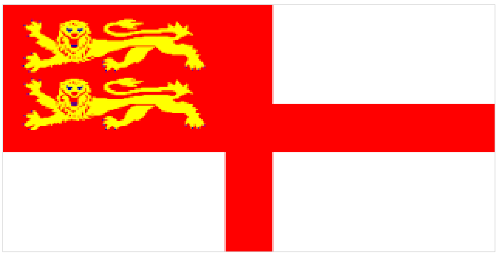

Report of a study on the costs of supplying electricity in Sark using a mix of wind, solar, diesel and battery storage.

energypeople

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1 Executive summary

Purpose

This report presents the findings of a study into the costs of providing electricity supplies in the Island of Sark. It is prepared for the Electricity Price Control Commissioner for Sark to support his consideration whether the tariff for electricity supplies in Sark is fair and reasonable. It considers the existing electricity generation and distribution infrastructure in Sark and the opportunities to update this along with installing renewable generation and energy storage.

Sark Electricity Demand

Annual Demand for electricity in Sark was recorded by SEL at 1,865,000kWh approximately ten years ago. Since then, due to a number of business premises, including hotels, closing it has dropped to a current level of around 1,400,000kWh with a corresponding reduction in peak demand. The underlying reasons for the business closing are unclear. A further contributory factor in the decline in electrical energy consumption is reported as the move to other energy forms by customers because of the current price, considered by many to be unacceptably high and unaffordable. There is likely to be suppressed demand, which would be taken up if the price were more acceptable to customers.

Current situation

Electricity is currently supplied by Sark Electricity Limited, the only supplier of electricity in Sark. Sark Electricity Limited currently has an effective monopoly over electricity distribution, and has recently disconnected some customers. It is a particularly difficult situation for customers in Sark as their water supplies are from boreholes, dependent on electrically operated pumps.

Previous Studies

One previous study has looked at opportunities for deploying renewable energy connected to the existing distribution network, while another report has described the existing distribution network as "not fit for purpose" and "inherently contains serious safety concerns and liabilities".

This study draws on those reports as sources of information. It then takes an independent view of what is needed to enable electricity supplies to be provided in a safe, continuous, reliable manner, complying with internationally accepted good practice. Much of the internationally accepted good practice would be a statutory requirement elsewhere.

The distribution network

The current distribution network consists of largely time expired assets, and, in our opinion, too many of them for the capacity of the network. The transformers are old and not of current low loss design and need replacing with a smaller number, more strategically placed, to meet the demand. Whilst the switchgear is of a type that has given good service over many years, subject to proper maintenance, it is obsolete and there is no indication that it has been adequately maintained, or inspected to confirm or address the need for modification to remove the various safety operational restrictions that have been applied to it over the years. It is not properly locked and is installed in positions that could be a risk to operators in the event of an incident while operating it.

Five different approaches are reviewed for developing a future electricity distribution network that is fit for purpose, with scope for growth. These are reviewed technically to confirm that they can deliver the required level of service, within acceptable power quality limits and then reviewed financially to arrive at the most cost-effective solution. One potential solution, the low voltage only scheme though financially attractive is considered to be too restrictive technically. Three others left ongoing concerns over network safety leaving the option of a complete replacement network as the preferred, and not the most expensive, way forward, making no use of existing assets. The most expensive way forward was like for like replacement of the existing system.

The preferred solution was used as a base on which to connect all options for sources of generation.

Generation

Generation is from a single power station equipped with four diesel engines, one of which is reported to be unserviceable. The three remaining engines each have the capacity to individually provide the peak demand that is currently experienced. If demand picks up there is still scope to run two engines with one as spare for security. We understand, though do not have it confirmed, that the remaining period of the lease is short in terms of power station life and that there could be significant ground remedial costs to the site on expiry of the lease. Because of the uncertainty over the length of the lease and the potential for significant remedial costs which we could not evaluate, we did not consider re-use of the existing power station.

We considered a diesel only option, three renewable only options and four mixed diesel and renewable options, three without storage and one with. The variation between the options is the balance between diesel, wind and solar. Our financial model allows for different combinations to be applied and could be used to test firm quotes that are received in response to tenders that may be received at a future date.

At present, the economic case favours these technologies over diesels. However, we recognise that the island may wish to consider the impact on the visual environment of these technologies.

Tariff

Each of the potential combinations results in a different unit cost of generation and distribution (including a return on capital of 5%). The cost of electricity, ranges from 43p to 48p per kWh for the mixed solutions, and is 57.9p per kWh for a 100% diesel solution at current diesel prices. For fully renewable solutions, i.e. with no fossil generation, the unit cost would be greater than 75.5p per kWh depending upon the level of storage installed.

The way forward and next steps

Our cost estimates are based on procurement of equipment and materials imported to the island but installed using the maximum possible amount of island resource. This approach will incur project management costs which are included in our capital estimates. Much of the costs will be civil works, for which we believe there is capacity in Sark. The labour for high voltage electrical works can either be imported or delivered by training existing electrical staff in Sark for high voltage work, if they are not already familiar. The actual unit costs going forward will depend on the choice of generation mix. Only after this decision will it be possible to obtain firm and binding quotes from suppliers. Suppliers and contractors can be reluctant to provide firm quotations until they know that a project is real.

2 Introduction

2.1 Background

The Electricity Price Control Commissioner of Sark has appointed energypeople ltd to carry out a study to inform his consideration of the costs of supplying electricity in Sark, without the restriction of using the assets currently employed by Sark Electricity Limited (SEL). This, however, does not preclude a solution based on the use of all or part of the assets currently owned and operated by SEL, subject to any future arrangement between the Chief Pleas of Sark and the company.

2.2 Purpose

The objective is to support the Commissioner in understanding the costs of supplying electricity, in terms of p/kWh delivered, using a mix of diesel, wind, solar PV generation and, to the extent judged economic, batteries. The study is to consider all options to minimise the costs of electrical energy to customers in accordance with good regulatory practice for a monopoly utility provider.

2.3 Assumptions

All of the analysis in this report is underpinned by a number of key assumptions.

- That the current annual consumption of the island of approximately 1.4 GWh, with maximum power requirements not exceeding 300kW will continue for the immediate future;
- That a reasonable allowance for growth should be incorporated into any proposed solutions such that electricity supply does not become a constraint if there is growth in tourism, other industry or domestic use;
- That all distribution equipment requires immediate replacement with the possible exception of some of the underground cables; and
- That where no Sark specific legislation exists to cover any particular situation, then accepted good utility practice contained within relevant UK legislation will be applied. This is particularly with regard to system operation, staff and public safety, rights and the obligations of a monopoly utility provider. There may be exceptions to this where the requirements of a small islanded network with particular customer needs, demand that higher standards should be applied.

2.4 Scope

The scope of the study includes a review of the energy generation and energy conversion sources now available and economically viable on a utility scale, along with a review of the networks required to distribute electrical energy to all parts of the island. It then includes production of a financial model to project capital requirements and operating costs driving the cost calculations for each of the technically viable solutions.

3 Acknowledgements and references

We are grateful for the support and information we received during our visit to Sark, from Sark Electricity Limited and residents of Sark who provided us with information and guidance during and since our visit.

We also acknowledge the useful material contained within the two previous reports on SEL assets, prepared by WSP in September 2019 and by EIS in October 2021. While our focus and emphasis are on slightly different objectives, our analysis of the existing situation is largely in line with these reports in most significant respects.

Further information on renewable energy sources and solutions was presented in a May 2018 report by Narec, and while the basis of the financials has changed significantly and technology has developed in the last four years, the weather-related assumptions remain valid and have informed this report.

4 Approach & Methodology

4.1 Approach

Our approach to this study was to deploy a small team of electrical engineers and financial managers to carry out analysis of the options open to Sark. This analysis takes into account the existing situation regarding demand for electricity, the island's dependence upon electricity, customer's ability and willingness to pay for electricity and the current state of the assets supplying electricity.

The team was led by Bill Slegg, an experienced Chartered Electrical Engineer previously Head of Network Operations for Eastern Electricity in the UK, who has over 40 years of experience in electricity generation, transmission and distribution engineering in the UK and internationally. He has been assisted by Josh McAvoy and Les Waters.

Josh holds an MSc in Power Distribution Engineering and is an experienced designer of electricity connections for conventional and renewable generation and demand who, over the last six years has provided services in two major UK companies holding five distribution licences and has worked internationally on regulatory and advisory projects.

Les is an experienced electricity utility engineer and manager with 40 years of experience in all aspects of distribution engineering and was a regional manager for United Kingdom Power Networks, having previously managed the implementation of distribution management technology.

In parallel with the technical analysis, Glen Chapman, an experienced power industry accountant and financial manager has carried out the financial analysis and developed the underlying financial model that supports our conclusions on potential network configurations and tariffs that could be applied in Sark.

At an early stage we visited Sark to make a first-hand assessment of the island's requirements, the current status of the network and the geography of the island. This was to determine for ourselves the overall network configuration, the condition of the individual assets and to make an assessment on issues including network asset requirements, network safety and, network operations. This enabled us to form an opinion on the suitability for re-use of any or all of the current networks. We carried out non-intrusive inspections only and did not attempt to gain access to any site or equipment where operational authorisation would be expected to be a requirement, other than those that were open to the general public.

Prior to the visit we had been provided with copies of two previous reports on asset condition and valuation which were helpful in understanding the asset head count. Both of these reports were incomplete, for differing valid reasons, and neither had been required to consider the network as a whole, their focus was an asset-by-asset condition assessment and valuation.

Having completed the brief asset inspection, we moved on to consider the immediate and future needs of the island. The immediate priority is for a sustainable electricity network to provide safely and reliably up to 300kW of power, delivering 1,400,00kWh of energy per annum at an affordable price. The future needs should, as a minimum, consider for the growth of the island back to the level prior to the closure of hotels and other businesses which has seen the drop in electricity consumption from1,865,000kWh, to 1,350,000kWh over a period of ten years and according to some sources from an even higher level prior to that. Ideally this would also include maximising the use of renewable energy to improve the island's carbon footprint.

We considered the distribution network and energy sources independently. First, we looked at different approaches to refurbish or replace the existing network and to consider what part the existing assets could and should play going forward, based on their age, condition and suitability. A replacement distribution network is expected to be of longer life than individual energy sources and must be built to accommodate future changes as energy technology develops.

Second, we looked at currently feasible energy sources of diesel, wind, solar, with and without battery storage. We did not consider technologies involving wave or tidal power at this stage, as we know of no commercial readily available solutions; we believe that experimental solutions are too risky and expensive and therefore do not provide an appropriate platform on which to base the island's future power supply. Energy from waste could be a future consideration if small scale plants become commercially available.

We considered the information included in the previous reports into Sark's electricity supply situation. Whilst they required updating with regard to costs, we have used information from them that we believe to remain valid and applicable in the current context. These are described more fully in section 5.

5 Previous Reports and Studies

5.1 Narec 2018

In 2018 Narec prepared a report for the Electricity Price Commissioner with the objective of determining the cost of a new system, using PV, batteries and small-scale wind, which could provide the same reliability as the current grid. The report recommended a new electricity distribution infrastructure totally supplied from wind and solar renewable energy sources, consisting of a single wind turbine of blade tip height of 77m and a space requirement for solar panels of 16 acres. Sufficient battery storage capacity to last for two days was included. With two days of storage and ongoing charging during day light hours from surplus solar energy the proposal was considered, by the author, adequate to maintain supplies in the event that the single wind turbine became unavailable. The estimated cost of the full system (including distribution) was £11,100,000. We have seen Narec's high level outline proposals for a replacement distribution network, which were covered in a separate report and appear to be expensive. However, we agree with the approach and component selection they have applied.

Our view is that if the single turbine proposed became unavailable the island would be reliant on other sources for considerably more than two days while repairs were carried out and would need to have diesel generation as a contingency. The Narec proposal also acknowledged this and discussed the benefits of multiple turbines.

5.2 WSP 2019

In 2019 WSP prepared a report on the Regulated Asset Base Valuation on behalf of the Electricity Price Commissioner. The report that was presented was incomplete and included significant assumptions. WSP reported that it did not receive either the co-operation on site or information required from SEL to complete the work. Missing information was related to the original costs of the assets, the maintenance records, the condition of the assets, when first installed. This prevented WSP from carrying out a realistic and robust Regulatory Asset Base (RAB) valuation.

As an indicative approach WSP assigned a current replacement value to each asset and applied straight line depreciation to it. We agree that on an asset-by-asset basis this may be applicable, though likely to be over generous given the unconfirmed condition of the asset when installed second hand. The lack of records, or access to records of any proper maintenance or modification to address known defects since installation is problematic when the visible data indicates the opposite and supports the view that the assets are of little more than scrap value if removed and present a high risk if they remain.

Also, the approach of aggregating the individual asset values to a whole system total value presupposes that all existing assets are actually required to deliver the island's electrical energy. This is inappropriate in the case of SEL. Surplus to requirement assets on an electricity distribution network add nothing to the business value but do add to risk.

We consider that, as a result, the WSP report did, on balance tend to over value the existing assets as an entirety.

5.3 EIS 2021

In October 2021 EIS produced a study entitled "HV Assessment Report" for The Chief Pleas of Sark. This report was based on non-invasive inspection of the high voltage assets on SEL's network.

This EIS report concluded:

"It is the opinion of the author, that the present network is currently not fit for purpose, in need of many immediate upgrades and replacements and inherently contains serious safety concerns and liabilities as detailed in this report. The report does not cover the main generators, which were not inspected, but are believed to also be at, or past their design life".

This conclusion does not support an asset valuation of anything above scrap value for the assets. From our own inspections, this is a view with which we concur. However, in Sark, where the system conditions are well within the switchgear ratings the chances of a catastrophic failure are significantly reduced[1].

What the existing assets do have is a limited term, business continuity value. They are currently installed and delivering electricity in Sark, and will probably continue to do so for a period of months and possibly longer, but at a level or risk that would be unacceptable elsewhere.

6 Energy Consumption and Maximum Demand

6.1 Historic

Over the last ten years the electricity consumption in Sark has dropped by 28% from approximately 1,865,000 kWh per annum to its current level of approximately 1,350,000kWh per annum. In the same period the peak demand from the system has dropped from a reported peak in excess of 300kW to less than 250kW. This is partly due to the closure of hotels and businesses and, anecdotally, through a self-imposed reduction in consumption due the current price which many users consider to be prohibitively expensive. The suppressed demand could be significant if all of the hotels reopened and the price was considered by customers more attractive and affordable.

