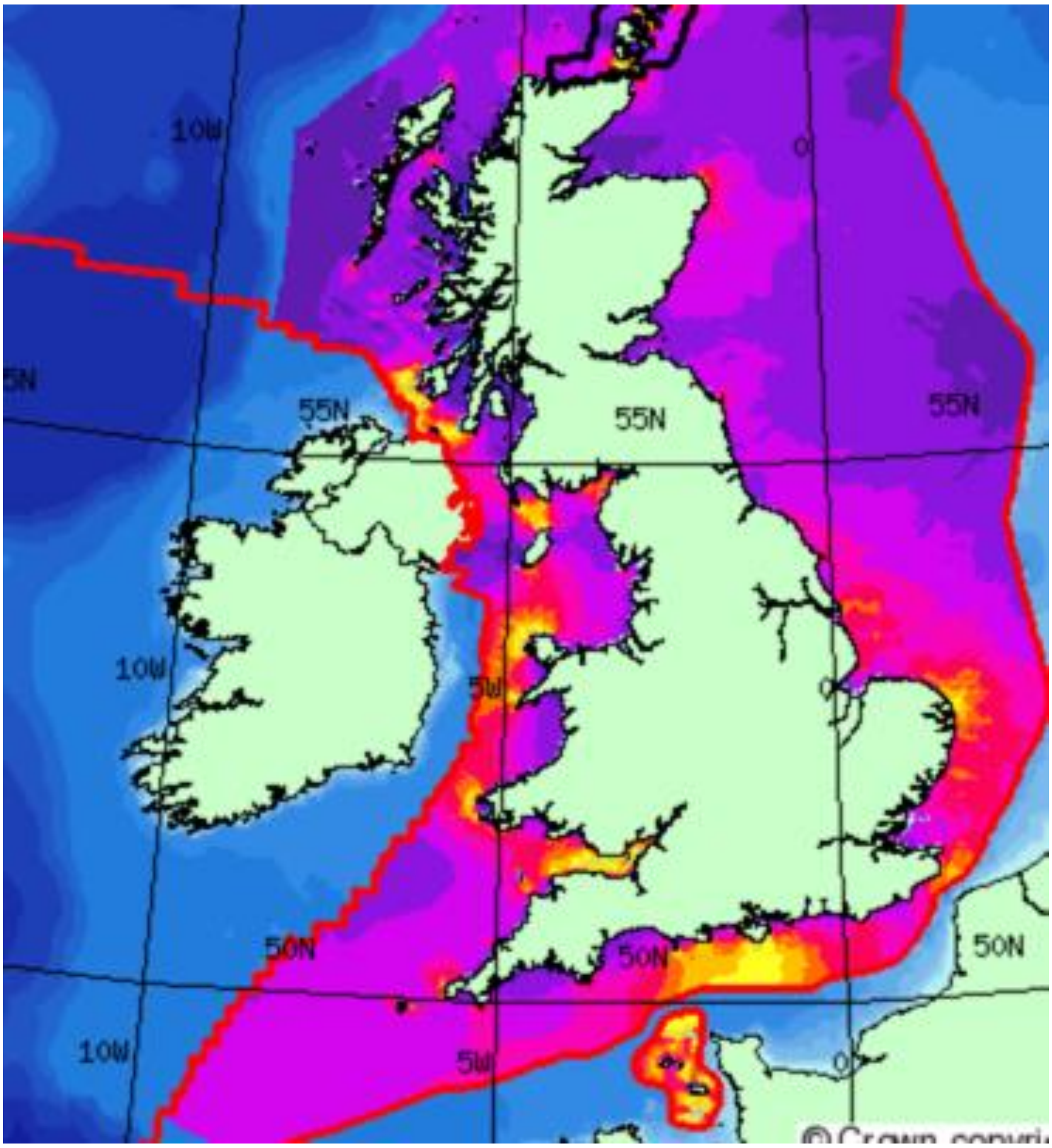
The sector has transitioned in recent years from small-scale prototype devices through to full-scale demonstration and early commercial arrays are now in development.

There is a demonstrable route to making tidal stream energy competitive with other low carbon technologies; tidal stream has the potential to be a material part of the future UK energy system. The UK leads the rest of the world in the development of tidal devices, though they are all generally pre-commercial. This may be attractive to IoS due to the innovative nature of the technology, but being not near market, rather than far market as is the case for most wave devices.

Array and device design integration is vital to ensure a good load factor and durability. Siting of the devices is a key consideration to ensure operability and good output. Finally, other marine factors such as fishing areas, conservation zones and leisure need to be factored in to the siting.

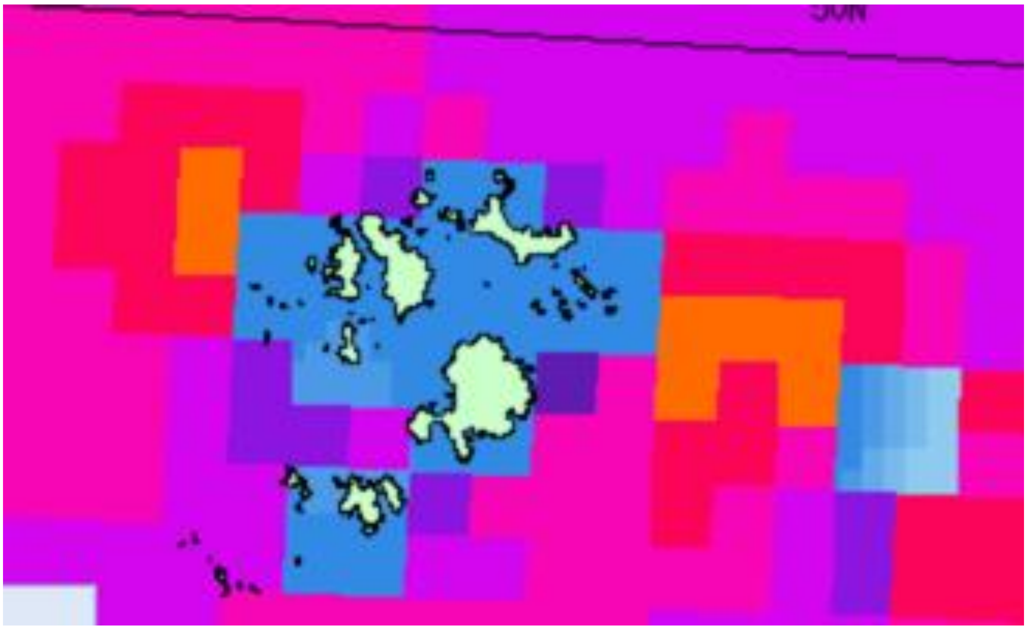
The Marine Energy Atlas produced by ABPMer shows tidal flows around the UK, unfortunately the resolution is not high enough for the purpose of resource mapping, but it gives a general indication of the overall flows, see Figure 4.4.2. The more yellow areas the better the resource.

Figure 4.4.2: Tidal resource in the UK (Marine Energy Atlas)




Source:
http://vision.abpmer.net/renewables/map_default.phtml?config=tide&resetsession=groups,resultlayers

Figure 4.4.3: Close up of the IoS (Marine Energy Atlas)



Source:
http://vision.abpmer.net/renewables/map_default.phtml?config=tide&resetsession=groups,resultlayers

It can be seen that the IoS is not a prime location for tidal stream, but should have areas where the technology may work.

Tidal stream generation will depend on the tides and, very roughly, will have a period of 11.5 hours between tides and so will gradually move the generation curve each day. This is entirely predictable, but would need to be factored into planning running the IoS electricity system.

We have spoken to both the Energy Technologies Institute (ETI) and a potential supplier on the viability of the IoS for tidal stream. The issues are the depth of the water column at places where the tidal stream flow is strong. The depth of water is rather shallow on the waters between the islands and this would mean a further offshore option.

The technology is close to commerciality.

- The turbine needs a depth of water of 32m (+/-).
- Blade diameter is 15m.
- The tripod base is roughly 50 m on each side.
- The capital cost is likely to be £5 million for the turbines and tripod superstructure and 2-3x that for total project cost is about right (approx. £10-15 million).
- Capacity factor is expected to be 30% - so 1.2 MW would generate 3,150 MWh/a, a little less than 1 MW of wind.

The locations identified for this initially are likely to be too shallow. Further work will be needed to develop this option.

What follows are several example projects that give an idea of costs and scale for tidal stream systems.

**Ramsey Sound**

Ramsey Sound is off the coast of Pembrokeshire and will be the site of a tidal stream demonstration project. A Lease Agreement has been signed with The Crown Estate for a test development programme for up to seven years. A site survey has been completed and the project has received the Marine Licence necessary to proceed with the offshore part of the project in Ramsey Sound, and planning permission has been granted for the temporary onshore works at St Justinians and the first 400kW turbine was installed in the Sound in December 2015, with a view to scaling up to a full scale device by 2017. The 400kW turbine can produce enough power for between 400-600 homes. This project is supported by £8 million funding from the European Regional Development Fund (ERDF) supplied through the Welsh government. The total project cost is £15 million.

**Holyhead Island**

A 10 MW marine energy array is planned at Holyhead Island, which will supply electricity to approximately 8,000 households. The first step will involve the commissioning of a 0.5 MW plant in 2017. For this step, the Welsh Government is investing €13 million of ERDF. The Holyhead Deep site is located approximately 7 km from the shore where the water depth is 80-90 m. The tidal currents are 1.5-2.5 m/s. The area has been carefully selected to maintain separation from shipping lanes and to minimise the impact on other sea users.

**Anglesey**

A 10 MW tidal stream array was given planning permission from the Welsh Government in February 2013, and was to be Wale's first commercial tidal energy farm. This project was a £70 million project involving seven tidal generators located in up to 40m of water at the Skerries, off the North West coast of Anglesey. This array could generate enough power supply electricity to up to 10,000 homes – approximately 20% of Anglesey's electricity demand.

As of March 2016, it was announced that the project has been put on hold (again).

## 4.5 Wave Power

The opportunity for wave power in the IoS is large in theory. The resource is substantial, but the technology is yet to be proven and is certainly not yet commercial. In completing this work, we spoke with the ETI, who confirmed that the commercial application of wave power is at least a decade away although there may be potential for a small scale test array. Thus we have not considered in any depth wave power and we would propose that this option is kept on watch in case the technology does become commercial.

Wave power also poses some issues for the IoS:

- The size of projects to be economic is likely to be large, from 5 MW upwards. This amount of electricity generation cannot be absorbed by the IoS and so will need a route to the mainland. The 33 kV cable capacity is 7.5 MVA and so maximum export of around 7 MW is possible. However, as already stated the network in the SW of England is heavily constrained and so export will not be acceptable. Reinforcement of the SW England network is unlikely in the foreseeable future.
- The marine impact of wave power is not fully understood and so a considerable amount of work is needed to be done before any projects are contemplated.

## 5. Opportunities for Demand Side Actions

### 5.1 Demand Response and Energy Storage

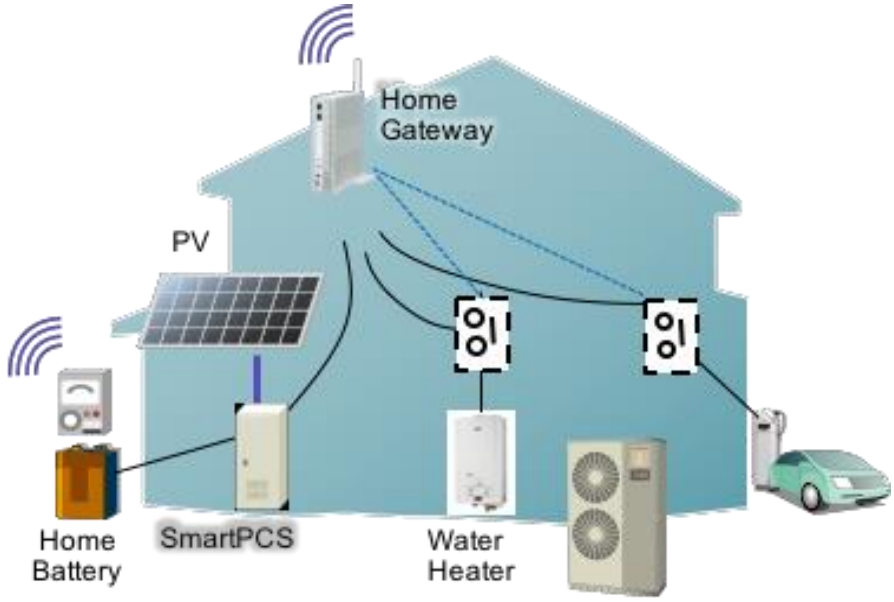
The opportunities for DR and energy storage are presented in this section. With the exception of some energy storage and desalination most of these technologies can be installed over most of the islands and can be installed in households.

