Guernsey Energy Analysis and Strategy Recommendations to 2050

in co-operation with the Guernsey Renewable Energy Team

RE | 2013

STATES OF GUERNSEY

UNIVERSITY OF EXETER

Guernsey Energy Analysis and Strategy Recommendations to 2050

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Report created for:

STATES OF GUERNSEY

Guernsey Renewable Energy Team

States of Guernsey

P.O. Box 459

Raymond Falla House

Long Rue

St. Martins

GY1 6AF

Report Created by:

RE | 2013

Renewable Energy Third Year Students

University of Exeter

Tremough Campus

Treliever Road

Penryn

Cornwall

England

TR10 9EZ

Executive Summary

Guernsey's current energy system is wholly reliant on imports, lacking the stability and price-security that indigenous solutions can bring. However, the island boasts an impressive range of renewable energy resources and global experience is driving down capital costs such that many technologies now economically viable and others are expected to be in the coming decade or so. The economic, social and environmental benefits of renewable energy sources mean that these should take pride of place in Guernsey's future energy strategy and this report outlines one possible pathway to 2050.

One of Guernsey's most impressive renewable energy resources is tidal stream and, whilst currently relatively expensive, capital costs decreasing at a rate that indicates the levelised cost of electricity will become competitive around 2020. Guernsey also has areas with no slack water, so as devices with the ability to 'yaw'[1] are developed a constant power output is possible. One reason for Guernsey's superb tidal stream resource is the fact that it also benefits from one of the largest tidal ranges in the world. However, analysis has shown that no tidal range projects are economically viable and any demonstration projects are unlikely to see much public support.

Offshore wind is the other marine energy technology that is rapidly gaining experience and is likely to approach grid parity in the short term. A number of previous studies have identified 4 key sites, but this report finds that interference with radar monitoring is likely to pose a problem unless system upgrades are implemented. Given this, two new sites located in Sark and Alderney waters are highlighted as feasible. Additional wind data is analysed and confirms the excellent resource, but it is suggested that an offshore meteorological mast is deployed to reduce investor risk as the capital required is estimated at £70m and £250m for 30MW and 105MW projects, respectively. Funding is most likely to be equity-based by equipment manufacturers as research shows that debt funding for construction is currently not possible.

An onshore wind project could be used to improve public perception to aid investment in offshore wind. However, constraint mapping analysis shows that the high population density leaves little scope for significant capacity. A 225kW turbine at Chouet is the most attractive option with a small positive return on the required £1m investment and fairly low visual impact. However, strong opposition from certain demographics is expected to hinder development.

Solar photovoltaics on residential properties could make a meaningful contribution to annual energy demand and developing an industry to reduce installation costs could dramatically improve

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[1] Rotate around a vertical axis to optimise energy extraction from any flow in a horizontal direction

economic viability whilst generating jobs. A 500kW development at the Airport is currently financially viable, with a net present value of £630,000 on an investment of £680,000, and should be pursued now. Commercial-scale PV projects are also economically viable now but are less financially attractive. A change in planning legislation would help drive investment at a variety of scales.

Heating and energy efficiency solutions currently represent the most sensible and attractive use of capital funds. Awareness of the scale of the challenge is currently lacking but this could be resolved through developing a definition for fuel poverty and rating the energy performance of housing. Following this with an ‘energy services company’ to incentivise action would be a strong move towards reducing energy demand and increasing warmth in homes at little cost to the consumer. Other island resources such as waste biomass and geothermal are highlighted and it is recommended that the State takes stronger action in public procurement; leading by example.

Guernsey is commonly cited as being a perfect place for electric vehicles but uptake thus far is extremely limited. This report therefore highlights drivers for change and suggests a range of policy instruments that could be used to encourage high-efficiency vehicles and increased penetration of electric vehicles. Highlights include a fuel-credit trading scheme and priority parking for electric vehicles.

Energy storage is a critical enabling technology for large proportions of variable renewable energy sources. Whilst the necessity is reduced by stronger interconnection links, this does reduce energy security slightly. The feasibility of pumped hydropower is outlined with three possible sites identified, though social and environmental impacts are not investigated in depth. A review is also conducted for other storage solutions; such as compressed air, cryogenic, flywheels, electric car batteries, vanadium redox flow batteries and hydrogen technology.

It is important that any of the developments showcased are conducted with knowledge and appropriate consideration of the environmental impacts; be these ecological, visual, hydrodynamic or a variety of other key receptors. Scoping requirements for marine and onshore projects are explained and a ‘terms of reference’ is included for tidal, offshore wind, onshore wind, commercial solar photovoltaics and pumped hydropower.

For most of the projects considered, a clear and supportive regulatory and legislative environment is crucial. A focus by the States on the development of marine licensing and the draft Ordnance is a sensible step towards tidal and offshore wind deployment but lessons should be taken from failures and successes of other jurisdictions. Research has also shown that it is possible to benefit from support mechanisms in other countries if a joint financing arrangement is reached with investors in that country with the UK identified as the most attractive candidate. The anticipated ‘energy services company’ arm of Guernsey Electricity Limited is also considered in more detail.

Economic modelling of large-scale energy development options is carried out using discounted cash flow analyses and considering the cost of capital in various funding scenarios. The type of displaced generation is highly sensitive when calculating return on investment so this variable plays a key role in the analysis; with displacement of diesel being highly favourable.

An energy strategy is essential to a smooth and low cost energy transition. Island case studies of Samsø and Jersey are included as examples of stunning success and the strategy of a similar island in direct competition with Guernsey, respectively. A brief outline of the expected impacts of shale gas on Guernsey’s energy options is included, with the conclusion that any deviation from the natural gas market development is likely to be negligible. Finally, a possible pathway for energy strategy to 2050 is outlined based on the conclusions from each section, illustrating that Guernsey has the potential to develop a brilliantly diverse and secure energy system.

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Common Abbreviations

Abbreviations	Meaning
AD	Anaerobic Digestion
a.g.l.	above ground level
AS	Ancilliary Services
ASHP	Air Source Heat Pump
a.s.l.	above sea level
BEV	Battery Electric Vehicle
BoS	Balance of Systems
CAES	Compressed Air Energy Storage
CAPEX	Capital Expenditure
CES	Cryogenic Energy Storage
CfD	Contracts for Difference
CIEG	Channel Islands Electricity Grid
CO_2	Carbon Dioxide
CRC	Carbon Reduction Commitment
CV	Commercial Vehicle
CWI	Cavity Wall Insulation
CZ	Congestion Zoning
dB	decibel
DECC	Department of Energy and Climate Change
EAB	Eco-Active Business
EEA	European Economic Area
EfW	Energy from Waste
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EMEC	European Marine Energy Centre
EMS	Energy Management System
EPC	Energy Performance Certificate
ES	Energy Storage
ESCo	Energy Service Company
EU	European Union
EV	Electric Vehicle
FiT	Feed in Tariff
FRP	Fibreglass Reinforced Plastic
GBP	Great British Pounds
GDP	Gross Domestic Product
GEL	Guernsey Electricity Limited (find and replace all)
GHA	Guernsey Housing Association
GIB	Green Investment Bank
GIS	Geographical Information System
GSHP	Ground Source Heat Pump

GW	Giga Watt
HCT	Contractor on Guernsey
HGV	Heavy Goods Vehicle
IRR	Internal Rate of Return
JEL	Jersey Electricity Limited
JP	Joint Project
kg	kilogram
km	kilometre
kW	kilowatt
kWe	kilowatt electric
kWh	kilo Watt hour
kWp	kilowatt peak
LCOE	Levelised Cost Of Energy
LEZ	Low Emission Zone
LGV	Light Goods Vehicle
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
m	metres
MCAA	Marine and Coastal Access Act
MCT	Marine Current Turbine
MCZ	Marine Conservation Zone
Met	Meteorological
mm	millimetres
MMO	Marine Management Organization
MoU	Memorandum of Understanding
MS	Member States
MSA	Motor Sports Association
MV	Megavolt
MVA	Megavolt-ampere
MW	Megawatt
MWh	Megawatt hour
NPV	Net Present Value
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturers
OPEX	Operational Expenditure
PCS	Power Conversion System
PEM	Proton Exchange Membrane
PPA	Power Purchase Agreement
PV	Photovoltaics
RE	Renewable Energy
REA	Regional Environmental Assessment
RE 2012	University of Exeter Renewable Energy Graduates of 2012

RE 2013	University of Exeter Renewable Energy Graduates of 2013
RED	Renewable Energy Directive
RES-E	Renewable Energy Sources - Electricity
RET	Guernsey Renewable Energy Team
ROC	Renewable Obligation Certificate
rpm	Revolutions per minute
SCADA	Supervisory Control And Data Acquisition
SEV	Smart Electric Vehicle
SIP	Structurally Insulated Panels
SNCI	Site of Nature Conservation Interest
SoDAR	Sonic Detection and Ranging
STOR	Short-Term Operating Reserve
SWF	Sovereign Wealth Fund
SWI	Solid Wall Insulation
TER	Target Emissions Rate
TINA	Technology Innovation Needs Assessment
TNUoS	Transmission Network Use of System
UK	United Kingdom
UPS	Uninterrupted Power Supply
US / USA	United States / United States of America
V	Volt
VAr	Volt Amps reactive
VAWT	Vertical Axis Wind Turbine
VED	Vehicle Excise Duty
VMM	Virtual Met Mast
VRFB	Vanadium Redox Flow Batteries
V2G	Vehicle to Grid
ZTV	Zone of Theoretical Visibility

The University of Exeter RE 2013 Team

The University of Exeter Team is formed by group of 45 BSc Renewable Energy students and academics.

Order: Left-to-right

Front Row: Anthony Vickers, Thierry Reid, Adam Campkin, Paul Hardman, Emma Gerrard, Jie Tan, Beatriz Furtuna, Joanna Stavridi, Max Fenn, Joseph Moon, Lyndon Smith, Sebastien McClay, Andrew Foulkes, Graeme Steer, Matthew Fry

Second Row: Craig Siddons, Istvan Nagy, Henry Crone, Guilherme Schmitz, Daniel Sinclair, Charlie Dunn, Nathan Collins, Matthew Pitman, Chris Barrell, Katheryn Simpson, Narciso Lozano, Matthew Landick, Ryan Pascoe, Joshua Charnley, Robin Duval, David De Lisle*

Third Row: Al Brouard,* George King, Daniel McGarvie, Daniel Duncan, Marcus Lynch, Edward Schofield, Jessica Howell, Dr Ian Ashton, Mateusz Przelomski, William Sandall, Richard Baker, Charlie Baker, Christopher Smith, Dr. Justin Hinshelwood, Alec Mason, Dr. Lars Johanning, Shawn Brown, Peter Barnes,* Mat Desforges,* Dr. Adam Feldman

Not in the picture: Michael O’Brien, Gabriel Rowling, Mr. Martyn Haywood

*Not part of University of Exeter Team

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- Adam Feldman
- Ian Ashton
- Justin Hinshelwood
- Lars Johanning
- Martyn Haywood

The Guernsey Renewable Energy Team:

- Mat Desforges
- Peter Barnes

Key stakeholders:

- Richard Lord (Sustainable Guernsey)
- Steve Morris (Policy Council)
- Captain Peter Gill (Harbour Master)
- Claire Barrett (Planning and Environment Department)
- Colin Le Ray (Guernsey Airport)
- Damon Hackley (Policy Council)
- Jim Rowles (Planning and Environment Department)
- Keith Hounsell (Kesell Wind Turbines)
- Martin Crozier (Met Office)
- Peter Miller (Ernst & Young)
- Rupert Dorey (Chamber of Commerce)
- Stuart Blondel (Asset Development Management for Guernsey Electricity Ltd)
- Year 13 Geography students (Guernsey Grammar School)
- Anyone not on this list but who contributed to the study

1 Introduction

The current energy portfolio of Guernsey is extremely vulnerable to a range of uncontrollable factors. Almost all sources of electricity, heat and transport fuels are imported either as gas, oil or electricity through the interconnector to Jersey and France. Historical events such as the interconnector failing and spiking oil and gas prices illustrate the need for a diverse, low-cost and secure energy supply. This will only become more critical as oil and gas reserves decline in the coming decades with the strong likelihood of soaring energy prices.

Fortunately, Guernsey is blessed with a range of significant renewable energy resources and has a superb opportunity to implement the policies and infrastructure required to realise an independent, low-carbon and holistic energy future. This is not limited to surviving the impending energy and climate challenges; it is possible to turn these challenges into an opportunity for waste management and even Guernsey's economy as a whole.

This represents the ambition of both the Guernsey Government's Renewable Energy Team (RET) and the University of Exeter Renewable Energy 2013 graduates (RE 2013). The purpose of this report is to extend the research conducted and recommendations put forth by the University of Exeter Renewable Energy 2012 graduates (RE 2012).[2]

The scope of this report has been developed in collaboration with RET, who commissioned the study. Building on the main focus of the RE 2012 study, analysis of potential for offshore wind farms and tidal stream continues, with additional considerations of tidal barrage. Further to this, the feasibility of onshore renewable energy sources such as solar photovoltaics (PV), wind, biomass and waste are explored. Environmental impacts are inherent in most forms of renewable energy so it is important that the scope of environmental analysis is identified early.

Most renewable energy sources are variable, so export and storage options are also considered, with particular emphasis on how the shift to electrification of transport might be achieved. However, the best opportunities often arise from energy efficiency in combination with a shift in generation infrastructure.

A clear policy framework and long-term energy strategy is very important for investment, though both of these must be based on an economically viable pathway in order to minimise the cost of energy to the public and maintain a competitive economy on Guernsey.

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[2] (RE 2012, 2012)

2 Tidal

2.1 Opportunity

Guernsey has an excellent tidal resource in the ‘Big Russell’ and elsewhere in its territorial waters. It also has a tidal range of approximately 8m, which could possibly be exploited using tidal range devices. Furthermore, it may be possible to integrate tidal range technologies into sea defences.

RET has asked the University of Exeter to assess the potential of Guernsey’s tidal resources and investigate ways in which they can be exploited. At present, tidal stream devices are still very costly due to their technical immaturity. However there are tidal range projects, for example La Rance, which have been operating successfully for several decades and therefore tidal range, may be considered a more mature technology than tidal stream. RET has asked the tidal group to update them on tidal stream technology and to look into the feasibility of tidal range projects.

2.2 Hypothetical Tidal Projects

It is helpful to explain the main factors that determine the power output and profitability of a tidal barrage. In simple terms, the potential power output is determined by the flow rate. The flow rate is a function of the available surface area, the tidal range and the tidal period; the greater the potential volume, the greater the potential power output. The civil works represents the largest proportion of the total cost of a tidal barrage, therefore the shorter the length of the retaining structure compared to the available surface area, the more profitable the project will be. Suitable sites would be: a narrow deep fjord; a deep tidal river; an estuary. Sites would also require a large tidal range. The swimming pool and marina case studies were undertaken at the request of others. The hypothetical tidal range case studies at Havelet Bay and Cobo Bay were undertaken to demonstrate that, although it is possible to increase the available surface area of a given site, it is unlikely to be financially viable. Calculation methods may be found in the appendices.

2.2.1 Tidal Swimming Pools

It was suggested to the members of the Tidal Group that the tidal swimming pools at Havelet Bay may offer an opportunity to demonstrate the potential output available from a tidal barrage. A site inspection revealed: the ‘Men’s Pool’ is in a state of disrepair and neglect; the ‘Women’s Pool’ is used regularly and is a popular amenity; the ‘Children’s Pool’ is a shallow, three-sided construction.

Figure 1: Men’s Pool - Havelet Bay

A rough order calculation based on the approximate dimensions of the ‘Men’s Pool’ shown in figure 1 indicated a potential rated power of 2.2kW. An outlet of 250mm is assumed and based on the volume and resultant flow rate the pool would run dry in approximately one hour. The educational benefits of such a project are unlikely to justify the cost of repairing the pool structure and installing a turbine.

2.2.2 Victoria Marina

Following a specific request to do so, the potential output and possible revenue that could be generated by installing a tidal barrage device at Victoria Marina was investigated. For the purposes of the rough order calculation, it is assumed that the marina is unused during the winter months and that during this time a removable barrier will be installed on the sill. Generation would only occur when the barrier was in place i.e. for three months each year. The marina has an estimated surface area of 16,000m^2 and an average tidal range of 5m is assumed. The annual output was calculated to be 14MWh, which would provide annual revenues of approximately £650. This level of revenue is obviously not sufficient to warrant further investigation. It should be stated that it is undesirable to restrict the flow of the out-going tide anywhere within the port area as it serves to prevent siltation as seen in figure 2. Victoria Marina is within the St Peter Port harbour and any development there will have repercussions throughout the port area.

Figure 2: Victoria Marina - silt and debris at sill

2.2.3 Beaucette Marina

Beaucette Marina is converted from a disused quarry. There is a restaurant, amenities for visiting mariners and marine engineering facilities. For the purposes of the calculation it is assumed that the installation of a tidal barrage device would necessitate a change of use. This will allow the calculation to be based on year round uninterrupted generation. It should be noted that the calculation is for illustrative purposes only; it is not a proposal. The marina has an approximate surface area of 14,400m^2 and an average tidal range of around 6m. It is estimated that a tidal barrage device installed here would achieve an annual output of approximately 75MWh providing a corresponding revenue of £3400. The marina has a large number of berths, most of which were observed to be occupied at the time of the site visit. The annual mooring fees for a 20m vessel are £10,320 per year (@ £516/m)[3]. The potential revenue would not justify a change of use. If there was not a change of use it would be necessary to install lock gates rather than a barrier. The cost of lock gates is estimated to be £55,000; the cost of the civil works to accommodate them is likely to be several times this and a significant volume of stored energy would be lost each time they were opened. There would be substantial capital costs for the supply and installation of turbines and grid connection. Clearly, it is not possible to make a credible business case for either scenario.

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[3] (Beaucette Marina, 2013)

Beaucette Marina is shown in figure 3:

Figure 3: Beaucette Marina (left) and its entrance (right)

2.2.4 Havelet Bay and Cobo Bay

The Guernsey Renewable Energy Commission's own report states: "Whilst many of the bays and inlets around the island appear to have good tidal range, the small surface areas that could be enclosed by barrage limits make them unsuitable. The actual volumes contained could not generate enough electricity to justify the initial capital investment or environmental impact."[4] Although the bays and inlets may have small surface areas it may be possible to increase the area by incorporating a bay in a lagoon-type construction. This is likely to be cost prohibitive due to the unfavourable enclosing-wall length to enclosed area ratio. Rough order cost calculations and financial analysis were performed for two sites to demonstrate this.

The first of these is Havelet Bay. An area of 0.45km^2 with an enclosing-wall length of 2.8km is assumed (see figure 5). The construction cost metric is based on the Swansea Bay tidal lagoon project[5] with a cost of approximately £650m and a 9km enclosing-wall. This is equivalent to an approximate cost of £72.2m per kilometre wall length. This is taken in preference to a cost per megawatt installed capacity metric as the largest proportion of the total cost will be due to civil works. The total cost calculated for the hypothetical tidal range project at Havelet Bay is £202m. The potential revenue is estimated to be £105,000 per annum assuming a selling price of 4.5p/kWh. The hypothetical tidal project at Cobo Bay has a wall length of 10.5km enclosing an area of 8.1km^2 (see figure 4). Assuming the same cost metric and selling price, the project would cost £758m and generate estimated revenue of £1.9m per annum.

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[4] (Halcrow Group Ltd, 2011)

[5] (Swansea Bay, 2013)

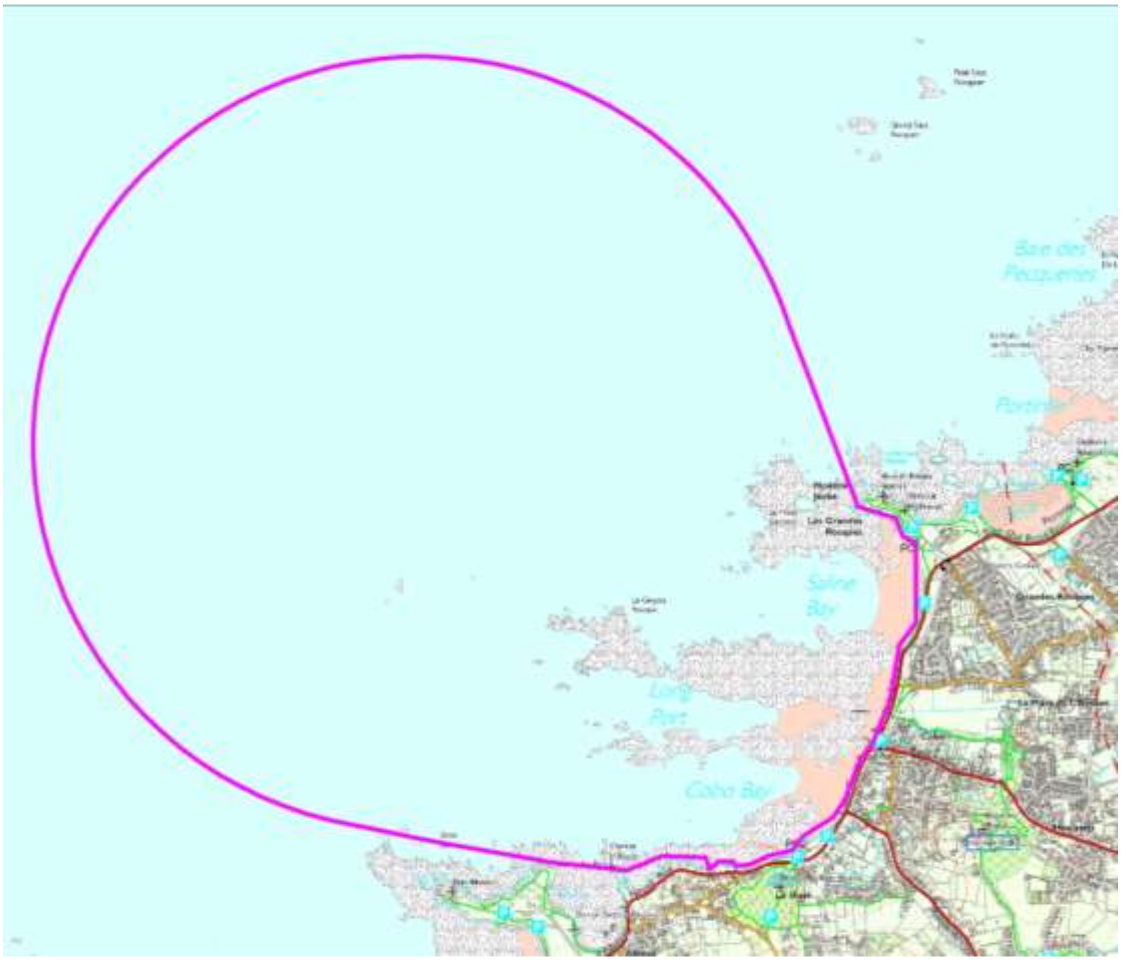

Figure 4: Hypothetical Tidal Range Scheme at Cobo Bay

Figure 5: Hypothetical Tidal Range Scheme at Havelet Bay

Comparing the capital costs with the annual revenues of both the hypothetical projects, it is clear that they are unlikely to be financially viable. However, in the interest of completeness they were appraised using Graeme Steer's financial modelling tool. The following assumptions were used:

- No grants
- No loans
- No fixed or variable costs
- Discount rate of 3%
- Retail price index set at 3%
- Energy inflation rate set at 3%
- 60 year project life

The results are shown in table 1:

Table 1: Financial Analysis-Hypothetical Tidal Schemes[6]

	NPV	IRR	Payback Period
Havelet Bay	-£196m	-5.37%	NEVER
Cobo Bay	-£648m	-2.14%	NEVER

Obviously, neither of the schemes would be financially viable. However, it is also reasonable to assume that there would be opposition to any development in either bay on grounds of loss of amenity and visual impact.