Also, the population of the island decreased from a reported 513 in 2014 to 453 in 2019, while in the same period vacant premises across all categories increased in number from 50 to 90.

6.2 Current

We have been provided with an estimated 2021 hourly energy consumption data by the Electricity Price Commissioner. This data was provided in hourly summaries through the 24-hour period for four seasonal groups of days, in each case separating weekdays from weekends. The maximum recorded consumption was 237 kWh, which occurred at 7:30 pm on 22 March and the minimum was 83 kWh, which occurred at 2:30 am on 27 January.

This maximum consumption and demand could be served from a single generator 300kVA with no requirement for any high voltage network if it were a single point demand. Spread across the island the situation is different however.

Our analysis also shows that the current consumption, spread across the island could just be met using an entirely low voltage network but that there would be very limited scope for growth with voltage levels at or very close to the limit at the extremes of the network. This is based on an assumption that demand is evenly distributed across the network, which we cannot validate. While we believe a completely low voltage solution is unlikely to be a success over the longer term, we consider it further for completeness.

The minimum and maximum hourly consumption profile is presented in Table 1.

[1] The switchgear installed is of a design that is rated at 13.1kA (250MVA at 11kV, 150MVA at 6.6kV). The estimated maximum short circuit level and earth fault level on Sark, with all generators running (a rare occurrence) is less than 10% of this value, significantly reducing the chances of switch gear failing on passage or interruption of fault current. No switchgear on the high voltage network is called on to interrupt fault current, this is carried out on the low voltage circuit breakers at the power station.

	Minimum (kWh)	Weighted Average (kWh)	Maximum (kWh)
00:30	98	110	134
01:30	92	101	124
02:30	83	96	113
03:30	84	94	114
04:30	84	93	111
05:30	86	96	112
06:30	99	114	133
07:30	118	153	173
08:30	146	181	209
09:30	161	192	225
10:30	163	192	226
11:30	170	190	222
12:30	163	189	211
13:30	157	182	208
14:30	150	173	205
15:30	139	172	201
16:30	143	179	216
17:30	163	191	234
18:30	166	203	237
19:30	167	197	229
20:30	163	183	201
21:30	147	170	202
22:30	133	149	186
23:30	104	124	151

Table 1: Sark hour by hour Minimum and Maximum consumption profile

Figure1 and 2 show the hourly consumption profiles.

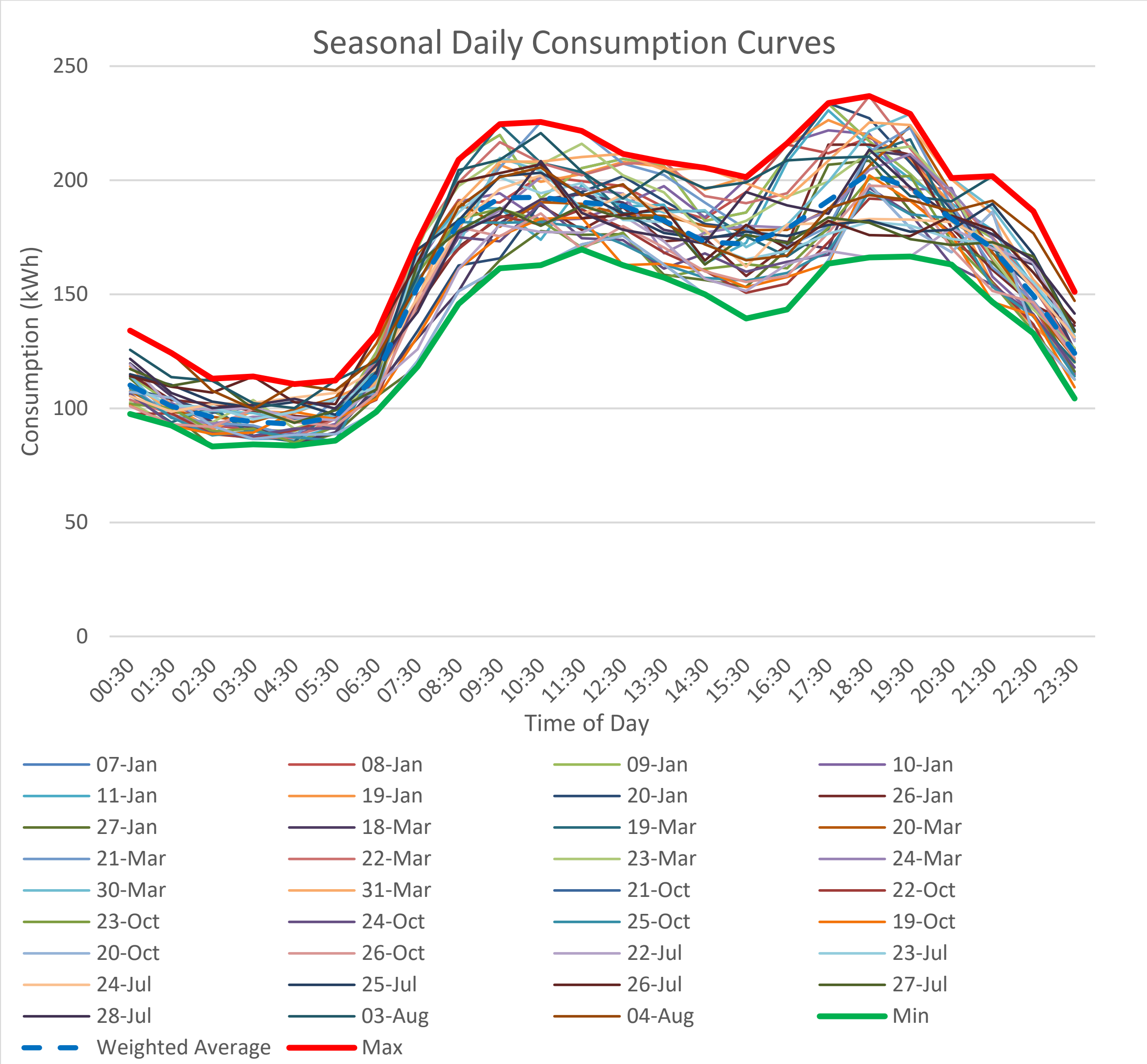


Figure 1: Seasonal daily consumption curves

Figure 1 shows 35 daily profiles which demonstrate the relatively consistent daily pattern of consumption throughout the year. Also shown are the hourly maximum and minimum consumptions throughout the year along with a weighted average.

In Figure 2 the individual daily curves are removed, showing just the hourly maxima and minima and the weighted average consumption.

While there would be no security of supply, the consumption could be satisfied by a single 300kVA generator running at approximately a 53% load factor. We have no peak demand figures available but a single 300kVA generator would also satisfy a peak demand of 270kW assuming a 0.9 power factor.

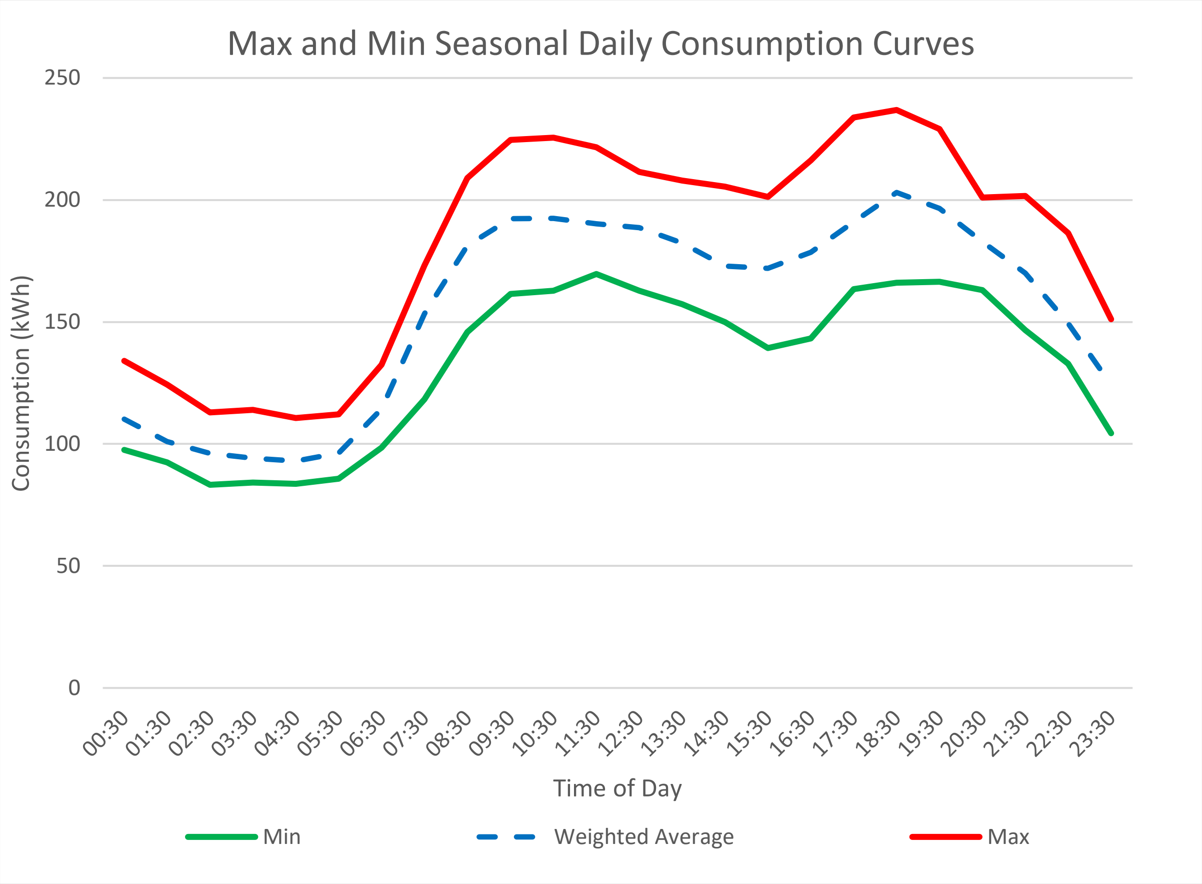


Figure 2: Maximum, minimum and weighted average daily consumption curves

7 Generation

Generation of electricity is currently carried out at a single power station located on Harbour Hill. While we have no evidence to confirm the situation, we understand that the lease on the power station premises has less than 10 years until expiry and includes dilapidation and ground remediation clauses in its terms. A diesel fuelled power station may be expected to have significant ground remediation costs, representing a significant liability to the current or future owners of the business.

In terms of resilience, should the station suffer a total shut down through a catastrophic event such as a fire, Sark has no alternative source of electricity and in the case of prolonged shut down would have to implement contingency plans using portable generation. The island is dependent upon electricity supplies for pumping water from boreholes.

The station is equipped with four diesel-powered, three phase generators, two rated at 375kVA, one at 600kVA and one at 720kVA, giving a total installed capacity of 2070kVA. One of the larger generators is reported as being beyond the end of its useful life and permanently out of service. The generators produce electricity at low voltage, (400/230 volts). Any one of the generators can alone run the entire island's maximum demand and currently just one set is normally run at any time, meaning that the island does have resilience in terms of the failure of a single generating set.

Connections from the generators to the distribution system are through a low voltage switchboard, to two 600kVA transformers stepping the voltage up to 6600volts and supplying the majority of the island, while some customers close to the power station are fed direct from the station at low voltage.

The power station high voltage switchboard has no circuit breakers, but instead has four switchfuses controlling the outgoing circuits. The network was all energised during our visit so no inspection of the high voltage fuse ratings was possible but we understand, anecdotally, that protection against faults on the high voltage network depends upon circuit breakers on the low voltage switchboard, either because the fuses have been replaced by solid links, or are of a larger size than the prospective fault current when a fault occurs.

The electrical configuration at the power station is shown in Figure 3.

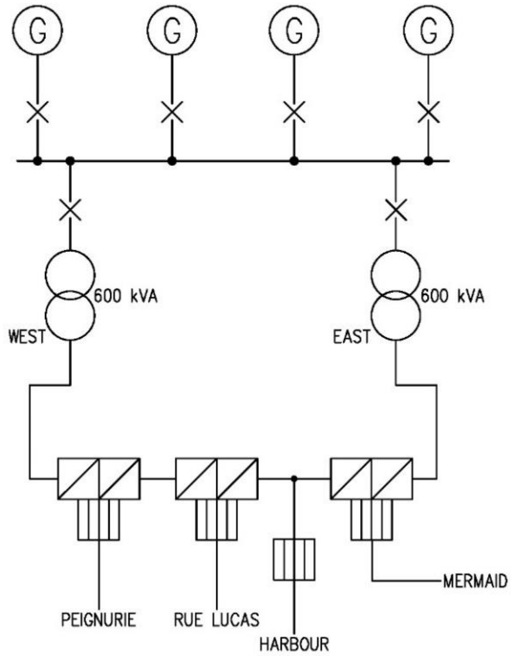


Figure 3: Electrical Configuration at Power Station

In the absence of a detailed network operating diagram (see section 8.1), circuit names in Figure 3 have been deduced from cable records.

8 Distribution System

8.1 High Voltage

The two 600kVA step-up transformers at the power station connect to the power station high voltage switchboard, which as stated above does not have circuit breakers but three ring main units and a switchfuse as shown in Figure 3. There are three feeders out to the open ring 6.6kV network and one spur direct to the Harbour substation. From the ring there is a single feed of approximately 1.5km which crosses La Coupee to little Sark. This cable is exposed and is in very poor condition immediately on the Sark side of La Coupee. From the information we have seen the geographic records of cable and equipment locations appear to be accurate, though we have not seen a complete set.

There is currently no accurate or updated network operating diagram available, something that is normally considered a fundamental and essential operational safety requirement. From the various lists of equipment provided and the geographic cable records we have seen, we have put together a first attempt at preparing an operating diagram. This is to a standard that would be acceptable in a small UK utility and in compliance with the sound principles required by the UK's Electricity Safety, Quality and Continuity Regulations 2002 (ESQCR). This operating diagram is currently not complete or fit for operational use, nor should it be considered as such until it has been confirmed operationally on site. This diagram with areas of doubt highlighted is shown in Figure 4.