DR opportunities on IoS cover:

- EVs
- Heat pumps
- Immersion heaters
- Battery-based energy storage
- Other DR resources (such as water pumps or desalination)

In the case of households, DR is enabled through the use of a Home Energy Management System (HEMS) that controls various household energy consuming assets. A general arrangement is shown in Figure 5.1.1.

Figure 5.1.1: Example of DR-capable technologies that can be installed in a house or cottage




For the IoS we estimate the suitable sizes of the technologies to be:

- Rooftop PV around 3 kWp
- Air-sourced heat pumps (ASHP) of 6 kW
- Battery storage of 2 kWh

The numbers of EVs, small scale battery storage and ASHPs that could be deployed across IoS depends on the need for dispatchable load. In theory all houses with PV could have energy storage, all vehicles could become EVs in time and much of the housing stock could have ASHPs installed.

In addition, some properties may be suitable for solar thermal water heaters. Clearly space is an issue and a property may need to choose between PV or solar thermal.

Energy storage can be thermal storage such as the use of immersion heaters (though this will be seasonal) or battery systems in the case of electricity.

- Immersion heaters can be controlled to use electricity at times of surplus power, as long as this does not interfere with the lifestyle of the occupants of the property
- If district heating is deployed then a large thermal store should be used to balance the heat supply with the load. These are used commonly in places such as Denmark, which allows the combined heat and power plants to be dispatchable.
- Battery-based electricity storage is becoming increasing commercial, In Germany, there is a government-supported programme to use energy storage with residential PV. A 10 kWh battery system will cost around £6,000.
- Grid-based energy storage using batteries is being trialled in a number of projects, but the business case is yet to be proven. However, where grid services or a UPS function can be provided, as is the case in IoS, the economics are stronger.

**EVs**

IoS daily driving distances are low suggesting that EVs are practical for private and commercial transportation. The target is 40% of vehicles on the IoS being EVs by 2025. The current number of vehicles on IoS is 1,253 (DVLA, 2014). To meet the 40% target requires 500 vehicles to be EVs by 2025 in need of daily charging, assuming the vehicles are used daily. It is possible that each vehicle will need 2 or 3 kWh of charging each day. This could provide a DR capability of 1,000 to 1,500 kWh. This is a useful amount of energy, especially during the peak PV output period in the middle of the day when there is low demand. This means that for EVs to be useful in the context of DR, they would need to be available for charging from mid-morning through to mid-afternoon.

Generally, EVs are likely to act mostly as a sink for electricity (i.e. charge when there is too much electricity or when it is cheap). It is viable to maintain vehicles at low charge due to the short driving distance, i.e. there is greater flexibility in using the batteries as a buffer than there would be on the mainland. However, it is less likely that they will be a source for electricity given the round trip costs of an EV kWh. Special cases where the economics could make sense include Triads.

**Heat Pumps**

The wider use of heat pumps could help both reduce energy consumption overall and their operation will be a function of:

- Performance of a given building fabric,
- Personal preferences in terms of thermostat setting

ASHPs, and possibly ground source heat pumps, will be able to provide DR, and given that the main need for DR is spring/summer/autumn and mid-morning through to mid-afternoon it is possible that heat pumps will contribute a modest amount of DR, perhaps a few hundred kWh across IoS.

**Immersion Heaters**

Water can store a great deal of energy. Working on the basis of people showering in the morning and possibly when coming back from the beach this points to a useful potentially multi-MWh storage system (given that each immersion heater has a 6 kW element and can store 200 to 300 litres of water). Again, this asset has the potential (provided it is controlled) to provide a few hundred kWh of DR.

## 5.2 Energy Efficiency

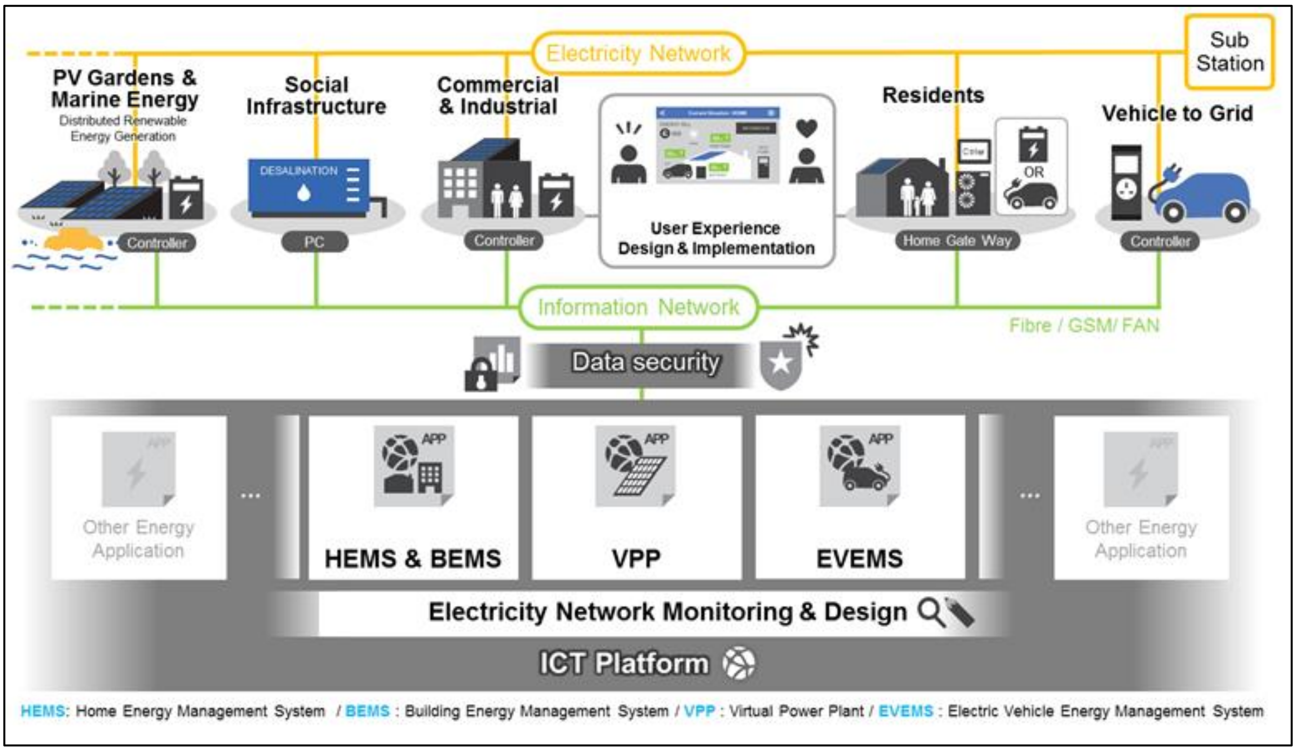
The role of energy efficiency is out of scope for the EIP, but is in scope of the wider Smart Islands Programme. The deployment of energy efficiency measure will reduce the demand for energy and as such is of relevance with respect to the infrastructure plan. In the case of IoS, most domestic energy efficiency measures, such as LED lighting and insulation will reduce electricity demands and so will improve the affordability of energy and reduce the overall level of electricity needed by IoS, but may consequently reduce the ability to offset excess generation.

## 5.3 Smart Control of the IoS Network

The EIP aspirations of achieving a 40% renewable energy share of the IoS supply and the issues around constraint for new power generation in SW England requires control embedded in the electricity system. This "control functionality" can be provided by an ICT platform that is used to control generation assets and dispatchable loads. Without an ICT platform it will be possible to realise only a small fraction of the potential for renewable electricity on the IoS.

The exact architecture of the ICT platform is not a subject of the EIP, but the fundamental requirement for such a platform is acknowledged. This platform will need to be able to control electricity loads in houses and businesses, other DR options, such as battery storage, EVs and dispatchable generation. Figure 5.3.1 shows pictorially the concept of the ICT platform and how it could function on IoS.

Figure 5.3.1: High-level concept of an IoS energy management ICT solution




Source: Smart Islands Partnership

# 6. The Energy Infrastructure Plan

This section of the report draws together all the aspects considered in the work to develop the EIP. This plan will provide a contribution to the revised Infrastructure Plan for the IoS currently being drawn up by Council.

The IoS current situation can be summarised as follows:

- Supplied by a single 33 kV cable installed in 1989.
- The original island power station is used for back up and grid services, and if there was a desire for the owner to modernise would require substantial investment
- Use of renewables is very limited – a total of 270 kWp of PV only – generating 300 MWh/a or 1.6% of the IoS demand
- IoS energy challenges – the high societal cost of providing energy to IoS, reliance on diesel fuel and electricity, a high share of fuel poverty (22.4% against a national average of 10.4%, source: https://www.cornwall.gov.uk/media/17512672/reducing-fuel-poverty.pdf)
- Sewage treatment is limited and the existing solution for Hugh Town via an offshore pipe disposal is not fit for purpose
- No island solution for green waste, waste wood and food waste – either limited composting and storage or sent to mainland at huge cost
- St Mary's desalination plant suffers from nuisance shutdowns due to power supply quality on the end of the line

The IoS electricity system has evolved from a non-interconnected system to being connected to Cornwall and so is fairly robust with currently good redundancy.

- Island electricity network is well engineered and overall has sufficient capacity for the future
    - 4 * 11 kV circuits
    - 2 * emergency generators
- 3-phase circuits should be able to cope with the installation of moderate amounts of new generation
- 1-phase circuits can support only modest amounts of PV such as a standard roof-top residential system or will need to be reinforced to allow larger generation to connect
- Most load is on St Mary's, so most generation will need to be installed on this island.

A staged approach to the energy infrastructure is practical and fits the stage of development of technologies. Table 6.1 presents the overview of this staged approach. The rest of the plan will focus on Stage 1, with a few comments on Stage 2 at the end.

Table 6.1: A staged approach to the EIP

| | Stage 1 | Stage 2 |
|---|---|---|
| Time frame | Next 5 years | 6-10 years |
| Renewables | PV, AD, gasifier<br>Wind and/or tidal stream | PV, wave, micro-technologies for sewage |
| Capacity | 3.1 MW | Further 3 MW or more |
| Infrastructure | Sewage treatment, district heating, new power station*<br>Energy storage | New cable to islands?<br>Wave to connect to island busbar, power to gas |
| Share of electricity | 40% | 100% |
| Share of non-electricity energy | Maximum 10% | Up to 100%<br>(if power to gas is implemented and all diesel is replaced by synthetic natural gas) |
| DR | Heat pumps, EVs, immersion heaters | |
| Energy Efficiency | LEDs and insulation | |
| Comment | All proven technologies, integration issues understood | New technology and deeper integration, more challenging |

* Note: This is not under the control of the Council and is a matter for WPD

The solutions for IoS need to be integrated and holistic to work. The IoS is too small to treat each item in isolation and so the traditional silo approach will not work effectively. The types and amount of renewable generation has to be balanced and single generation types will be sub-optimal and will be limited in impact.

The solution must address issues around sewage, drinking water, the future of the power station, green waste, wood waste and food waste, and it must be integrated with the smart energy options of renewable generation and flexible loads with system intelligence.

Generation options:

- PV – up to 2 MWp – any more is difficult to integrate
- One of or a mixture
    - Wind – around 1 MW – cheapest generation
    - Tidal Stream – 1.2 MW – still pre-commercial & expensive
- AD for sewage/food waste/green waste – around 100-200 kW
- Gasifier for the sewage cake/waste wood and woody green waste – around 500 kW
- New power station – relocated, greater flexibility and modular
- Energy storage of around 1.5 MWh.