2.3 Tidal technology update – Range

Tidal barrage is a mature technology renewable energy generating technology with an additional advantage of being a reliable source. The main barrier that is seen to this generating technology is the initial high capital costs associated with its construction[7].

Although considered a mature technology, this does not mean that there are not opportunities to improve and reduce costs. In the United Kingdom (UK) a new tidal lagoon proposed in Swansea Bay is proposing to use the GeoTubes as the main part of the wall construction. The proposed installation methods are to use materials dredged from the sea bed to fill the textile type capsule GeoTubes. The main wall material being made from more natural materials reduces the imbedded carbon of the structure as well as a cost. Figure 6 shows the proposed construction of the barrage wall:

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[6] NPV is the Net Present Value; IRR is the Internal Rate of Return

[7] (Etemadi, et al., 2011)

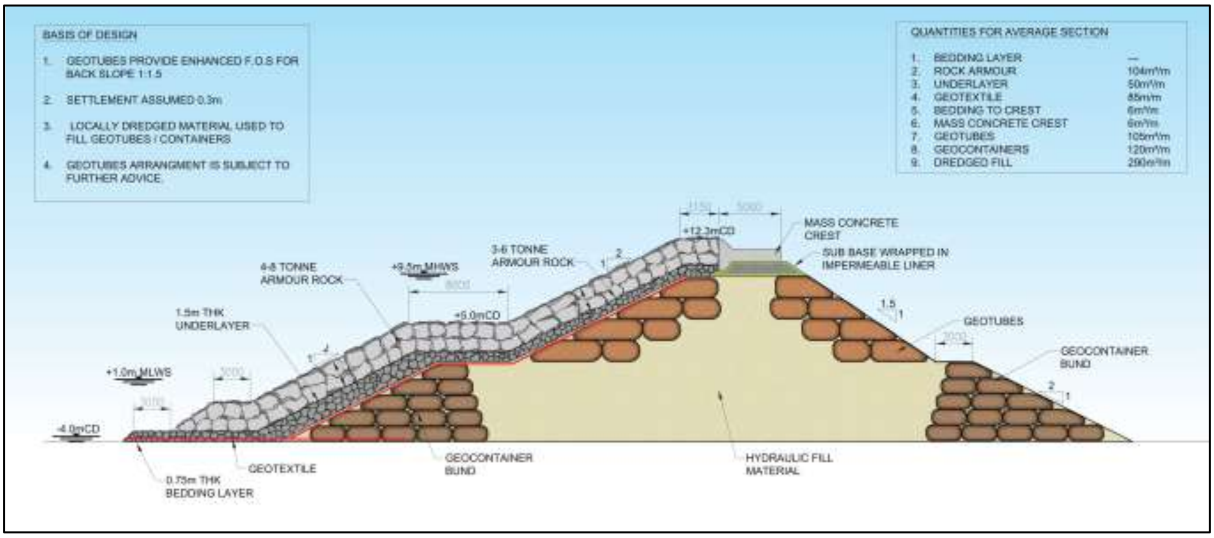

Figure 6: Side view including GeoTubes[8]

GeoTubes and geotextile materials have been successfully deployed to reduce both the costs and the imbedded carbon in previous land reclamation projects and dike construction.[9]

2.4 Tidal Stream Technology

Although tidal barrage schemes are not suitable for Guernsey there is great potential for tidal stream devices as highlighted in the report done by RE 2012. This section builds on the work carried out in this report; it contains a brief update on the current tidal stream technologies and provides recommendations for the deployment timeline of tidal stream devices.

The tidal stream industry is still a relatively immature technology when compared to other renewables such as onshore wind. The slow development of tidal stream devices can be explained by companies needing to find the capital to set up test sites, which poses an even greater financial risk. Dedicated test sites such as the European Marine Energy Centre (EMEC) remove this barrier by providing test sites. The recent development of such test sites has seen a dramatic increase of tidal stream devices entering the testing and pre-commercial stages of development with 12 large scale prototypes deployed around the UK coast in the last year.

2.5 Devices and Market Leaders

2.5.1 OpenHydro

The Open-Centre developed by OpenHydro was the first tidal stream device to be grid connected and successfully produce electricity on the UK national grid (250kW). Following on from its success

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[8] (Swansea Bay, 2013)
[9] (J. Chua, 2012)

there are plans to develop a tidal array in Brittany, France consisting of four turbines each with a diameter of 16m. OpenHydro has already deployed a commercial device in the Bay of Fundy, Nova Scotia[10] and the test rig is shown in figure 7:

Figure 7: OpenHydro test rig[11]

2.5.2 Andritz Hydro Hammerfest

The Andritz Hydro Hammerfest series of turbines are regarded as one of the current industry leaders. A 300kW machine (the HS300) has been successfully tested and has been proven to be reliable over 17,000 hours of operation with a 100% up-time between service intervals. In December 2011 a 1MW pre-commercial tidal turbine was successful deployed at EMEC's test site at Orkney (~2-3m/s peak tidal flow) in some of the worst weather conditions Scotland has seen in more than a decade. This device has successfully produced grid electricity to around 500 homes. Further testing at the Orkney site will lead to product certification with plans to deploy a 10MW commercial array in the near future.[12]

2.5.3 Marine Current Turbines

Another leader in the tidal stream market is Siemens who are developing the Marine Current Turbine (MCT) shown in figure 8. A 300kW device was first deployed in Lynmouth, Devon with a 1.2MW grid connected device installed Strangford Lough. Following the successful testing of the 1.2MW device a grid connection was secured for an array at Skerries (North Coast of Anglesey).

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[10] (The European Marine Energy Centre, 2013)

[11] (Education Scotland, 2013)

[12] (ANDRITZ HYDRO Hammerfest, 2012)

The array will consist of up to 9 SeaGen devices (10MW). The foundations for his project are expected to be completed by the end of 2014 with the devices being installed in 2015. There are further plans for an array at Kyle Rhea, this project is in its early stages with the Environmental Impact Assessment (EIA) completed and formal consultation process recently completed.[13]

Figure 8: MCT Strangford Lough[14]

2.6 Tidal Stream Learning Curve

Due to the commercial immaturity of tidal stream devices the levelised cost per megawatt hour of electricity produced is yet to become cost competitive with other renewables and traditional generation methods. Figure 10 from the Technology Innovation Needs Assessment - Marine Energy Summary Report (TINA) illustrates the projected learning curve of tidal stream devices up to 2050. This learning curve correlates with the projected costs of the proposed Swansea Bay tidal scheme for the year 2017 adding to the credibility of the projected costs.

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[13] (Marine Current Turbines, 2013)

[14] (Sustainable Guernsey, 2012)

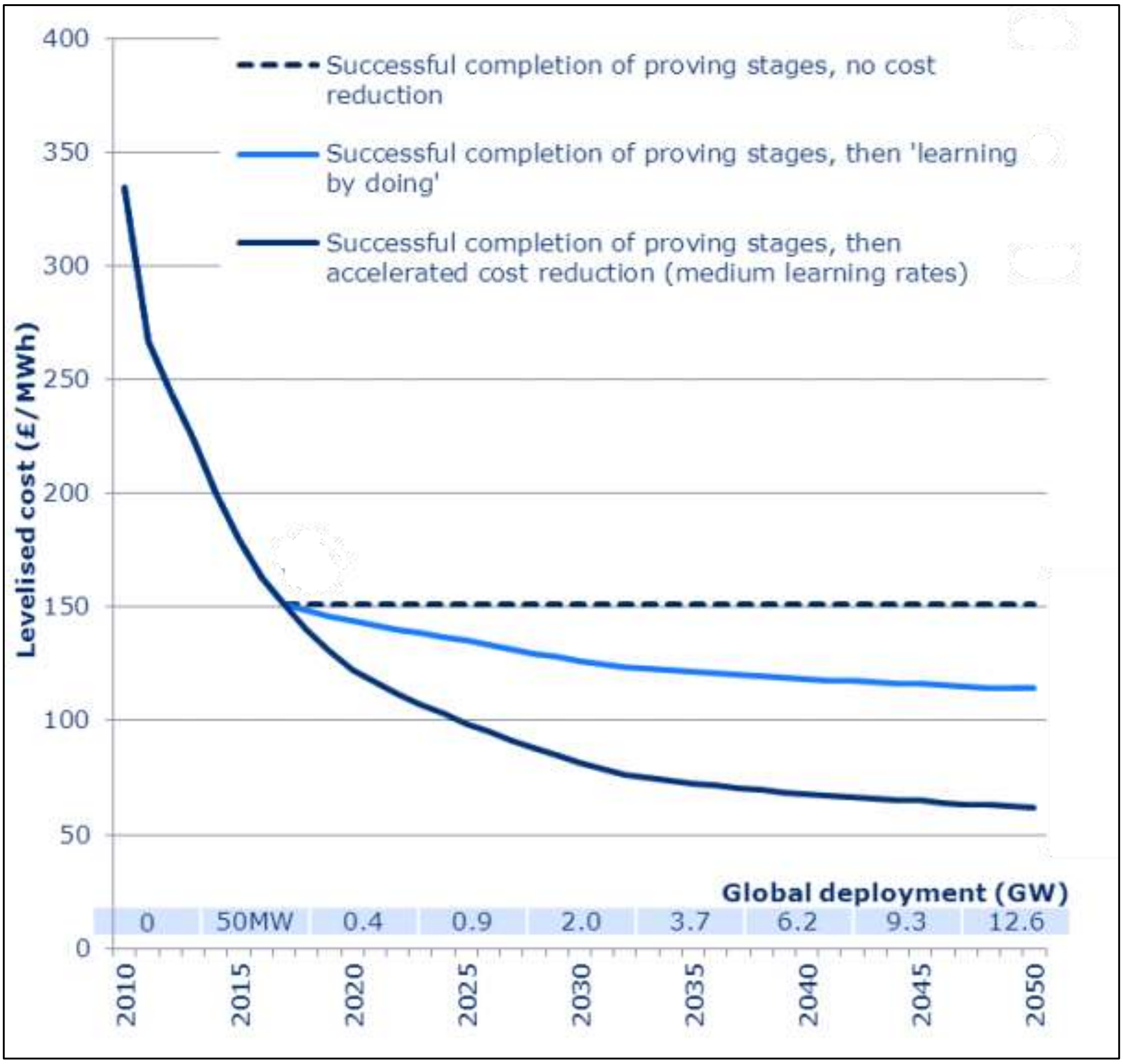

Figure 9: Chart adapted from TINA report[15]

2.7 Tidal Reefs

Tidal reefs are a new design, which have been proposed for the Severn Estuary as part of an Atkins Rolls-Royce partnership to harness the potential energy offered by the river Severn. In particular this new design is directly aimed at reducing the impact that is often associated with the environmental impacts as well as the costs associated (financial and time) with tidal barrages whilst offering a longer and smoother generation curve.[16]

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[15] (Low Carbon Innovation Coordination Group, 2012)

[16] (Rolls-Royce plc, Atkins Ltd, 2010)

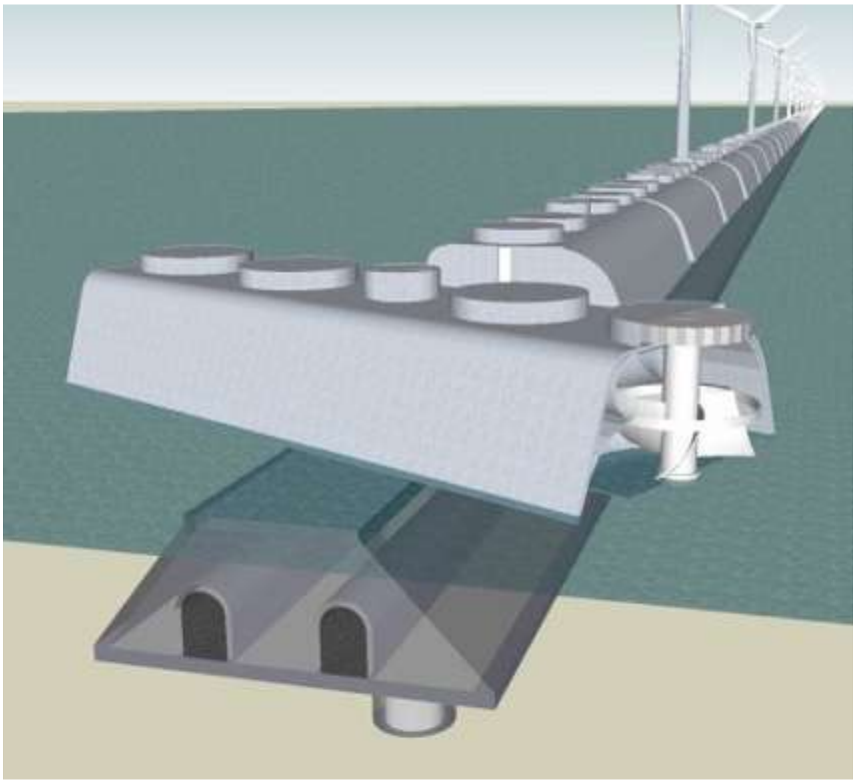

Figure 10: CGI of a tidal reef[17]

Tidal reefs are also claimed to offer protection from flooding using an 'Active Tidal Control System'. This system is proposed to not only help with protecting low lying areas and storm surges it is also proposed to help with the grid balancing of renewables.[18] None of the systems that are proposed have been tried and tested in the real world.

2.8 Tidal fences

Tidal fences are a form of tidal stream generating technology. These are commonly cited to replace the use of barrages to minimise the impacts often associated from tidal impoundment schemes.[19] There has not been any large scale deployment of any tidal stream based generating devices which has made studying the effects of these installations based only on modelling.

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[17] (Evans Engineering, 2013)
[18] (Evans Engineering, 2013)
[19] (Frida, et al., 2012)

Figure 11: Conceptual tidal fence schematic[20]

For this report, the investigation focuses on the effects that these generating technologies could have to help desperate the energy in the seas to aid costal protection schemes. It was viewed that if moneys was going to be spent on costal defences, perhaps paying a little extra and having energy generated and sold would make these schemes attractive. It was found that although energy will be dissipated for these devices there was no suggestion that these devices are suitable for sea defence applications, or that these have been tested or studied for this application.

2.9 Hypothetical hydro project

As requested, an investigation into the potential installation of a hydro turbine at the St Saviour's reservoir was also investigated. The reservoir has a 19m wall height which can be used to estimate the potential energy that can be recovered at 175kW. Further investigation found that the flow rate from the reservoir to the treatment works is limited to only 10 million litres per day at full production.[21] This restriction changes the potential to 22.4kW, yielding ~196MWh/year assuming 100% conversion efficiency; whilst 90% is more realistic.

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[20] (EnergyBC, n.d.)

[21] (Water.gg, 2013)

Figure 12: St Saviours treatment works[22]

It should also be noted that there are other uses for this energy potential are already in use. This includes the filtration system which for the second section is gravimetrically operated, which will take some potential energy away from availability mentioned above.[23]

2.10 Summary

The potential for exploiting Guernsey's tidal range was investigated using hypothetical tidal barrage installations at Cobo Bay and Havalet Bay. Neither was found to pay back within the assumed 60 year project life. Smaller opportunities were investigated at the request of others; Victoria and Beaucette marinas and the 'Men's' swimming pool at Havelet Bay. The outputs and generation calculated were too small to justify further investigation. Furthermore, a passive form of renewable energy was observed when scoping the Victoria Marina. The tidal flows keep the ports, marinas and bays free of siltation. By restricting the flow in these areas, siltation would become a problem and result in the need for regular dredging. It is important to keep the port area clear as Guernsey is reliant on them to receive essential imports.

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[22] (Water.gg, 2013)
[23] (Water.gg, 2013)

It was also observed that there are sewerage outflows in the vicinity of the harbour and many of the bays. If barrages were constructed they would restrict tidal flows thereby reducing their ability to wash raw sewerage out to sea.

2.11 Conclusions

The tidal range schemes considered would: have significant capital costs; adverse visual and environmental impacts; would result in loss of income and amenity due to displacement; would result in negative net present values (NPVs). They are not suitable for Guernsey.

The States of Guernsey are encouraged to start baseline environmental scoping to enable tidal stream devices to be installed soon as they become financially viable. From the TINA report it is estimated that a levelised cost of electricity of 14p/kWh should be achieved by 2018.

Tidal stream will be more financially attractive by 2023 at a predicted cost of 11p/kWh and with further technological progress (deployment is currently the largest challenge). This timescale will allow the technologies and their needs to be fully assessed allowing the development of a clear cost strategy.

3 Offshore Wind

3.1 Opportunity

Guernsey's position relative to the Atlantic Ocean means that it has a significant offshore wind resource. Increasing experience and the maturing of the global offshore wind industry is seeing the capital expenditure and the operating cost of an installation reducing and thus decreasing the cost of energy.

Previous studies by the Guernsey Commerce and Employment Department and also the University of Exeter have identified the potential for Guernsey to develop offshore wind, finding three promising 30MW sites and a 100MW+ site. The development of a 30MW site would match a proportion of Guernsey's demand and Guernsey Electricity Limited (GEL) have stated that they could incorporate such a site into the current generation program. A 100MW+ wind farm would at times exceed Guernsey's demand and the excess electricity would need to be exported.[24]

This report aims to further the studies mentioned above by consulting with key stakeholders, updating and analysing the available wind data, building a business case through obtaining the most accurate costing available, and then projecting these costs to a time when the project is likely to begin. Typical finance options for offshore wind projects have also been considered to give an overview of funding options.

3.2 Industry Update

3.2.1 Global

The offshore wind industry has had a relatively measured and steady development since the commissioning of the world's first offshore wind farm 21 years ago in Vindeby off the coast of Denmark. In 2013 the offshore wind industry has grown significantly and now accounts for 4.62GW of generating capacity, which although substantial still only actually equates to 2% of total global installed combined capacity from offshore and onshore wind.[25]

It is anticipated that there will be considerable strides forward in offshore wind deployment over the next decade, currently 90% of the installed capacity from offshore wind is installed in northern Europe, with the rest accounted for by two large demonstration projects off the east coast of China. With interest and involvement growing from large industrial powerhouses such as Governments and companies in Japan, the United States, Korea and India, the industry is expected to evolve rapidly.[26]

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[24] (GEL, 2013b)
[25] (GWEC, 2013)
[26] (GWEC, 2013)

All this adds weight to the findings of the Crown Estates Cost Reduction Pathways Report that the overall cost associated with the deployment of offshore wind should reduce significantly over the coming decade and beyond.[27]

3.2.2 In proximity to Guernsey

Four offshore wind farms are planned within reasonable proximity to Guernsey and are shown in figure 13.

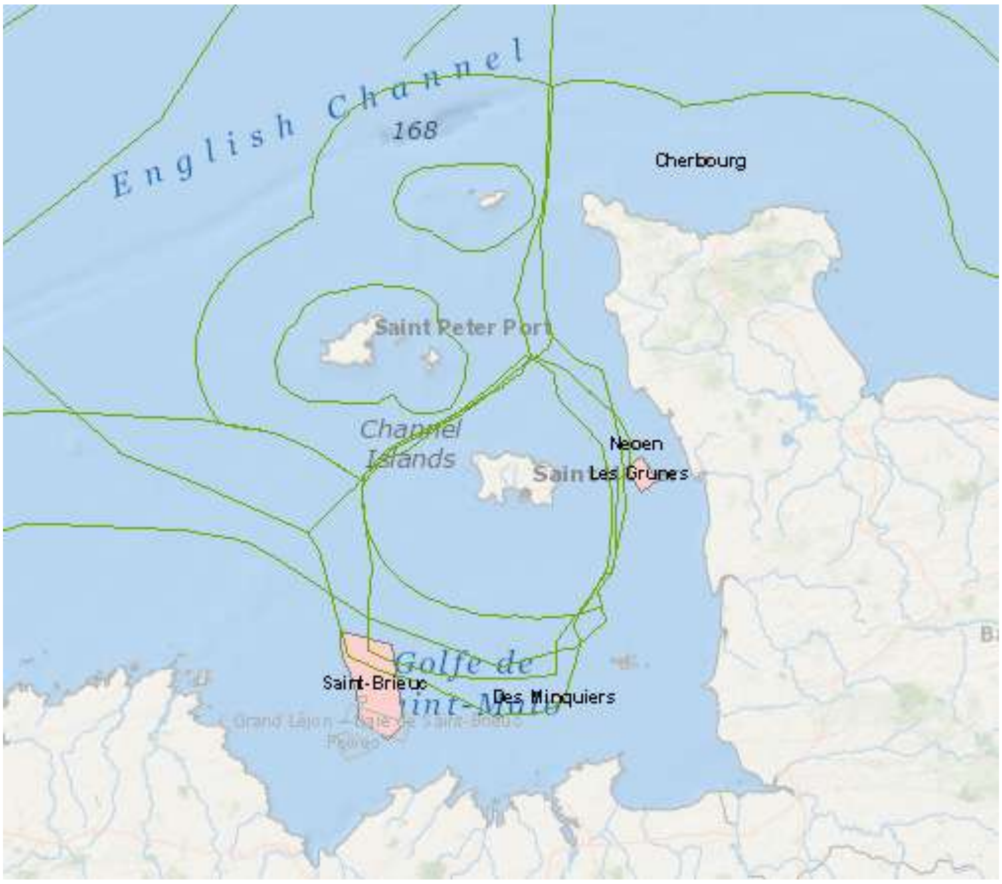

Figure 13: Planned offshore wind farms in proximity to Guernsey[28]

A joint partnership between Iberdrola Renovables (70%) and Eole RES (30%) has secured ownership of two of these with a potential 500MW capacity at each site. The most advanced project, Saint – Brieuc (Cortes-d'Armor), is to be developed by Ailes Marines SAS in waters ranging between 26 – 41 m deep. Public consultation began on the 25th May 2013 while operation is planned for 2020. The second site, Des Minquiers, will be developed by Nass & Wind Offshore (Groupe Nass & Wind) who intend to use the same turbines as Saint – Brieuc namely the Areva Wind 5MW M5000 -135. This project is also expected to begin operation in 2020. Neoen offshore windfarm, owned by Direct Energie, also plans to install 5MW turbines to a capacity of 100 MW, but as yet the manufacture has

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[27] (Crown Estate, 2012)
[28] (4coffshore, 2013)

not been disclosed and the project has no expected operational date. Eole RES who have a stake in Saint – Brieuc and Des Minquiers have further plans to build Les Grunes (Portbail), a 100MW offshore wind farm using the port of Cherbourg for operations.[29]

3.3 Previously identified sites

The four previously identified sites are shown in figure 14. RET's 'Offshore Wind Costing Scope of Work' document has analysed the advantages and disadvantages of each of these sites and the aim for this report is to develop these options into a more detailed case.