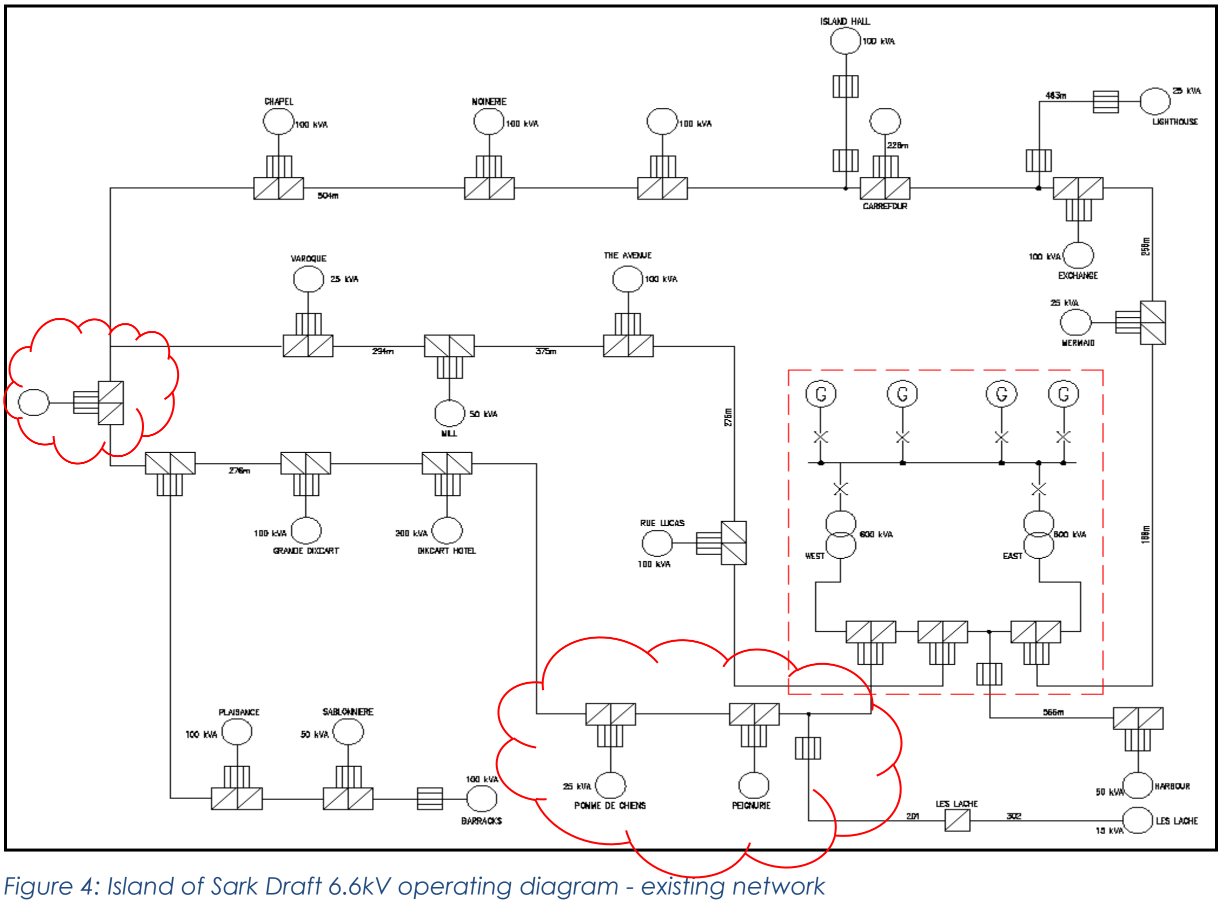


Figure 4: Island of Sark Draft 6.6kV operating diagram - existing network

There are then 26 step-down transformers on the asset list for the network, ranging in size from 15kVA to 200kVA, with a total capacity of 2000kVA, (one of which, La Tour, rated at 50kVA, we know to have been removed as a result of a recent dispute, disconnecting 19 customers from the SEL network in the North of Sark).

Putting this in context, there is currently a useable generating capacity of 1,350kVA, step-up transformer capacity of 1,200kVA, step-down transformer capacity of 1,950kVA supplying a demand currently not exceeding 250kW. While we would expect to see some surplus capacity, a load factor of less than 15% given the relatively consistent demand profiles expected, is extremely low and suggests that the network is over capitalised.

Each of the transformers has fixed losses. None of them are modern European Union Ecodesign Regulations Tier 1 or Tier 2 low loss transformers. The WSP report showed that the newest of the step-down units is 12 years old, and the oldest 66 years, with an average age of 33 years. These transformers are operating 24 hours per day and while no accurate fixed loss figures are available, we estimate the total cost of annual fixed losses could amount to £15,000 -£25,000 at the current unit tariff.

Figure 5: Typical transformer and low voltage cabinet installation

In addition, WSP reported that the switchgear on the high voltage network also has an average age of 33 years and an age range between 23 and 43 years. It is rated at 11kV with a 13.1kA fault making capacity. All switchgear that we saw was of Long and Crawford Manufacture, mainly type T4GF3 ring main units, using oil as the arc extinction medium and of a type that has given reasonable service over many years. However, over the years of service it has had operational restrictions imposed through Suspension of Operational Practice (SoP) notices under the Energy Networks Association National Equipment Defect Reporting Scheme (NEDeRS), preventing live operation and imposing an exclusion zone around any live equipment. These restrictions were only able to be removed following a unit-by-unit internal inspection and confirmation that the problem either did not exist or had been cleared. We are unaware that any inspections have either been carried out or are planned on the Sark network. According to the records we have seen, which were partly verified on site, there are 27 ring main units and 13 switchfuses. In terms of operational safety, the entire switchgear population is inadequately secured compared with good practice, no switchgear is fenced nor has operational locks fitted on main switches, earth switches or removeable covers. In most locations there are no circuit labels.

The switchgear is, in many cases, installed in what we consider to be an unsafe manner, facing a concrete wall such that an operator could easily be trapped with only a very hazardous means of egress including inadequate egress route width, trip hazards caused by above ground cables and earthing connections and in many cases further impeded by brambles.

We saw no evidence of reverse operation delay handles and so cannot comment on whether they are being provided or used.

Figure 6: Typical high voltage ring main unit operating space & trip hazards

The high voltage cables are a mix of 6.6kV rated and 11kV rated cables, all operating at 6.6kV. Our experience of upgrading 6.6kV networks to operate at 11kV is that the cables can usually withstand the higher voltage but that cable joints often cannot. Unless all joints are well recorded and replaced as part of upgrading this cable, attempting to operate this network at 11kV is not advisable as there could easily be a period of joints failing, causing outages and requiring replacement under emergency conditions.

In summary, the high voltage network has more high voltage assets than a network of 300kW requires. Like for like replacement is unlikely to be justified. As a minimum some network rationalisation is required. The assets themselves; transformers, switchgear and cables; have no intrinsic value beyond scrap value, which could only be realised if removed from site. This would involve decommissioning and transportation costs.

The assets have some residual economic value as part of a going concern simply due to the fact that they are installed where they are, and are doing the job that they do. However, in terms of functionality they are not all necessary to provide the island's power needs and do not all need to be replaced.

As already stated, the October 2021 "HV Assessment Report" by EIS concluded that "the *present network is currently not fit for purpose, in need of many immediate upgrades and replacements and inherently contains serious safety concerns and liabilities*". During our inspection we have also identified and described issues that require resolution on the high voltage network, fundamentally to address the safety and operational requirements of all above ground physical assets.

A like for like replacement of the existing high voltage network which we cannot justify or support, is estimated to cost approximately £ 2,800,000 in material and installation costs if completed to internationally acceptable standards. Our estimate is supported by the bill of quantities presented in Table 5 in section 13.3.1. This is approximately 35% lower the Narec estimate of £4,344,000 in 2018.

We do not believe a like for like replacement of the existing is the only, or best, approach. A rationalised high voltage network, again to internationally acceptable standards with capacity to cater for the island's peak demand to increase from the current 300kW to 1,500kW is estimated to cost £2,450,000 in material and installation costs and is also supported by a bill of quantities in Table 7 in section 13.3.3.

8.2 Low Voltage

A small number of customers are fed direct from the power station on low voltage feeders. The majority are fed through a high voltage network running at 6600 volts which is then stepped down to low voltage, again to supply customers with three phase (400 volts) or single phase (230 volts) supplies.

A superficial, restricted by safety access, inspection of the low voltage assets indicates that they are all functional and appear to be in serviceable condition, although with doubts over the efficacy of some of the earthing arrangements. Proper earthing is essential for personal safety.

The records of low voltage cable, which are very precise on network lengths and cable sizes, show that there is 28.2km of low voltage cable on the Sark network. Of this, 9.2km is single phase cable, which can only be for domestic and small commercial service connections with a further 14.2km of three phase cable which is of a size that would normally only be considered suitable for service connections.

Some of the singe phase service cable is of 6mm^2 and even 1.5mm^2 cross sectional area, and the majority is 16mm^2, with a maximum service length of 240m. We have no customer specific loading data but generic calculations show that this length of cable at this size could be at the limits for GB statutory volt drop levels, and earth loop impedance values with as little as 4kW of demand. We could not recommend the continued use of cables of this size.

The remaining 4.8km of underground cable is a mixture of 50mm^2, 70mm^2, 95mm^2 and 120mm^2 copper cored cable that can reasonably be considered as mains cable. Although still of relatively small size, it is adequate for the demand.

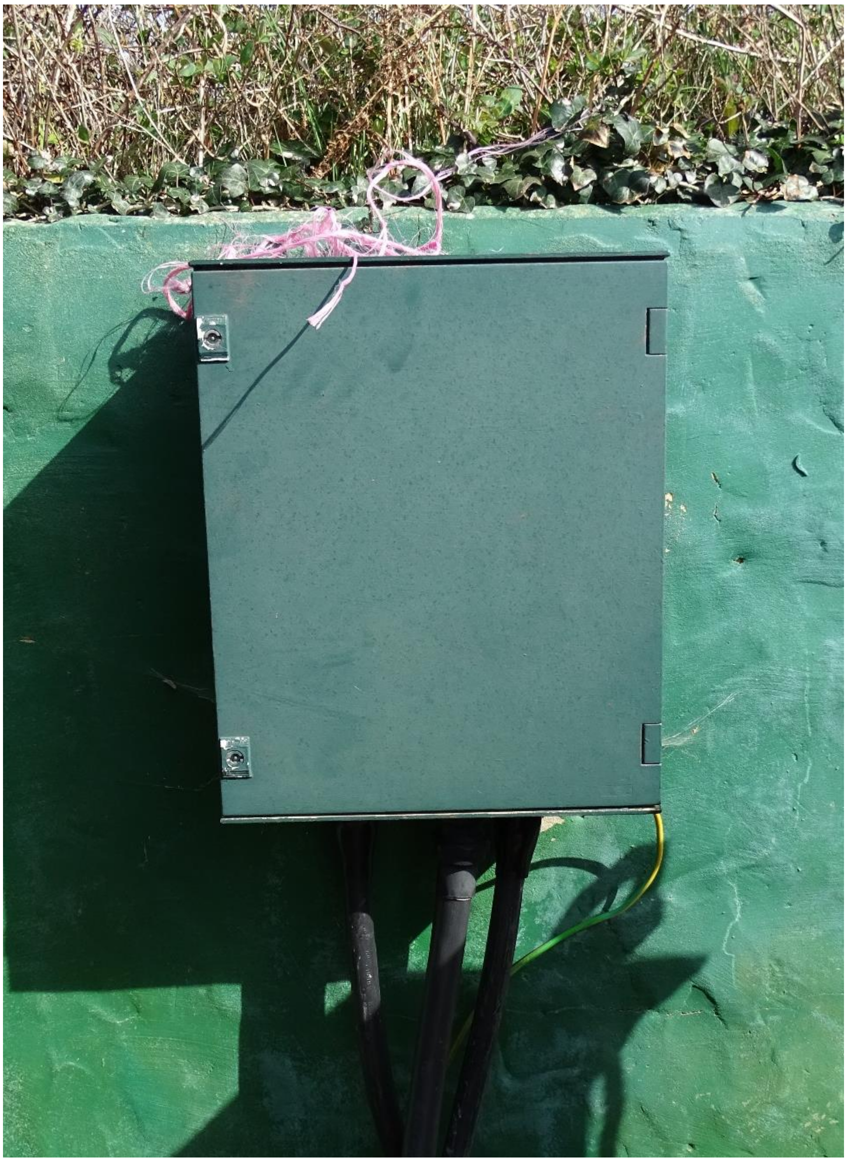


Figure 7:Typical substation LV cabinet

We understand that the low voltage systems are generally protected by a single set of fuses on the incoming side of a low voltage distribution box supplying a number of customers, as illustrated in Figure 7. We had no access to examine these boxes internally or to comment on the fusing policy applied by Sark Electricity Limited. This would require that operational access is granted by Sark Electricity Limited.

8.3 Commercial and Domestic Service terminations

We only saw two service terminations, a newly made 3 phase termination in commercial premises which was made to a high standard and a longer standing 3 phase termination also of a high standard. On a return visit with more time available we would wish to inspect a selection of commercial and domestic service terminations and meter positions and carry out basic checks including visual inspection, fuse ratings, polarity and earth loop impedance as applicable, before commenting further.

Again, this could only be carried out with the agreement and co-operation of the Sark Electricity Limited.

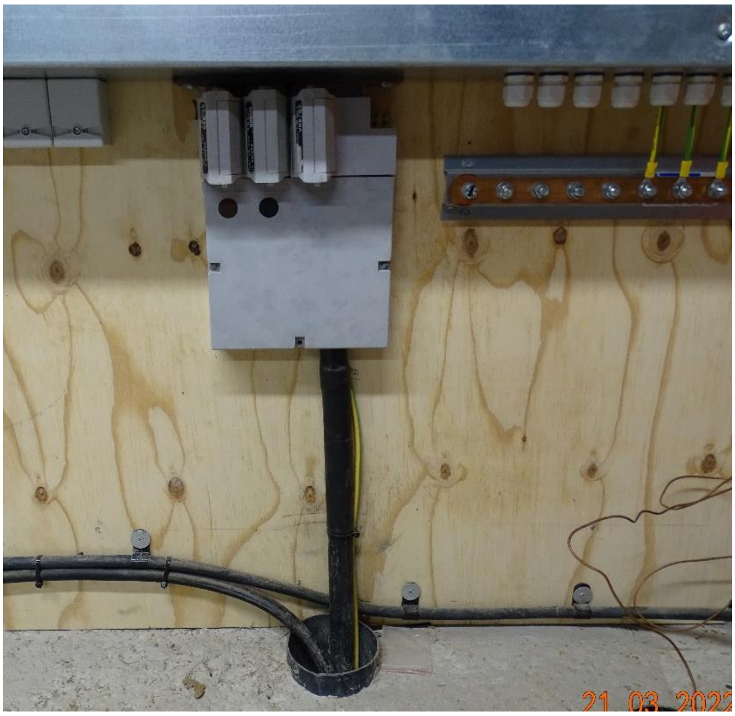


Figure 8: Recent three phase service termination

8.4 Network Operations

All power station and network operations are carried out by two experienced members of staff who over the years have either built, supervised or otherwise been part of developing the network. This includes transferring it from an overhead line network to an entirely underground network, which could account for the many transformers, which are relatively low costs on overhead networks but much more costly using ground mounted substations with switchgear, civil works and enclosures.