## 6.1 PV

Some 75 sites use PV at present totalling 270 kWp, generating around 300 MWh/a or 1.6% of the IoS electricity demand. New, additional PV of 1,230 kWp would increase the total IoS capacity to 1,500 kWp. This would comprise:

- 4,500 panels
- Total space 1.6 hectares
- 75% on roofs (barns, council buildings, private houses)
- Around 180 roofs
- 25% as solar gardens
- Around 9-10 gardens

It is worth stressing that there is no shortage of sites for PV at this level. Annex A1 identifies a list of potential sites where PV can be installed, based on field work done for the EIP. These sites are illustrative and will require formal site surveys to confirm their suitability. One example is presented in Figure 6.1.1. Here a mix of farm buildings and houses in the north of St Mary's that could support 36 kWp on a selection of buildings.

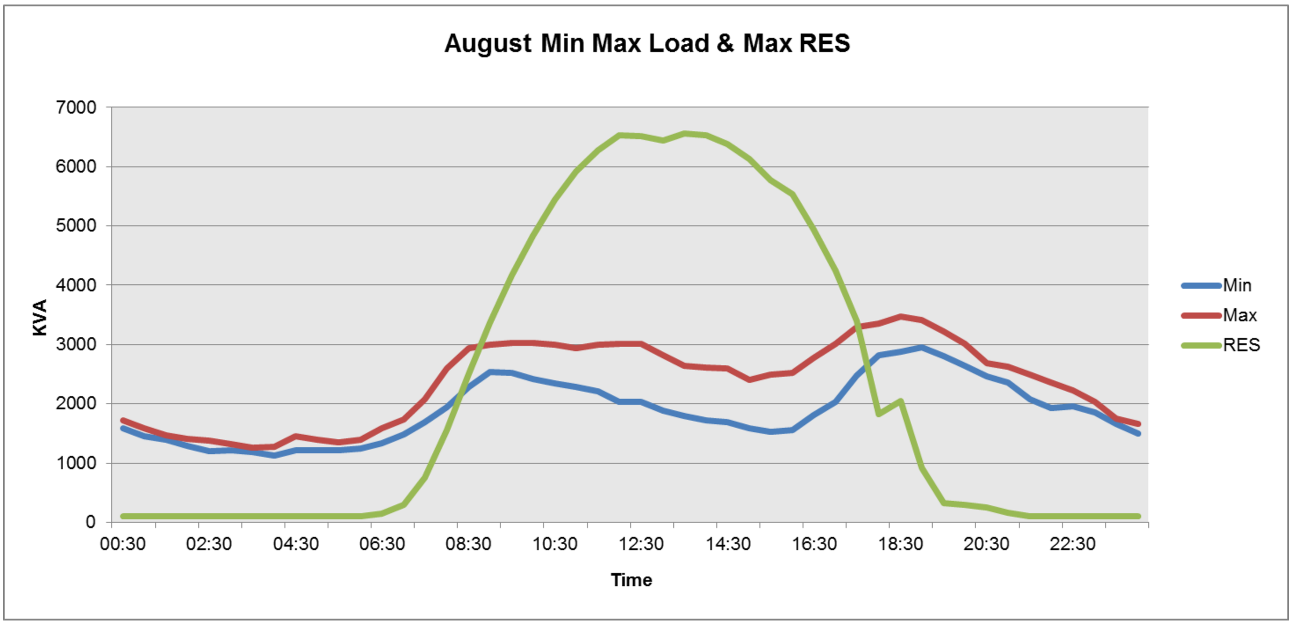
Figure 6.1.1: An example of PV on St Mary's


As stated earlier, PV alone cannot provide the sole solution for renewable generation on IoS. To meet the 40% target set by the Council would require a total installed capacity of 6.75 MWp. This would need:

- 23,560 panels
- Total space of 6.5 hectares

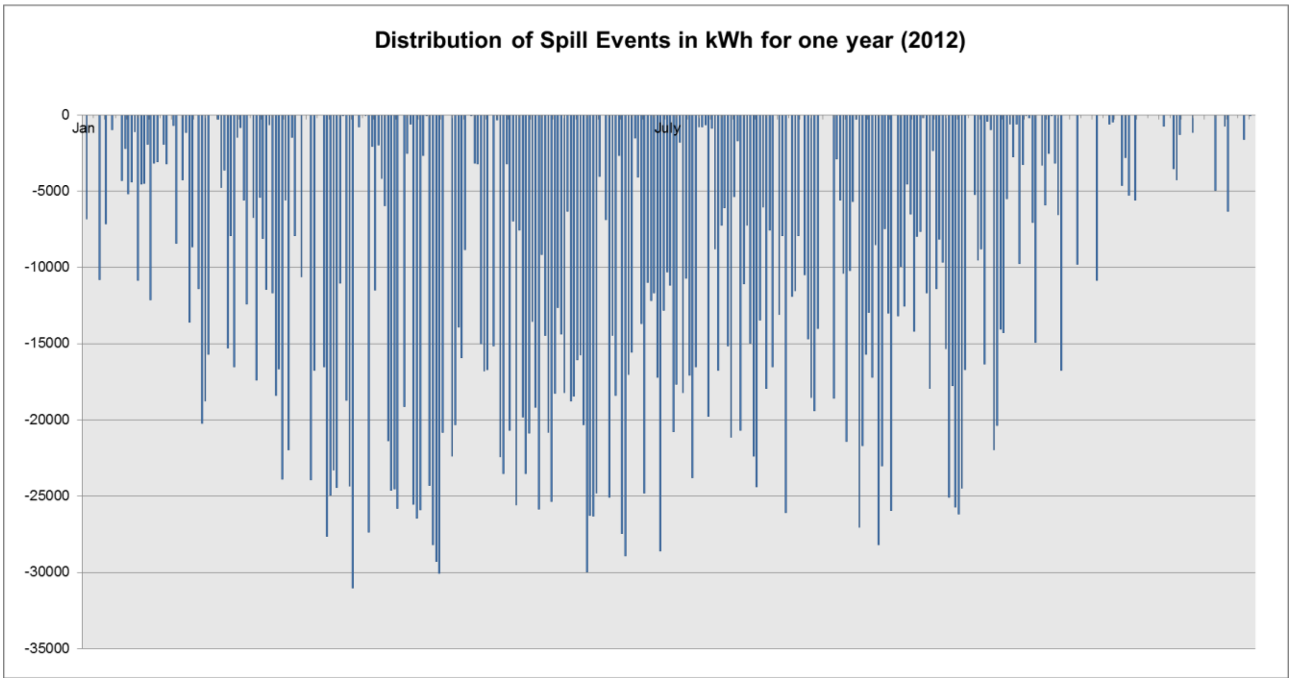
This would mean 845 roofs and 42 solar gardens, an impact that is too great for IoS. However, even if this was acceptable, the impact on the electricity network would be severe. Given the constraint of no backfeed to Cornwall, this level of PV would cause serious problems and would effectively be impossible to implement. Figures 6.1.2 and 6.1.3 show the impact of this level of PV on the IoS system.

Figure 6.1.2: PV generation at 6.75 MWp on an August day




It can be seen that the generation in the middle of the day far exceeds the demand on IoS. More than half the power generated would need to be exported to Cornwall and this is currently not possible.

Figure 6.1.3: The amount of generation in excess of load




Here it can be seen that for most days in the year there is surplus generation. On the days of peak generation the total excess power can reach 30 MWh. This is far beyond the abilities of IoS to use DR or energy storage.

## 6.2 Wind

The use of wind power is not without its challenges on IoS, however, it is the most cost effective generation from renewables as the IoS is a particularly good wind resource area with average wind speeds exceeding 7 m/s and capacity factors on wind turbines expected to reach 45% or so. Around 1 MW of wind would be a good fit for the IoS needs. As outlined in the wind section in Section 4, we have considered three options: a single 1 MW turbine; two 250 kW and five 100 kW machines; and ten or more smaller machines. We have rejected the last of these options as having too much visual impact, but have looked at locations for the others.

There are a few candidates for a single 1 MW turbine, located away from areas of population and away from very sensitive sites. We have considered Telegraph Hill and on a small uninhabited island near St Agnes as the most credible locations. Although Telegraph Hill would be a suitable for connection to the electricity grid, the size of the turbine may disqualify this location. It should be noted that a 1 MW is approximately 75-100 m in height (mast at around 50-60 m and blade radius of 25-45 m), this is approximately the same height as the radio mast, which stands at 74 m. The preferred location is on one of the islands to the south of Castle Brose on St Agnes. There are a number of small islands where the turbine could be erected and then cabled into the 11 kV line at the end of Carter's Lane. The grid in St Agnes may require reinforcement to accommodate this amount of generation to prevent voltage rise. The choice of the exact island would need a formal feasibility study, but candidates are: Lethagus Rocks, Great or Little Shoal of Mackerel.

A small number of more distributed wind turbines (two 250 kW machines and five 100 kW machines) would allow more diversity of generation than the single machine. A distribution of turbines could be placed around the islands in places where the location is practical and would not cause too much visual impact. The possible locations for the turbines are (note that for the 100 kW turbines more locations have been proposed than required, as some locations will not be acceptable):

- 2 * 250 kW on Telegraph Hill (Halangy Down). This location already has a number of masts (TV and Radio masts). This means that the area is out of the IoS airport's flight paths. Grid connection would be at the 11 kV substation at the TV station.
- 1 * 100 kW at the water desalination plant at Mount Todden on St Mary's. This location is the place where a research wind turbine was installed in the 1980s. Grid connection would be to the substation at the desalination plant.
- 2 * 100 kW at the waste transfer station. These could be placed on the bunding surrounding the site. Grid connection would be at one of the substations around area.
- 1 * 100 kW on Tresco at Middle Carn, Old Grimsby. Grid connection would be via the 11 kV ground-mounted substation at Old Grimsby.
- 1 * 100 kW on Tresco at the old quarry, used for waste disposal. Grid connection here is more challenging and could be at Borough Farm, Blockhouse Cottages or at the Tresco Estate offices. All are ground mounted 11 kV substations.
- 1 * 100 kW on St Martin's at the fire station.
- 1 * 100 kW on St Agnes at the Community Hall.

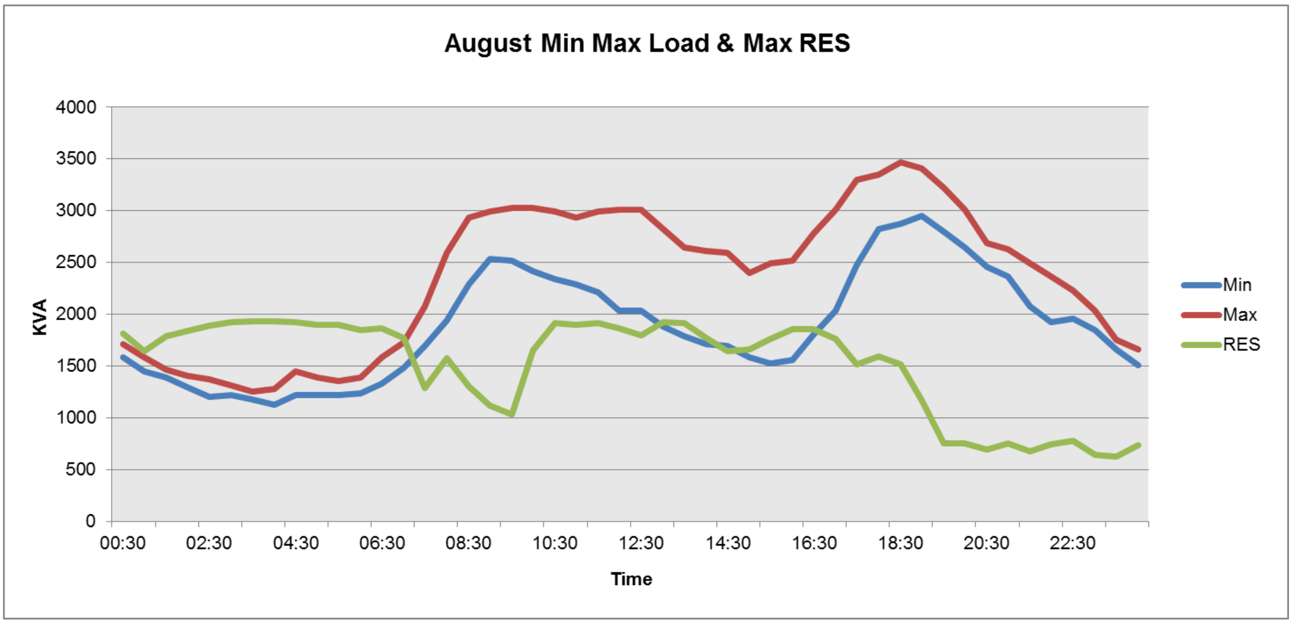
Figure 6.2.1 shows potential locations that may be acceptable, minimises visual intrusion and allows integration with the electricity grid.