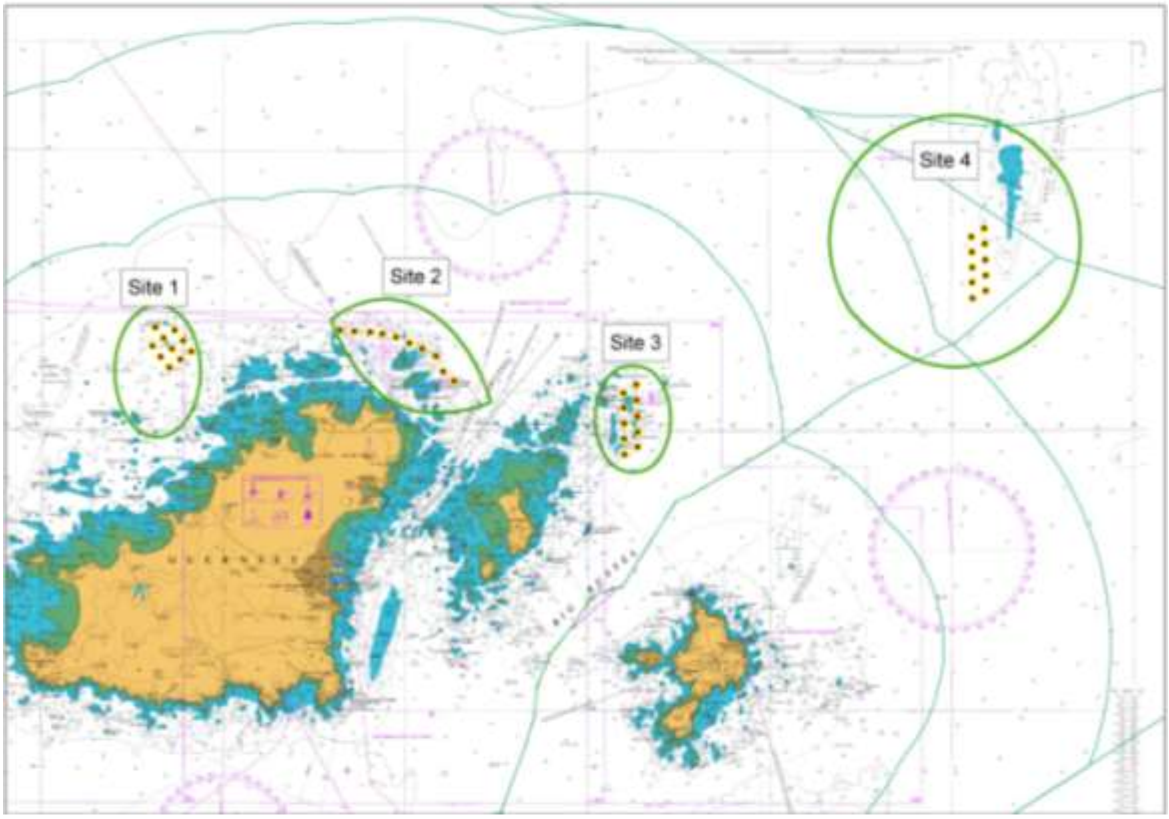

Figure 14: Previously identified wind sites under consideration[30]

Two constraints that have been under represented in previous reports are the effects of wind turbines on aviation and also the effect of a wind farm on the fishing industry.

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[29] (4coffshore, 2013)
[30] (RET,2013)

3.3.1 Aviation

Guernsey Airport operates a radar system that monitors the local airspace and waters, as shown by Figure 15. Wind turbines create a large moving surface that reflects the radar’s high frequency waves, this causes radar clutter, blind spots and disrupts the radar’s ability to see its targets. The signal interference causes track seduction, which distorts the Doppler signature of objects around the turbines.

Guernsey airport scans the surrounding airspace up to a distance of 60 nautical miles but is solely responsible for a smaller area surrounding the island of Guernsey and extending to the runway on Alderney, the Guernsey air traffic control are also responsible for aircraft flying in and out of Alderney. Figure 16 shows that this key region covers all of the originally proposed sites. Hence the importance of choosing the most cost effective solution of mitigating the radar disruption.

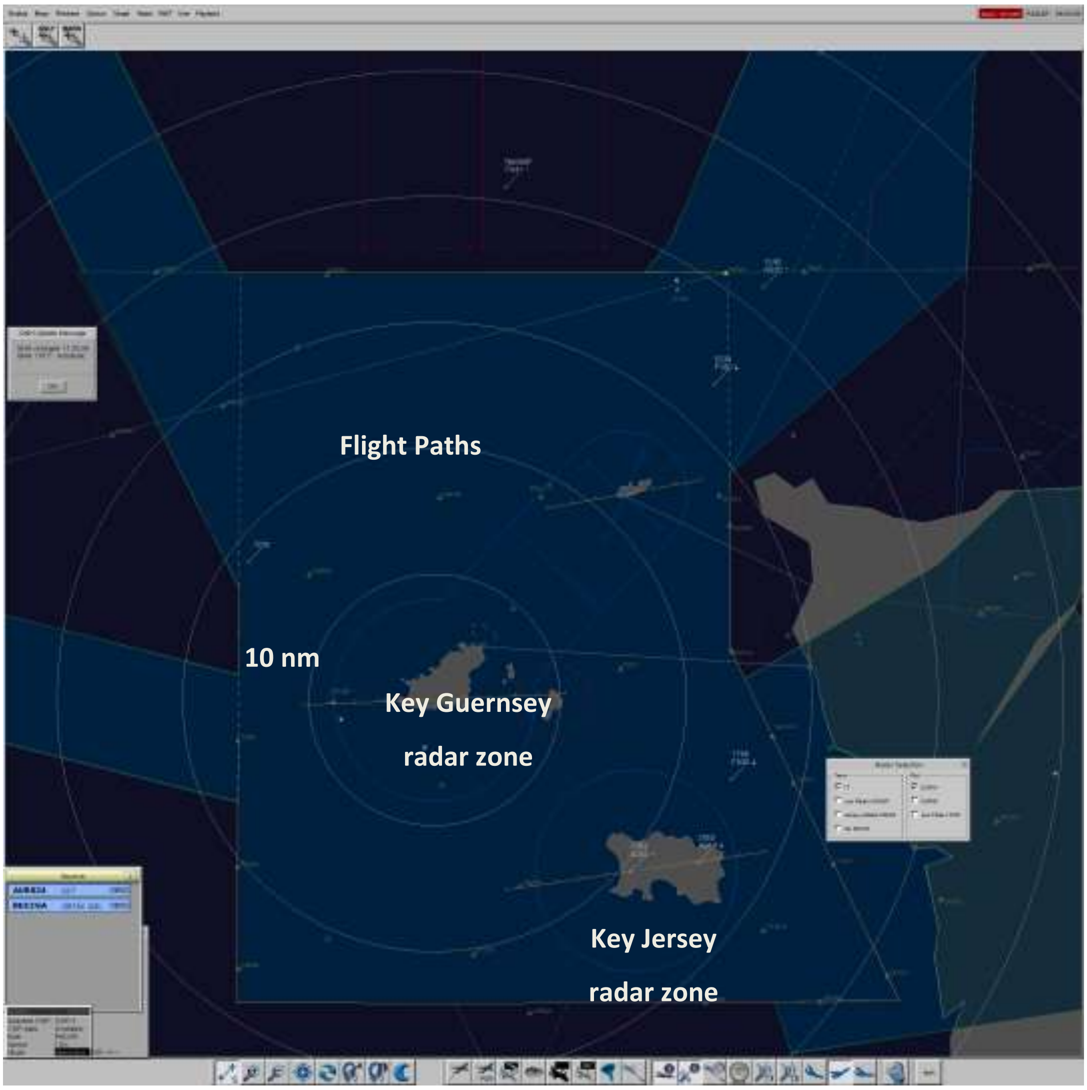

Figure 15: Guernsey airport radar screenshot

The map shown in figure 16, produced using a Geographical Information System (GIS), also shows two further possible regions that could potentially have a lower impact on the radar interference. However, as yet these are speculative as the marked North-East potential lies within Alderney's waters and the Sark option is within Sark's jurisdiction. These suggestions exist to demonstrate that there are more regions within the Bailiwick of Guernsey's 12 nautical mile seabed rights proposal that could be utilised in the future if ordinance is acquired.

A new radar system has recently been constructed at Guernsey airport and is in the final stage of the site acceptance procedure. Built by Thales, the Star 2000 has inbuilt capabilities to mitigate the interference caused by 4G mobile communication and wind turbines by the use of algorithms which distinguishes between aircraft and wind turbines.

To advance an offshore wind farm the location and height of each turbine must be decided on through detailed consultation with the radar operators. This will likely incur costs for modelling and simulation of the radar interference. A solution to the loss of radar vision could be to integrate with radar at Jersey airport or construct a new radar tower on Alderney to give an extra pair of eyes behind the proposed wind farms. But this will likely need extra planning permission and additional expenditure.

A further possible, yet costly form of mitigation is to consider the use of Aveillant's Holographic Radar. The system is designed to be located within an offshore wind farm and continuously measure the whole hemisphere resulting in 'unambiguous differentiation between aircraft and turbines' therefore tracking aircraft in the vicinity of the turbines – protecting the farm and mitigating object tracking problems.[31]

The development of 'Stealth turbine technology' that can significantly reduce the size of the radar signature may also provide mitigation to radar interference in the future.

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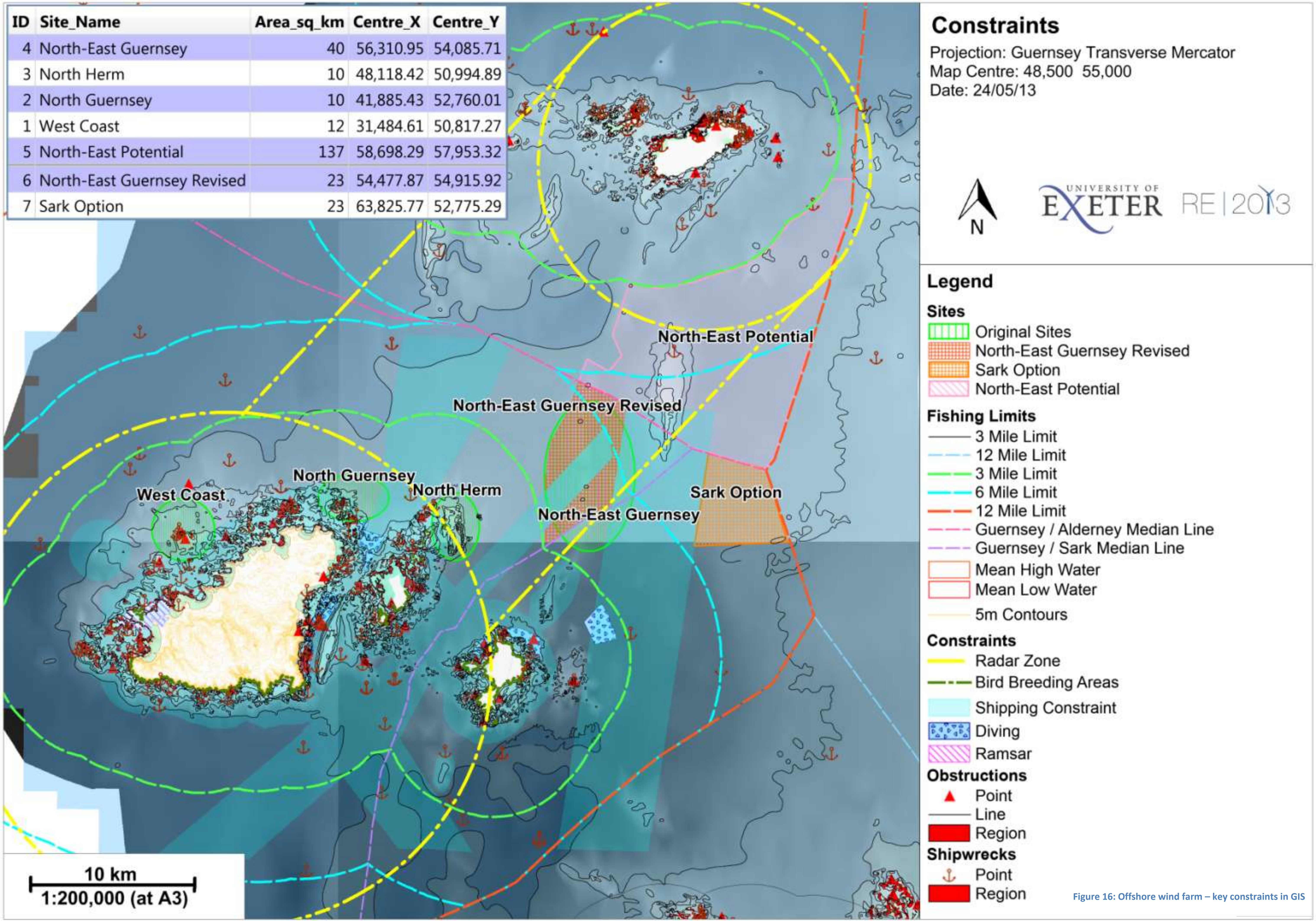
[31] (Aveillant, 2013)



ID	Site_Name	Area_sq_km	Centre_X	Centre_Y
4	North-East Guernsey	40	56,310.95	54,085.71
3	North Herm	10	48,118.42	50,994.89
2	North Guernsey	10	41,885.43	52,760.01
1	West Coast	12	31,484.61	50,817.27
5	North-East Potential	137	58,698.29	57,953.32
6	North-East Guernsey Revised	23	54,477.87	54,915.92
7	Sark Option	23	63,825.77	52,775.29

Figure 16: Offshore wind farm – key constraints in GIS

3.3.2 Fishing

Consultation with local fisheries and the Harbour Master, has highlighted the conflict between offshore wind farms and the fishing industry. The sea fisheries agency is the only department that deals with marine environment in Guernsey and they report that in the areas identified for potential offshore wind farms there are no significant known migration routes of seabed marine life. However, so far limited research on the seabed beyond the 3 nautical mile limit requires further surveying to mitigate the environmental impacts of turbines.

In relation to human activity, they identify that a displacement of effort due to a wind farm would be of key concern. Currently 175 fishing licences have been issued for Guernsey waters, ten of which support full time employment while the remainder support part time work. The Banc de la Schole to the north east of the 100MW site is regularly used for commercial fishing trips from Alderney and the Sea Fisheries agency predict that this will likely be an expensive area to compensate. Guernsey has previously negotiated compensation to a localised part of the fishing industry when a telecommunication link was installed from the north west of Guernsey to England.[32]

Impacts of wind farms on fisheries can occur during the exploration, construction, operation and decommissioning phases. They work through the physical, chemical and biological environmental factors that change ecological marine habitats and consequently the fisheries they support, as well as through the direct impacts upon fishing activities due to conflicting resource use.

Figure 17 maps data on fishing in Guernsey's waters provided by the RET. But the majority of the GIS layers supplied only extend to Guernsey's 3 nautical mile limit. The harbour master advised that some form of fishing normally takes place up to and beyond the 12 nautical mile limit. However he remained positive that the construction of a wind farm would not have long term adverse effects. Compensation may be required but experience of undersea cable laying suggests that offering direct refunds such as disruption of pots can lead to some taking advantage of the cash hand-outs.

After construction the wind farm will create an artificial reef that can be enhanced by the layout of the farm. Fish living in the water column tend to be attracted to submerged structures, apparently benefiting from the shelter from currents, wave action and predators. The foundations and base of towers will affect the current flow across the seabed that can lead to localised sediment scour in the lee of foundations, and associated changes to the species composition of the seabed. Scour affects are likely to be greatest around gravity foundations due to their larger size, and may need protection

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[32] (Morris, 2013)

using boulders. Boulder protection enables foundations to better function as artificial reefs having positive impacts on local species diversity and numbers.

Creating hydrodynamic niches, matching the scour conditions to the natural environment and using materials such as reef balls that encourage colonisation can inprove seabed re-colonisation, provided the seabed has not been contaminated and does not substantially differ after disturbance from original conditions. Depending on habitat stability, species groupings and natural disturbance levels, the area will typically take between 3-5 years to fully recover.

Yet fishing within the windfarm region remains a point of contention with policing the area an issue. As plans progress the fishing industry should be kept in constant consultation to ensure their vital cooperation.

Fisheries implications can be covered both within the EIA process and represented by fisheries stakeholders during the consents process at public consultation meetings and in writing to the consenting authorities. The aim is to minimise the negative effects to the fishery resource and associated industry. Where it is not possible to reconcile conflicting interests by amending development arrangements or finding alternative solutions, then arrangements for compensation will be required.

Compensation:

Arrangements for any compensation are generally undertaken between individual fishermen, fishermen's representative organisations and developers. It is likely that forming agreement over appropriate levels of compensation for fishing grounds exclusion issues will be more achievable than for any claims associated with environmental impacts to fisheries, due to the uncertainty in defining and quantifying such impacts, and the trade-off between negative and positive impacts from the development. In the case of fisheries compensation fishermen are expected to provide proof of earnings, registry certificates, and audited accounts or tax returns. A study of rural inshore fishers in Ireland demonstrated that one fisher at sea supports about 7 people ashore and that each fisher was worth an aggregated £34,000 per annum to the community.[33]

Other groups whose livelihood is dependent on the exclusion zone may also be entitled to compensation, such as divers, tourists, conservation groups, aboriginal groups and management agencies, etc.

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[33] (Meredith, 1999)

Claims may also arise once the installation is in operation from the sacrificing or damaging of anchors, net or fishing gear on wind farm infrastructure. A formal agreement containing general guidelines between offshore wind energy operators and fishing representatives could be appropriate in reconciling fishing related conflicts.

Given the wide variation in fishing techniques and the scope for a wide range of approaches to dialogue between the two industries, there is no “right way” to decide on settlement and distribution of any compensation. The process of dialogue may take different approaches. The suitability of these approaches will vary from case to case which are not mutually exclusive:

1. Individual site by site negotiations and discussions between developers and individual local fishermen
2. Multi-site approach engaging with larger fishing groups
3. The Community Fund approach.

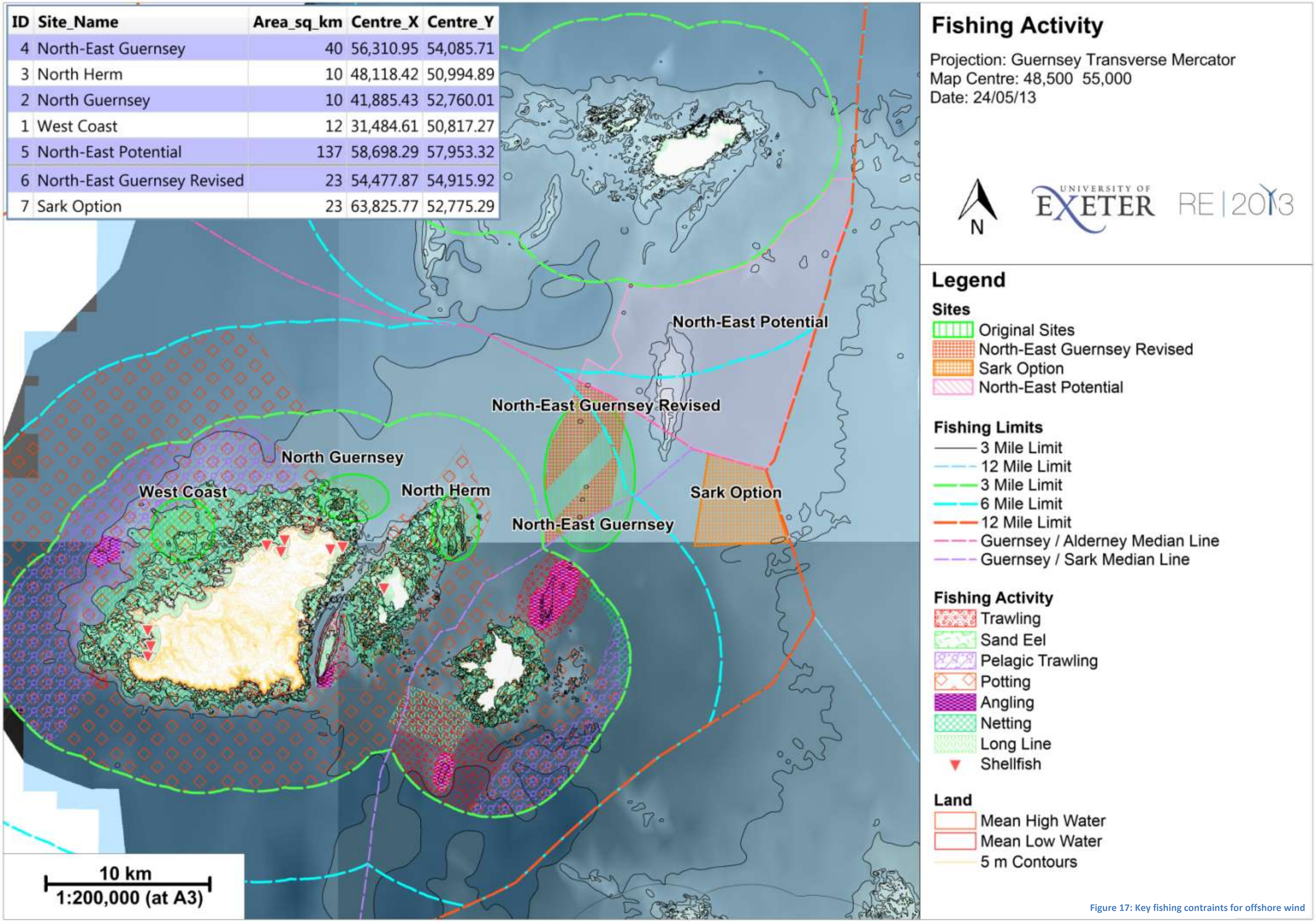

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Figure 17: Key fishing contraints for offshore wind

3.3.3 Revised Sites

Based on the information presented above the four sites were reviewed, our findings are summarised below and the new sites are presented in figure 17:

1. West Coast:
   Although potential favourite of the near shore sites, this site remains overall unfavourable. The close proximity to the airport radar coverage zone and the large perceived visual impacts are the crucial disadvantages for the site.
2. North Guernsey:
   This site will have a large visual impact. It also lies in many fishing areas and in an important position for the radar.
3. North Herm:
   In a similar position to site 2, visual impact, fishing conflicts and radar obstruction remain key deterring constraints.
4. North-East Guernsey:
   Being the largest of the sites it offers the greatest potential for deployment. The site lies outside the 3 nautical mile limit so requires confirmation of seabed rights, but the larger distance significantly reduces visual impact. The site still obstructs the key Guernsey radar zone but the implications may be reduced due to the larger distance and the less crucial position. These factors lead to the selection of this site for further research.

Based on these findings, this report focused on detailed development of site 4, which resulted in revising the shape of the proposed site boundary. Also, two potential future sites have been suggested however they lie outside of Guernsey waters so depend on a joint project:

5. North-East Potential:
   This marked boundary merely marks a large area of water within a 40m depth that could be considered for offshore wind turbines. If in the future a joint agreement could be struck with Alderney to share power, responsibilities and conflict mitigation, this 137km^2 region could provide a large amount of clean energy. The South-Eastern corner of this site is particularly attractive as it is outside of Guernsey's vital radar zone.
6. North-East Guernsey Revised:
   This site is based on the original site 4 however the boundary has been more accurately defined with respect to the considered constraints. It remains highly obstructive of radar so would require radar mitigation strategies to be pursued. However this area remains the most favourable site as it is at the greatest distance from shore but remains in Guernsey

waters. The sea depth is estimated at a maximum of 40m. The 23km^2 area provides more than ample space for a 100MW wind farm.