The two key staff are of an age at which they could reasonably be expected to have retired within the next two years. There have been changes in ownership but consistency of staff to date. It has to be seen as a high risk to the business and hence electricity supplies in Sark that the two could retire, become sick or otherwise unable to work at the same time and at very short notice. There is a less experienced member of staff supporting them but we are not aware of any formal succession plan or training programme. We anticipate that for safety reasons any staff brought in to the island in case of emergency, if both experienced operators were unavailable, would be reluctant to operate the network in the absence of a more comprehensive set of operating diagrams, circuit labels and operating procedures. The likely result would be that operations would be carried out under ‘dead operation only’ conditions and could lead to extended outages.

9 Future Requirements

9.1 Consumption and Peak Demand

The immediate requirement is for a safe, reliable and affordable supply of electricity delivered within acceptable voltage and frequency limits to meet all Sark residents domestic and business needs. Currently this is around 1,400,000kWh per annum with a peak demand below 300kW. In the medium to long term, growth has to be allowed for. Electricity consumption in Sark has dropped from a recorded 1,865,000kWh in the last ten years to the current level of less than 1,400,000kWh. Taking into account that a number of businesses including hotels are closed, potential for growth to enable the island's economy to make a significant restart has to be factored into any electricity network requirements. The network proposed in section 10.8 allows for growth to approximately four to five times the current demand without additional expenditure. Due to largely fixed costs of some elements of the network scaling back this growth factor would not deliver any significant cost saving.

9.2 Safe, cost effective, operation

The future electricity distribution system must have low operating costs, primarily in terms of fuel and other material and products that have to be transported to the island and it must be able to be operated efficiently by suitably trained staff equipped with the right information and tools. In the longer term they will not have the level of experience of the network of the present staff. Moreover, the network must not pose any form of safety risk either to customers supplied by it, members of the public being in proximity to it or staff working on it. This requires a significantly different operating regime from the current situation, with a properly constructed, maintained and recorded power station and network. Most of these operational essentials require no additional costs above the network costs beyond basic personal protective equipment and robust operational procedures that are rigidly adhered to. This includes an up to date operating diagram that is available to any authorised operator, operational security by locked fences, barriers and switches. A simplified network built to current standards and regularly inspected is the most likely route to achieve this requirement. A revised set of geographic and operational records must be developed during any network modification.

10 Distribution System Options

There are potentially at least five options to consider going forward for redevelopment of the Sark distribution network. Any one of them could theoretically work regardless of ownership of the electricity distribution network. This could be carried out under current ownership or by others. Costs of acquisition of the existing network by any new owner are discussed in section 10.6.

We have prepared best estimates of costs for each of a number of options going forward and make a recommendation on the most suitable way forward. All costs are based on the information we are able to gather from reliable industry sources but they could vary considerably when a tender is released to develop the network. Suppliers are reluctant to put a lot of time into competitive quotes until a project is certain to go ahead so we expect that our prices could be improved upon. The prices bid when the work is offered will also depend upon suppliers' and contractors' appetite for the work at the time.

10.1 Continue with existing network and replace on failure / over a period

The network is currently operating and delivering what is understood to be a relatively reliable supply of electricity to customers in Sark. Professionals, who at different times have been employed to study and review on the network, report, with varying strengths of opinion, that the high voltage, switchgear and transformers, which were second-hand when installed, are poorly installed, have no substantive maintenance or defect remediation records available, are not secure, effectively not safe to operate and not fit for purpose.

The reliable supply that the network continues to deliver has a high dependence upon the skills of two key staff who could retire at any time. There is no evidence of any succession or contingency plans which provide for this eventuality.

The network as configured is asset intensive and has transformers that are of an age where their fixed losses will be much higher than would be the case for replacement transformers.

The network is not considered sustainable without significant short-term expenditure to bring it up to acceptable standards, establish operating diagrams and procedures that bring the network up to accepted norms for public and operator safety.

This approach does not lend itself to upgrading the high voltage network to 11kV so the end result would be a sub optimal network, still over asset intensive but brought up to ESQCR standards. There would be an extended transition period while the network continued to be non-compliant with ESQCR requirements.

The replacement cost amounts to a sum in excess of £2,800,000, spread over a period of up to ten years. Given the current condition of the assets however, this is expected to be necessarily incurred over a shorter period.

10.2 Like for like replacement of assets of the existing network

This is effectively the same as the first option but with an early complete replacement of the network, upgrading as appropriate to take maximum advantage of current technology and to remove some of the immediate risks. This approach would replace like for like, all of the existing generators, transformers, and switchgear, much of which is not required on a network supplying this level of maximum demand or annual energy consumption. Sensibly, for the longer term good, it would also upgrade the network from 6,600volts (6.6kV) to 11,000 volts (11.0kV) mainly because 11kV is a standard UK voltage (meaning that cables and transformers are generally available at lower cost). There is no difference in switchgear costs as the same types would be used for either voltage. There would be civil works costs required to make operating positions safe and to provide some form of barrier to protect members of the public from any hazards presented by inappropriate access to high voltage switchgear.

Replacing assets would present the opportunity to use European Union Ecodesign Regulations Tier 2 transformers which have a much lower level of fixed losses than those currently installed.

This piecemeal approach does not lend itself to a redesigned network reducing the asset base to that which is necessary to deliver the needs of the island.

This approach could more easily address upgrading the high voltage network to 11kV but would still be a sub-optimal network, still over asset intensive though brought up to ESQCR standards more quickly. There would be an extended transition period while the network continued to not comply with ESQCR requirements.

We would expect the replacement cost to amount to a sum in excess of £2,800,000.

10.3 Replace high voltage network and use existing low voltage

This approach would replace the existing high voltage network, substantially like for like and re-use the existing low voltage networks. This is an approach that would reduce overall costs of developing a replacement network. We see from cable records that many service connections are of $16mm^2$ cross sectional area and smaller, which may not be adequate for supplying current demand maintaining the minimum voltage above 230V-6%. It would also require thorough inspection and testing to confirm whether the network is properly and adequately protected and earthed, that customer's installations are either provided with an adequate connection with earth or have their own arrangements and are in accordance with the principles of BS7671. Without this level of inspection on a substation-by-substation and customer-by-customer basis, along with completion of any remedial work we could not recommend the continued use of the existing low voltage network.

The cost of this approach is estimated at £1,975,000 plus the costs of carrying out a full inspection and completing currently unknown remedial works on the low voltage network.

10.4 Complete replacement network from energy source to customers

This approach would involve complete redesign and replacement of the existing network. It would sensibly be a redesigned, much less asset intensive network using modern equipment compliant with the principles of the UK's ESQCR 2002 regulations in terms of safety and management requirements. It would utilise modern European Union Ecodesign Regulations Tier 2 transformers.

From the information available on demand and network distances this could be achieved with approximately six transformers in Sark strategically placed around a high voltage ring, with one more on Little Sark, feeding out radially to existing transformer locations to connect to low voltage networks.

In the absence of figures for demands on each existing transformer it is not possible to precisely plan a network that addresses the island's needs and is unwise to do so from a purely desk top analysis. Natural geographic and other obstacles to idealised planning need to be taken into account.

A reasonable assumption would be that potential for demand to be served is approximately related to capacity ratings of existing transformers and on this basis a costed network proposal has been developed which will be easily adapted as firm demand readings become available. This is based on grouping the network into geographically based groups that could readily be supplied by a single transformer. This grouping of substations is unlikely to change as this is primarily geographical but the infeed point to each is group subject to review as actual load readings become available under final design confirmation.

This approach, showing the likely high voltage ring in green with six probable hubs in Sark and the additional hub in Little Sark is shown in Figure 9. It illustrates the overlapping supply areas where the electrical demand is expected to most concentrated giving connection options in those areas, spreading further in the less populated areas.

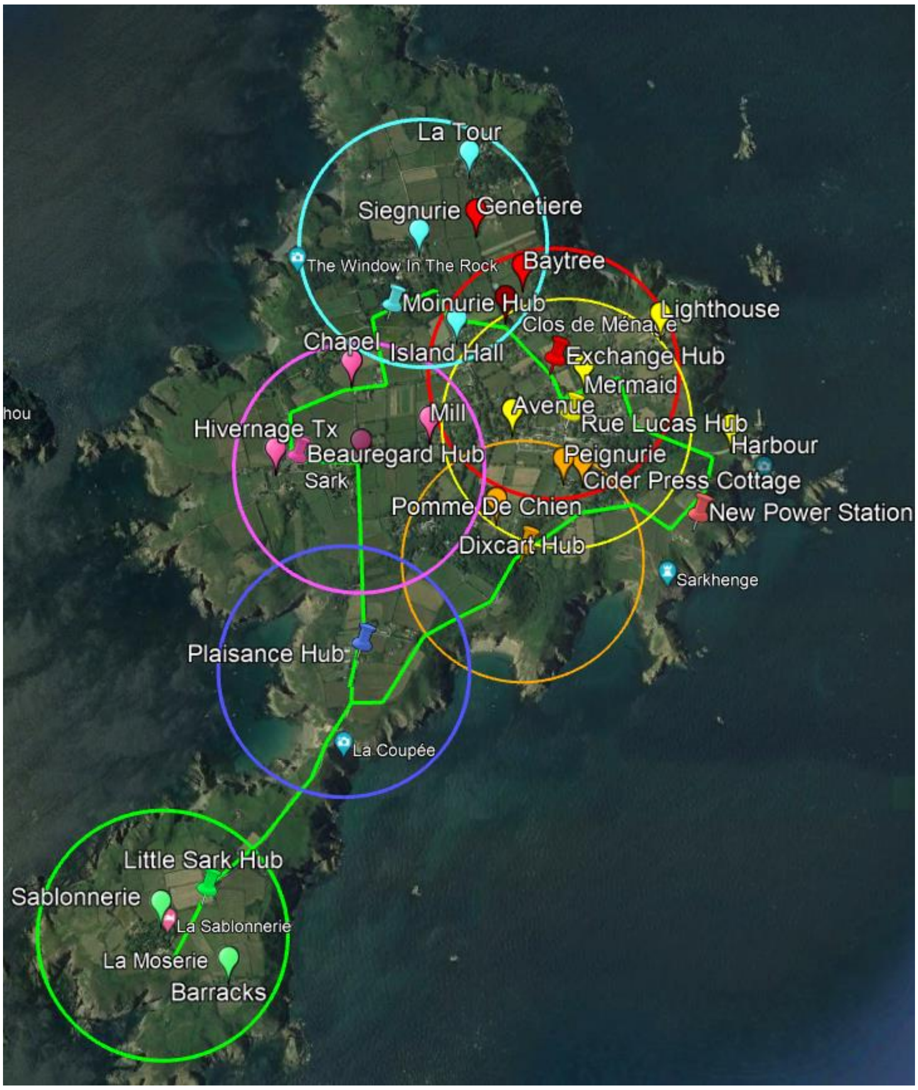


Figure 9: Proposed approach to distribution system hubs in Sark and Little Sark

The proposed substation equipment that will be visible would be modern 'pad mount' transformers, which are free standing items, approximately 1.2m cubes as shown in Figure 10. They are designed to be installed outdoors but may also be installed with associated switches in GRP housings as shown in Figure 11 or behind boarded or wire fences whichever is considered most suited to the aesthetics of Sark.

Figure 10: Free standing pad mount substation

Figure 11: GRP substation enclosure

The cost of developing this replacement network is estimated at £2,450,000.

10.5 Dispense with all high voltage, operating a low voltage only network

This option is included for completeness of analysis and for a demand as small as 300kW should be considered. It would be a desirable situation as it would remove all transformer fixed losses, allow for the network to be operated without staff trained for high voltage operations, and reduce capital costs and operating costs. The savings in fixed losses would, however, be partly offset by increased variable losses.

The current maximum demand of less than 300kW could be supplied by a small number of three phase low voltage connections to local hubs then supplying customers. If all demand were located close to the generation source, within approximately 400-500m it could be made to work.

In a distributed system the voltage drops and losses along feeders require transformation to a higher voltage to maintain supplies within tolerable limits at the extremes. We have reviewed and modelled a number of theoretically available solutions, including locating generation at the centre of the island and distributed generation at multiple locations around the island. While some combinations can just be made to work with the current demand, the networks would be running at the extreme with no scope for growth. While this would be a potentially costs saving solution, we conclude that Sark's requirements are beyond what can be delivered effectively by a low voltage only network.

Having reviewed the current low voltage asset list it is highly likely that some Sark customers would currently be receiving voltage outside the normally accepted 6% tolerance, which is a statutory requirement in Great Britain. This has not been tested and we would look to confirm voltage levels on a return visit.

The estimated cost of developing this network is £1,370,000 including freight and a contingency of 10%, but as already stated there would be significant technical limitations on growth and the locations of generation.

10.6 Network replacement/new build time

Rebuilding or replacing the network will involve a degree of disruption in Sark, possibly over a period of a few months for all works to be completed. Roads will need to be excavated for cables to be laid and there may be short periods of time when some roads are blocked, this will be for hours, not days, at any one time and prior notice can be given for these works. During the construction works customers' supplies need not be interrupted for more than the two to three hours that it will take to replace the connection to their properties. A high-level outline programme is provided at Appendix 13.7.

10.7 Value of existing distribution assets in a future network

The report by EIS on the existing distribution system described it as not fit for purpose and effectively condemning it on safety grounds.

We largely agree with these findings but do consider the electrical safety risk in Sark is reduced due to the very low short circuit levels that may be expected. The access and locking concerns remain valid. Based on the cost estimates we have made, the price of a like for like asset replacement of the existing network would be very similar to the cost of a new, designed for purpose, network.