Figure 6.2.1: Potential wind turbine locations


Wind power alone could achieve the target of 40% using 2 MW of wind generation capacity. However, in the absence of very large amounts of demand response or storage this implies significant backfeeding to Cornwall.

Figures 6.2.2 and 6.2.3 show the generation from this amount of wind. Note that wind has the potential to generate at any point in a 24-hour period and not just between sunrise and sunset. It is clear that as with the PV-only scenario there would be a substantial amount of surplus generation.

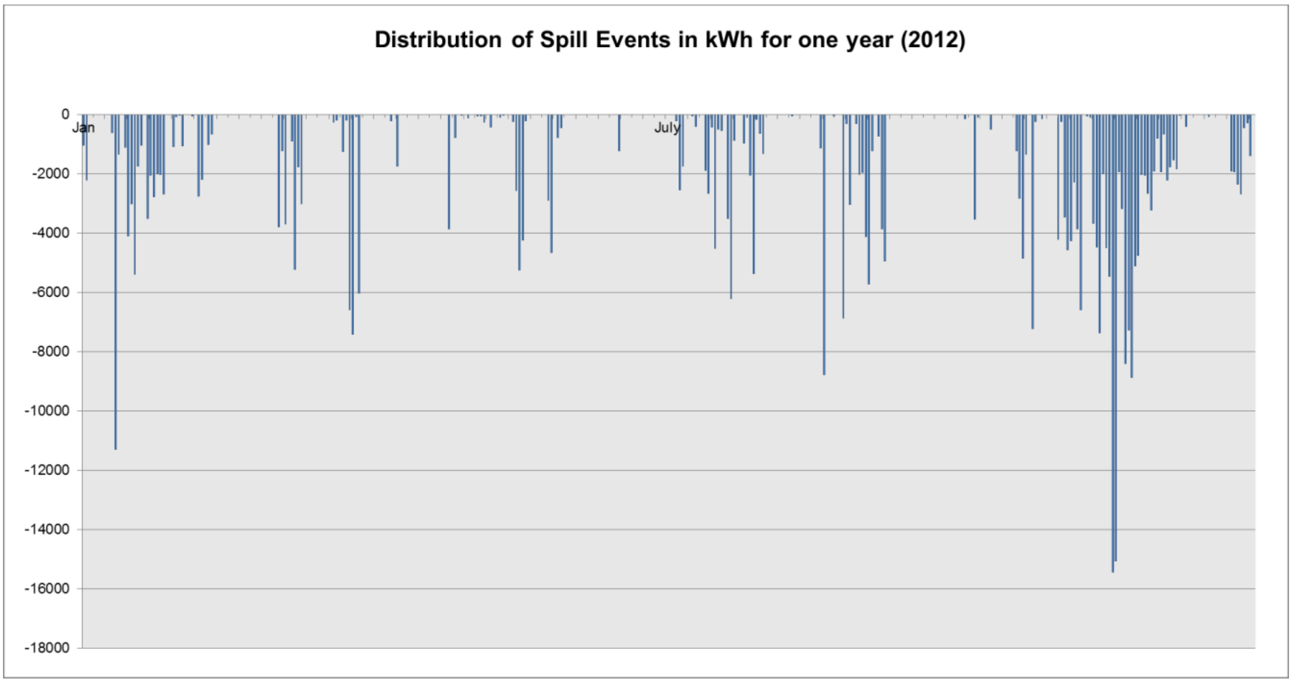
Figure 6.2.2: Wind generation from 2 MW on a typical August day




Unlike PV the daily wind profile is more stochastic due to weather conditions. However, this day was selected for its good wind conditions. Generation from 2AM to 6:30AM and from 10:30AM to

4:30PM is close to a maximum. It is clear in this 24 hour period that DR and storage is required to fully utilise the energy produced and prevent net export to the mainland. The wind data set used is from a coastal location in Cornwall, which approximates to conditions on IoS, although it has been normalised to achieve a capacity factor of 45%. Figure 6.2.3 shows how surplus energy tends to be seasonal, reflecting the strong winds of winter, spring and autumn.

Figure 6.2.3: Daily surplus generation from 2 MW of wind power




## 6.3 Tidal Stream

Tidal stream has the advantage of no visual impact, unlike wind, but the marine impacts are less well known and integrating this generation option in the IoS's various environmental designations (e.g. SAC, SPA, MCZ, Ramsar and wreck sites) will be challenging. Careful selection of suitable sites which balance the technical requirements (water depth and tidal flow) with marine conservation and commercial and leisure uses will be required. It should be remembered that this is new technology and not fully commercial yet. To implement this option much more evaluation will be required.

The tidal stream array evaluated for this work requires a water depth of 32 m and a tidal stream flow velocity of 2.5 m/s or so. With this the capacity factor is likely to be around 30%. The size of the array is 1.2 MW.

Possible locations identified in the initial screening work may be too shallow to cope with the depth required to install the array. If the locations shown in Figure 6.3.1 are not appropriate, then the array would have to be installed outside the island group in deeper waters, but this would come with greater grid connection and cabling costs.

Figure 6.3.1: Potential tidal stream locations


## 6.4 AD, Gasification and District Heating

The option of using AD and gasification to process and recover energy from St Mary's sewage and waste streams brings multiple environmental benefits and provides predicable and dispatchable generation.

As discussed in Section 4, the sizing of the AD plant requires a full feasibility study due to the complexities of the sizing versus feedstock volumes and the uncertainty around the tonnages available to process. The sizing of this facility, in energy terms, could be from around 100 kW to up to 300 kW. At the present time we have been cautious and assumed that the facility is 100 kW. The AD plant would run continuously and there would be limited dispatch capability.

Nevertheless, the AD plant can be designed to treat sewage, green waste and food waste, thus reducing two waste disposal volumes (and costs) and would obviate the use of a sewage outfall pipe from the Garrison, which is important due to historic sensitivities. The AD plant would also produce heat that can be used for district heating.

The gasifier would treat wood, wood waste, the AD plant's solid digestate and possibly part or all of the paper and card waste streams. The gasifier could be sized with a generation capacity of 500 kW and would be dispatchable. With the waste volumes the plant is likely to run for around 2,000 hours per year (load factor of 25%). Again, the generation produces both electricity and heat and so the heat can be used for district heating.

The location of the AD plant depends primarily on the logistics for sewerage. As the pipe infrastructure is only in Hugh Town and Old Town and there is no plan to extend this system massively, the location must be close to these two towns. The location should be chosen to minimise infrastructure costs, operational costs (pumps for example), in an area that is not designated, such as a scheduled monument or SSSI, and would have limited impact on the landscape or residential amenities. This limits the options to only one suitable location, the "Wet Meadow" in Old Town.

This site has a number of advantages:

- It is adjacent to the Old Town bio-bubble that treats sewage from Old Town.
- It is flat and large enough to accommodate both the AD plant and gasifier and associated water treatment works and thermal store for the district heating.
- It is at sea level so that pumping costs would be minimised.
- It is close to heat loads (school, Health and Wellbeing Centre, hospital and areas of new housing) to facilitate district heating.
- It is close to the waste transfer centre, so that food waste and green waste could easily be transferred to the site.
- The site appears not to have any archaeological or other designations.
- It will have limited landscape impact on the AONB and limited impact on residential amenities.

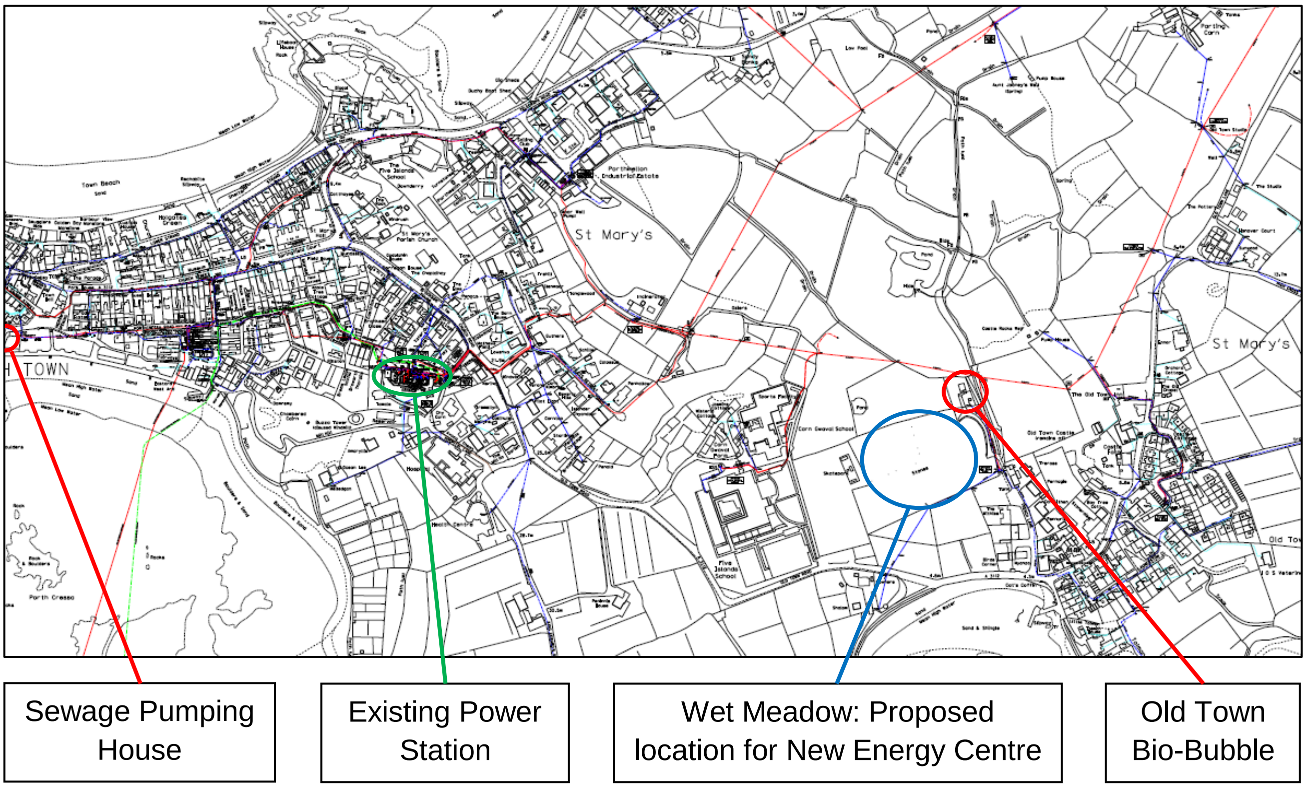
However, as the site is at sea-level it would require flood protection, such as bunding.

Finally, it would also be possible to relocate the power station to the site to create an energy centre for IoS. The relocation of the power station would bring multiple benefits to the IoS, but there are technical issues that would need to be addressed as well and the ultimate decision lies with WPD.

These include:

- Upgrading of the power station to modern technology, with lower emissions, reduced visual impact, faster acting generators and easier operations and maintenance.
- The liberation of a prime housing site in the centre of Hugh Town.
- Savings on essential maintenance at the current site.
- Reduced impacts on residents and the hospital (noise, threat of legionella).