7. Sark Option:

   Again this would require extension of Guernsey's seabed rights or collaboration with Sark Authorities but this site is the shallowest of those considered and furthest from the radar so has good potential. It is also offers the minimum visual impact compared to the other sites.

3.4 Wind Resource Assessment

When considering the possibility of siting a wind farm the single most important factor to the viability of the installation is the expected wind speed at the site. This will determine how much potential power and therefore income the installation will generate, which in turn will form the basis for the economic appraisal.

3.4.1 Data Sources and Analysis

The Guernsey Meteorological Office provided a wealth of wind speed and direction data for analysis. Two meteorological (Met) masts located on Guernsey itself, one at Guernsey Airport in the South and one at Chouet on the North East of the island (figure 18) provided 17 months-worth of concurrent data between November 2011 and March 2013. In addition to this four months of data from the airport on Alderney covering January to April 2012 were supplied and gave a valuable comparison. In addition to these physical measurements the European Wind speed Atlas shown in figure 20 was also consulted to corroborate the logged data.

Figure 18: Met mast at Chouet facing West

The data is provided as one minute averages of the wind speed and direction measured in knots and degrees from North, respectively. Collectively the data sets amounted to over 1.5 million individual data points.

Initially all data points had to be converted from knots into the industry standard unit of metres per second. The anemometer and wind vane used to collect the data at each site are mounted on Met masts at 10m from ground level, however the hub height of an installed wind turbine will be around 100m, so it is necessary to calculate the mean wind speed at this height using the principle of windshear.

As the wind rushes across a surface, the friction between the wind and the ground causes the air to slow down and creates what is known as a boundary layer (figure 19). The height of this boundary layer is determined by the roughness of the surface it is flowing over. For instance, over a smooth surface such as the sea the boundary layer is very low, 5-10m, and wind speeds remain almost constant down to the surface. In contrast over a rough surface such as a city, the boundary layer could be 100m or more with almost no wind at the surface.

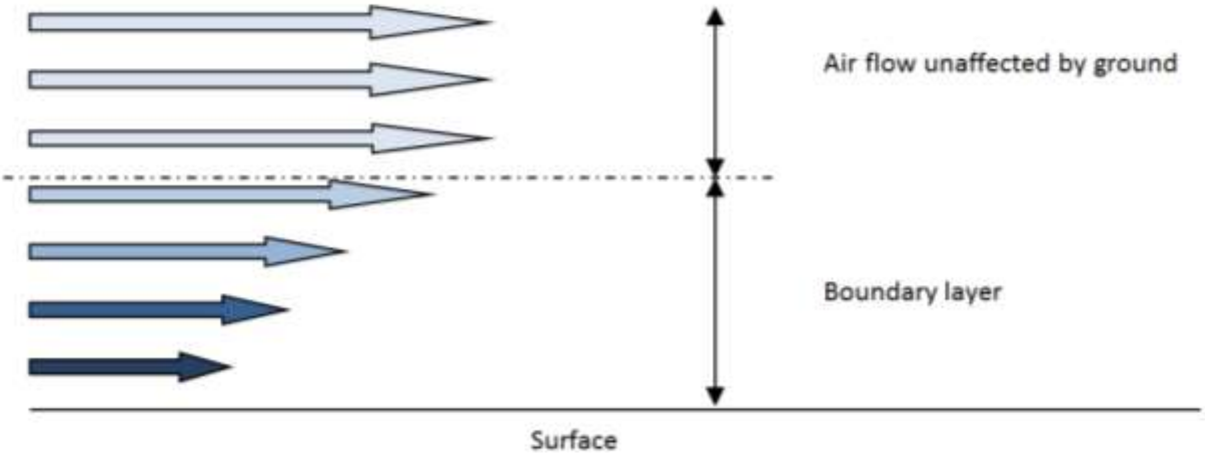

Figure 19: Principle of wind shear

This action is called windshear and by giving various terrains a 'roughness class' it is possible to calculate the windshear and therefore likely wind speeds at any height, given a reference wind speed and height. Using the formula:[34]

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[34] V = wind speed, z = height that wind speed needs to be found, h = reference height and β = power denoted by roughness class

Table 2: Roughness classes for windshear calculations

Surface	Roughness class	Power
Water surface	0	10.94
Completely open terrain with a smooth surface, e.g. concrete runways in airports, mowed grass, etc.	0.5	8.46
Open agricultural area without fences and hedgerows and very scattered buildings. Only softly rounded hills	1	5.95
Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 1250 metres	1.5	5.34
Agricultural land with some houses and 8 metre tall sheltering hedgerows with a distance of approx. 500 metres	2	4.75
Agricultural land with many houses, shrubs and plants, or 8 metre tall sheltering hedgerows with a distance of approx. 250 metres	2.5	4
Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and very rough and uneven terrain	3	3.38
Larger cities with tall buildings	3.5	2.69
Very large cities with tall buildings and skyscrapers	4	2.01

For the height adjustment calculations the data was assumed to have a roughness class of 0 in order to represent the wind speeds over an open water surface as would be the case for an offshore site (table 2). Following this the data can be categorised and analysed to determine a variety of factors as follows.

3.4.2 Model Outputs and Resource Predictions

Table 3: Monthly mean wind speeds and overall mean wind speeds

	Chouet		Airport		Alderney	
	Data mean	Adj. mean	Data mean	Adj. mean	Data mean	Adj. mean
Nov	6.6	8.2	5.3	8.6		
Dec	11.5	14.1	8.8	14.3		
Jan '12	8.9	11.0	7.1	11.5	7.4	12.1
Feb	6.7	8.3	5.1	8.4	5.4	8.8
Mar	5.2	6.4	4.6	7.5	5.3	8.6
Apr	8.6	10.6	6.9	11.2	7.0	11.4
May	5.9	7.2	5.0	8.2		
Jun	7.0	8.7	5.6	9.1		
Jul	6.8	8.4	5.6	9.0		
Aug	6.0	7.4	4.7	7.6		
Sep	6.8	8.3	5.0	8.1		
Oct	7.9	9.7	5.8	9.5		
Nov	8.1	10.0	6.0	9.7		
Dec	10.3	12.7	7.6	12.4		
Jan '13	7.6	9.3	5.8	9.3		
Feb	8.6	10.6	6.5	10.6		
March	7.5	9.2	6.1	9.9		
Overall mean	**7.6**	**9.4**	**6.0**	**9.7**	**6.3**	**10.2**

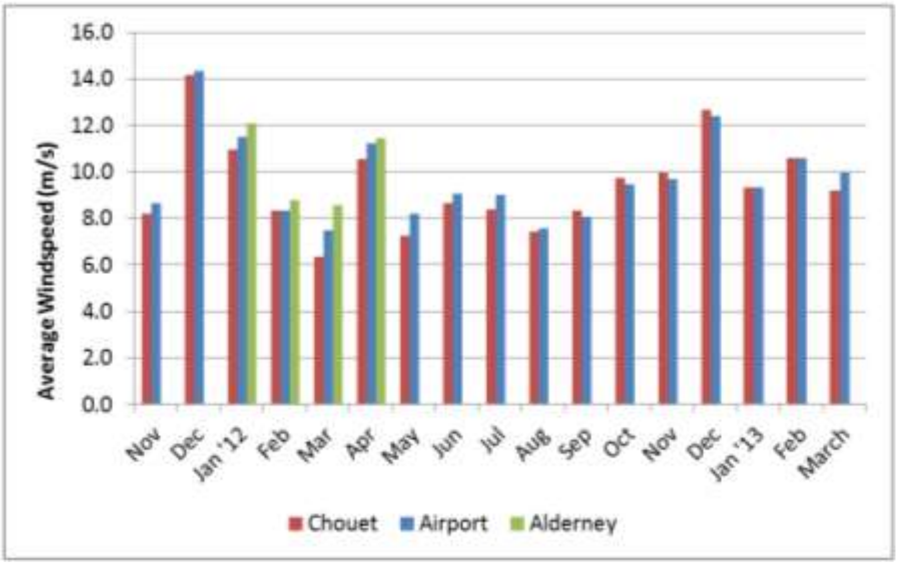
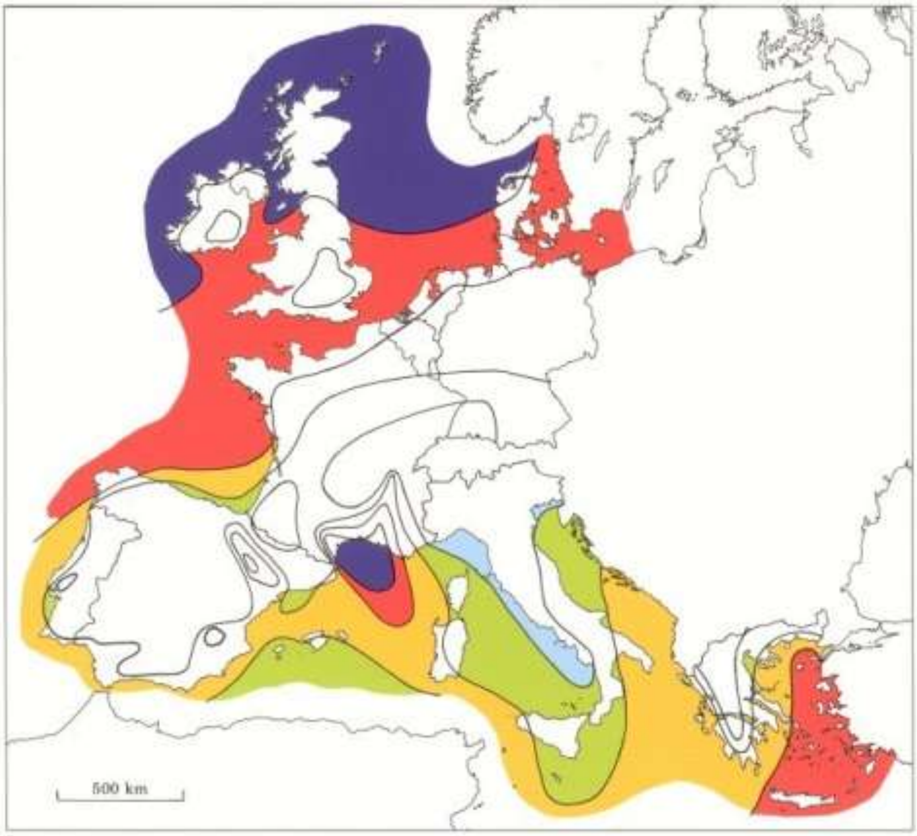


Figure 20: Seasonal variation of wind speeds

As can be seen all three data sets (table 3 and figure 17) correlate fairly well, usually with less than a 1m/s difference in mean wind speed across all three sites. This shows that all equipment is functioning well and that the wind speeds recorded are indicative of the local wind regime. The data shows that the overall mean wind speed at 100m is between 9.4 and 10.2m/s. The European Offshore Wind Atlas (figure 20) corroborates this, predicting a mean wind speed at 100m of between 8.5 - 10m/s.



Wind resources over open sea (more than 10 km offshore) for five standard heights	10 m		25 m		50 m		100 m		200 m	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
🟦	> 8.0	> 600	> 8.5	> 700	> 9.0	> 800	> 10.0	> 1100	> 11.0	> 1500
🟥	7.0-8.0	350-600	7.5-8.5	450-700	8.0-9.0	600-800	8.5-10.0	650-1100	9.5-11.0	900-1500
🟧	6.0-7.0	250-300	6.5-7.5	300-450	7.0-8.0	400-600	7.5- 8.5	450- 650	8.0- 9.5	600- 900
🟩	4.5-6.0	100-250	5.0-6.5	150-300	5.5-7.0	200-400	6.0- 7.5	250- 450	6.5- 8.0	300- 600
🟦	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 6.0	< 250	< 6.5	< 300

Figure 21: European Offshore Wind Atlas[35]

With the Chouet Met mast being the closest to the potential wind farm site and being surrounded on three sides by open seas, this site has been chosen for further analysis as it is most likely to be representative of the conditions to be expected at the site.

By 'binning' the data into 1m/s categories the probability of a given wind speed occurring can be established and used to plot the probability distribution curve at the site as shown in figure 21. The blue bars show the probability of each wind speed as calculated from the data, whereas the red line represents the optimised Weibull function with a shape factor of 1.9.

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[35] (Risø National Laboratory, 1989)

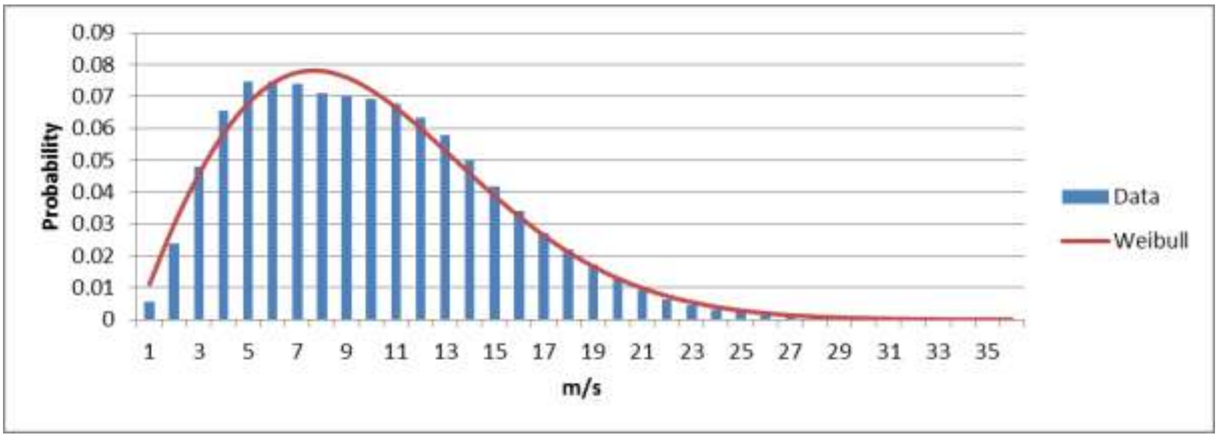

Figure 22: Probability distribution curve for Chouet Met mast

This distribution curve is used in combination with the power curve supplied by a wind turbine manufacturer to determine the likely power output of a machine located at the site.

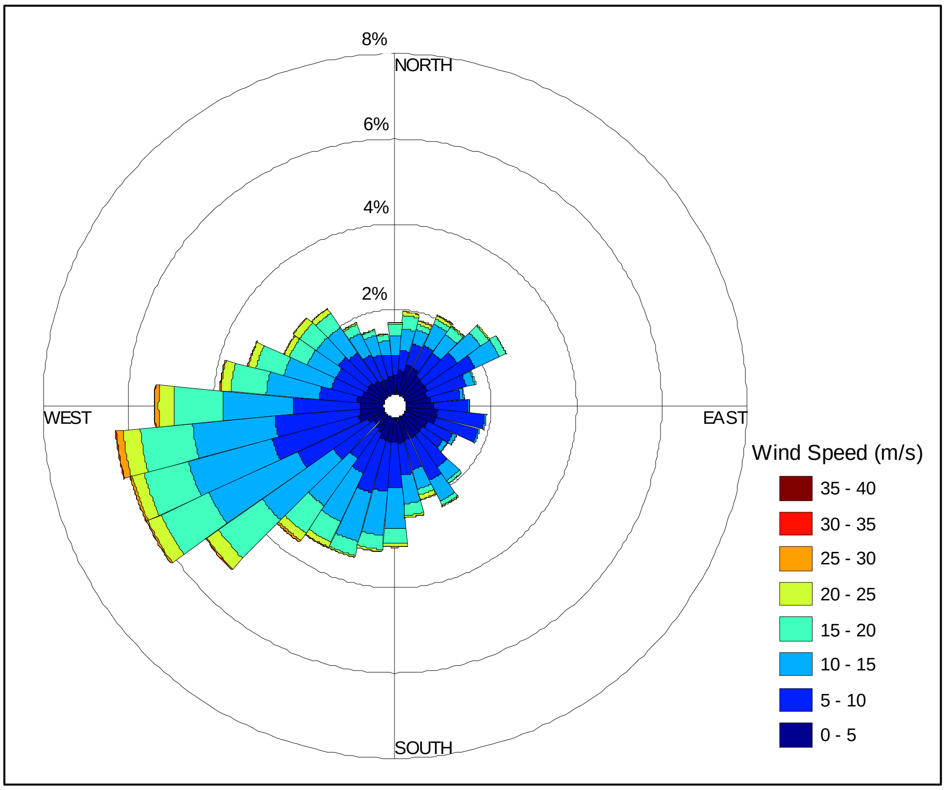

Figure 23: Wind rose for Chouet at 100m

Using the directional data together with the wind speed it is possible to plot a wind rose as shown above in figure 23. The bars represent the probability of the wind coming from each direction whilst the colours represent the probability of wind speeds. As can be seen the wind is predominantly from a West South West direction with most of the higher wind speeds also coming from this direction.

3.4.3 Future Offshore Resource Assessment

Although the data presented is representative of the local wind conditions it must be pointed out that all data was taken from Met masts located onshore. In order to assess the resource fully it is vital that data is collected for a minimum of one year at the offshore site itself before any installation commences. Traditionally this is done by installing at least one if not two or three dedicated Met masts at the site, requiring a stable platform to be fixed into the sea bed at each location. This comes at a substantial cost of around £ 3-5 million[36] for each mast. However recently there have been some technological advances that may be able to minimise this cost. The UK Met Office has recently launched a service it calls Virtual Met Mast (VMM).[37] This makes use of the Met Office's vast historical data sets and powerful computing power to generate wind climatology for any European site at any hub height. The Met Office claims that the VMM can be used to correlate with a single Met mast located at the site in order to verify the resource, considerably reducing the cost of resource assessment.

Another advance in wind resource assessment is the use of SoDAR and LiDAR (Sonic/Light Detection and Ranging). These devices work on a similar principle to Radar and have been shown to work effectively for onshore applications, however the deployment in the offshore environment is still in the experimental phase. It is hoped that in the near future these devices will be able to be mounted on floating platforms and moored on site, negating the need for a fixed platform at all.

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[36] (The Crown Estate, 2013)

[37] (MET Office, 2013)

3.5 Turbine Selection

The turbine selected for potential installation at the site is the Enercon E-126 7.5MW. This is currently the largest turbine being deployed however it is expected that by the time an installation is given the go ahead, turbines of this size will be industry standard. Larger turbines mean that less are required for a given output, for example 4 for a 30MW installation and 14 for a 105MW installation. This provides savings in the form of reduced installation time/cost as well as reduced operation and maintenance (O&M) costs. Larger turbines also have higher capacity factors and a given installed capacity will return higher power generation than the equivalent capacity composed of smaller machines.

3.5.1 Foundations and Bathymetry

The crucial consideration for any wind farm is the sea bed depth. Both maps in Figures 16 and 17 display two separate layers of bathymetry data; one a thematic scale and the other banded by contours. The Noth-East Guernsey site has been revised during this study with the maximum depth of 40m. Although previously the suggested maximum depth was 30m the extra room generated by relaxing this constraint may ease they layout of a windfarm to minimise local conflicts and radar interference. Besides, the ever advancing development of offshore foundations means that depths of 40m will soon be very normal and should not be considered a significant price increase.[38] Currently it is expected that each increase in depth of 1m will represent a 0.5% increase in cost.[39] This is significant but few turbines would likely be forced to go deeper and by the time the farm is built the increase in cost may be neglible.

This gives an indication of where a wind farm could be situated however more accurate data is required for wind farm layout to be completed. The company Gurnsey based Seazone offer further detailed bathymetry data but RET has justifiably declined to purchase it as the level of detail is insufficient for detailed turbine placement. When the site is selected to a higer level of confidence a detailed sea bed survey should be carried out around the site to ensure each turbine is located safely and at the most favourable depths in the region.

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[38] (Crown Estate, 2012)

[39] (Dicorato, M.; Forte, G., et al., 2011)

3.5.2 Potential Power Generation

Using the power curve for the E-126 shown in figure 24, and in conjunction with the wind probability distribution established for the Chouet Met mast the potential generation of a turbine array can be determined.

- 30MW site consisting of 4 turbines will generate approximately 115GWh/yr
- 105MW site consisting of 14 turbines will generate approximately 401GWh/yr

This gives a 44% capacity factor that although on the high side is also a reasonable estimation and verifies the wind analysis. The energy output calculated is likely to be on the conservative side as it is based on the Met mast site at Chouet at 100m with a mean wind speed of 9.4m/s, the wind regime should not be very different from the one used however the mean wind speed at an offshore site may be slightly higher giving an increased output.

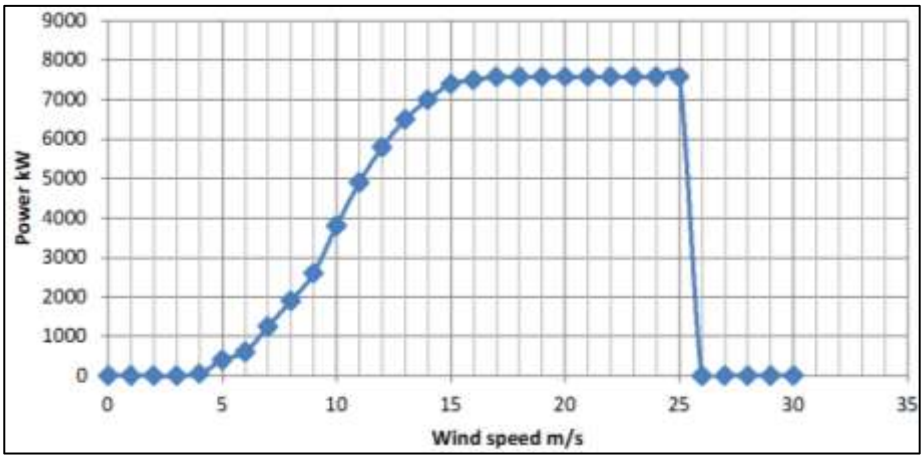

Figure 24: Enercon E-126 power curve

3.6 Business Case and Economic Assessment

To establish an as accurate cost estimation this report considered two approaches to economic assessment was considered, the top down and bottom up approach.

3.6.1 Top down approach

When considering the development of any renewable energy project one of the first considerations is whether a project is financially viable, this feasibility is assessed by the completion of an economic appraisal.

In order to assess the economic viability of an offshore wind farm for Guernsey, it would first be necessary to ascertain as much financial information relating to project revenue and expenditure as possible. This information was gathered in a number of ways, data analysis and modelling was used to ascertain available resource and hence project revenue, relevant literature was reviewed in particular the Crown Estates document "Offshore Wind Cost Reduction Pathways Study"[40] and experience was gained from other similar projects to assess project expenditure.

There is an array of factors to consider when dealing with the expenditure of a large project such as this, but typically these outgoings can split into two main groups,

- Project capital expenditure (CAPEX)
- Project operational expenditure (OPEX)

Project CAPEX in offshore wind is made up of all the required variables to bring the project to realisation, and OPEX is the expenditure, which maintains a project and enables it to keep functioning and fulfilling its purpose. Figure 25 details project expenditure.