This would render the existing network to be of no value going forward compared with a replacement meeting all modern standards, particularly considering that after the necessary remedial work costs it will remain a partly time expired asset.

What the existing network does have is the continuity value that may be assigned to enable a new network to be built and commissioned with an orderly and managed changeover. In addition, there is the scrap value of the assets though this is likely to be offset by removal costs.

As a result, we see that the existing network has very limited value going forward, either to the current or any potential owner.

10.8 Distribution System, Summary of Options

Option	Continue with existing and replace on failure or over a 10-year period	Like for Like replacement	Replace High voltage assets and use existing low voltage	Complete replacement Network	Replace with a complete low voltage network
Estimated cost	£2,800,000, spread over a 10-year period	£2,800,000	£1,975,000	£2,450,000	£1,370,000
Overall Time to build	N/A	6-9 months	3 months	3-6 months	3-6 months
Advantages	No transition period between networks Minimum inconvenience to customers during construction	Early compliance with ESQCR principles	Partial early compliance (HV) with ESQCR principles. Minimum inconvenience to customers during construction	Early compliance with ESQCR principles End result is a network designed for accepted safety standards and optimised investment	Early compliance with ESQCR principles
Disadvantages	Remedial work is needed now. Continuing high risk on network safety for extended transition period. Continuing high dependence on limited staff resource. End result is a sub optimal network Requires SEL agreement	Some inconvenience to customers (access to replace every service termination) End result is a sub optimal network.	Continued potential partial and higher risk non-compliance (LV) with ESQCR principles. Requires SEL agreement	Some inconvenience to customers (access to replace every service termination)	Difficult to design a network that keep all customer within 6% of declared voltage. Not technically viable with any level of growth and very restricted on possible locations of generation
Recommended?	Not recommended for risk and safety reasons	Not recommended for network design reasons	This approach cannot be supported without more detailed evaluation of low voltage network	Recommended solution	Not recommended, too limited technically

Table 2: Comparison of options for Sark distribution network

10.9 Distribution System Conclusion

Our view is that the future electricity supply in Sark would be most safely and reliably served, and in the longer term most economically served, by a complete replacement distribution network, designed to meet the precise needs of the island's customers. Earthing systems, electrical protection and other safety requirements would be brought up to current standards for the system as a whole.

The estimated cost of upgrading the existing network to a standard that most distribution operators would consider acceptable is actually calculated to be greater than the cost of installing a completely new network, mainly due to the opportunities to upgrade and rationalise as the network is rebuilt.

An indicative replacement network design, able to be amended and added to, is shown in Figure 12:

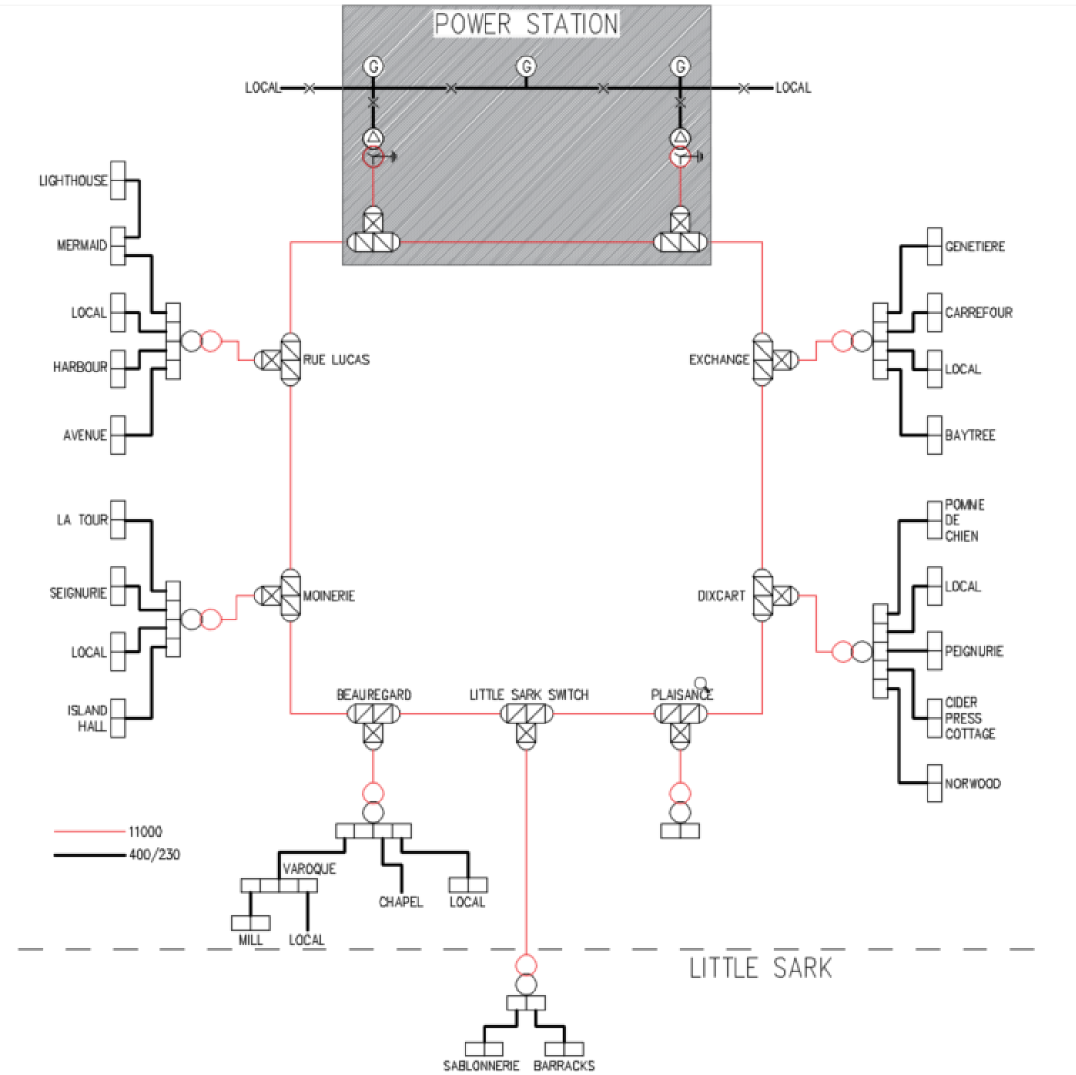


Figure 12: Indictive replacement electricity distribution network for Sark

In each group the hub position could be changed if improved demand information indicates it would be appropriate. For example, we originally proposed Seigneurie, Varoque and Carrefour as hubs based on location but changed to Moinurie, Beauregard and Exchange based on existing transformer size. These changes could easily be reversed. There are networks at the extremes that could be moved as more information is available; for example, La Tour could be transferred to Carrefour /Exchange and the Harbour may be better connected to the high voltage network with its own transformer.

The current proposed configuration has all been modelled in DigSilent Power Factory software and the low voltage networks individually modelled using WinDebut software showing that all works as presented, with volt drops at a maximum of 4%, allowing 2% for service volt drops. This modelling should be re-run as part of final design as demands are confirmed and precise routes are known.

Renewable generation sources are not shown on this diagram and, depending upon capacity could be connected to the system at almost any location on the low or high voltage system. Some would sensibly be co-located with the diesel power station but solar energy distributed around the island and connected to the network at different locations would be also be appropriate. In the case of Little Sark, some solar capacity would feed back to the Sark network and also provide some resilience in the event of a failure of the single cable across La Coupee.

In our overall modelling of costs for electricity in Sark, we have used the costs for developing the network as shown in Figure 9 as the basis of distribution costs.

11 Generation options

11.1 Refurbish Existing Power Station

It is our understanding that the existing power station is leased to Sark Electricity Limited on a lease which terminates in less than 10 years. While this is still some way off, there is a reported need to replace one of the diesel generators at the power station along with a need to replace the high voltage switchgear. The long-term future of the existing power station in the electricity supply for the Island should be considered before any significant expenditure is approved for addition to the regulatory asset value.

11.2 New Diesel Power Station

Diesel is currently the sole source of energy used by Sark Electricity Limited and is the base case for comparison of other options. It is likely to be required as a cost-effective capital option to cover for extended periods of low output from renewable sources, including any down time of any wind turbine(s). In capital terms it is relatively cheap but with very high running costs so the objective should be to install sufficient diesel capacity to run the island as a back-up system and to minimise its operating hours.

Modern generators are more efficient than those currently installed and the particular 200kVA example used in our calculations uses 42 litres of diesel per hour on full load and 24 litres per hour on half load. Assuming a 0.95 power factor this delivers between 3.96kWh and 4.52kWh per litre of diesel used. The lower value has been used in our calculations.

The final choice of generator would depend upon capital cost and fuel efficiency. With the information we have we are recommending three 200kVA generators such that two could meet maximum demand with the third providing an (n-1) level of redundancy when there is no renewable energy available.

We have a assumed a single location for all diesel generation using silenced generators are largely self-contained, that require minimal conventional balance of plant and a secure agricultural type shelter from the weather as opposed to a more conventional power station building.

Figure 13: Typical building style suitable for new power station

11.3 Renewable energy

Revising or replacing the existing power station in Sark presents an opportunity to design and instal a network taking full advantage of renewable energy sources. Renewable energy sources are relatively costly in capital but the potential ongoing fuel savings of approximately 22 pence/kWh could provide up to £308,000 a year in fuel cost savings towards repayment of that capital. Assuming interest at 5% p.a. this saving would provide for repayment of a mortgage of approximately £4,300,000 over a period of 25 years.

There would be an accompanying annual reduction in carbon dioxide emissions by something in the order of 300 tonnes if all of the demand were transferred to renewable sources.

11.3.1 Wind

The Narec studies carried out in 2018, for which the meteorological data remains valid, estimated a yield of between 37% and 51% from installed capacity, depending upon which turbine was selected. This is in line with industry expectations. The larger 500kW turbine with a tip height of 77m yielded 51%. A single unit would be sufficient to supply the whole island's requirement but there would be no resilience in case of failure, without resorting to diesel, solar or storage. The Narec proposal included no diesel so was heavily dependent upon solar and storage. This made it a very expensive proposal in terms of capital which was reflected in projected unit costs. Smaller turbines of 55kW and 100kW were also considered by Narec with tip heights of 45m-50m. Using smaller turbines would require more of them, thereby providing resilience in the case of failure of a single turbine. Narec estimated that seven 100kW turbines would be required, we estimate that coming down further in size to the 55kW could require twelve turbines.

This aligns with other more generally available wind energy production data.

The key decision for wind is whether one or more turbines of tip height between 46 and 77 metres are acceptable in Sark. The great advantage of the single turbine is that the capital cost/kWh is much lower.

11.3.2 Solar

The Narec studies also proposed 3000kW of solar capacity. Narec used the industry accepted software PVSyst to model the output of selected solar panels and came up with a yield of 13%, which again is in line with industry norms. We have repeated studies using PVSyst using a range of solar panels and achieve similar results. The actual yield will again depend upon the type of panels selected but varies through a very small range of between 12% and 15% from data that we have seen.

Solar panels require in the order of 2500m^2 per 100kW of installed capacity. The proposal by Narec to install 7500kW of solar would require approximately 16 acres of land, which may or may not be available for this purpose in Sark.

11.3.3 Other renewables

At this stage we have not considered the cost of other renewables such as wave, tidal, biomass or energy from waste as we have not found any suitable, scalable, commercial solutions that meet the island's needs. Any, or all of these could be future sources of energy that could be integrated electrically into the proposed distribution network.

11.4 Energy Storage

To maximise the use of renewable energy sources some storage capacity to utilise stored energy from renewable sources is an option. While the capital cost of storage capacity is decreasing it remains expensive compared with diesel as a back-up supply.

11.5 Value of existing power station in future electricity supply

The existing power station could remain the base for future generation but with the lease expiring in the medium term some certainty would be required before any significant expenditure is incurred. The existing station is an old building in which structural alterations could be difficult and there is a need to carry out structural reviews to determine its longer-term suitability.

Given the potential for ground remediation costs it could become a liability.

11.6 Generation Conclusion

Similar to the distribution network, we have prepared best estimates of costs for each of a number of options going forward and make a recommendation on the most suitable way forward. All costs are based on the information we are able to gather from reliable industry sources but they could vary considerably when a tender is released. Suppliers are reluctant to put a lot of time into competitive quotes until a project is certain to go ahead, so we expect that our prices could be improved upon. The supply and installation of generators and equipment is likely to be less dependent upon suppliers' and contractors' appetite for the work at the time, as it is heavily biased towards equipment costs.

Whilst a 100% renewable solution is very desirable it would require much higher capital investment to include wind and solar with sufficient storage to power the island through the hours of darkness and periods when the wind speed is below the minimum pick up speed of the turbines, or when the turbine (if a single turbine is used) is shut down for maintenance or repair.

Our view is that the overall solution should be a mix of diesel and renewable generation. There should be sufficient renewable generation to supply a typical day, always accepting that with weather dependency there will be days of over generation and days when the diesel plant may need to be used to make up shortfalls unless some storage is installed. Using the renewable sources as far as is reasonably practicable for regular use will minimise fuel usage while retaining diesel back-up as a security of supply assurance.

We have modelled a number of mixes of energy sources.

Of those tested the optimum economic mix to deliver the current demand is 600kW of diesel, using 3*200kVA generators, which will provide sufficient back up for the whole island on a dark, still night and could meet the island's peak demand at any time of day. Combining this with 500kW of wind generation (optimum cost turbine) and 400kW of solar, or 200kW of wind (more expensive unit cost) and 600kW of solar, in each case without any storage, would minimise the diesel running time and deliver the electricity at the lowest unit costs.

Other mixes may be applicable as demand grows and using one of the optimum arrangements as a start point would allow incremental growth of solar, wind and/or storage.

12 Comparison of Options

In Table 3 we present a comparison of the base case options with key outputs from the overall financial model.