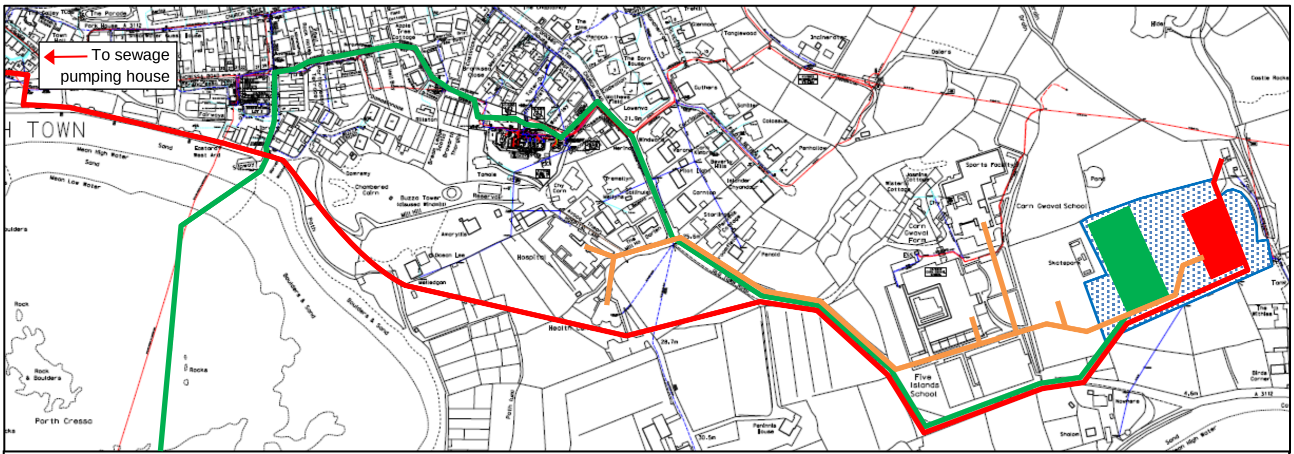
Figure 6.4.1: Location of the existing infrastructure (map sourced from WPD map response team)



Various works would be needed to develop the site. These would include:

- Installation of a new sewerage pipeline from the Bishop pumping station to the site. The likely route would be along the shoreline, around Buzza Hill, up the hill to the south of the health centre and then into the road, past the school and health and wellbeing centre. This would require an additional pumping house next to Buzza Hill.
- Installation of 33 kV cable, which could follow some parts of the same routing as the sewerage pipeline in the road.
- Installation of district heating mains to the School, Carn Gwarval Health and Wellbeing Centre, Hospital and Health Centre and possibly to new housing at the old school site.
- New access road from near the school and Carn Gwarval Health and Wellbeing Centre to the site.
- Bunding of the site for flood defence.
- There is the possibility of developing a new swimming pool next to the Carn Gwarvel Health and Wellbeing Centre.

Figure 6.4.2: Potential infrastructure routes (map sourced from WPD map response team)




Key: Red Line = New sewerage pipeline from pumping station to new sewage treatment works and from bio-bubble to new works

Green Line = Existing 33 kV cable to existing power station and extension to suggested new power station location

Orange Line = Heat network from AD plant to school/swimming pool (option) and hospital

## 6.5 Dispatchable Load and Energy Efficiency

There are a number of options for dispatchable loads that can be controlled as part of a smart grid solution. These loads are important to accommodating the levels of generation and to prevent the export of power through the 33 kV capable to Cornwall.

As part of the energy infrastructure some new devices will need to be deployed. These will include heat pumps, controllable immersion heaters, controllable storage heaters, EV charging points and small house-scale battery energy storage. The precise number of each of these depends on the dispatchability of load required. There are multiple locations for these, though a significant part of the deployment will be on St Mary’s.

In addition, the desalination plant at Mount Todden could be retrofitted to have limited dispatchability, through control between low throughput and high throughput.

Finally, there is a case for a couple of significant energy storage projects. The first is at the desalination plant, which suffers from nuisance tripping caused by power fluctuations. The deployment of around 150 kWh of storage at this location would provide a uninterruptable power supply or “UPS” function as well as providing capacity for dispatchable load.

The second location would be at the energy centre, where a MW-class battery storage system could be deployed, subject to agreements with WPD. This storage could be sized to be able to hold the IoS load in the case of a power outage and before the power station could be energised. If the storage had to hold the IoS load for say 15 minutes while the diesels were brought online, then it would need to be sized to discharge sufficient power to meet the maximum demand of the islands and have sufficient energy in the battery to last this duration. The peak demand is 4.5 MW, which occurs rarely and usually at Easter time. At peak demand for 15 minutes this is an energy demand of 1.13 MWh. Sizing the storage should give a safety margin and account for depth of discharge and charging and discharging rates. Thus, it would make sense to install a 1.5 MWh energy system (70% depth of discharge gives a useable output of 1.05 MWh), however final sizing of such a system would require a full feasibility study.

Though not within scope of this EIP, the use of energy efficiency is also an important option for IoS. Two key measures are appropriate for widespread deployment on the IoS: the use of LED light bulbs and building insulation (space heating can account for up to 60% of a home’s energy consumption). These measures can be applied in both private residential properties, Council and Duchy owned properties and commercial enterprises. The Council and the Duchy are progressively refurbishing their housing stock and when this is done better insulation is deployed in these properties. These measures will reduce the overall energy consumption of the IoS thus make it easier to achieve the 40% renewables and 40% energy cost savings targets.

## 6.6 Renewable Energy Options

The contribution from renewables has to be balanced between various sources to achieve the optimal mix to meet the IoS 40% target, but without straining the grid or backfeeding electricity to Cornwall. The first table presents the case where there is no wind and no tidal stream and PV is maximised at 2 MWp. In this case the share of renewable energy to electricity demand is capped at 22%. The next three tables present this mix, and considering wind power, tidal stream or both.

In each case the same assumptions have been used:

- PV 1100 kWh/kWp Based on IoS experience
- Wind 45% Capacity factor 44% at 7 m/s - IoS will be higher
- Tidal Stream 30% Capacity factor Based on multiple sources
- AD 8000 h/a CHP availability
- Gasifier 25% Load factor Dependent on volumes
- Annual Load 18500 MWh/a IoS Electricity Demand

Table 6.6.1: Case with no wind, no tidal and 2 MWp of PV

| Renewable Energy | Capacity (kW) | Annual Generation (MWh) | Share of IoS Demand |
|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% |
| New PV | 1,730 | 1,903 | 10.29% |
| Wind | 0 | 0 | 0.00% |
| Tidal Stream | 0 | 0 | 0.00% |
| AD | 100 | 800 | 4.32% |
| Gasifier | 500 | 1,095 | 5.92% |
| **Total** | **2,600** | **4,095** | **22.14%** |

Table 6.6.2: Case with 1 MW of wind and no tidal stream (base case)

| Renewable Energy | Capacity | Annual Generation (MWh) | Share of IoS Demand |
|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% |
| New PV | 1,230 | 1,353 | 7.31% |
| Wind | 1,000 | 3,942 | 21.31% |
| Tidal Stream | 0 | 0 | 0.00% |
| AD | 100 | 800 | 4.32% |
| Gasifier | 500 | 1,095 | 5.92% |
| **Total** | **3,100** | **7,487** | **40.47%** |

Table 6.6.3: Case with no wind and 1.2 MW of tidal stream

| Renewable Energy | Capacity | Annual Generation (MWh) | Share of IoS Demand |
|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% |
| New PV | 1,230 | 1,353 | 7.31% |
| Wind | 0 | 0 | 0.00% |
| Tidal Stream | 1,200 | 3,154 | 17.05% |
| AD | 100 | 800 | 4.32% |
| Gasifier | 500 | 1,095 | 5.92% |
| **Total** | **3,300** | **6,699** | **36.21%** |

Table 6.6.4: Case with 200 kW of wind and 1.2 MW of tidal stream

| Renewable Energy | Capacity | Annual Generation (MWh) | Share of IoS Demand |
|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% |
| New PV | 1,230 | 1,353 | 7.31% |
| Wind | 200 | 788 | 4.26% |
| Tidal Stream | 1,200 | 3,154 | 17.05% |
| AD | 100 | 800 | 4.32% |
| Gasifier | 500 | 1,095 | 5.92% |
| **Total** | **3,500** | **7,487** | **40.47%** |

It can be seen that the balanced approach delivers the 40% target for renewables. We have modelled the requirements for dispatchability to cope with surplus generation. This has been done on the case of 1 MW of wind and no tidal stream. The next four figures show the match between generation and demand on four days across the year for the base case.