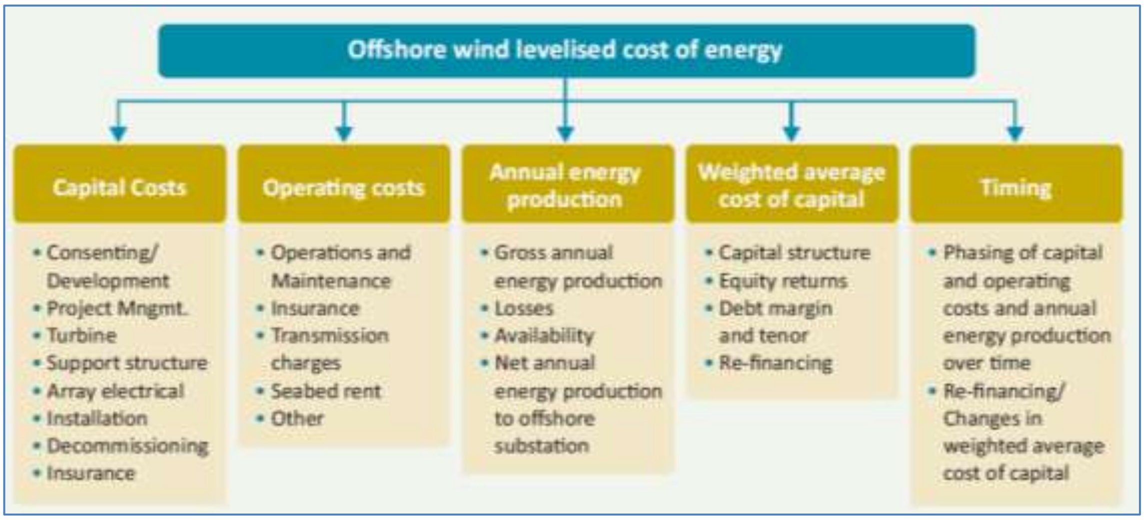

Figure 25: Project expenditure[41]

To establish the project baselines of CAPEX and OPEX for the Guernsey offshore wind case study, the basis of the Crown Estates Pathways study was used. In the study they establish a baseline CAPEX for offshore wind of £3-3.5M/MW in 2012 (including transmission CAPEX) and a baseline OPEX of £164-167,000/MW/yr. The study then uses four scenarios shown in figure 26, to ascertain as accurately as possible how offshore wind project expenditure will develop up to 2020, the results across the four scenarios vary, but enable a trend to develop where project expenditure will decrease at an average of 39%, shown in figure 27.

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[40] (Crown Estate, 2012)
[41] (Crown Estate, 2012)

3. 'Supply Chain Efficiency'

- 36GW in Europe by 2020 (17GW in UK)
- Incremental technology evolution (e.g. steady progress to 5-7MW turbines)
- Greater competition, investment, project collaboration and better risk management
- Deeper financial markets, lower risk/lower cost of capital

4. 'Rapid Growth'

- 43GW in Europe by 2020 (23GW in UK)
- High levels of technology evolution across all wind farm elements (e.g. turbines progress rapidly to 5-7MW+)
- Greater competition, investment, project collaboration and better risk management
- Challenging volume of finance required

1. 'Slow Progression'

- 31GW in Europe by 2020 (12GW in UK)
- Incremental technology evolution, progress limited by market size
- Limited competition/economies of scale
- Modest developments in financing solutions, reduced in risk/cost of capital

2. 'Technology Acceleration'

- 36GW in Europe by 2020 (17GW in UK)
- High levels of technology evolution across all wind farm elements (e.g. turbines progress rapidly to 5-7MW+)
- Fragmented supply chain with some improvement in collaboration
- Limited improvement in cost of capital due to ongoing changes in technology

Figure 26: 4 scenarios[42]

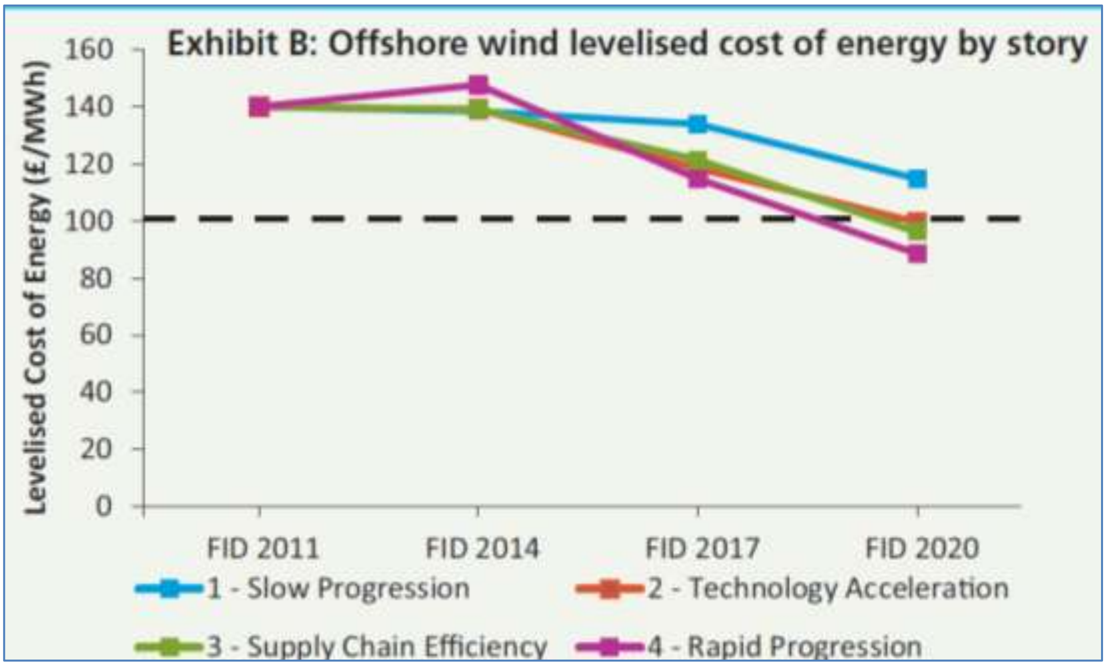

Figure 27: Results of Pathways Study[43]

Once the baselines were established and the trends of the study known it was then possible to establish the project expenditure looking forward to 2020 and 2030, each scenario was considered in a low, mid and high case to ensure thoroughness, tables 4 and 5 and figure 28 detail this information.

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[42] (Crown Estate, 2012)
[43] (Crown Estate, 2012)

Table 4: CAPEX projection

CAPEX (£M/MW/yr)			
Years	**CE Lower Case**	**Mid Case**	**CE Higher Case**
2012	3	3.25	3.5
2020	1.8	2.1	2.3
2030	1	1.1	1.2

Table 5: OPEX projection

OPEX (£M/MW/yr)			
Years	**CE Lower Case**	**Mid Case**	**CE Higher Case**
2012	0.164	0.165	0.167
2020	0.095	0.096	0.097
2030	0.048	0.048	0.05

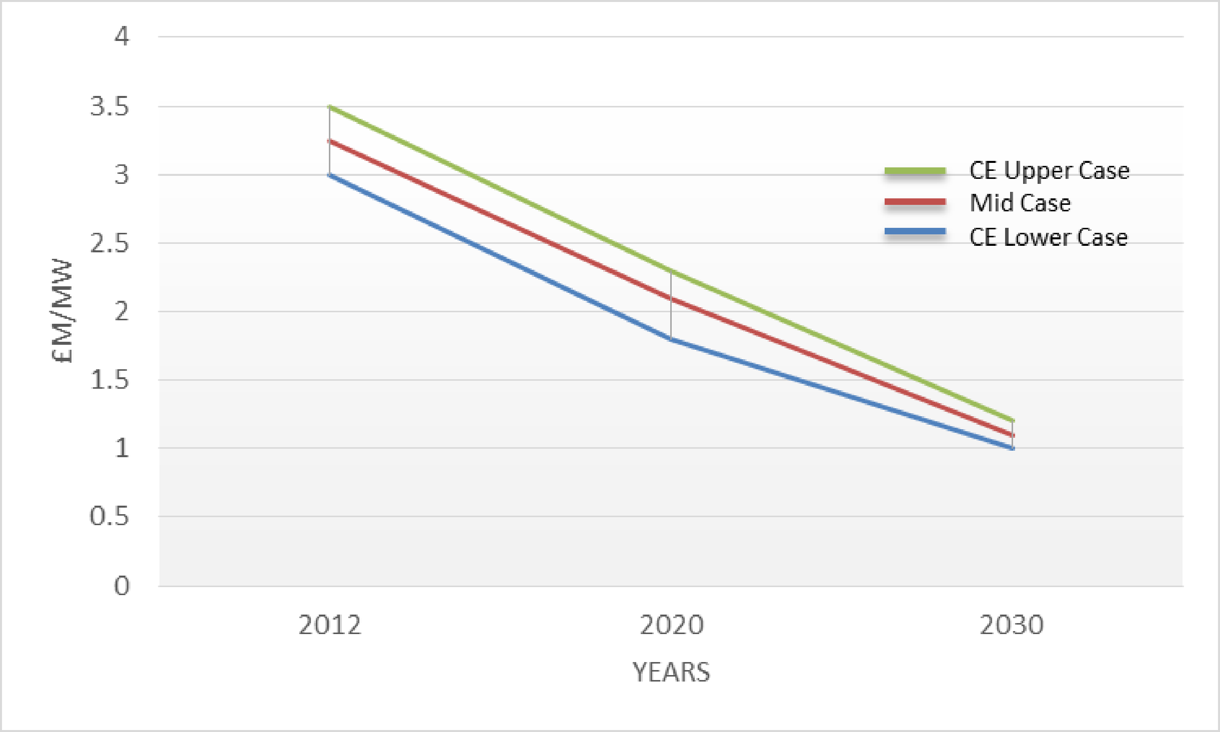

Figure 28: CAPEX projections

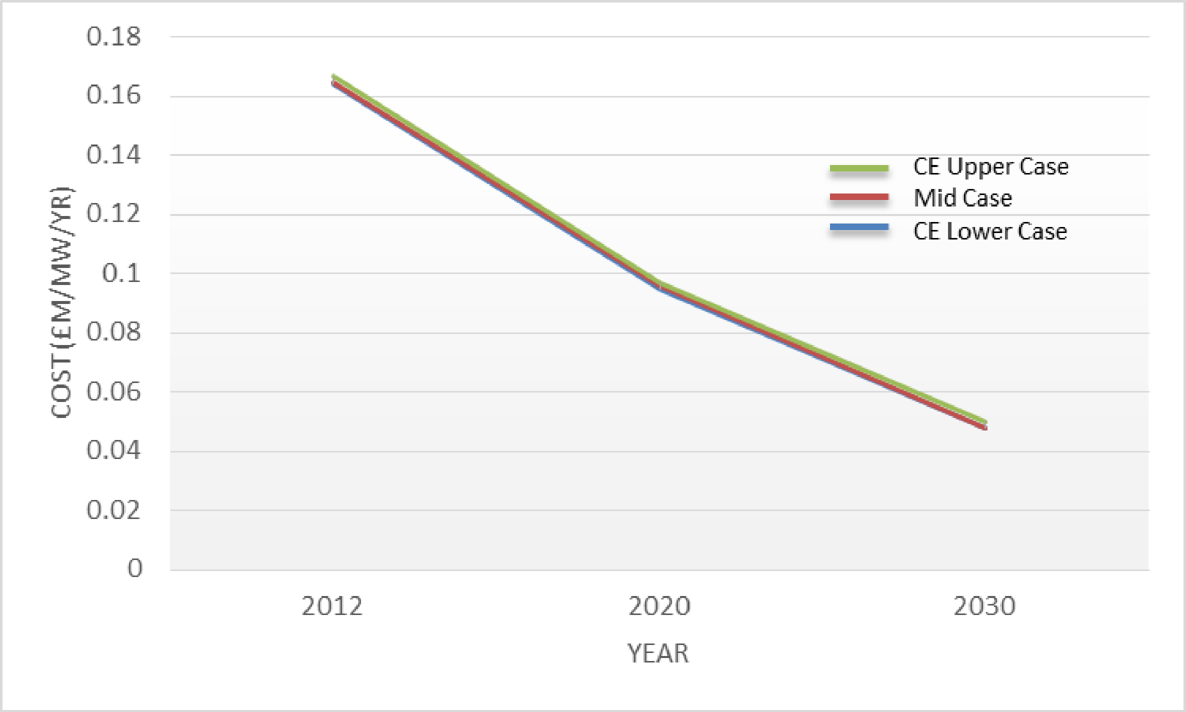

Figure 29: OPEX projections

Once the output of the two projects was successfully established by data acquisition and correlation from a number of sources it was then possible to establish the revenue the projects would generate. Table 6 details the outputs and the capacity of the projects.

Table 6: Details project output and capacity

Site	Capacity (MW)	Case	Capacity factor (%)	Output (MWh/y)
A	30	Low	40	105,120
		Mid	44	115,000
		High	48	126,144
A	105	Low	40	367,920
		Mid	44	404,000
		High	48	441,504

A spreadsheet was then constructed which would aid in the financial analysis of the Guernsey offshore wind project. Two main scenarios were considered as detailed below,

- Private Finance Model – In this model it was considered that the project would be funded by a private developer, and the revenue source would be solely the price at which GEL would buy the electricity at per unit, which was set at 9.5p/kWh after consultation with GEL. The key statistics for this scenario are set out in table 7.

Table 7: Results of private finance model

Project Capacity (MW)	**30MW**		
Case	Worst	Mid	Best
Net Present Value (NPV) (£)	-£ 27,238,659	-£ 22,059,944	-£ 3,351,818
Internal Rate of Return (IRR) (%)	-3.17%	-3.05%	-0.54%
Payback (years)	17.7	17.2	13.91
Levelised Cost Of Electricity (LCOE)(£)	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.10	£ 0.10	£ 0.10
Additional Subsidy Required (£/kWh)	£ -	£ -	£ -
Total Price of electricity from Wind (£/kWh)	£ 0.10	£ 0.10	£ 0.10
Project Capacity (MW)	**100MW**		
Case	Worst	Mid	Best
NPV (£)	-£ 172,417,429	-£ 75,676,525	£ 89,666,770
IRR (%)	-7.03%	-2.99%	3.34%
Payback (years)	21.24	17.15	11.67
LCOE (£)	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.10	£ 0.10	£ 0.10
Additional Subsidy Required (£/kWh)	£ -	£ -	£ -
Total Price of electricity from Wind (£/kWh)	£ 0.10	£ 0.10	£ 0.10

The next aspect to consider was how the finances of the project would be affected if GEL were to finance the project instead of a private financier, with 25% equity and 75% debt. This will have a direct effect on the financial outcomes of the project because if financed by GEL the cost of oil or French imported electricity can be offset. The resulting figures from this scenario are shown in table 8. It is clear that if the project were to be financed by GEL a much stronger financial case is made, this is clearly demonstrated in figures 30 and 31.

Table 8: Results of GEL financed project

Capacity (MW)	**30MW**		
Case	Worst	Mid	Best
NPV (£)	£ 19,985,180	£ 157,434,644	£ 300,039,008
IRR (%)	2.43%	15.16%	27.64%
Payback (years)	11.3	7.12	5.5
LCOE (p/kWh)	0.111	0.095	0.077
Capacity (MW)	**100MW**		
Case	Worst	Mid	Best
NPV (£)	£ 69,948,130	£ 554,895,766	£ 1,050,136,527
IRR (%)	2.43%	15.25%	27.64%
Payback (years)	11.29	7.10	5.52
LCOE (p/kWh)	0.111	0.094	0.077

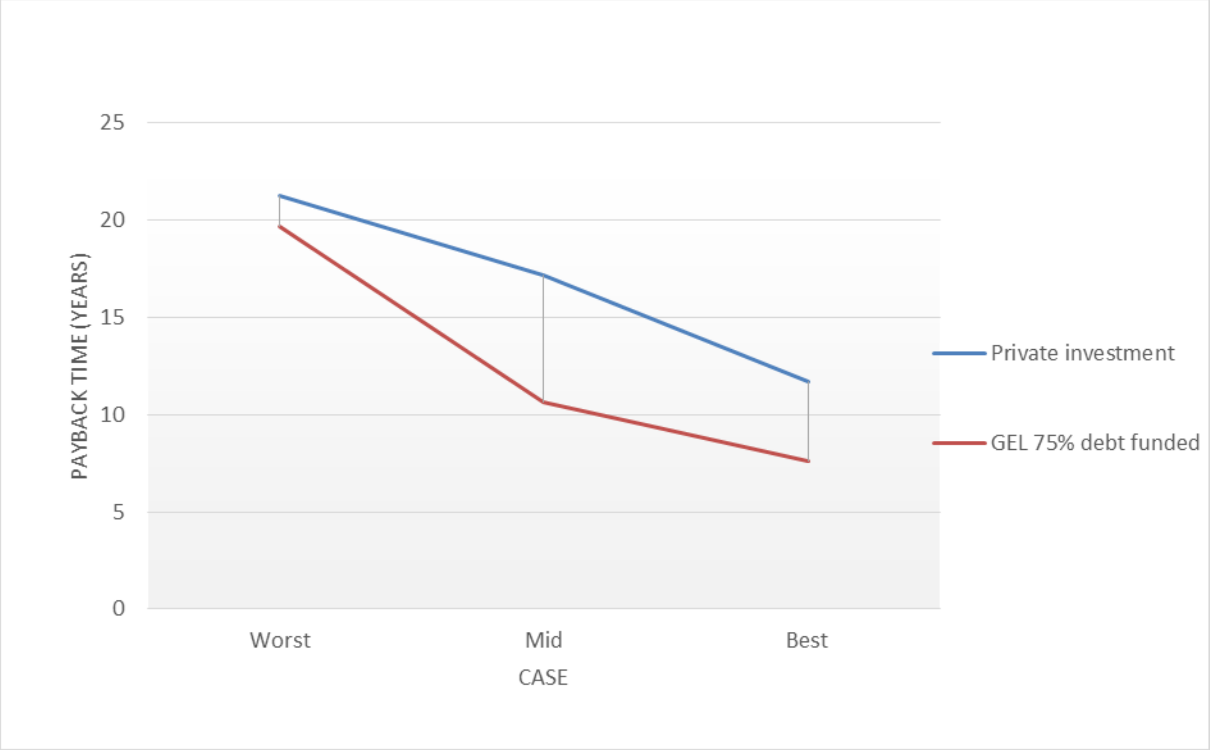

Figure 30: Project payback GEL scenario verses private finance

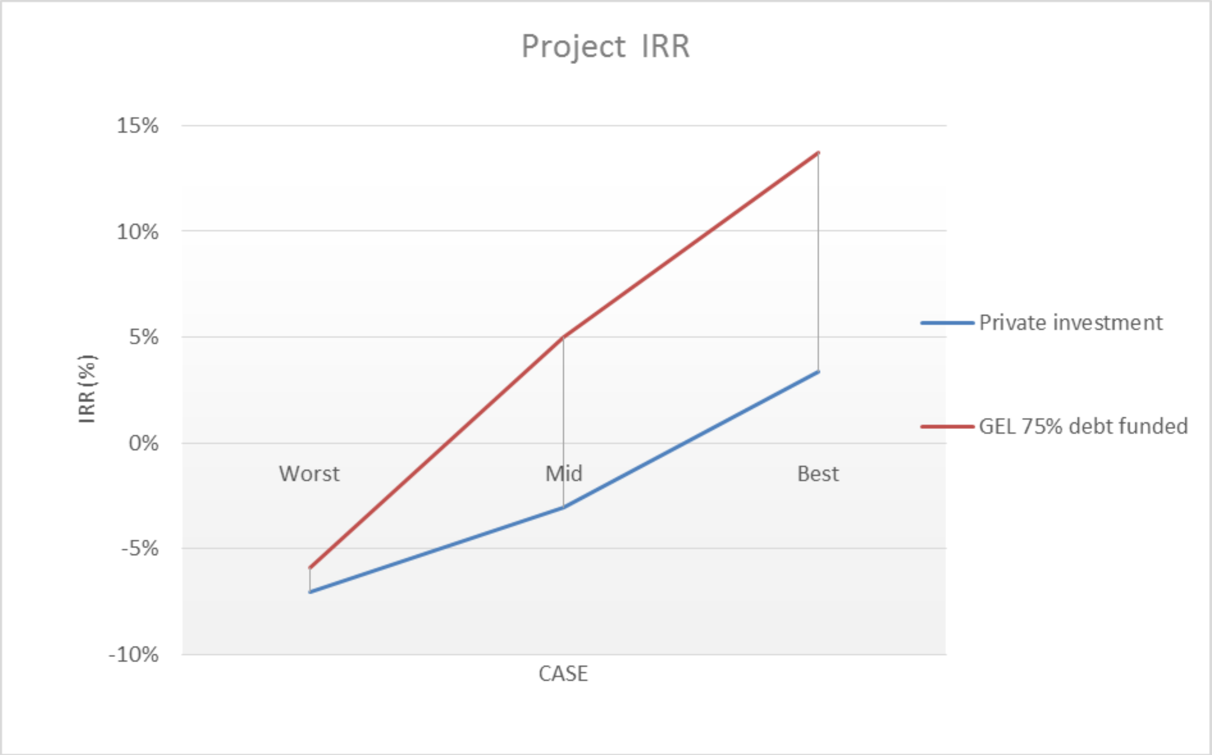

Figure 31: Project IRR GEL finance scenario verses private finance

Taking heed of the extensive work completed by the Crown Estates and the Department for Energy and Climate Change (DECC), it is projected that the cost of offshore wind should drop by 39% by 2020. This said, to attract a private investor to develop a project in Guernsey waters some sort of subsidy would be beneficial, akin to that of the Renewables Obligation in the UK. If GEL were to finance the project the returns would be much better as there is more financial benefit to offsetting other methods of generation in particular that of heavy fuel oil.

3.6.2 Bottom up approach

Offshore wind farm projects require much higher initial capital investments when compared to onshore wind developments. Due to remarkable economic efforts involved with offshore projects, the accurate projection of total investment costs and the identification of most economical system components are of vital importance.

The financial model developed by Dicorato[44] offers a reliable assessment tool allowing the developer to accurately project the total investment cost by providing a set of basic parameters of the allocated site and some of the key technical features of the subsystems affecting construction, installation and development costs. The costing model was established by reviewing technical and economic features of recent completed small scale (<150MW) offshore wind farm developments

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[44] (Dicorato, M.; Forte, G., et al., 2011)

with alternating-current connections with the aim of providing a general model for offshore wind farm projects of the same scale.

Following the papers methodology it is possible for developers to assess and project total offshore wind development investment cost for different project scenarios as far as the following parameters are known and are concerned.