		100% Diesel (current)	Mix 1 Wind, Solar Diesel standby	Mix 2 Wind, Solar Diesel standby	Mix 3 Wind, Solar, Storage, Diesel standby	Mix 4 Wind, Solar, Storage, Diesel standby	100% renewable, Wind, Solar, Storage (updated Narec)	100% Wind & Storage	100% Solar & Storage
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 5% cost of capital		57.9	42.4	43.2	45.0	48.7	200.2	75.5	82.8
Annual cost to deliver 1.4GWh per annum assuming 25-year loan at 5% (£s)	Fuel	341,895	-	-	-	-	-	-	-
	Interest (year 1)	143,051	215,802	223,667	239,397	268,437	1,502,637	484,059	552,878
	Repayment of principal (year 1)	59,945	90,432	93,728	100,319	112,488	629,679	202,845	231,683
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**810,888**	**592,931**	**605,491**	**630,413**	**681,422**	**2,803,313**	**1,057,180**	**1,159,338**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**(25,383)**	**164,859**	**149,302**	**118,388**	**56,316**	**(2,535,744)**	**(401,583)**	**(529,957)**
Cash flow (year 1 £s) assuming tariff of 60p/kWh		**29,112**	**247,069**	**234,509**	**209,587**	**158,578**	**(1,963,313)**	**(217,180)**	**(319,338)**
NPV over 25 years at 5% (£s)		**410,308**	**3,482,184**	**3,305,152**	**2,953,908**	**2,234,987**	**(27,670,819)**	**(3,060,928)**	**(4,500,726)**
Cost per kWh to deliver 1.4GWh per annum assuming 25-	Fuel	24.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	10.2	15.4	16.0	17.1	19.2	107.3	34.6	39.5

		100% Diesel (current)	Mix 1 Wind, Solar Diesel standby	Mix 2 Wind, Solar Diesel standby	Mix 3 Wind, Solar, Storage, Diesel standby	Mix 4 Wind, Solar, Storage, Diesel standby	100% renewable, Wind, Solar, Storage (updated Narec)	100% Wind & Storage	100% Solar & Storage
year loan at 5% (£000s) (p/kWh)	Repayment of principal (year 1)	4.3	6.5	6.7	7.2	8.0	45.0	14.5	16.5
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**57.9**	**42.4**	**43.2**	**45.0**	**48.7**	**200.2**	**75.5**	**82.8**
Margin at tariff of 60p /kWh		2.1	17.6	16.8	15.0	11.3	(140.2)	(15.5)	(22.8)
Comments		Single source of energy, but multiple units giving (n-1) security, expensive fuel	Retains (n-1) level of security on diesel, reduced diesel running hours	Retains (n-1) level of security on diesel, further reduced diesel running hours	Retains (n-1) level of security on diesel, but diesels unlikely to run -weather dependent	Retains (n-1) level of security on diesel, but diesels unlikely to run -weather dependent	100% renewable, heavy capital cost. Requires 16 acres of land for solar and 77m turbine	Entirely Wind Single source of energy - high risk, single 77m high turbine	Entirely Solar, totally dependent upon storage for approx. 55% of time (hours of darkness). Requires 8 acres of land for solar

Table 3: Comparison of options for Sark Generation

13 Appendices

13.1 Glossary of abbreviations and short forms

Acronym	Definition
ENA	Energy Networks Association
ESQCR	Electricity Safety, Quality and Continuity Regulations 2002
high voltage (HV)	by definition, a voltage of greater than 1000V, in this context a voltage of 6600 volts or 11,000 volts
kVA	kilovolt-ampere
kVAr	kilovolt-ampere reactive
kW	kilowatt (real power =kVA*power factor)
low voltage (LV)	by definition, a voltage of less than 1000V, in this context a voltage of 400/230 volts (3 phase/single phase)
NEDeRS	National Equipment Defect Reporting Scheme (run by the UK Energy Networks Association)
PV	Photovoltaic, a form of solar energy
RMU	Ring main unit
SEL	Sark Electricity Limited
SOP	Suspension of Operational Practice

13.2 Operational Risks

Risk	Description	Probability (1-5)	Impact (1-5)	Risk (1-25)	Mitigation	Timescale/ Accountability
Loss of skilled staff to operate power station and distribution system.	The Sark power system operates largely in the absence of any operational procedures, accurate operational diagrams or safety systems. The distribution network information, that should be formally recorded, appears to be entirely in the heads of two very experienced staff, who have both worked in SEL for many years and effectively built the underground network mirroring the previous overhead network. This is a significant issue, any well-trained operator brought in to the island to take over is likely to find the network unsafe to operate without basic network information. One member of staff is already at an age where he could retire immediately. The second is very close. The succession plan does not appear to be robust. If both left or were absent at the same time the network could not be safely operated, nor an incident dealt with.	**4**	**5**	**20**	Develop basic operational policies, procedures, safety rules. Develop an accurate high voltage operating diagram. Assess the suitability of the existing 'junior' member of the team to take on the responsibilities for a high voltage network. (Within 12 months)	12 months / SEL Management

Risk	Description	Probability (1-5)	Impact (1-5)	Risk (1-25)	Mitigation	Timescale/ Accountability
Catastrophic loss of power station, e.g. fire	Any major event in the power station would disconnect the whole island for repair time. There is a credible but low risk of a total loss of the power station, the impact of which would be loss of electricity supplies to the whole island for repair time, which could be significant is spares or have to be imported or rebuilds considered.	**1**	**5**	**5**	With a single site the only realistic mitigation for an extended loss of the site is to have emergency contracts in place for temporary mobile generation to be deployed around the island. The probability of an event is low and the mitigation costs can be relatively high. At the very least a contingency plan needs to be in place.	3 months / network owner
Failure of a second generator	The failure of a second generator is a realistic possibility. The immediate impact would be low as there would still be two generators left in service and with current levels of demand a single generator can maintain supplies for most of the day, with the second cutting n when needed. Normal system security standards	**3**	**1**	**3**	The contingency plan referred to above would cover this eventuality.	3 months / network owner

Risk	Description	Probability (1-5)	Impact (1-5)	Risk (1-25)	Mitigation	Timescale/ Accountability
Operational Incident injuring a member of staff	The operating regime in the company Is not conducive to safe operations. The lack of a network operating diagram, the absence of locks on switches and the open nature of the substations leaves questions over the operational integrity of the business. The probability of a serious electrical incident on the network has been given the relatively low value due to the very low short circuit level on the network (elsewhere it would have been 4/5). However, the operating positions and the egress routes at the power station and substations still leave cause for concern.	**2**	**4**	**8**	Formalise a network operating diagram, fit locks on switches, clear egress routs and remove trip hazards. Obtain full information on switchgear types installed from ENA NEDeRS system. Consider dead operation only restriction on high voltage switchgear until inspections are carried out.	1 month / network owner
Injury to a member of public resulting from failure of or interference with a substation	High voltage substations and the main power station switchboard have no barrier to prevent unauthorised staff from entry, and the switches have no locks to prevent operation. Potential injury to a member of public simply by being in proximity in the event of a failure is also a credible risk.	2	5	**10**	Take necessary measures to prevent unauthorised access and operation of switches. Install fences / barriers to protect against injury to member of public / small children playing in the area	3 months / network owner

Table 4: Sark Electricity Supply Risk Register

13.3 Distribution Options Bill of Quantities

Bill of Quantities		Like for Like Replacement		HV Only Replacement		Complete Replacement to new design		Replace with LV Only Network	
Underground Cable	**Price (£)**	**Quantity**	**Total (£)**	**Quantity**	**Total (£)**	**Quantity**	**Total (£)**	**Quantity**	**Total (£)**
11kV 95mm² cable (km)	26,500	11	291,500	11	291,500	7	185,500		0
LV cables from existing S/S positions to services (km)	15,600	10.5	63,800	0	0	10.5	163,800	22	343,200
LV cable hubs to existing S/S positions (km)	15,600	0		0	0	5	78,000	0	0
Three phase service cable (km)	4,000	3	12,000	0	0	3	12,000	3	12,000
Single phase service cable (km)	2,000	12	24,000	0	0	12	24,000	12	24,000
70mm Earthing cable (km)	2,000	15	30,000	0	0	15	30,000	15	30,000
Freight	10%	10%	52,130		29,150		49,330		40,920
Sub Total			573,430	0	320,650		542,630		450,120
Substations									
Ring main Units Including Generation switchgear	15,000	29	35,000	29	435,000	9	135,000		0
315kVA pad mount transformers	12,173	10	121,730	10	121,730	6	73,038		0
100kVA pad mount transformers	9,200	16	147,200	16	147,200	2	18,400		0
LV pillars	5,000	0	0	0	0	20	100,000	26	130,000
Freight	10%		70,393		70,393		32,644		13,000
Sub Total			774,323	0	774,323		359,082		143,000

Bill of Quantities		Like for Like Replacement		HV Only Replacement		Complete Replacement to new design		Replace with LV Only Network	
Service Terminations									
Three phase service terminations 100A	70	95	6,650	0	0	95	6,650	95	6,650
Single phase service terminations 100A	65	401	26,065	0	0	401	26,065	401	26,065
Three phase meters	240	95	22,800	0	0	95	22,800	95	22,800
Single phase meters	160	401	64,160	0	0	401	64,160	401	64,160
Single Phase Earth Leakage Trips	100	401	40,100	0	0	401	40,100	401	40,100
Three Phase Earth Leakage Trips	200	95	19,000	0	0	95	19,000	95	19,000
Freight	10%		17,878		0		17,878		17,878
Sub Total			196,653		0		196,653		196,653
Miscellaneous									
11kV joints (no.)	300	88	26,400	88	26,400	30	9,000	0	0
11kV Cable Terminations (no.)	300	116	34,800	116	34,800	36	10,800	0	0
LV joints (no.)	300	50	15,000	0	0	50	15,000	50	15,000
LV Pillar Cable terminations (no.)	300	52	15,600	0	0	52	15,600	52	15,600
Earth pins (no.)	5	100	500	50	250	100	500	100	500
LV Fuses * 52 ways (no.)	27	156	4,212	0	0	156	4,212	156	4,212
125mm Internal/150mm Ridgiducts (units)	40	1167	46,667	1167	46,667	1167	46,667	0	0
Cable Warning Tape £20 per 365m (no.)	20	55	1,100	20	400	55	1,100	35	700
Freight	10%		14,428		0		10,288		3,601
Sub Total			158,707	0	108,517		113,167		39,613

Bill of Quantities		Like for Like Replacement		HV Only Replacement		Complete Replacement to new design		Replace with LV Only Network	
Civil Works									
Bases for 11kV Switchgear	4,000	29	116,000	29	116,000	8	32,000	0	0
Pad Mount Base	4,000	29	116,000	29	116,000	6	24,000	0	0
LV Pillar Bases	4,000	0	0	0	0	20	80,000	0	0
HV Cable laying (estimated 50m/day, 2 men +digger, island resource) (days)	672	220	147,840	220	147,840	140	94,080	0	0
LV Cable laying (estimated 50m/day, 2 men +digger, island resource) (days)	672	210	141,120	0	0	610	409,920	440	295,680
HV jointing (days)	600	87	52,200	87	52,200	59	35,400	0	0
LV Cable routes jointing from Hubs to LV Pillars (days)	600	0	0	0	0	100	60000	0	0
LV Cable routes jointing from pillar to Services (days)	600	200	120,000	0	0	200	120000	200	120000
Sub Total			693,160	0	432,040		855,400		415,680
Project Management			160,000	0	160,000		160,000		150,000
Total			2,556,272	0	1,795,530		2,226,931		1,245,066
Contingency	10%		255,627		179,553		222,693		124,507
	Total		**2,811,899**		**1,975,083**		**2,449,624**		**1,369,572**

13.4 Sensitivity Analysis

Cost Comparison - Delivery of 1.4 GWh per annum @ 5% cost of capital, diesel at 80pence per litre (Base Case)		100% Diesel (current)	Mix 1 Wind, Solar Diesel standby	Mix 2 Wind, Solar Diesel standby	Mix 3 Wind, Solar, Storage, Diesel standby	Mix 4 Wind, Solar, Storage, Diesel standby	100% renewable, Wind, Solar, Storage (updated Narec)	100% Wind & Storage	100% Solar & Storage
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 5% cost of capital		57.9	42.4	43.2	45.0	48.7	200.2	75.5	82.8
Annual cost to deliver 1.4GWh per annum assuming 25-year loan at 5% (£)	Fuel	341,895	-	-	-	-	-	-	-
	Interest (year 1)	143,051	215,802	223,667	239,397	268,437	1,502,637	484,059	552,878
	Repayment of principal (year 1)	59,945	90,432	93,728	100,319	112,488	629,679	202,845	231,683
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**810,888**	**592,931**	**605,491**	**630,413**	**681,422**	**2,803,313**	**1,057,180**	**1,159,338**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**(25,383)**	**164,859**	**149,302**	**118,388**	**56,316**	**(2,535,744)**	**(401,583)**	**(529,957)**
Cash flow (year 1 £) assuming tariff of 60p/kWh		**29,112**	**247,069**	**234,509**	**209,587**	**158,578**	**(1,963,313)**	**(217,180)**	**(319,338)**
NPV over 25 years at 5% (£s)		**410,308**	**3,482,184**	**3,305,152**	**2,953,908**	**2,234,987**	**(27,670,819)**	**(3,060,928)**	**(4,500,726)**
Cost per kWh to deliver 1.4GWh per annum assuming 25-year loan at 5% (£000s) (p/kWh)	Fuel	24.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	10.2	15.4	16.0	17.1	19.2	107.3	34.6	39.5
	Repayment of principal (year 1)	4.3	6.5	6.7	7.2	8.0	45.0	14.5	16.5
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**57.9**	**42.4**	**43.2**	**45.0**	**48.7**	**200.2**	**75.5**	**82.8**
Margin at tariff of 60p /kWh		2.1	17.6	16.8	15.0	11.3	(140.2)	(15.5)	(22.8)