Figure 6.6.1: Generation and load on a day in January for the base case

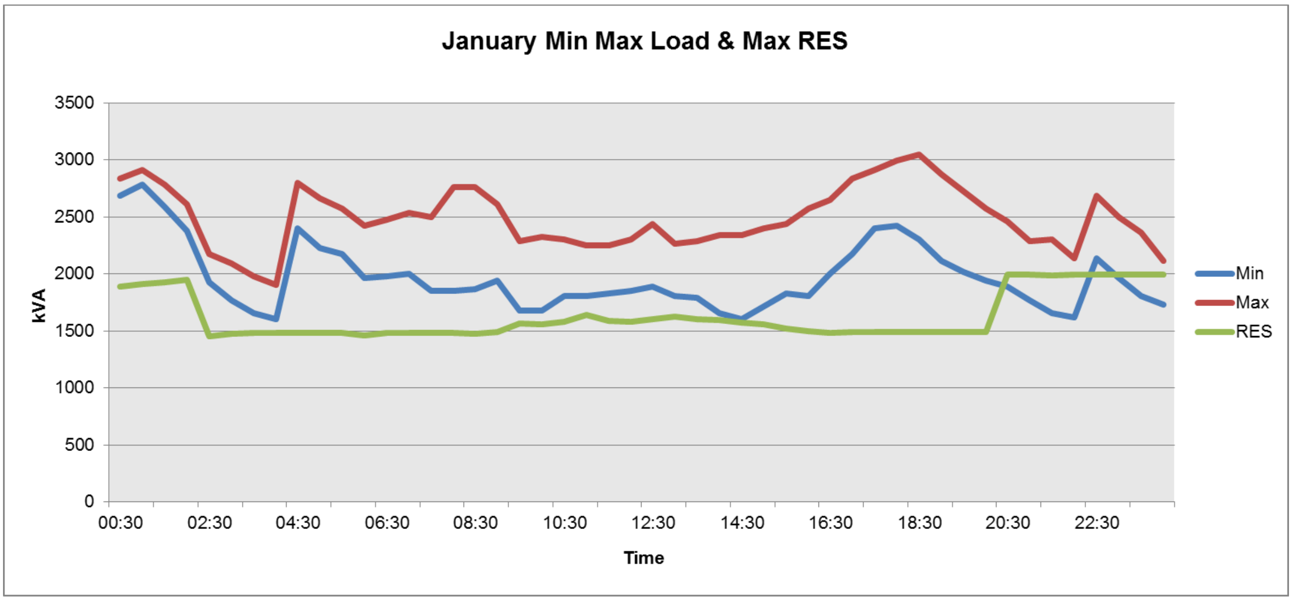



Figure 6.6.2: Generation and load on a day in May for the base case

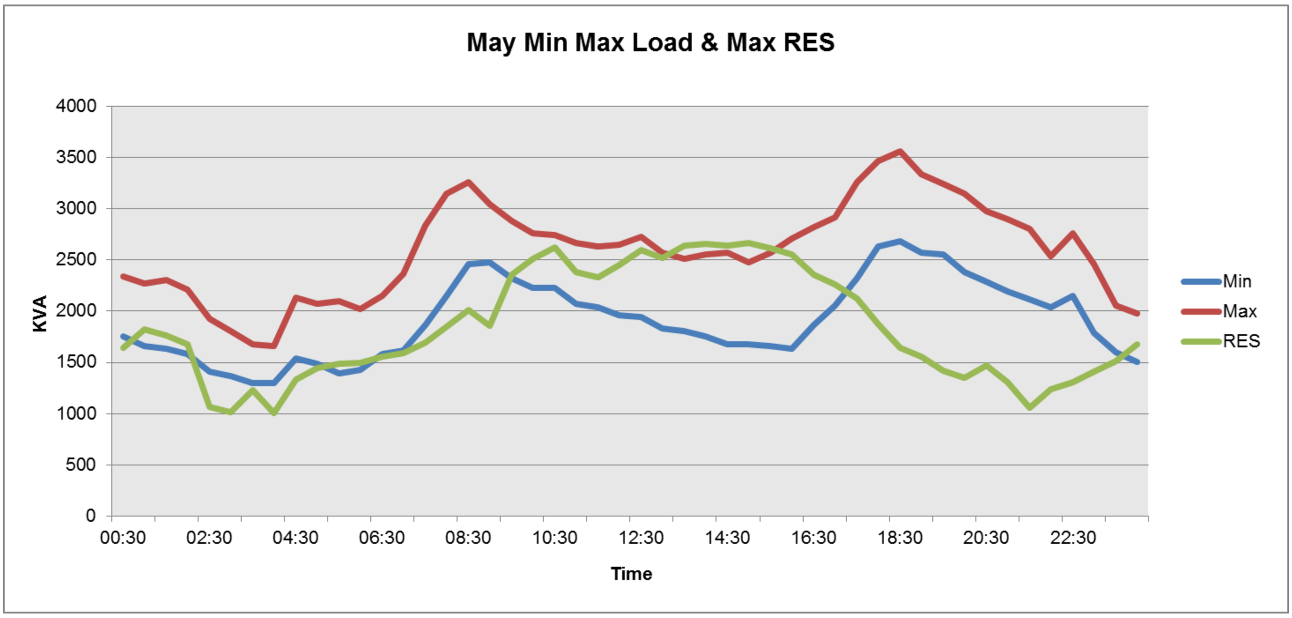


Figure 6.6.3: Generation and load on a day in August for the base case

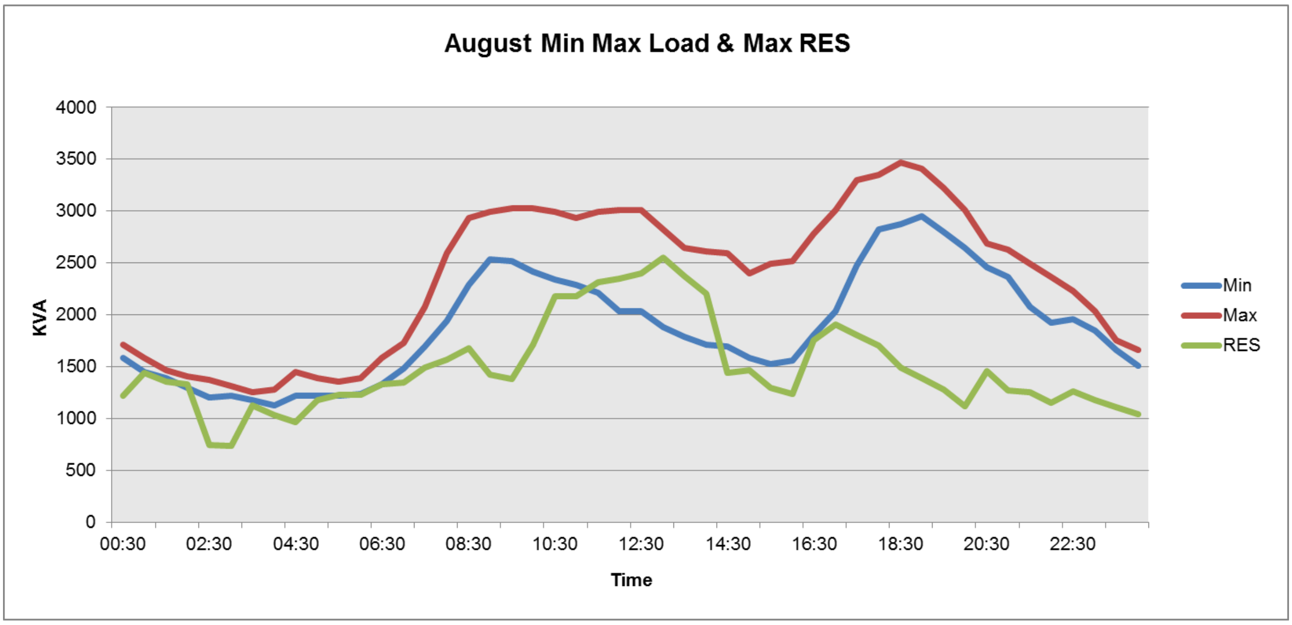
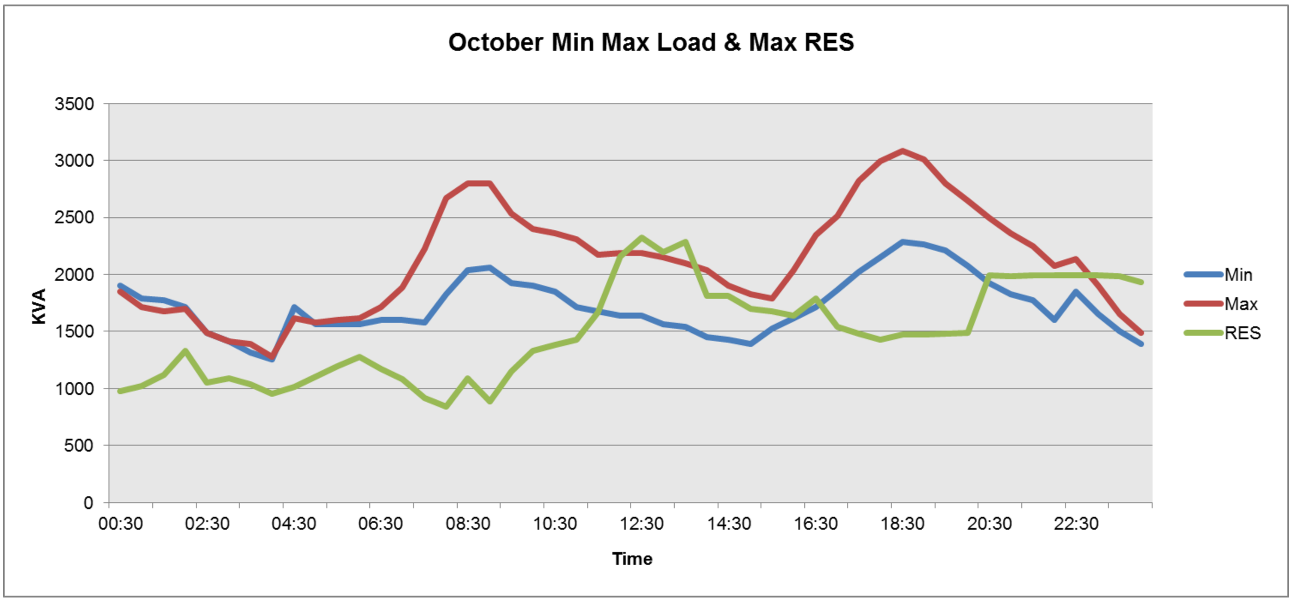


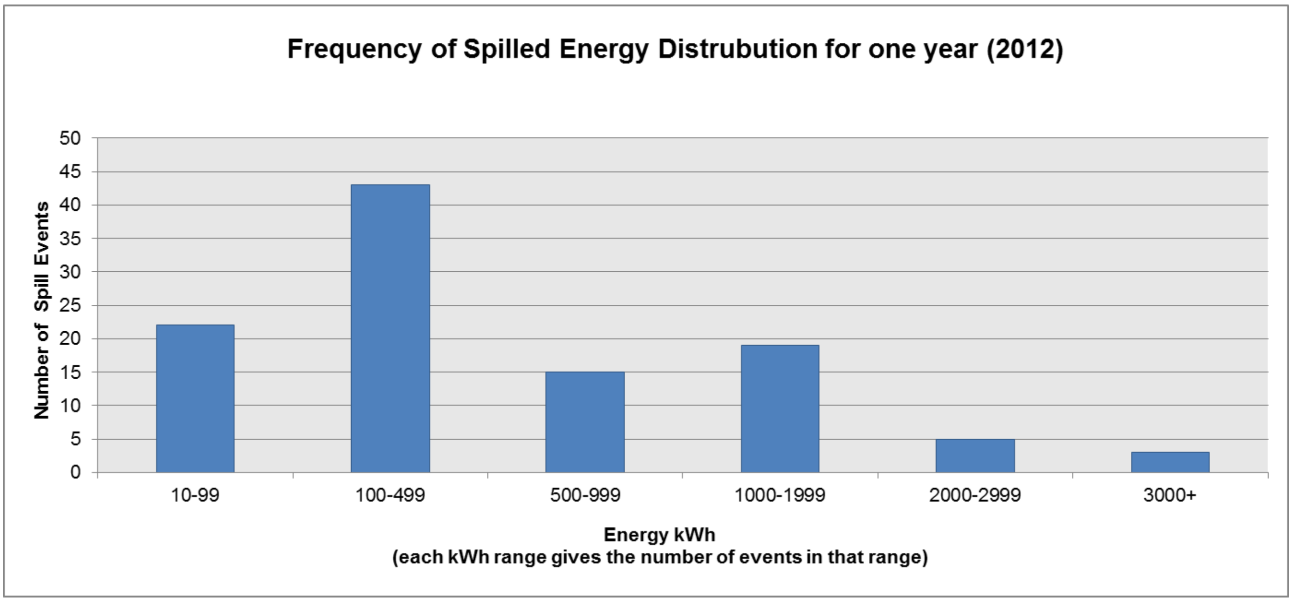

Figure 6.6.4: Generation and load on a day in October for the base case




It can be seen that generation and load are more balanced and the number of times when generation exceeds demand is relatively low. We have then modelled this for each day of the year to look at the number of occurrences when there is surplus energy and the daily total for surplus. Surplus energy causes a net export or backfeed of energy from IoS back to Cornwall, thus breaching one of the main framing constraints of renewable generation we referred to earlier in this document.

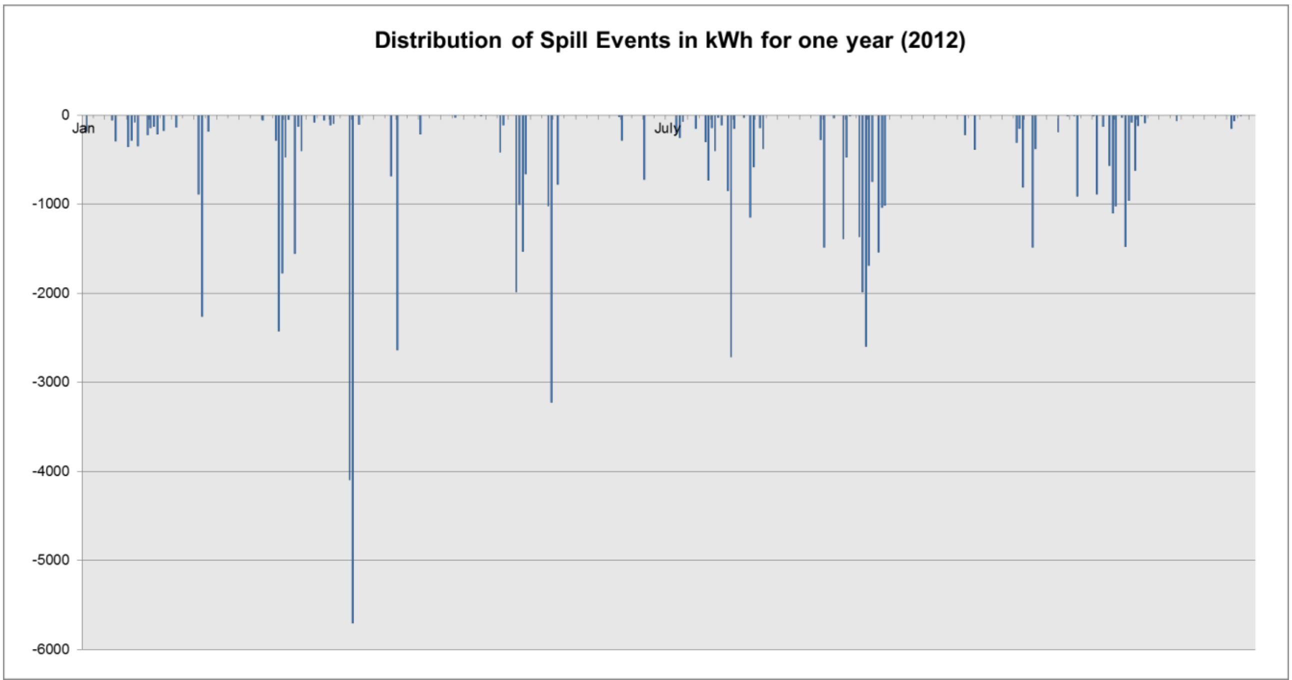
For the following graphs, spill events refer to instances of net export or backfeed of energy at half hourly intervals. Thus backfeeding over a continuous period of 2 hours can be considered as 4 separate spill events.