Variables required for cost estimate:

1. For turbine and foundation cost

    1. *Rated power of a single wind turbine [MW]*
    2. *Hub height [m]*
    3. *Rotor diameter [m]*
    4. *Average sea depth at proposed site [m]*

Electric system cost / Integration system cost

1. *Length of collection cable [km]*
2. *Diameter of subsea MV collection cables [mm^2]*
3. *Number of transformers*
4. *Rated power of transformers [MVA]*
5. *Nominal voltage of switchgear [V]*
6. *Number of high voltage circuits*
7. *Type (single/double) and voltage (150/230V) of busbars and switchgear*
8. *Choice between onshore or offshore substation.*
9. *Insulation of offshore substation (air-insulated or gas-insulated)*

Transmission cost

1. *Average distance of the wind farm from the coast [km]*
2. *Diameter of high voltage subsea collection cables [mm^2]*
3. *Total length of onshore connection to the main transmission system [km]*
4. *Length of the above covered by overhead lines [km]*
5. *Nominal voltage and rated power of overhead lines underground cables [V, MWA]*
6. *Number of overhead lines*

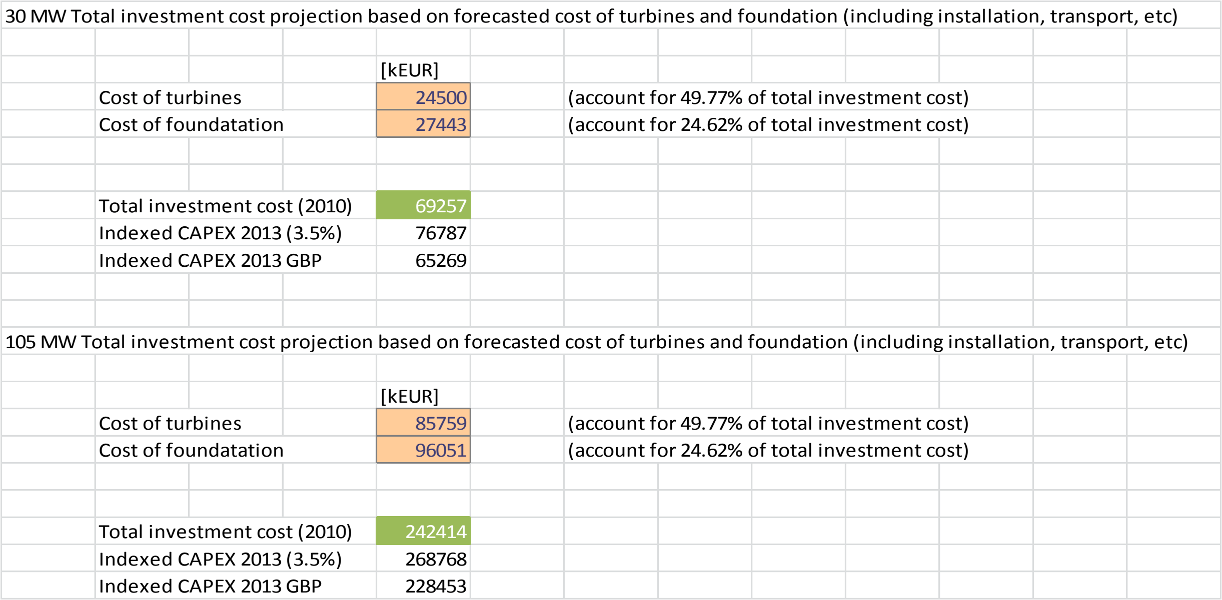
2. Grid interface cost (including SCADA/EMS)[45]

    1. *Capacity of shunt reactor, capacitor, static VAr capacitors [MVAr]*

3. Project development cost

    1. *Total installed capacity of the wind farm [MW]*

Using the above mentioned investment cost approximation model the costs for both a 30MW and 105MW wind farm were estimated based on the number, power rating, hub height, rotor diameter of the selected turbines and average sea depth at the installation sites. These costs are shown in figure 32:



30 MW Total investment cost projection based on forecasted cost of turbines and foundation (including installation, transport, etc)

	[kEUR]	
Cost of turbines	24500	(account for 49.77% of total investment cost)
Cost of foundatation	27443	(account for 24.62% of total investment cost)
Total investment cost (2010)	69257	
Indexed CAPEX 2013 (3.5%)	76787	
Indexed CAPEX 2013 GBP	65269	

105 MW Total investment cost projection based on forecasted cost of turbines and foundation (including installation, transport, etc)

	[kEUR]	
Cost of turbines	85759	(account for 49.77% of total investment cost)
Cost of foundatation	96051	(account for 24.62% of total investment cost)
Total investment cost (2010)	242414	
Indexed CAPEX 2013 (3.5%)	268768	
Indexed CAPEX 2013 GBP	228453	

Figure 32: Projected total investment costs[46]

These cost estimates are in 2010 values, to project them they were indexed with the average annual general UK inflation rate of 3.5% (based on monthly inflation rates since January 2011 until April 2013) and converted from EUR to GBP[47] at a rate which was valid at the time of writing. Adding 10% contingency to the projected indexed CAPEX in GBP costs yield £71.8million and £250.8million for the 30MW and the 100MW offshore wind farm respectively.

It must be noted that these figures are based on the typical share of turbine and foundation cost of the total investments cost and in order to estimate total cost more accurately further technical parameters of the system components would be needed.

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[45] Supervisory Control and Data Acquisition (SCADA); Energy Management System (EMS)

[46] Based on (Dicorato, M.; Forte, G., et al., 2011) model.

[47] Euros (EUR); Great British Pounds (GBP)

Besides projecting a total investment cost for a specific offshore wind farm project, the extensive review of recent completed developments also allow for the formulation of some general assumptions and recommendations.[48]

Experience shows that turbine and foundation costs represent approximately 50% and 24% of the total investment cost respectively. The cost of the electrical system (including collection, integration, transmission components) account for approximately a further 23% towards the initial capital investment, while the cost of monitoring and regulation systems is worth around 1%. Development costs are in the region of 2% of the total project costs. Moreover:

- The presence of an offshore substation is advised as long as the wind farm is located further than 3km offshore
- 1km increase in distance from shore translates into around 0.5% increase in total investment cost
- Each meter increase in sea-depths accounts for approximately 0.5% rise in total investment costs

3.6.3 Summary of CAPEX

The two costing approaches applied to ascertaining likely project CAPEX are vastly different, but the results correlate exceptionally well with very little variation in projected CAPEX in both cases. Table 9 displays the capital expenditures for both financial modelling techniques.

Table 9: Projected CAPEX cost in million GBP

Capacity [MW]	Approach	
	Top down	Bottom up
30	69.3	71.83
105	242.6	250.8

3.6.4 Economic Modelling

Further economic modelling and the effects on electricity rates are reported in the economics section of this report.

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[48] (Dicorato, M.; Forte, G., et al., 2011)

3.7 Finance options

3.7.1 Equity Finance

The majority of offshore wind projects in the UK and Europe are currently financed by equity investments. The bulk of these investments come mainly from balance sheet funded equity, with utilities and offshore construction companies presently supplying 80-90% of finance for UK projects from reinvested profits. Indications suggest that these developers are currently looking for a post-tax equity return of 9-11% on an offshore wind project.[49]

Original Equipment Manufacturers (OEMs), such as turbine and cabling manufacturers, are willing to take minority shares in projects, usually between 10% and 20%, in order to secure technology sales. This equity position generally lasts throughout the construction stage and initial warranty period, with the exit time being 2-5 years into the operation phase.

The remainder of equity investments can come from a variety of financial investors including:

- Pension and insurance funds
- Sovereign Wealth Funds (SWFs)
- Public equity markets
- Private equity companies[50]

Although all of these investors have a proven track record in financial investments, they only hold a small share of UK offshore wind projects, currently less than 5%. This is primarily due to the perceived risk of the offshore wind sector and the lack of a standardised model of investment to reduce the uncertainties and risks.

Pension and insurance funds and public equity markets can bring together many investors, from individuals to businesses, across many sectors and countries to invest in a single project making the potential size of the investment highly varied depending on the project.

SWFs, investments provided by a government or country, can be a major form of backing, not just in terms of a large scale investment but also the political support gained for the project. RET have indicated that the States of Guernsey government could be willing to provide a significant investment in an offshore wind project.

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[49] (Pwc, 2012)
[50] (OWDF, 2011)

Generally pension funds, SWFs and public equity markets are looking to invest in projects that provide:

- Predictable drivers of cash flow to ensure a safe return profile
- Low technology risk with minimum operational uncertainty
- Existing operational assets

The private equity sector is slightly different to the public equity sector, tending to make investments with greater risk, for example construction phase funding, and therefore demanding higher returns. These investors are looking for projects that have a core market that is well understood and have the opportunity to influence the projects to create value. Therefore previous experience and expertise in sectors related to offshore wind is highly favourable.

Another form of potential funding is from commercial pre-payers that can be used to gain construction and development funding. This method involves electricity customers, either individually or as a group of commercial and industrial users, supplying funds for a discounted future purchase of electricity from the developer. If the payments are designed acceptably then both parties benefit, with the customer gaining a secure, long term supply of electricity, and the developer gaining access to upfront funds.

3.7.2 Debt Finance

Currently, debt finance is rarely used for offshore wind projects, partly due to the higher returns demanded from interest over a 20 year lifetime. Commercial banks have indicated that they are willing to provide funding during the operation phase but not the construction phase. This is mainly due to the higher risk associated with construction phase and the lack of a track record of developers finishing projects on time and on budget. However, both the European Investment Bank (EIB) and the Green Investment Bank (GIB) follow a policy where they only provide construction stage funding to encourage new projects. There is a possibility that one or other of these investment banks would provide funding for an offshore wind project near Guernsey. Despite Guernsey not being part of the European Union (EU), if a joint project with an EU member state is undertaken, the EIB could provide funding for a 100-300MW wind farm. If the member state for a joint project is the UK then the GIB could provide construction phase funding.

3.7.3 Lending Factors

Regardless of the investor in the project, there are several key lending factors, which will be sought after to increase the attractiveness of the project as an investment. These include:

- Proven technologies with a suitable warranty from reputable suppliers are highly favourable
- All construction parties must be reputable and financially sound
- Construction risk must be supported by an acceptable mitigation mechanism such as contingent equity provisions[51]
- Any debt term must last a maximum of 15 years operational stage plus construction stage and tenor must always leave a minimum of 5 years tail over expected life
- There must be a cash return guarantee, usually in the structure of a Power Purchase Agreement (PPA) due to the nature of wind power being intermittent. This should also be subsidised by some form of support mechanism to ensure reasonable profits and encourage investment

While investors may seek some or all of these parameters, the main features that they encourage in an offshore wind project investment are reduced uncertainty and risk.

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[51] (OWDF, 2011)

3.8 Further Development Options

3.8.1 Interconnection with French Infrastructure

GEL has recently announced that it has signed an agreement with Jersey Electricity Limited (JEL) to develop connectivity with France through the Channel Islands Electricity Grid (CIEG). This will increase the potential to import electricity from 16MW to 60MW theoretically by 2016. This will provide the opportunity for Guernsey to receive up to 90% of its current demand through the interconnector, thus increasing security of supply and reduced reliance from ‘on island’ generation from fossil fuels.[52] GEL has considered the future potential of large scale marine renewable energy and states that the forthcoming interconnector has been designed to handle the export of approximately 200MW of renewable energy.[53] They also report that they are continuing to evaluate the possibility of a direct Guernsey-France cable but this has been a consideration since the 1980s and faces financial and technical issues.

For this reason it seems unnecessary for further research into the potential for a direct cable form a Guernsey wind farm to a either a French wind farm or directly to the French mainland.

3.9 Summary

This report found that Guernsey has a fantastic wind resource which could be exploited through the development of an offshore wind farm, specifically the Chouet Met mast appears to be located in a prime position to measure wind speeds similar to those likely to be available at an offshore location in Guernsey waters. Through the refinement of constraint mapping it is clear to see that detailed consultation with the radar operator and also the fishing industry is of key concern to mitigate risk and indirect project costs.

By approaching the project cost of a 30MW and 100MW site from two angles the report has shown that although not specific the cost of £3-3.5million is likely to be an accurate current cost, and that when projected forward to 2020 these costs are expected to decrease by approximately 39%. Using these projections a comprehensive set of financial scenarios were investigated to ascertain the most effective form of investment without the benefit of any subsidy. Typical offshore wind farm finance options from other countries were considered and found that utilities and offshore construction companies make up the majority of investors while the remainder is largely provided by OEMs.

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[52] (GEL , 2013a)

[53] (GEL, 2013b)

3.10 Conclusions

- Chouet Met mast is a valuable and relatively low cost asset
    - Planning permission should be extended beyond October 2013
- Need for detailed consultation with the Guernsey airport to negotiate radar mitigation and establish associated indirect costs
- Need for detailed consultation with the fishery agency to understand the best approach to mitigating displacement of effort and impact on marine life. Which will lead to a understanding of associated indirect costs
- CAPEX costs are site specific and variable but two different costing approaches from reliable sources have resulted in similar projects costs of
    - 30MW ≈ £69million
    - 105MW ≈ £243million
- Access to subsidies would encourage private investment although it can be shown that it is not essential if GEL invest and offset imported diesel
- Deployment of an offshore Met mast would further decease project risk
- Prioritise consultation with radar operators and the fishing industry
- Deploy offshore Met mast or floating LiDAR to accurately record onsite wind speeds if the constraints can be economically mitigated
- Consider joint partnership with EU member state to potentially access finance options and foreign subsidies

4 Onshore Wind

4.1 Opportunity

One area that has been undervalued in the past on the island of Guernsey is looking into the viability of onshore wind energy generation. There have already been extensive studies undertaken into the use of marine technologies, including large-scale offshore wind energy generators. However when discussing with RET, these were seen as being a more long-term solution. In order to achieve a more short term approach in reducing emissions and becoming more energy independent, the development of onshore wind generators became an attractive proposition.

Wind turbines are now considered as one of the most mature renewable technologies available, and as a result are also one of the most cost effective; a significant factor to consider, particularly as there are currently no financial incentives available, such as the Feed in Tariff (FIT) that is offered in the UK.

Application of skills and experience in the development of onshore wind developments allows an assessment of the viability and acceptability of onshore wind turbines for Guernsey.

4.2 Wind Resource

Guernsey has a significant wind resource due to the island's location within the English Channel and proximity to the south-westerly prevailing wind from the Atlantic Ocean. There are two meteorology data collection masts on the island which partnered with European Wind Atlas data provides a confident understanding of the available wind energy resource.

4.2.1 Wind Data

Guernsey Met Office collects data from two Met masts on the island as follows:[54]

- Guernsey Airport – two 10m masts 101m a.s.l
- Chouet – one 10m mast 20m a.s.l

Wind data from both these locations for January-December 2012 have been used to determine the wind resource for the island. However, it should be noted that the data provided by the Guernsey Met Office is only over one year (2012) and therefore should not be taken as a long-term prediction of the wind resource. A long-term study into historical and future data should be undertaken to understand annual variations and predict accurate project output.

Using masts positioned in two different locations provides a great opportunity for understanding the wind conditions for an inland site compared to the coastal conditions at Chouet. This allows for a better comparison of geographical effects to the wind.

The European Wind Atlas[55] has a range of data for Europe for wind speeds at 50m a.g.l across various terrains. The atlas does not include data collected from Guernsey. However Cherbourg and Dinard in France, are the closest data collection points to Guernsey. This means that the European Wind Atlas data should only be used as a guideline in support of collected data from the Guernsey Met Office.

4.2.2 Wind Speeds

The European Wind Atlas outlines the wind speeds at 50m a.g.l which when compared with data from Guernsey Met Office data after height adjustments, are considered in line with expected wind conditions.

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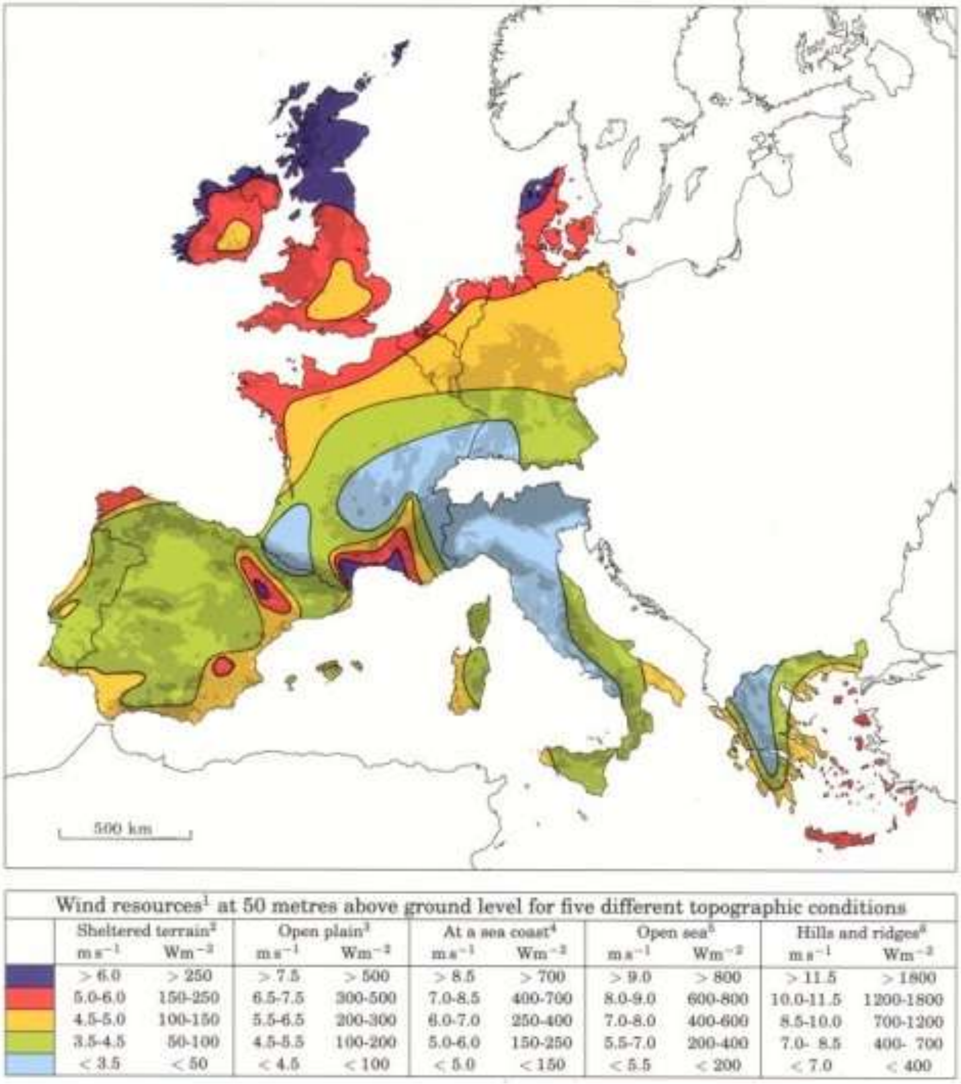
[54] (Guernsey Gas, 2013)
[55] (European Wind Atlas, 1989)



Wind resources[1] at 50 metres above ground level for five different topographic conditions										
	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	m s⁻¹	Wm⁻²	m s⁻¹	Wm⁻²	m s⁻¹	Wm⁻²	m s⁻¹	Wm⁻²	m s⁻¹	Wm⁻²
🟪	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
🟥	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
🟨	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
🟩	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
🟦	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Figure 33: Wind speeds at 50m a.g.l[56]

The Guernsey Met Office data predicts the average wind speed of 6.3 – 7.2m/s at 10m above ground level, which demonstrates the impact of changing land profiles on the wind turbulence. At Chouet, due to the coastal and exposed site conditions the average wind speed at 10m a.g.l is approximately 7.2m/s[57] which increases further above ground level, as the roughness caused by the land to the wind dissipates. When adjusted to 50m a.g.l, the wind speed at Chouet is approximately 9m/s which is in line with expected coastal and exposed areas.

4.2.3 Turbulence

Further consideration would need to be made to turbulence in the wind profile caused by wind shear from the cliffs or nearby features to any proposed wind site. It should be noted that installations of wind turbines close to cliffs is likely to produce turbulent wind conditions, so care must be taken in site design to position turbines back from the cliff. Installation of site specific Met

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[56] European Wind Atlas

[57] (Guernsey Gas, 2013)

masts should be advised to understand specific site characteristics and appropriately position turbines.

At present the extent of these effects are unknown, but the presence of the turbulent area behind the lip of the cliff may have a detrimental effect to the estimated generation. A wind turbine generates based on reasonably linear wind currents, so in an area where the wind flow is considered to be “messy”, this makes the energy conversion less effective.

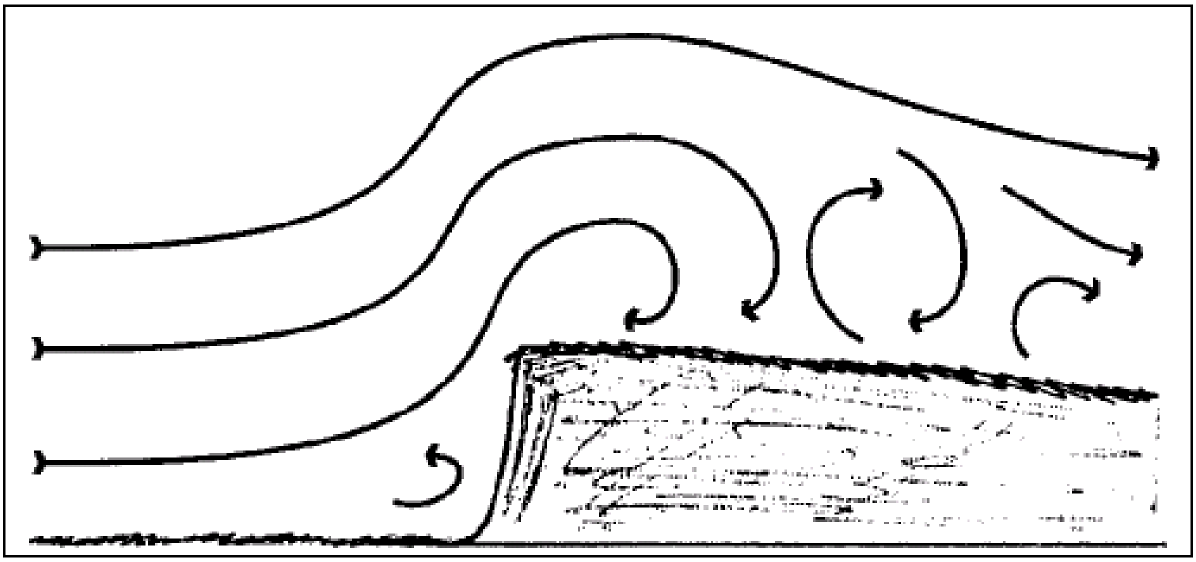

Figure 34: Representation of turbulence in wind currents caused by features such as cliffs[58]

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[58] (RAANZ, 2012)

4.3 Site Selection

Understanding the constraints for onshore wind presented by Guernsey required in depth consideration and consultation with various stakeholders to determine appropriate locations of onshore wind.

4.3.1 Methodology

In order to identify potential development sites for onshore wind, within the constraints presented by the island, GIS was used to map the island with all available and relevant information. This visual information database led to the identification of several sites and further analysis of site development.

Stakeholders were consulted where possible to devise the best understanding of the island and relevant constraints for the development of onshore wind sites.

4.3.2 Site Constraints

The following summarises key factors that restrict and depict areas for onshore wind developments, which may need further consultation when developing a wind site. Throughout all sites identified as potential wind energy locations, these constraints and stakeholder involvement need to be considered. UK best practise standards were adopted and as shown in the table below buffered areas were applied to sensitive receptors to reduce the impact of a wind development.

Table 10: Best practise UK standard guidelines for wind turbine buffering

Constraint	UK Best Practise Standards
Water Bodies	25m from closest part of development
Protected and Designated Area	Specific consultation required
Radar	Guernsey Specific – 120m maximum above sea level though further consultation required
Rights of Way	Tip height
Communication Links	Tip height plus 10%. Specific consultation required
Grid Infrastructure	Tip height plus 25%
Sensitive Receptors	5 times tip height; consideration of noise under ETSU-R97 guidance could reduce this buffer.
Roads	Max tip height for main roads, Rotor radius for unclassified.