Table 5: Base Case Financial Summary

Cost Comparison - Delivery of 1.4 GWh per annum @ 6% cost of capital, diesel at 80pence per litre **(Increase in costs of capital of 1% from base case)**		**100% Diesel (current)**	**Mix 1 Wind, Solar Diesel standby**	**Mix 2 Wind, Solar Diesel standby**	**Mix 3 Wind, Solar, Storage, Diesel standby**	**Mix 4 Wind, Solar, Storage, Diesel standby**	**100% renewable, Wind, Solar, Storage (updated Narec)**	**100% Wind & Storage**	**100% Solar & Storage**
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 6% cost of capital		59.4	44.6	45.6	47.5	51.5	215.9	80.5	88.6
Annual cost to deliver 1.4GWh per annum assuming 25-year loan at 6% (£s)	Fuel	341,895	-	-	-	-	-	-	-
	Interest (year 1)	171,661	258,963	268,401	287,277	322,125	1,803,165	580,871	663,454
	Repayment of principal (year 1)	52,147	78,667	81,534	87,269	97,855	547,763	176,456	201,543
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**831,699**	**624,327**	**638,032**	**665,242**	**720,476**	**3,021,924**	**1,127,604**	**1,239,773**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**(53,993)**	**121,699**	**104,569**	**70,509**	**2,629**	**(2,836,271)**	**(498,395)**	**(640,533)**
Cash flow (year 1 £s) assuming tariff of 60p/kWh		**8,301**	**215,673**	**201,968**	**174,758**	**119,524**	**(2,181,924)**	**(287,604)**	**(399,773)**
NPV over 25 years at 5% (£s)		**116,987**	**3,039,689**	**2,846,531**	**2,463,033**	**1,684,567**	**(30,751,918)**	**(4,053,473)**	**(5,634,381)**
Cost per kWh to deliver 1.4GWh per annum assuming 25-year loan at 6% (£000s) (p/kWh)	Fuel	24.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	12.3	18.5	19.2	20.5	23.0	128.8	41.5	47.4
	Repayment of principal (year 1)	3.7	5.6	5.8	6.2	7.0	39.1	12.6	14.4
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**59.4**	**44.6**	**45.6**	**47.5**	**51.5**	**215.9**	**80.5**	**88.6**
Margin at tariff of 60p /kWh		0.6	15.4	14.4	12.5	8.5	(155.9)	(20.5)	(28.6)

Table 6: Financial Summary with 1% increase in cost of capital from base case

Cost Comparison - Delivery of 1.4 GWh per annum @ 4% cost of capital, diesel at 80pence per litre (Reduction in costs of capital of 1% from base case)		100% Diesel (current)	Mix 1 Wind, Solar Diesel standby	Mix 2 Wind, Solar Diesel standby	Mix 3 Wind, Solar, Storage, Diesel standby	Mix 4 Wind, Solar, Storage, Diesel standby	100% renewable, Wind, Solar, Storage (updated Narec)	100% Wind & Storage	100% Solar & Storage
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 4% cost of capital		56.5	40.2	41.0	42.7	46.0	185.3	70.7	77.3
Annual cost to deliver 1.4GWh per annum assuming 25 year loan at 4% (£s)	Fuel	341,895	-	-	-	-	-	-	-
	Interest (year 1)	114,441	172,642	178,934	191,518	214,750	1,202,110	387,248	442,303
	Repayment of principal (year 1)	68,699	103,637	107,414	114,968	128,914	721,625	232,464	265,514
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**791,031**	**562,975**	**574,444**	**597,182**	**644,160**	**2,594,732**	**989,988**	**1,082,593**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**3,227**	**208,020**	**194,036**	**166,268**	**110,004**	**(2,235,216)**	**(304,771)**	**(419,381)**
Cash flow (year 1 £s)assuming tariff of 60p/kWh		**48,969**	**277,025**	**265,556**	**242,818**	**195,840**	**(1,754,732)**	**(149,988)**	**(242,593)**
NPV over 25 years at 5% (£s)		**690,170**	**3,904,375**	**3,742,730**	**3,422,260**	**2,760,153**	**(24,731,091)**	**(2,113,925)**	**(3,419,087)**
Cost per kWh to deliver 1.4GWh per annum assuming 25 year loan at 4% (£000s) (p/kWh)	Fuel	24.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	8.2	12.3	12.8	13.7	15.3	85.9	27.7	31.6
	Repayment of principal (year 1)	4.9	7.4	7.7	8.2	9.2	51.5	16.6	19.0
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**56.5**	**40.2**	**41.0**	**42.7**	**46.0**	**185.3**	**70.7**	**77.3**
Margin at tariff of 60p /kWh		3.5	19.8	19.0	17.3	14.0	(125.3)	(10.7)	(17.3)

Table 7:Financial Summary with1% decrease in cost of capital from base case

Cost Comparison - Delivery of 1.5 GWh per annum @ 4% cost of capital, diesel at 80pence per litre Demand growth of 0.1GWh on base case)		100% Diesel (current)	Mix 1 Wind, Solar Diesel standby	Mix 2 Wind, Solar Diesel standby	Mix 3 Wind, Solar, Storage, Diesel standby	Mix 4 Wind, Solar, Storage, Diesel standby	100% renewable, Wind, Solar, Storage (updated Narec)	100% Wind & Storage	100% Solar & Storage
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 5% cost of capital		55.8	39.6	40.4	42.1	45.5	187.0	70.5	77.4
Annual cost to deliver 1.5GWh per annum assuming 25-year loan at 5% (£s)	Fuel	341,895	-	-	-	-	-	-	-
	Interest (year 1)	133,514	201,416	208,756	223,438	250,542	1,402,462	451,789	516,020
	Repayment of principal (year 1)	55,949	84,403	87,479	93,631	104,989	587,700	189,322	216,238
	Operating costs	249,196	268,516	269,823	272,250	281,396	627,196	346,524	350,724
	Total annual cost	**780,555**	**554,335**	**566,059**	**589,319**	**636,927**	**2,617,358**	**987,635**	**1,082,982**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**9,196**	**223,859**	**208,302**	**177,388**	**115,316**	**(2,476,744)**	**(342,583)**	**(470,957)**
Cash flow (year 1 £s) assuming tariff of 60p/kWh		**63,691**	**306,069**	**293,509**	**268,587**	**217,578**	**(1,904,313)**	**(158,180)**	**(260,338)**
NPV over 25 years at 5% (£s)		**897,662**	**4,313,726**	**4,136,695**	**3,785,451**	**3,066,530**	**(26,839,277)**	**(2,229,386)**	**(3,669,183)**
Cost per kWh to deliver 1.5GWh per annum assuming 25-year loan at 5% (£000s) (p/kWh)	Fuel	24.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	9.5	14.4	14.9	16.0	17.9	100.2	32.3	36.9
	Repayment of principal (year 1)	4.0	6.0	6.2	6.7	7.5	42.0	13.5	15.4
	Operating costs	17.8	19.2	19.3	19.4	20.1	44.8	24.8	25.1
	Total annual cost	**55.8**	**39.6**	**40.4**	**42.1**	**45.5**	**187.0**	**70.5**	**77.4**
Margin at tariff of 60p /kWh		4.2	20.4	19.6	17.9	14.5	(127.0)	(10.5)	(17.4)

Table 8: Financial Summary with 0.1GWh increase in consumption from base case

Cost Comparison - Delivery of 1.4GWh per annum @ 5% cost of capital, diesel at 85pence per litre **(Increase of 5p per litre on base case)**		**100% Diesel (current)**	**Mix 1 Wind, Solar Diesel standby**	**Mix 2 Wind, Solar Diesel standby**	**Mix 3 Wind, Solar, Storage, Diesel standby**	**Mix 4 Wind, Solar, Storage, Diesel standby**	**100% renewable, Wind, Solar, Storage (updated Narec)**	**100% Wind & Storage**	**100% Solar & Storage**
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 5% cost of capital		59.3	42.4	43.2	45.0	48.7	200.2	75.5	82.8
Annual cost to deliver 1.4GWh per annum assuming 25 year loan at 5% (£s)	Fuel	361,544	-	-	-	-	-	-	-
	Interest (year 1)	143,051	215,802	223,667	239,397	268,437	1,502,637	484,059	552,878
	Repayment of principal (year 1)	59,945	90,432	93,728	100,319	112,488	629,679	202,845	231,683
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**830,537**	**592,931**	**605,491**	**630,413**	**681,422**	**2,803,313**	**1,057,180**	**1,159,338**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**(45,032)**	**164,859**	**149,302**	**118,388**	**56,316**	**(2,535,744)**	**(401,583)**	**(529,957)**
Cash flow (year 1 £s)assuming tariff of 60p/kWh		**9,463**	**247,069**	**234,509**	**209,587**	**158,578**	**(1,963,313)**	**(217,180)**	**(319,338)**
NPV over 25 years at 5% (£s)		**133,374**	**3,482,184**	**3,305,152**	**2,953,908**	**2,234,987**	**(27,670,819)**	**(3,060,928)**	**(4,500,726)**
Cost per kWh to deliver 1.4GWh per annum assuming 25 year loan at 5% (£000s) (p/kWh)	Fuel	25.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	10.2	15.4	16.0	17.1	19.2	107.3	34.6	39.5
	Repayment of principal (year 1)	4.3	6.5	6.7	7.2	8.0	45.0	14.5	16.5
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**59.3**	**42.4**	**43.2**	**45.0**	**48.7**	**200.2**	**75.5**	**82.8**
Margin at tariff of 60p /kWh		0.7	17.6	16.8	15.0	11.3	(140.2)	(15.5)	(22.8)

Table 9: Financial Summary with diesel increased in price by 5 pence /litre from base case

Cost Comparison - Delivery of 1.4GWh per annum @ 5% cost of capital, diesel at 75 pence per litre **(Decrease of 5p per litre on base case)**		**100% Diesel (current)**	**Mix 1 Wind, Solar Diesel standby**	**Mix 2 Wind, Solar Diesel standby**	**Mix 3 Wind, Solar, Storage, Diesel standby**	**Mix 4 Wind, Solar, Storage, Diesel standby**	**100% renewable, Wind, Solar, Storage (updated Narec)**	**100% Wind & Storage**	**100% Solar & Storage**
Estimated total capital cost (£)		**2,861,024**	**4,316,049**	**4,473,349**	**4,787,949**	**5,368,749**	**30,052,749**	**9,681,189**	**11,057,564**
tariff required at 5% cost of capital		56.5	42.4	43.2	45.0	48.7	200.2	75.5	82.8
Annual cost to deliver 1.4GWh per annum assuming 25 year loan at 5% (£s)	Fuel	322,246	-	-	-	-	-	-	-
	Interest (year 1)	143,051	215,802	223,667	239,397	268,437	1,502,637	484,059	552,878
	Repayment of principal (year 1)	59,945	90,432	93,728	100,319	112,488	629,679	202,845	231,683
	Operating costs	265,996	286,696	288,096	290,696	300,496	670,996	370,276	374,776
	Total annual cost	**791,239**	**592,931**	**605,491**	**630,413**	**681,422**	**2,803,313**	**1,057,180**	**1,159,338**
Net profit before tax (year 1 £s) assuming tariff of 60p/kWh		**(5,734)**	**164,859**	**149,302**	**118,388**	**56,316**	**(2,535,744)**	**(401,583)**	**(529,957)**
Cash flow (year 1 £s)assuming tariff of 60p/kWh		**48,761**	**247,069**	**234,509**	**209,587**	**158,578**	**(1,963,313)**	**(217,180)**	**(319,338)**
NPV over 25 years at 5% (£s)		**687,241**	**3,482,184**	**3,305,152**	**2,953,908**	**2,234,987**	**(27,670,819)**	**(3,060,928)**	**(4,500,726)**
Cost per kWh to deliver 1.4GWh per annum assuming 25 year loan at 5% (£000s) (p/kWh)	Fuel	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Interest (year 1)	10.2	15.4	16.0	17.1	19.2	107.3	34.6	39.5
	Repayment of principal (year 1)	4.3	6.5	6.7	7.2	8.0	45.0	14.5	16.5
	Operating costs	19.0	20.5	20.6	20.8	21.5	47.9	26.4	26.8
	Total annual cost	**56.5**	**42.4**	**43.2**	**45.0**	**48.7**	**200.2**	**75.5**	**82.8**
Margin at tariff of 60p /kWh		3.5	17.6	16.8	15.0	11.3	(140.2)	(15.5)	(22.8)

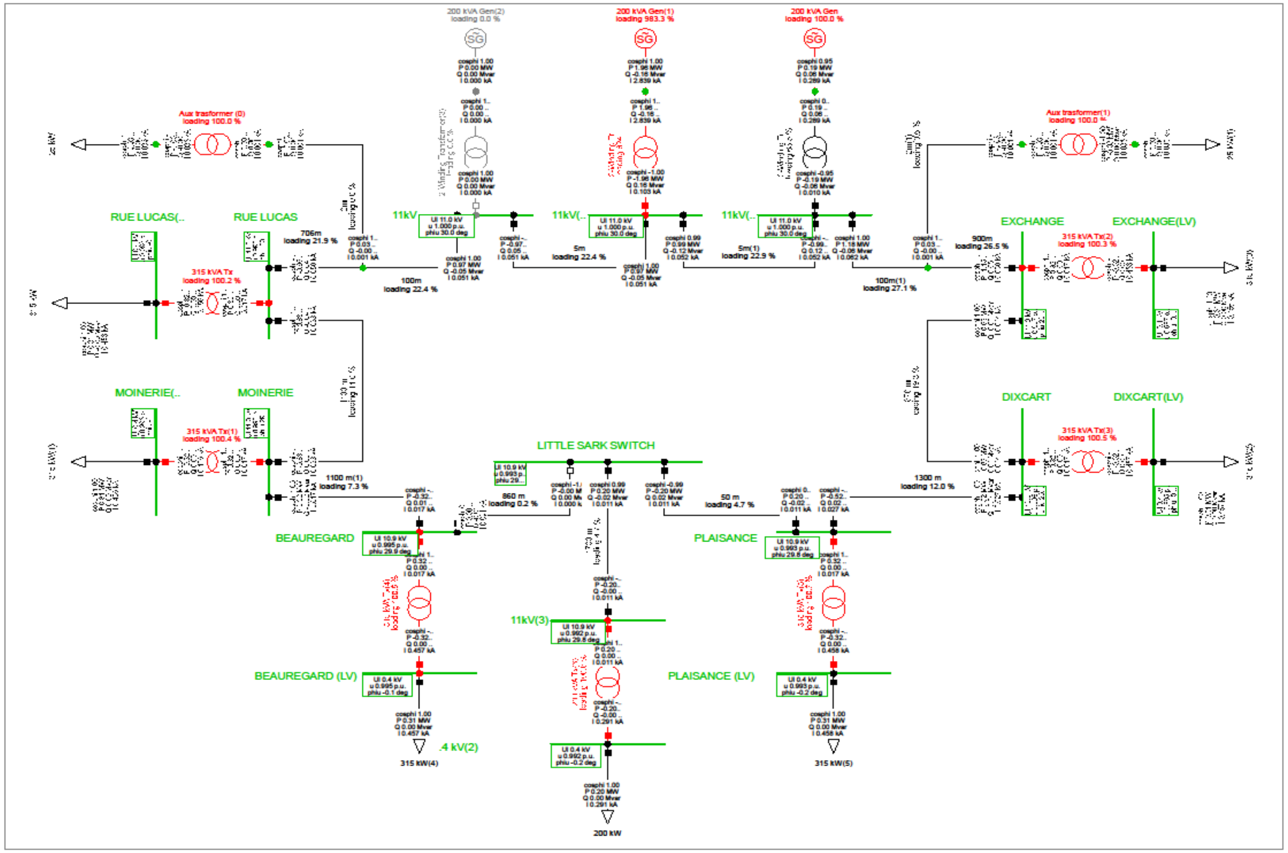
Table 10: Financial Summary with diesel decreased in price by 5 pence /litre from base case

	Base Case	I% increase on cost of capital	I% decrease on cost of capital	5p/litre increase on diesel	5p/litre decrease on diesel	Demand Growth of 0.1GWh (7%)
Minimum tariff	42.4	44.6	40.2	42.4	42.4	39.6
				Diesel fuel not used in best case scenario with optimum renewable mix. This will be weather pattern dependent		

Table 11: Summary of sensitivity analysis scenarios

13.5 DigSilent Network Model Output

This is a copy of the output from DigSilent model for the proposed 11kV network.