Figure 6.6.5: Number of spilled energy (backfeed) events for the base case




Referring to Figure 6.6.5 above, the first bar on the left shows that there were 22 spill (backfeed) events with a kWh spill in the range 10 kWh to 99 kWh. The next bar shows 43 spill events in the range 100 to 499 kWh and so on. Figure 6.6.6 shows the distribution over the year for these spill events.

Figure 6.6.6: Daily surplus power generation




Figures 6.6.5 and 6.6.6 demonstrate the need for DR and an ICT platform to operate in tandem with the renewable energy generation. The base case of 1.5 MWp of PV, 1.0 MW of wind, 100 kW of AD and a 500 kW gasifier shows the need for DR and storage in the range 1 MWh to 1.5 MWh. There would still be some events where generation would need to be curtailed, but this should be around 20 events a year.

Further modelling was done on various renewable mixes to understand when spill events start to occur and the spill trend. Table 6.6.5 summarises the results from this modelling, here scenario 3 represents the “balanced” scenario. The full analysis can be found in Annex A5.

Table 6.6.5: Summary of renewables mix spill events modelling exercise

| No. | Renewables (including 270 kWp existing PV) | Renewable Target | Spill Events & Amount | Estimated DR & Storage | Comments |
|---|---|---|---|---|---|
| 1 | 1.2 MWp new PV only | 8.74% | 1 event | Minimal / not needed | Net export events begin from 1.2 MWp of new installed PV |
| 2 | 1.23 MWp new PV<br>100 kW AD<br>500 kW gasifier | 19.16% | 1 event | Minimal / not needed | This does not meet the policy aims of the IoS |
| 3 | 1.23 MWp new PV<br>1 MW wind<br>100 kW AD<br>500 kW gasifier | 40.47% | 161 events<br>13.8 MWh | 1,000 to 1,500 kWh | Meets IoS policy objectives, spill spread throughout the year. Likely minimum in terms of capital costs |
| 4 | 1.93 MWp PV<br>800 kW wind<br>100 kW AD<br>500 kW gasifier | 40.37% | 638 events<br>89.4 MWh | 1,000 to 5,000 kWh | Meets IoS policy objectives. DR and storage would require careful consideration due to excessive generation |

Note: As described earlier, multiple events often occur on the same day

As seen in the table above, spill events start when 1.2 MWp of new PV alone is deployed, however it is interesting to note that a follow-on deployment of the proposed AD and gasifier does not increase the number of spill days. This is mainly due to the ability to run the AD and gasifier at more favourable times, though this can only be achieve with some form of a control system.

Cases 3 and 4 compare a different mix of PV and wind that achieves the same 40% renewables target. Here it is interesting to note that 700 kW of PV is required to displace 200 kW of wind, propelling the number of spill events and amount of energy exported back to the mainland, thus also increasing the DR and storage requirements to support higher levels of PV (mainly due to larger spikes (middle of the day when generation is at its peak). The mix of DR and storage is likely to come from home and/or grid-scale batteries, heat pumps, immersion heaters and EVs.

WPD takes a conservative approach to evaluating the impact of renewables on their network, and adopts a theoretical worst case day scenario approach (i.e. maximum generation and minimum demand). Based on discussions with WPD it was understood that the normalised generation profile used for evaluating renewables impact is based on historic data across multiple sites, taking the highest generation output values instead of an average, which results in a more “ideal” generation profile. This ensures adequate design of the network especially for LV and 11 kV where there is a lack of monitoring and active control.

Our modelling follows a different approach. Under a non-disclosure agreement, WPD supplied us with a normalised generation profile based on the historical data of a single site. This was then compared against historical IoS demand data, also supplied to us by WPD. Our modelling therefore would have more diversity than a theoretical worst day approach across multiple sites. However for completeness, we also modelled using the multi-site generation profile and found that in both cases, backfeed events start to occur at approximately 1.2 MWp of new PV alone, with the main difference being the rate of increase in the number of spill events and the amount of energy spilled much higher using the multi-site generation profile. This is demonstrated in the table below.

Table 6.6.6: Comparison of modelling utilising single-site and multi-site generation profiles

| **Renewables (including 270 kWp existing PV)** | **Single-site generation profile** | | **Multi-site generation profile** | |
|---|---|---|---|---|
| | Spill Events | Annual energy spilled | Spill Events | Annual energy spilled |
| 1.20MW new PV | 1 | 3 kWh | 1 | 4 kWh |
| 1.60MW new PV | 2 | 217 kWh | 16 | 593 kWh |
| 2.05MW new PV | 184 | 11,575 kWh | 291 | 23,380 kWh |
| 2.60MW new PV | 816 | 136,709 kWh | 935 | 177,676 kWh |

Please note that the above modelling uses data for specific years and generation profiles are representative of Cornwall, thus further analysis utilising a larger and more recent sample of demand data and actual IoS generation profiles (expected higher than Cornwall) may find that higher or most likely lower levels of PV will trigger spill events. In addition, the theoretical worse-case scenario approach adopted by DNOs (i.e. maximum generation and minimum demand) will reduce the allowable deployment of generation even further, likely 10-20% less than the above modelling. Taking this into consideration our view is that up to 1 MWp of PV can be connected with no additional intervention, but thereafter an ICT platform will be required to facilitate DR and storage functionalities to minimise backfeed. If considering the recommended mix of renewables as defined earlier (and without the use of a control system), this limit will be lower again.

**Summary**

The base case presents in our opinion the optimal mix of renewable generation to achieve the islands' 40% renewables target, whilst taking into consideration individual generation profiles of each technology to ensure the least impact on the distribution network, but also other island requirements such as waste and sewage. The base case also considers the cost implication (only estimates at this stage) as well as visual impact of technologies. However, the base case still presents the issue of excess generation (net export) to the mainland thus the only way to achieve this is through an overarching control system to balance generation with controllable demand.

A summary of the base case scenario with the associated annual generation and estimated capital investment costs are presented in Table 6.6.7.

Table 6.6.7: Base case renewable capacity, generation and investment costs

| **Renewable Energy** | **Capacity (kW)** | **Annual Generation (MWh)** | **Share of IoS Demand** | **Capital Investment (£)** |
|---|---|---|---|---|
| Existing PV | 270 | 297 | 1.61% | £0 |
| New PV | 1,230 | 1,353 | 7.31% | £1,552,320 |
| Wind | 1,000 | 3,942 | 21.31% | £4,080,000 |
| Tidal Stream | 0 | 0 | 0.00% | £0 |
| AD | 100 | 800 | 4.32% | £600,000 |
| Gasifier | 500 | 1,095 | 5.92% | £1,700,000 |
| **Total** | **3,100** | **7,487** | **40.47%** | **7,932,320** |

As can be seen from the table above, the total estimated capital investment required under this scenario is approximately £8 million, not including any associated WPD connection costs nor ongoing operating and maintenance costs. In addition, this cost can be significantly reduced if considering a single 1 MWe turbine, as the case currently considers 2 * 250 kW and 5 * 100 kW turbines.

## 6.7 ICT Platform

An underpinning requirement to achieving the EIP is an ICT platform extending into energy consumers' premises. This platform will enable the deployment of more renewables than would otherwise be possible, allow a better balancing of generation and demand, and the deployment of DR resources.

Furthermore, current assumptions in calculating the 40% renewable generation mix do not include curtailment due to the WPD LIFO stack. This is due to the uncertainty relating to the actual amount of curtailment that the renewables will experience, and which is likely to occur below the backfeed limit. At the time of writing this report, discussions with WPD are progressing towards using DR and storage to offset curtailment requirements.

## 6.8 Future Options

In the future it may be possible to push beyond 40% from renewables and even to consider 100% renewables IoS. However, this will require innovation and deployment of technologies that are not yet available.

Future options in Stage 2 could include:

- Wave is a long-term possibility
    - Technology is not yet proven or commercial.
    - Sizing of installation is important (island use /export to Cornwall).
    - Assuming energy infrastructure in Cornwall remains a constraint then size will be limited to IoS use.
    - Could supply remaining electricity demand.
    - Through power to gas technologies, could supply heat fuel, transport fuel for boats and land vehicles.
    - Gas can be stored, so could make IoS energy independent.
- Small scale technologies for waste water treatment at the family house scale.
- Seaweed farming for AD – to increase size of this generation subject to environmental consents.
- Power to Gas: the conversion of excess renewable electricity into synthetic methane. This could be used to provide fuel for ships and to replace other uses of oil on IoS.

# Glossary of Terms

| Category | Official Name | Abbreviation | Description |
|---|---|---|---|
| Technical | Ampere | A | Ampere or "Amps" is the SI (international system of units) unit of electric current and is one of the seven SI base units. |
| | Active Network Management | ANM | Active Network Management (ANM) describes control systems that manage generation and load. In the context of this report it is for the management of electricity distribution networks. |
| | Anaerobic digestion | AD | Anaerobic digestion is a collection of processes by which micro-organisms break down biodegradable material in the absence of oxygen. The process can be designed to treat sewage, green waste and food waste and to produce biogas, which can then be used as a fuel for power (and heat) generation. AD also produces a residual material, termed digestate. |
| | Air source heat pump | ASHP | A type of heat pump, air source heat pumps absorb heat from the outside air in the same way that a fridge extracts heat from its inside. The pump needs electricity to run, but uses less electrical energy than the heat it produces. The heat produced is used to heat radiators, underfloor heating systems, or warm air convectors and hot water. |
| | Backfeed / Net export | - | Backfeed or net export in the context of this report refers to when generation on IoS is greater than demand, thus electric power is being pushed back to the mainland. |
| | Building Energy Management System | BEMS | Computer-based systems that help to manage, control and monitor building equipment (e.g. lighting, air-conditioning etc.) and the energy consumption of devices used within the building. They provide the information and the tools to help building managers understand the energy usage of their buildings and to control and improve their buildings' energy performance. |
| | Bulk supply point | BSP | A point of supply from a transmission system to a distribution system, an exempt distribution system, a grid-connected composite site, or a grid-connected customer site. |
| | Combined heat and power | CHP | The use of a heat engine or power station to generate electricity and useful heat at the same time. |
| | Demand Response | DR | Demand Response provides an opportunity for consumers to participate in electricity markets by contributing to energy load reduction during times of peak demand or when the reliability of the grid is threatened. The demand response can be triggered automatically through a control system or manually by sending a dispatch message. |
| | Desalination plant | - | A process plant where salt water (sea water) is desalinated to produce fresh water suitable for drinking and irrigation. IoS has a desalination plant at Mount Todden on St Mary's |
| | Digestate | - | The material remaining after the anaerobic digestion of biodegradable feedstock. Anaerobic digestion produces two main products: digestate and biogas. |

| | | | |
|---|---|---|---|
| Technical | Dry matter | DM | Describes the % of dry content within the feedstock used for anaerobic digestion |
| | Electric Vehicle | EV | Electric vehicles use one or more electric motors for propulsion, and store electricity in an energy storage device, such as a battery. |
| | Electric Vehicle Energy Management System | EV EMS | An energy management system to monitor, control and optimise the charging schedules of connected EVs. The energy stored in the battery can be released back into the grid for demand response services. |
| | Engineering Recomendation G83 Issue 2 | G83/2 | An Energy Networks Association (ENA) document called Engineering Recommendation G83/2 is a procedure for connecting aggregated generation of 16 A (3.68 kW) per phase or less. Under this procedure, the installer must notify DNO of the installation within 28 days of commissioning. Issue 2 was published in August 2012. |
| | Gasifier | - | A device for converting substances (chemically or physically) into gas, which can then be used as a fuel for power (and heat) generation. In the context of this report the gasifier can use the dry digestate from the AD plant, the wood garden waste, waste wood, paper and card, thus reducing the transport of waste off the IoS. |
| | Home Energy Management System | HEMS | An energy management system to monitor, control and optimise energy consumption in homes by automatic control of certain home appliances, such as heat pumps, or by intuitive displays that recommend changes in consumption behaviour. |
| | Hours per annum | h/a | - |
| | Information and Communication Technology | ICT | An extended term for IT, ICT refers to any device or system that allows the storage, retrieval, manipulation, transmission and receipt of digital information. |
| | Information and Communication Technology Platform | ICT Platform | A data storage and management system which has the ability to host multiple applications, as well as enable data to be collected, stored, shared, and analysed. It often includes functionalities and characteristics that address the following themes: security, interconnectivity, interoperability, data processing, and privacy protection. In the context of this report, ICT platforms are seen as promoting a wider integration of renewable energy sources, promoting low-carbon transport options including electric vehicles and inducting structural shifts in electricity consumption. |
| | Kilovolt | kV | A measure of electric potential and refers to the energy that could be released if electric current is allowed to flow. In the context of this report this unit refers to the voltage levels of the distribution network and its associated cabling (e.g. 33 kV cable). 1 kilovolt is equivalent to 1,000 volts. |
| | Kilovolt-ampere | kVA | A unit used for the apparent power in an electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current in a 3-phase system. In ths context of this report this unit refers to diesel generator, cabling and transformer rated capacities. 1 kilovolt-ampere is equivalent to 1,000 volt-amperes. |