4.3.2.1 Land Use

Guernsey has a Rural Area Plan and Urban Area Plan that are used to depict what certain allocations of land can be used for.[59] There is a range of land classifications that need to be considered when choosing a development site, so to reduce any effects on the land area. For example, areas of environmental and ecological designations have additional guidelines for developments, which although considered on a case by case basis, will require thorough consultation with the planning department.

It is worth noting that the installation of wind turbines does not prevent the land being used for other means. Grazing of stock and farming can still take place up the base of the turbine with minimal impact to the existing land use.

4.3.2.2 Ecology and Conservation

There are several environmental designations on Guernsey including: Sites of Nature Conservation Interest, Conservation Areas, nature reserves and Area of High Landscape Quality. Heritage conservation is also important to Guernsey due the various historic presences on the island. Section 10 on Environmental Scoping, looks into studies and considerations to be made for an onshore wind development in order to mitigate and reduce any impacts on aspects of conservation and ecological importance.

Wind development on Guernsey requires an EIA under guidance set in 2009.[60] It is specified that a single non-domestic turbine would not require an EIA.[61] In comparison, UK Town and Country Planning Regulations 2011 require an EIA for turbines with a hub height of 15m or for more than one turbine on a site.[62] Having an EIA for a wind turbine development would demonstrate best practise standards that could enhance the credibility of a development.

Further details covering the requirements of an EIA for onshore wind projects has been covered in detail in §9.

4.3.2.3 Communication Links

Data access restrictions meant that accurate information in regards to communication links could not be included in this study. Locations of masts used for communication were identified and mapped as a general suggestion into the microwave links between masts. Telecommunication companies generally specify a distance of tip height plus 10% of buffering from any microwave links

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[59] (Island Development Committee - States of Guernsey, 2010)
[60] (Environment Department, 2009, p. 1)
[61] (Environment Department, 2009, p. 2)
[62] (Town and Country Planning, 2011)

to mitigate impact,[63] however consultation would be required with Guernsey's telecommunication operators. Should interference be an issue, relocation of a mast or rerouting of a link may be required which may be undertaken at the wind developer's expense.

4.3.2.4 Grid Infrastructure

GEL advised that connection to the electrical grid would require a case-by-case consideration, as the ease of connection would increase when the turbine is larger. [64] This suggests that consultation with GEL would result in a viable connection being established.

It should be feasible for domestic turbines below around 10kW to directly connect into the property's electricity connection, as the typical domestic service is designed for a maximum load of up to 14kW. Schools and community facilities would likely have a larger connection capacity, meaning that turbines installed on these sites could be equally viable under consultation with GEL. However, all installations would require power conditioning equipment to ensure power quality is maintained to secure stability.

When considering larger scale systems to install, it is more likely that a stand-alone generator would require a direct grid connection to the low voltage (415V) network. This would require laying new underground cabling, needing a wayleave agreement to be established with the land owner to permit access to allow the installation.[65]

4.3.2.5 Radar

Guernsey Airport is responsible for operating radar coverage across Guernsey and Alderney and is currently upgrading the radar system. The new £3.2million[66] radar system soon to be fully operational at Guernsey airport operates using both primary and secondary systems. The more traditional primary radar, reflects a wave which bounces back off the aircraft, and would be affected by the presence of a large turbine, as it would effectively block whatever is behind it.[67]

The secondary system is potentially less affected by the movement of the turbine blades, as a transponder is used on the aircraft to respond to any signal received. Although possible to reduce the noise created by the interference of a large turbine, this can be difficult as the direction of the turbine is constantly changing based on the wind direction, emphasising the need for consultation upon site development.

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[63] (Fisher German, 2011)
[64] (Blondel, 2013)
[65] (Blondel, 2013)
[66] (BBC News, 2013)
[67] (Guernsey Airport, 2013)

When identifying onshore wind locations, consideration should be made to natural features that may reduce the impact of a wind turbine on the radar. Hills and landscape features can block the radar, meaning that a subsequently placed turbine could have little impact on the radar. Consultation with the radar team at the airport identified that providing the tip height of the turbine is below 120m a.s.l then there is unlikely to be a significant effect on radar. It is possible for the airport to cross reference the position and impact of these turbines to predict any effects.[68] Therefore thorough consultation with the radar team at the airport is important to design the best possible site and promote best practise.

4.3.2.6 Rights of Way

UK best practise guidelines recommend a distance of tip height from rights of way including roads and footpaths. As an advisory guideline this can be adapted as seen appropriate for the site and the relevant stakeholders. This is advised as it reduces visual impact, distraction and the pass of blades over access routes.

4.3.2.7 Access

A common barrier for many large projects on Guernsey is access limitations to both the island and movement to a specific site. The import of turbine components to the island would be permitted and accepted by the port of St Peter Port,[69] however access to development sites is more limited.

Turbine components consistent with a macro sized wind turbine would be difficult to transport via road, so a barge would be used which would be beached into a nearby bay for transportation to the site.[70] This would reduce the strain on road links from the main port and be especially successful in the north of the island due to fewer cliffs and flatter access routes.

Smaller components for micro wind would be unlikely to warrant the cost of using a barge to transport to the site, especially if there are no bays near to the site or it would require steep access routes. This would require a creative approach to transporting components that must be reviewed on a case by case basis.

Guernsey has many narrow roads and lanes that would be unsuitable for long, wide or heavy vehicles. For the safety of all road users, a vehicle escort may be required to both ensure traffic is controlled and that the oncoming route is clear. As a result, there are multiple restrictions governing both the transportation of abnormal loads and oversized vehicles as well as the availability of vehicle escorts to ensure a safe route for all road users.

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[68] (Guernsey Airport, 2013)
[69] (Gill, 2013)
[70] (Gill, 2013)

Table 11: Rigid Vehicle Restrictions on Guernsey[71]

Rigid vehicle restrictions on Guernsey	
Length	9.45 metres
Width	2.31 metres
Weight	Maximum of 9 tonnes per axle, 28 tonnes gross weight

If there is a need for the removal of any street furniture to be carried out, then the Environment Department must be contacted to arrange this, with any cost incurred by the developer. Swept Path Analysis software should be used to calculate the path of the vehicle when manoeuvring by considering the available space along the route.

Access to the site would be required both during construction and for occasional maintenance purposes. This would also require an agreement with the landowner.

4.3.2.8 Visual

The landscape and visual impact can be assessed through a computer-generated Zone of Theoretical Visibility (ZTV). This would create a graphic showing areas of land within a specified radius where a chosen turbine could be seen, making it a great tool for initially understanding the visual impact.

In reality the visual impact would likely be less than predicted as only contours are considered for the modelling, and not features such as buildings and vegetation, which would create a natural visual barrier. A ZTV should be undertaken to understand and work to mitigate visual impacts of the turbine on the landscape. In addition photo montages can be used to provide a visual understanding of the turbine in the expected position from different surrounding viewpoints.

4.3.2.9 Noise and Proximity to Residences

Sensitive receptors such as houses and schools are identified to work to reduce any visual and noise impacts. Noise modelling can be undertaken under UK ETSU-R-97 guidance to understand the noise impacts of wind turbines.

ETSU-R-97 considers the background noise of the existing site and estimates the expected addition a turbine could make. If the turbine is predicted to be more than 5dB above background noise levels for a sensitive receptor, it is suggested that the proposal is changed to reduce the noise levels.

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[71] (States of Guernsey, 2013)

However, a financially involved property can experience higher noise levels up to 45dB than a none involved property.[72]

A noise study should be undertaken under ETSU-R-97 guidance, or of an equivalent standard to adopt best practise standards for the development of wind energy on Guernsey. It is worth noting that the close proximity of the sea of identified sites will likely reduce any significant impact to the noise levels produced by a wind turbine. During certain conditions, a rough sea would make up a large proportion of background noise, which would be favourable in reducing the impact of a turbine. When considering sites for development in this study, background noise levels have not been considered due to time and data constraints. However noise from the turbine has been modelled to understand what affect the turbine may have independently on sensitive properties.

It is best practise to buffer a sensitive receptor with a 5 times tip height distance. This is to reduce visual and noise impacts, however individual case by case consideration of noise is required to assess whether this distance could be reduced, especially for a financially involved property.

4.3.2.10 Hydrology and Geology

Studies into the hydrology and geology of any identified sites will be required to reduce the impact of turbine foundations on the site and ensure that the turbine is appropriately located.

4.3.2.11 Planning Permission

At present the Development Land Use Plans support the integration of wind energy projects[73]. However, planning policy is restrictive in the actual implementation of the plan for renewable energy. The Environment Department emphasise the case by case consideration of any submitted application, and have produced planning advice notice for domestic wind turbines[74] which outlines key considerations for developments. Using these guidelines in cohesion with UK best practise guidance, such as set out by Cornwall Council[75] and used as a basis for most of the UK, should enable a responsible development of wind energy on Guernsey.

It is hoped that changes in planning policy, due in 2015, will work on the existing guidance and provide an up-to-date and relevant, usable guide to renewable energy development on Guernsey.

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[72] (The Working Group on Noise from Wind Turbines, 1996)

[73] (Island Development Committee - States of Guernsey, 2010)

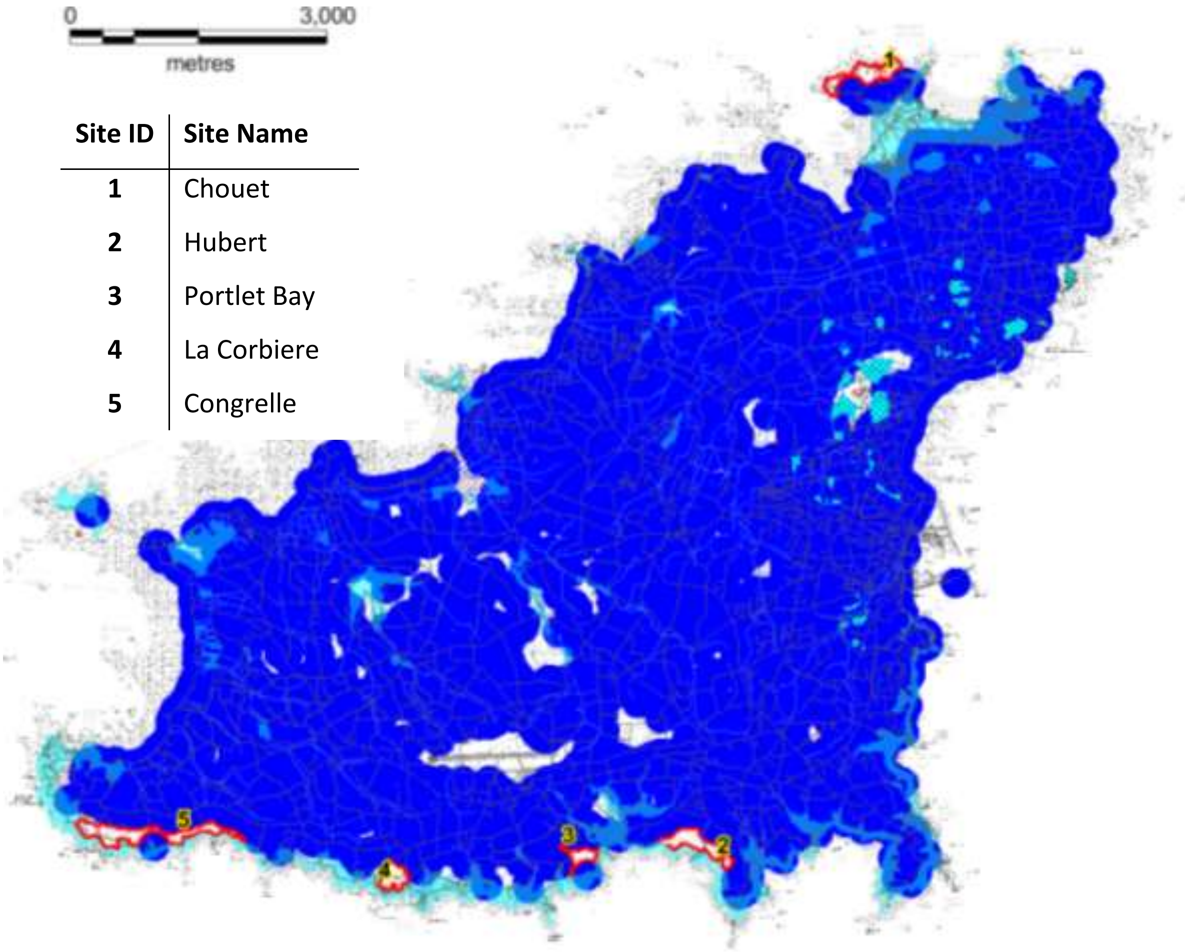
[74] (Stagecoach, 2012)

[75] (Cornwall Council, 2013)

4.4 Identified Sites

Initial identification of multiple sites across Guernsey has shown there is indeed the land area required for onshore wind. The various sites have been identified around the island based on typical environmental and social constraints. This does not mean they would all be suitable for development, particularly as the cumulative impact would then need to be assessed. Instead, the optimum site has been chosen and pursued further to give a better idea of the potential for onshore wind on Guernsey.

The several sites were identified from multiple constraints applied to the island, and are outlined as shown in figure 35:



Site ID	Site Name
1	Chouet
2	Hubert
3	Portlet Bay
4	La Corbiere
5	Congrelle

Figure 35: Constraint Mapping of Guernsey to identify potential onshore wind development sites

4.4.1 Chouet

Chouet is the largest potential wind development site of Guernsey. It can accommodate a single 225kW ACSA[76] turbine, but also provides flexibility for the installation of micro projects. Chouet has neighbouring properties and businesses that could benefit from the electricity directly or it could be exported to the GEL for distribution around the island.

Due to the potential flexibility of the site, it could act as a demonstration and educational facility to inform residents and visitors about wind energy and the technology. This could help develop the public's understanding of the technology should a large offshore wind project go ahead. Additional options include the short term use of the site as a demonstration facility for micro wind or refurbished turbines in turbulent conditions, for a local business.

4.4.1.1 Mapped Constraints

As identified above, there are a range of considerations to be made when considering a development at Chouet. The site is located adjacent to the Mont Cuet landfill site, Royal Guernsey Golf Club and in proximity to a Site of Nature Conservation Interest (SNCI). Ecological and conservation impacts need further analysis to understand any effect a turbine may have, in addition to investigation into hydrology and geology of the site. The wind resource of the site has been assessed by the neighbouring Met mast, and suggests an average wind speed of 7.2m/s,[77] which provides a usable and significant resource to harness.

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[76] Aerogeneradores Canarios Sociedad Anonima (ACSA)

[77] (Guernsey Gas, 2013)

4.4.1.2 Stakeholders

There are a range of stakeholders that need to be consulted throughout the development of Chouet to ensure that the best project is designed to best balance economic and public acceptance of the project. These include:

- Landowner
- GEL – Grid connection
- Guernsey Airport – Radar restrictions
- Telecommunication operator – Communication links restrictions
- Royal Guernsey Golf Club – Site neighbour
- Guernsey Model Club – Site user
- Mont Cuet Landfill Site
- States of Guernsey Planning Office
- Public Consultation

4.4.1.3 Access

Access to the site for a large turbine would be limited so the use of a barge that could beach in Ladies bay, Pembroke Bay or Baie De La Jaonneuse, thus limiting the use of the road networks. A micro turbine has the potential to be brought in by road, however a Swept Path Analysis would need to be undertaken to assess appropriateness of a route from St Peter Port.

4.4.1.4 Macro Wind

Site Layout

Constraints mapping led to the opportunity to install a 225kW ACSA turbine on the site. As seen from the figure below, the location of the turbine is within the unconstrained areas of the site, in order to reduce impacts on neighbouring sensitive receptors.

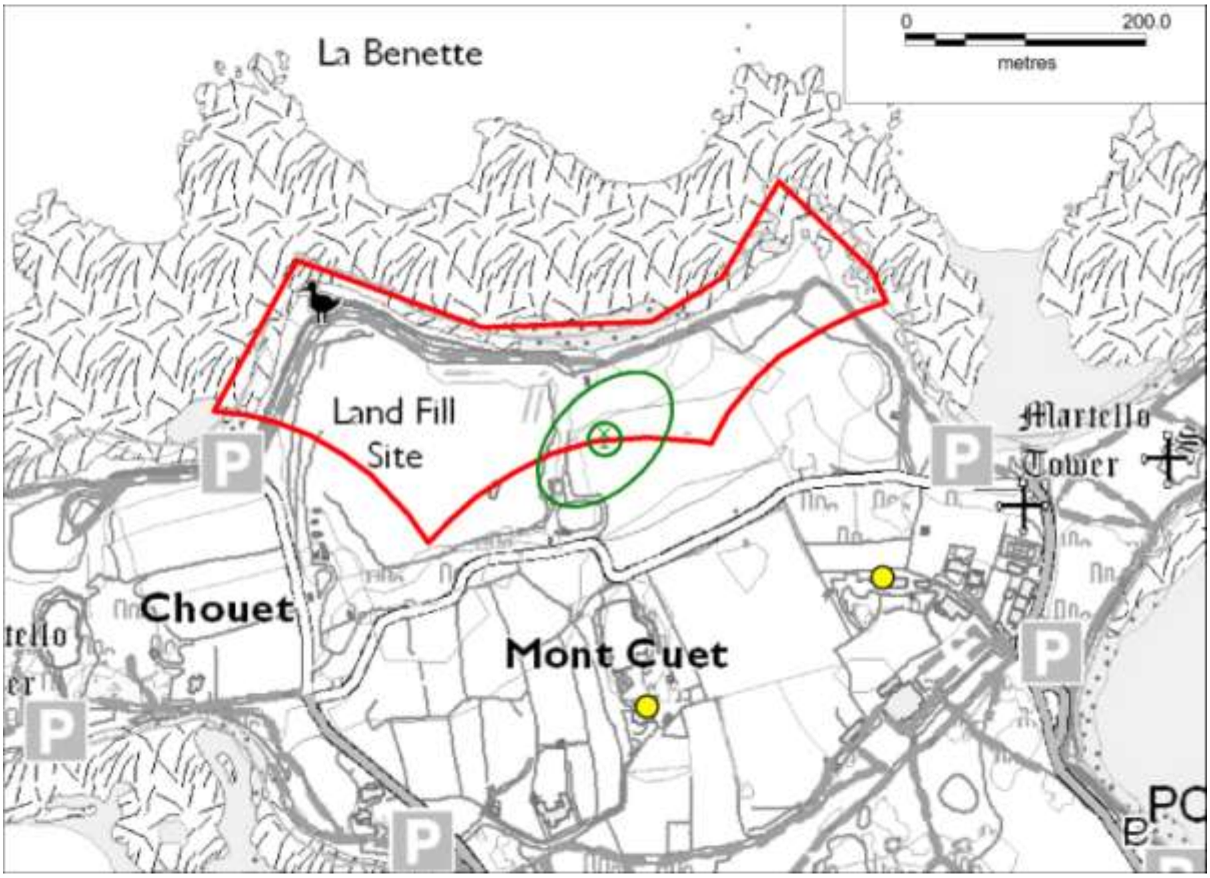

Figure 36: Site Layout of a 225kW ASCA turbine at Chouet

Energy Generation

The chosen turbine used to model the potential of the site could produce up to 873MWh/year of electricity for Guernsey. This equates to 135 Guernsey homes, based on the average consumption.

In addition to this carbon savings of 495 tonnes could be made from the displacement of on island electricity generation.

Noise Modelling

A noise model was undertaken to assess the effects the turbine may have on neighbouring properties. Industry standard software[78] was used to understand the dissipation of noise from the turbine across the site. However, it is worth noting that under ETSU-R-97 that background noise

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[78] Windfarm from ReSoft Limited

levels need to be studied to accurately assess the noise impacts on sensitive receptor properties. The proximity to the sea is likely to provide a significant background noise that will work to cancel out any turbine noise, but further analysis is required.

The figure below demonstrates that without consideration of background noise levels, the sensitive receptors are receiving approximately 42dB of noise from the turbine, which is within the levels from any financially involved properties.[79] Providing this is no more than 5dB above background levels, this is unlikely to require the relocation of the turbine for noise reasons.[80]

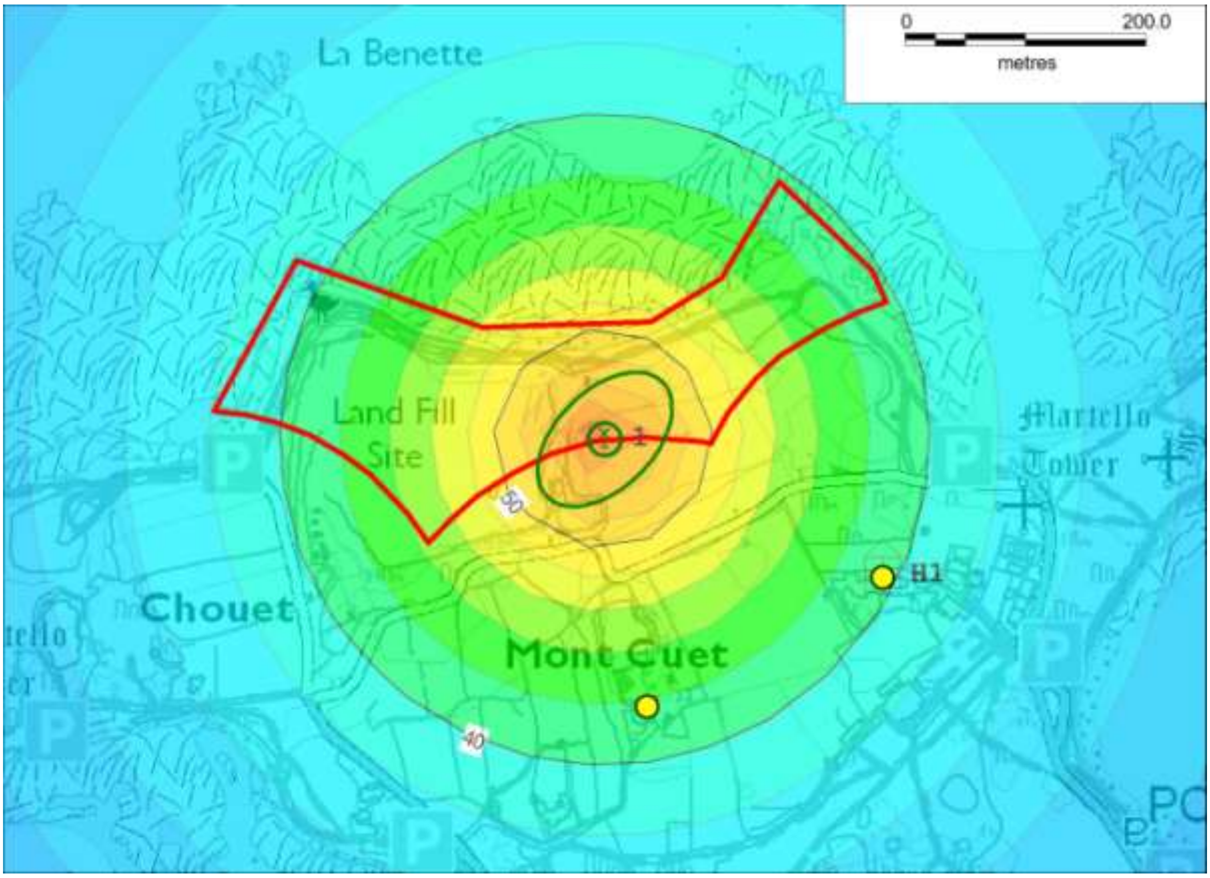

Figure 37: Noise model of a 225kW ASCA turbine at Chouet

Additional Considerations

It is vital throughout the entire development that in depth consultation is made with stakeholders identified previously. This will help find a balance between the economic returns and project acceptability by the island.