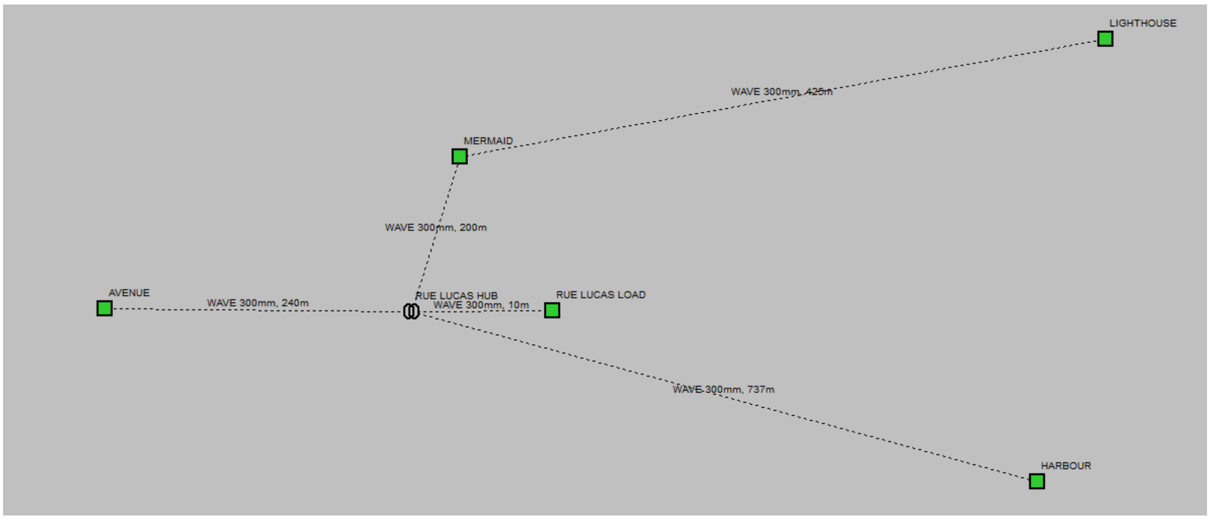


13.6 Low voltage network outputs from WinDebut

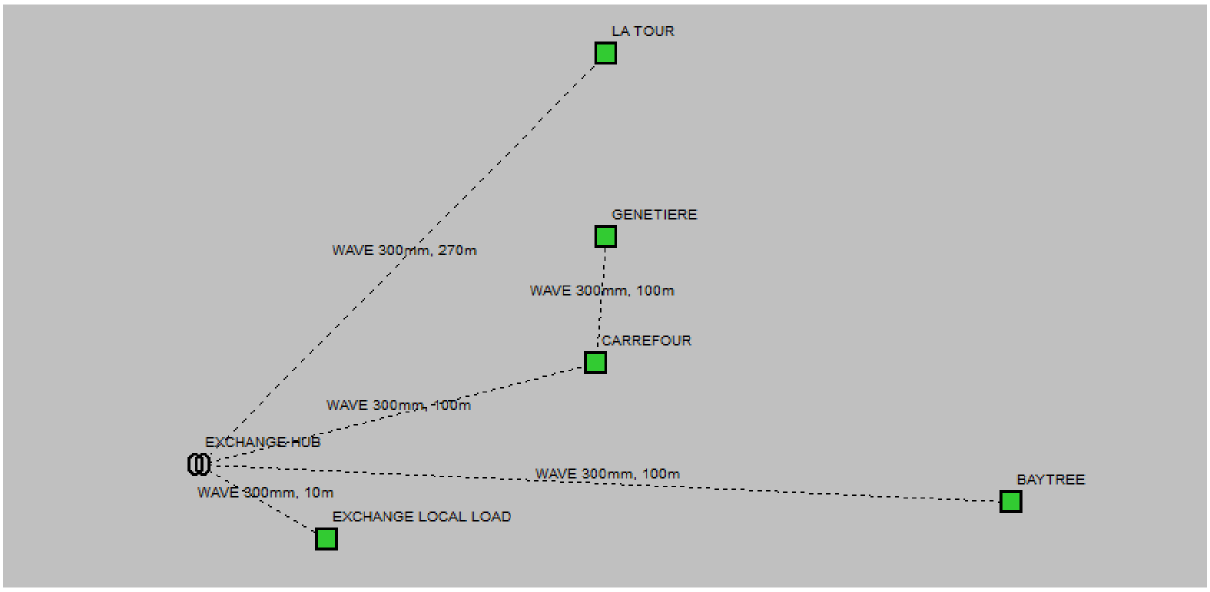
These output diagrams from WinDebut illustrate the low voltage network configurations that have been modelled, for the proposed network all of which show acceptable results in terms of cable ratings, voltage drop and earth loop impedance.

There is likely to be scope for using smaller cross section cables at lower costs when precise loadings are established.

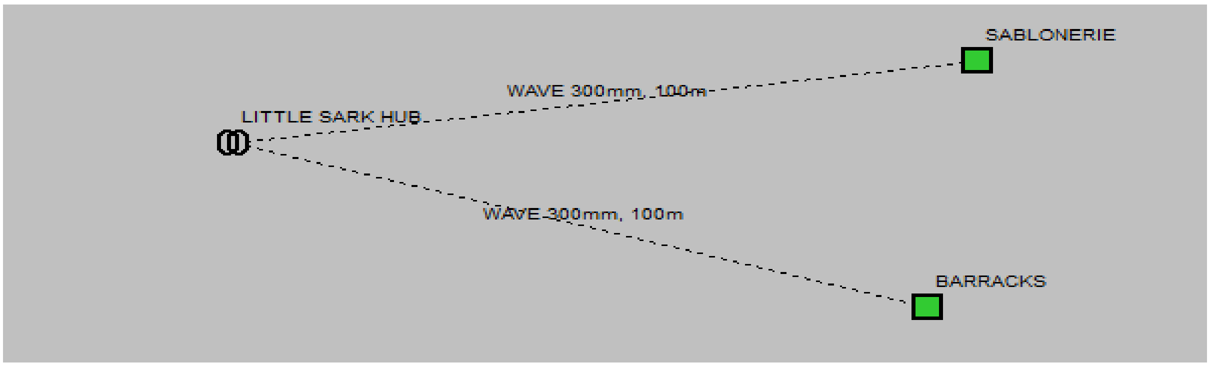
Rue Lucas Hub



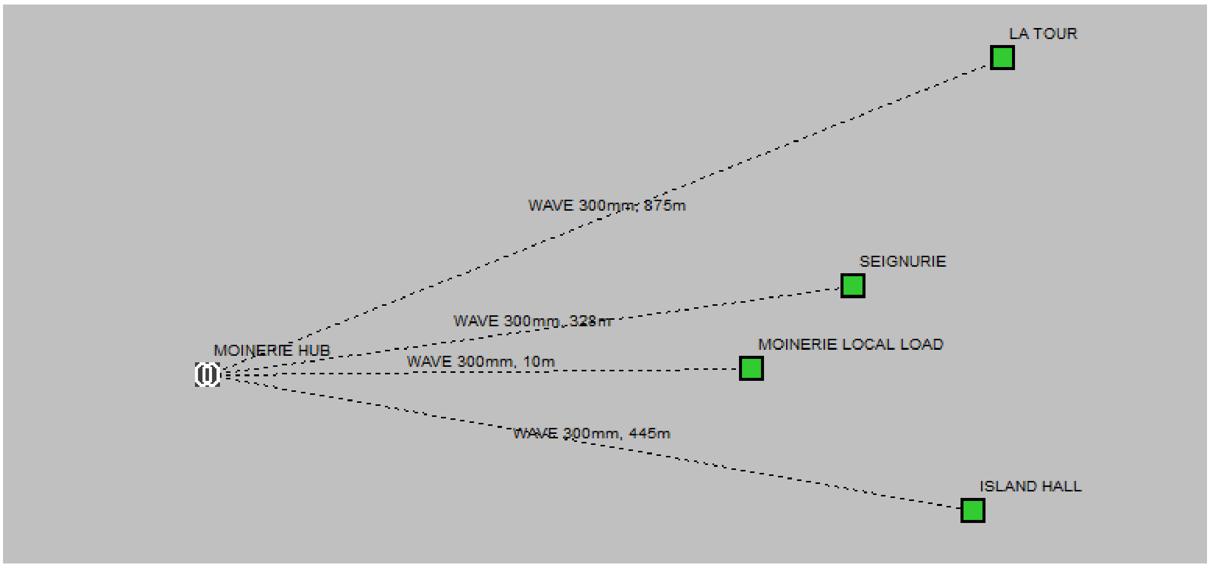
Exchange / Carrefour Hub



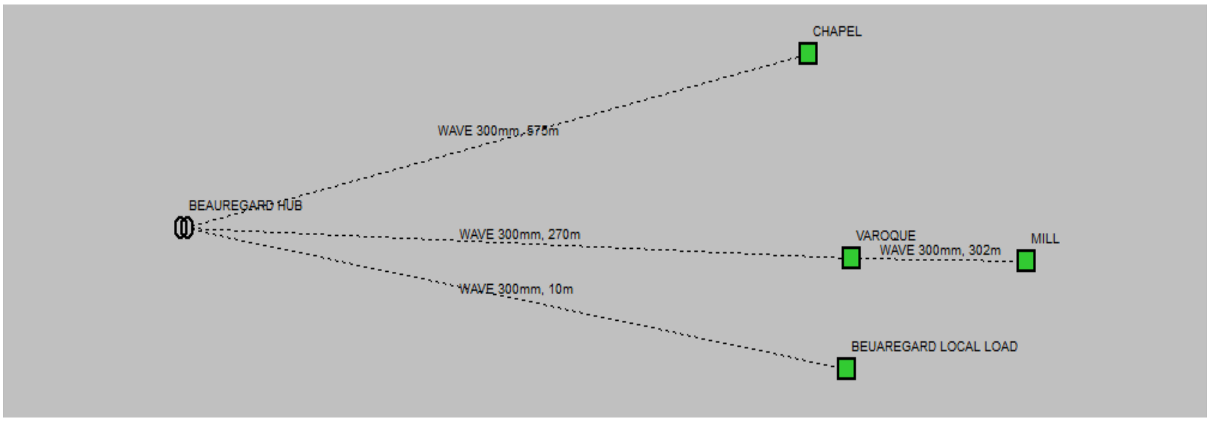
Little Sark Hub



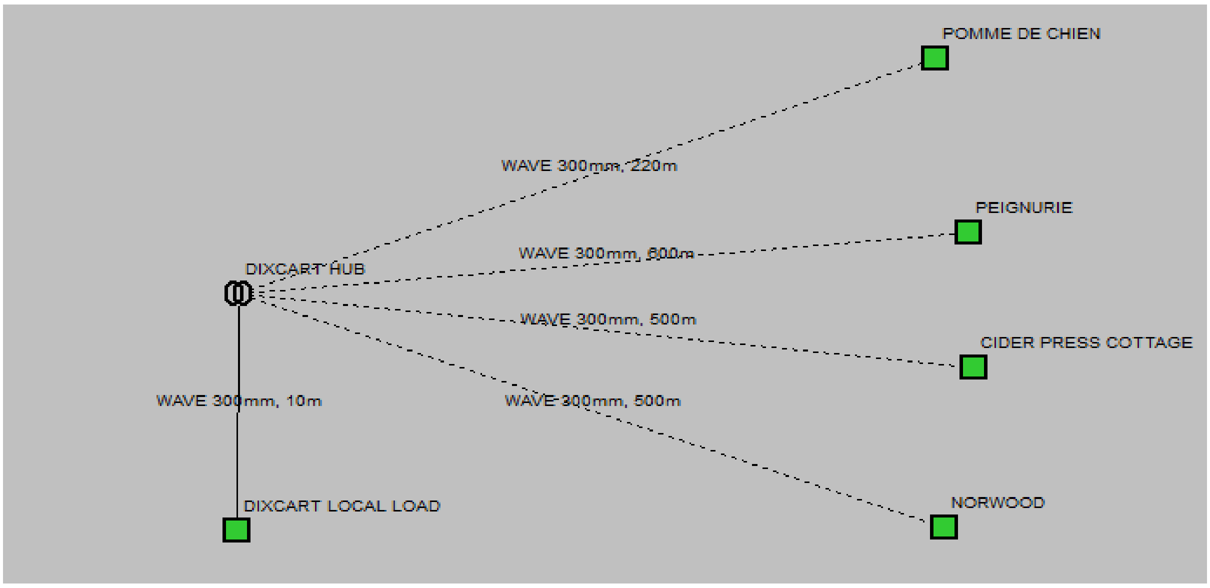
Moinerie/Seignurie Hub



Beauregard/Varoque Hub



Dixcart Hub



POMME DE CHIEN
WAVE 300mm, 220m
PEIGNURIE
WAVE 300mm, 600m
DIXCART HUB
WAVE 300mm, 500m
CIDER PRESS COTTAGE
WAVE 300mm, 10m
WAVE 300mm, 500m
NORWOOD
DIXCART LOCAL LOAD

13.7 High Level Programme of Works for Replacing the existing network

Month	1	2	3	4	5	6	7	8	9	10	11	12
Decision to Proceed												
Tendering and Appointment of Contractor(s)												
Allocation of Land for Generation and substations												
Contractor mobilisation												
Equipment order and Delivery												
Build and Commission Power Station												
Lay High voltage cables												
Lay low voltage cables												
Build and commission substations												
Lay services												
Changeover supplies												
Design, Build and commission renewable generation												

Table 12: High level programme of works