| | | | |
|---|---|---|---|
| Technical | Kilowatt | kW | A unit used to express power or the rate of energy conversion or transfer with respect to time. In the context of this report this unit refers to electrical power. 1 kilowatt is equivalent to 1,000 watts. |
| | Kilowatt-peak | kWp | Rating of power typically given to solar electricity systems. It defines the rate at which it generates energy at peak performance. 1 kilowatt-peak is equivalent to 1,000 watts-peak. |
| | Kilowatt-hour | kWh | A unit of energy used to measure the total amount of power generated or consumed over a period of time. 1 kilowatt-hour is equivalent to 1,000 watt-hours. |
| | Last in, first out | LIFO | In the context of this report, LIFO refers to a methodology that the distribution network operator uses to curtail connected generators when there is a network constraint. The most recently connected generator will be the first to be curtailed, working backwards through generators that have been connected the longest. When the network constraint is lifted, the connections are restored to normal in the opposite order, i.e. the most recently connected generator will be restored last. This is a purely commercial arrangement that distribution network operators use for managing constraints. |
| | Light-emitting diode | LED | A semiconductor diode that emits light when a voltage is applied to it and that is used especially in electronic devices. In the context of this report LED refers to lighting in buildings. |
| | Low-voltage | LV | Low-voltage refers to networks below 1000V, in the context of this report it refers to the 400V 3-phase or 230V single-phase network level. |
| | Megavolt-ampere | MVA | Similar to kVA, this is the unit used for the apparent power in an electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current. 1 megavolt-ampere is equivalent to 1,000 kilovolt-amperes or 1,000,000 volt-amperes. |
| | Megawatt | MW | Similar to kW, this is a unit to express power. 1 megawatt is equivalent to 1,000 kilowatts or 1,000,000 watts. |
| | Megawatt-hour | MWh | Similar to kWh, this is a unit of energy to measure the total amount of power generated or consumed over a period of time. 1 megawatt-hour is equivalent to 1,000 kilowatt-hours or 1,000,000 watt-hours. |
| | Megawatt-hour per annum | MWh/a | A unit of energy used to measure the total amount of power generated or consumed per annum. 1 megawatt-hour per annum is equivalent to 1,000 kilowatt-hours per annum or 1,000,000 watt-hours per annum. |
| | Megawatt-Peak | MWp | Similar to kWp, this is a rating of power typically given to solar electricity systems. It defines the rate at which it generates energy at peak performance. 1 megawatt-peak is equivalent to 1,000 kilowatts-peak or 1,000,000 watts-peak. |
| | Mesophilic | - | Mesophilic refers to mesophilic bacteria, a group of bacteria that grow and thrive in a moderate temperature range between 20°C and 45°C. The optimum temperature range for these bacteria in anaerobic digestion is around 30°C to 40°C. |

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| Technical | Metres per second | m/s | - |
| | Mono-Nitrogen Oxides (NO & $NO_2$) | NOx | A generic term for mono-nitrogen oxides NO and $NO_2$ (nitric oxide and nitrogen dioxide) which are by-products of combustion and are considered air pollutants. The emissions of NOx and other pollutants such as SOx are regulated to ensure minimal impact on the environment. |
| | Particulates | - | Atmospheric particulate matter – also known as particulate matter (PM) or particulates – are microscopic solid or liquid matter suspended in the Earth's atmosphere. |
| | Photovoltaic | PV | A method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons. |
| | Photovoltaic Geographical Information System (PVGIS) | PVGIS | A web-based tool that provides geographical assessment of solar resource and performance of photovoltaic technology. The version used by this report was designed by the Joint Research Centre of the European Commission (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php). |
| | Ring Main Unit | RMU | A totally sealed, gas-insulated compact switchgear unit. The primary switching devices can be either switch disconnectors or fused switch disconnectors or circuit breakers. |
| | Smart Grid | SG | An upgraded electricity network enabling two-way information and power exchange between suppliers and consumers. This network with ICT technology can integrate various distributed power sources, deliver electricity more effectively, and optimise the power supply and consumption. |
| | Sulphur Oxides | SOx | A generic term for Sulphur Oxides which are by-products of combustion and are considered air pollutants. The emissions of SOx and other pollutants such as NOx are regulated to ensure minimal impact on the environment. |
| | Substation | - | Substations house equipment that transform voltage from high to low (or the reverse) and distribute electricity to consumers. They also supervise and protect the distribution network to keep it working safely and efficiently. |
| | Thermophilic | - | Thermophilic refers to Thermophilic bacteria, a group of bacteria that grow and thrive in a relatively high temperature range between 41°C and 122°C. The optimum temperature range for these bacteria in anaerobic digestion is around 50°C to 60°C. |
| | Triads | - | The Triads are the three half-hour settlement periods with highest system demand and are used by National Grid to determine charges for demand customers with half-hour metering and payments to licence exempt distributed generation. They can occur in any half-hour on any day between November to February inclusive but are separated from each other by at least ten full days. The Triad charging system is one way that large industrial users of electricity can reduce their energy charges by reducing consumption over peak periods. It also represents an environmentally-friendly solution for meeting peaks in demand compared to simply building ever more infrastructure. |

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| Technical | Tonnes per annum | t/a | - |
| | Uninterruptable power supply | UPS | An electrical apparatus (such as a battery) that provides emergency power to a load when the input power source, typically mains power, fails. In the context of this report a UPS refers to a grid-connected device to maintain a constant stable supply of power to a plant or equipment. |
| | Virtual Power Plant | VPP | A system that integrates different types of energy sources for example wind turbines, small hydro, photovoltaics, etc. so as to give a reliable overall power supply. Sources of controllable loads are often included in a VPP, as a reduction of load can also release capacity on the network. |
| Groups / Organisations | Department of Energy and Climate Change | DECC | The Department of Energy and Climate Change (DECC) is a British government department working to ensure the UK has secure, clean, affordable energy supplies and promotes international action to mitigate climate change. |
| | Distribution Network Operator | DNO | A company which owns and operates the distribution network of towers and cables that bring electricity from the national transmission network to homes and businesses (i.e. from 132kV to 230V). DNOs do not sell electricity to consumers, this is done by the electricity suppliers. |
| | Energy Technologies Institute | ETI | The ETI is a public-private partnership between global energy and engineering companies and the UK. Government. ETI's role is to bring together engineering projects that accelerate the development of affordable, secure and sustainable technologies that help the UK address its long-term emissions reductions targets as well as delivering nearer term benefits. |
| | European Union | EU | - |
| | Isles of Scilly | IoS | - |
| | Office of Gas and Electricity Markets | Ofgem | The Office of Gas and Electricity Markets, supporting the Gas and Electricity Markets Authority (GEMA), is the government regulator for the electricity and downstream natural gas markets in Great Britain. It was formed by the merger of the Office of Electricity Regulation (OFFER) and Office of Gas Supply (Ofgas). |
| | Smart Islands Partnership | - | A partnership on the Isles of Scilly set up to develop smart, innovative solutions to address the Isles of Scilly's multifaceted infrastructure needs whilst improving the wellbeing of local people, the natural environment and the local economy. |
| | Western Power Distribution | WPD | A DNO responsible for managing the distribution network for the Midlands, South West and Wales. WPD delivers electricity to over 7.8 million customers over a 55,500 square kilometres service area. |
| Policy / Regulations / Designations | Area of Outstanding Natural Beauty | AONB | An area of countryside in England, Wales or Northern Ireland which has been designated for conservation due to its significant landscape value. There are 46 AONBs in Britain covering 18% of the countryside. |

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| Policy / Regulations / Designations | European Regional Development Fund | ERDF | The main objective of the ERDF is to support the projects and activities which reduce the economic disparity within the member states of the EU. It financially aids projects that stimulate economic development and increase employment in the poorest regions of the EU, help preserve the nature and environment in order to improve the quality of life as well as make the regions more attractive to tourists and investors, improve transport and basic infrastructure, increase the quality of education and a number of other projects which promote regional development and reduce the gap between the wealthiest and the poorest regions in the EU. |
| | Feed in Tariff | FIT | An economic policy created to promote active investment in and production of renewable energy sources, including PV, wind, hydro, anaerobic digesters and micro combined heat and power (microCHP). |
| | Low Carbon Network Fund | LCNF | The LCN Fund allowed up to £500m to support projects sponsored by the Distribution Network Operators to try out new technology, operating and commercial arrangements. The aim of the projects is to help all DNOs understand how they can provide security of supply at value for money as Britain moves to a low carbon economy. |
| | Marine Conservation Zones | MCZ | These zones are created under the Marine and Coastal Access Act 2009 to protect a range of nationally important marine wildlife, habitats, geology and geomorphology, and can be designated anywhere in English and Welsh territorial and UK offshore waters. Lundy Island, a former Marine Nature Reserve in the Bristol Channel became the UK's first MCZ in January 2010. More information on Marine Conservation Zones is available on Defra's website. To date 50 sites were designated within English waters. |
| | Ramsar sites | - | Ramsar is the name of a town in Iran where the Convention on Wetlands of International Importance was adopted in 1971. The UK Government signed up to the Convention in 1976. The mission of the Convention is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". |
| | Revenue = Incentives+ Innovation + Outputs | RIIO | RIIO is Ofgem’s new performance-based model for setting the network companies’ price controls, which will last for 8 years. There are three separate price controls that apply to the different areas of energy transportation: RIIO-T1 for transmission, RIIO-GD1 for gas, and RIIO-ED1 for electricity distribution. In the context of this report RIIO refers to electricity distribution. |

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| Policy / Regulations / Designations | Special Areas of Conservation | SAC | These are strictly protected sites designated under the EC Habitats Directive. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds). Of the Annex I habitat types, 78 are believed to occur in the UK. Of the Annex II species, 43 are native to, and normally resident in, the UK. |
| | Special Protection Areas | SPA | These are strictly protected sites classified in accordance with Article 4 of the EC Birds Directive, which came into force in April 1979. They are classified for rare and vulnerable birds (as listed on Annex I of the Directive), and for regularly occurring migratory species. The European Commission's website hosts a full copy of the EC Directive on the conservation of wild birds (79/409/EEC), within which all the Articles and Annexes (including amendments) are given, along with useful interpretation information. |
| | Site of Special Scientific Interest | SSSI | A Site of Special Scientific Interest (SSSI) is a conservation designation denoting a protected area in the United Kingdom. SSSIs are the basic building block of site-based nature conservation legislation and most other legal nature/geological conservation designations in Great Britain are based upon them, including national nature reserves, Ramsar sites, Special Protection Areas, and Special Areas of Conservation. |
| | Science, Technology, Engineering and Mathematics | STEM | An education grouping used worldwide. The acronym refers to the academic disciplines of science, technology, engineering and mathematics. |
| | Wreck sites | - | The Protection of Wrecks Act 1973 allows the Government to designate a restricted area around a wreck to prevent uncontrolled interference. Designated sites are identified as being likely to contain the remains of a vessel, or its contents, which are of historical, artistic or archaeological importance. |
| Other | Energy Infrastructure Plan | EIP | The Energy Infrastructure Plan (EIP) is a high-level plan focusing on infrastructure projects, such as sewage treatment, district heating and a new power station. The initial stage is to meet the targets of 40% renewables, 40% EVs (Electric Vehicles), 20% reduction in energy bills and implementation of energy efficiency measures. |
| | Household waste recycling centre | HWRC | A facility where the public can dispose of household waste and also often containing recycling points. Those sites are run by the local authority in a given area. |