Additional consideration could be made to installation of a refurbished turbine with a less than 20 year expected lifetime, as a shorter term project, maybe just for 2-10 years. This could reduce capital project costs and act as a short term educational tool to supplement an offshore wind development.

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[79] (The Working Group on Noise from Wind Turbines, 1996)
[80] (The Working Group on Noise from Wind Turbines, 1996)

Although the recommended turbine is a 225kW ACSA, it is possible that technological advancements in turbine technology could allow for a higher capacity turbine to be installed on the site. At present the restraining factor is the tip height of the turbine, which for sake of noise and visual intrusion to sensitive receptors, requires a five times tip height distance from residences. Having a turbine of similar or less tip height, but with a larger generating capacity could enable more electricity to be generated by the site without increased effect in landscape character.

4.4.1.5 Micro Wind

Site Layout

Another option for Chouet was for the situation of micro turbines on the site. These required a smaller buffer zone to account for noise and visual intrusions, with the site having the potential to accommodate up to three 50kW C&F Green Energy turbines. Variations in layout could be considered in regards to a combination of less than 50kW sized turbines as a demonstration and research facility for small wind.

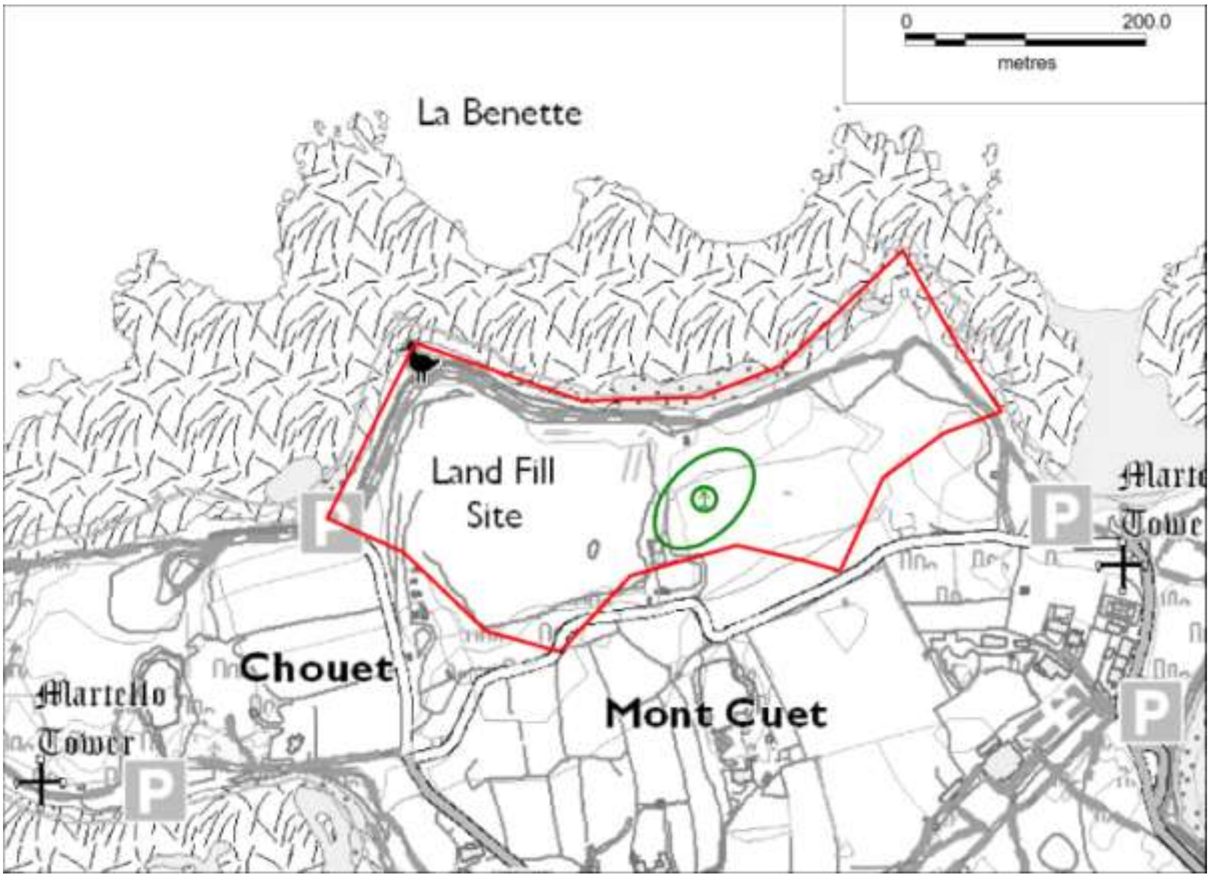

Figure 38: Site Layout of a 50kW C&F turbine at Chouet

Energy Generation

One 50kW turbine has the potential to produce 228MWh/year with an annual carbon saving of 135 tonnes. A 20kW could produce 93MWh/year with a 56 tonne carbon saving. Multiple turbines on the site could collectively increase the electricity output.

Noise Modelling

A 50kW C&F direct drive turbine was modelled on the site to investigate noise impacts. The chosen turbine is one of the quietest in its class due to having no gearing system.[81] When modelling this in Windfarm[82] it was found that there is likely to be minimal levels of noise disturbance to sensitive receptors nearby; especially once background noise levels are included in the model.

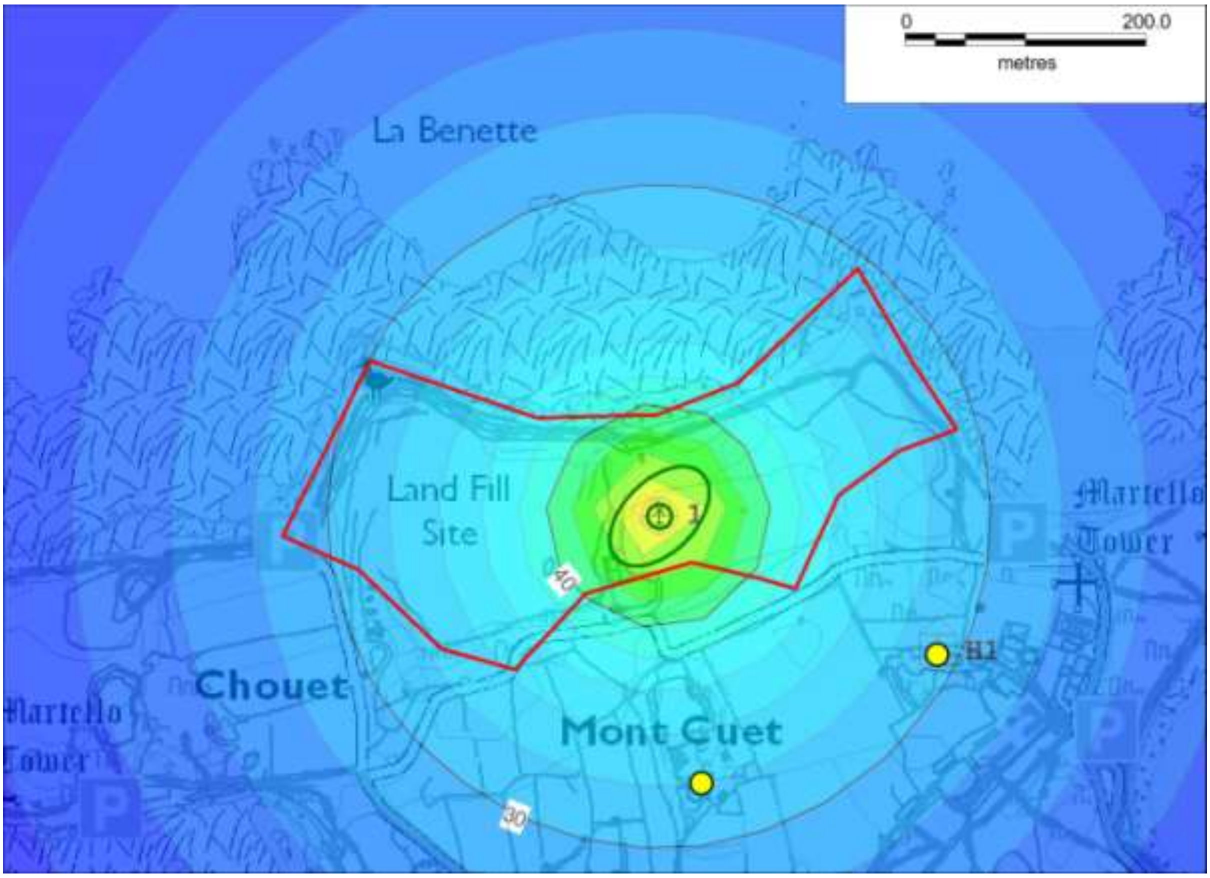

Figure 39: Noise model of a 50kW C&F turbine at Chouet

Should more than one micro turbine be installed on the site, cumulative noise impacts will need to be modelled to ensure that any cumulative effects are considered and minimised, especially if none direct drive turbines are installed.

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[81] (C&F, 2013)
[82] Windfarm by Resoft

Additional Considerations

Developing the site as a facility for demonstration of onshore wind turbines would require further consultation with the landowner in regards to access availability throughout the year for visitors. Additionally, a series of information boards about the site, possibly as part of an educational project set up for the residents of Guernsey, would add value to the development and aid acceptance of onshore wind.

4.4.2 South Coast

The sites that have shown to be viable at the southern end of the island are less ideal than the chosen site at Chouet. This is mainly due to constraints such as the limited radar ceiling and access which is restricted by the narrow roads.

This potentially reduces the viability for a demonstration project, but does show there is a possibility for local landowners to invest in the technology and consume generated electricity on site. This may also provide a stronger economic case as due to high cost of purchasing electricity on the island.

4.4.2.1 Site Considerations

As previously discussed with Chouet, the same array of constraints must also be considered for the sites discovered on the south coast. The land on the south coast is higher above sea level than at Chouet, at approximately 75-85m a.s.l. This means the radar ceiling is more restrictive due to the 120m a.s.l limit. Therefore the maximum height of a turbine would need to be below 35m tip height to avoid possible interference in some areas.

An additional consideration due to the close proximity to the cliff edge is the effect this has to the wind, as it may create turbulent conditions. Further considerations to this should be made with the possibility of a meteorology mast to gather in depth data.

Once the turbine is delivered by boat to St Peter Port it would have to be transported to the cliff-top sites, a distance of 9-13km.

Additionally, the south coast is an area that attracts many tourists both due to the natural scenery on offer and the German occupation landmarks. Inland from the coastline is largely used for farming and agriculture. Therefore, further consultation with these stakeholders must be undertaken to reduce and mitigate any impacts a wind development may have.

Identified sites have been mapped using GIS and are shown below. It should be noted that in some cases the red line indicating the site boundary appears smaller than the area of land that is unconstrained by buffers such as housing. This is due to the height of the land being so that the radar ceiling is restrictive of wind turbines.

4.4.2.2 South Coast Sites Identified

Four sites have been identified on the South coast and are summarised in table 12:

Table 12: South Coast Sites Identified

Site ID	Site Name	Suitable Turbine	Quantity
2	Hubert	C&F 20 kW	1
3	Portlet Bay	C&F 20 kW	1
4	La Corbiere	C&F 50 KW	Up to 3
5	Congrelle	C&F 50 KW	Up to 10 possible; 3 is judged more appropriate

4.4.2.3 Site 2 – Hubert

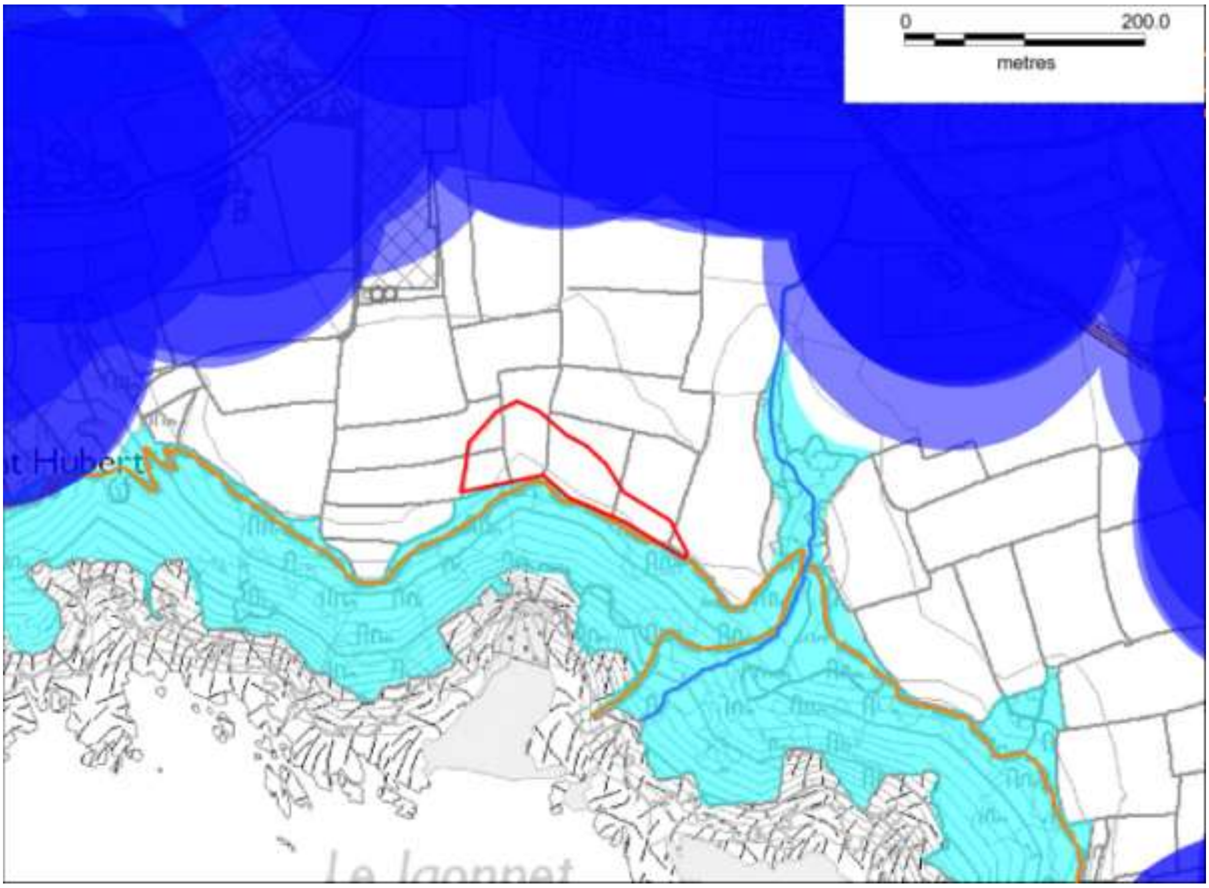

Figure 40: Site at Hubert shown by the red boundary where the land has initially been found to be suitable for a single 20kW wind turbine

Initially after applying available constraints at the Hubert site, the large area of land seemed to present a large viable development site. However, after consideration of the site contours, much of the site was constraint due to the radar ceiling. Based on the 20kW C&F turbine with a tip height of 26.6m, the site had to be below 93.4m a.s.l. This usable area is shown in figure 41 by the red boundary.

4.4.2.4 Site 3 – Portlet Bay

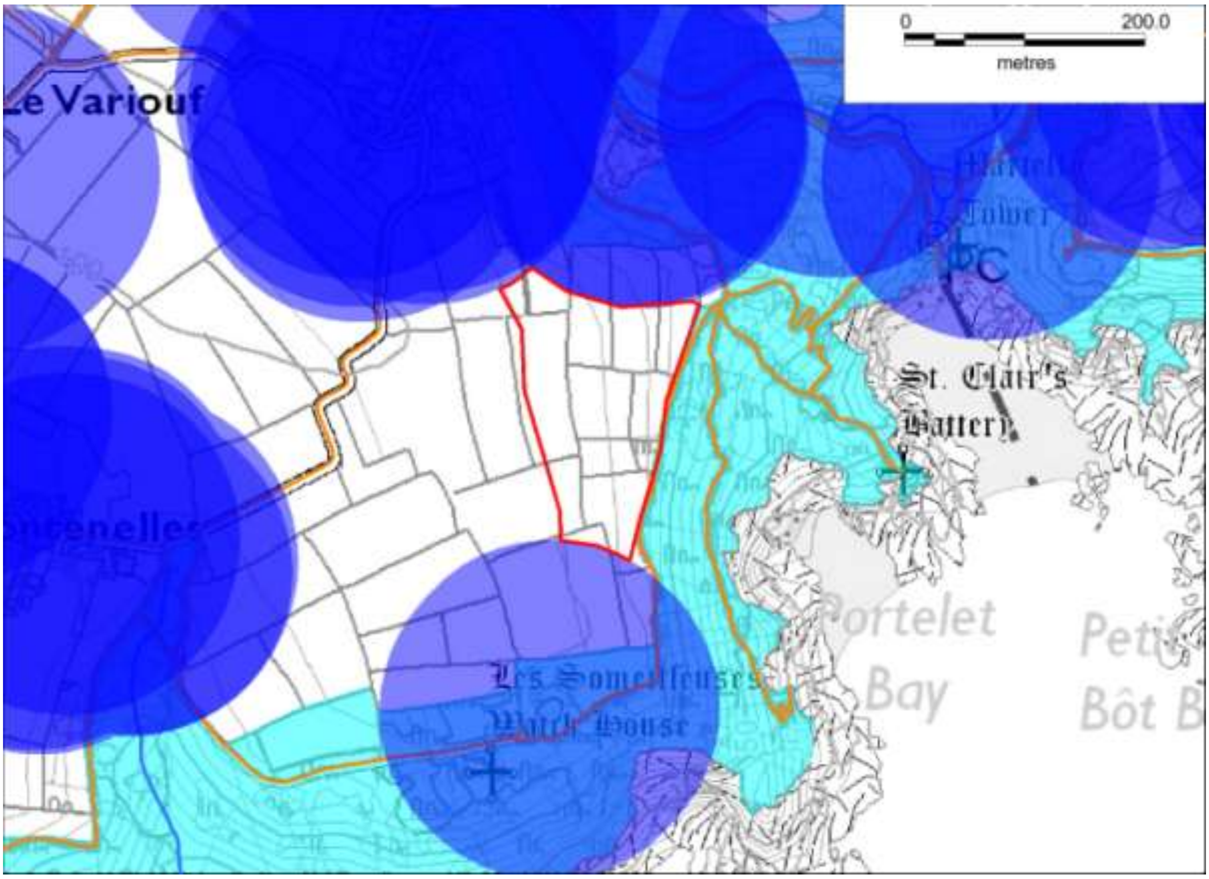

Figure 41: Site boundary at Portlet Bay showing the potential location for a single 20 kW wind turbine

As with the site at Hubert, the main constraint is the radar ceiling. The red boundary shows the area suitable for a 20kW C&F turbine, which was preferable over a 50kW C&F due to having a lower tip height of 26.6m compared to 35m.

4.4.2.5 Site 4 – La Corbiere

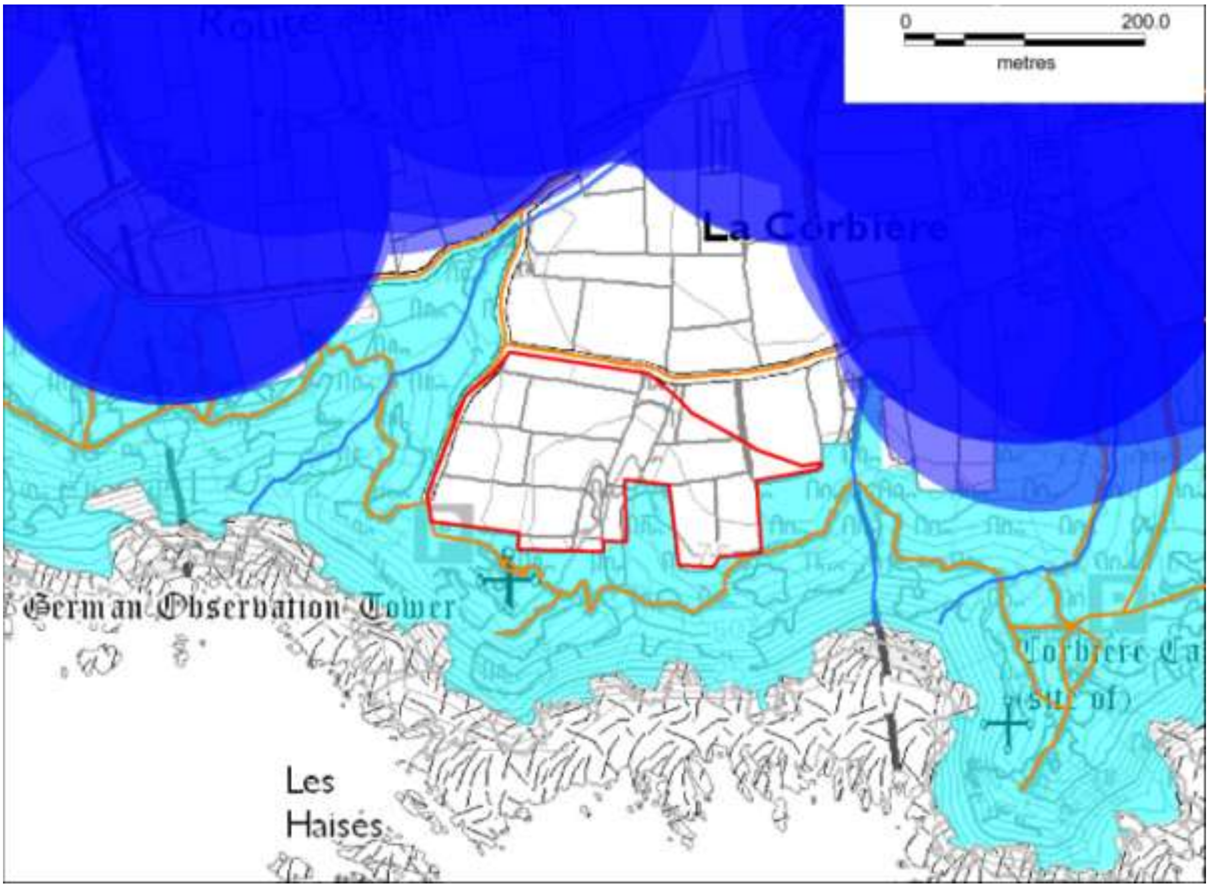

Figure 42: Site at La Corbiere showing the constrained boundary mainly constrained by the limited radar ceiling

Up to three 50kW C&F turbines have been modelled to fit on this site at La Corbiere. The entire unconstrained area has not been utilised due to the restriction of the 120m radar ceiling. This site presents a viable and flexible project for a landowner looking to generate their own electricity in addition to exporting to the grid.

4.4.2.6 Site 5 - Congrelle

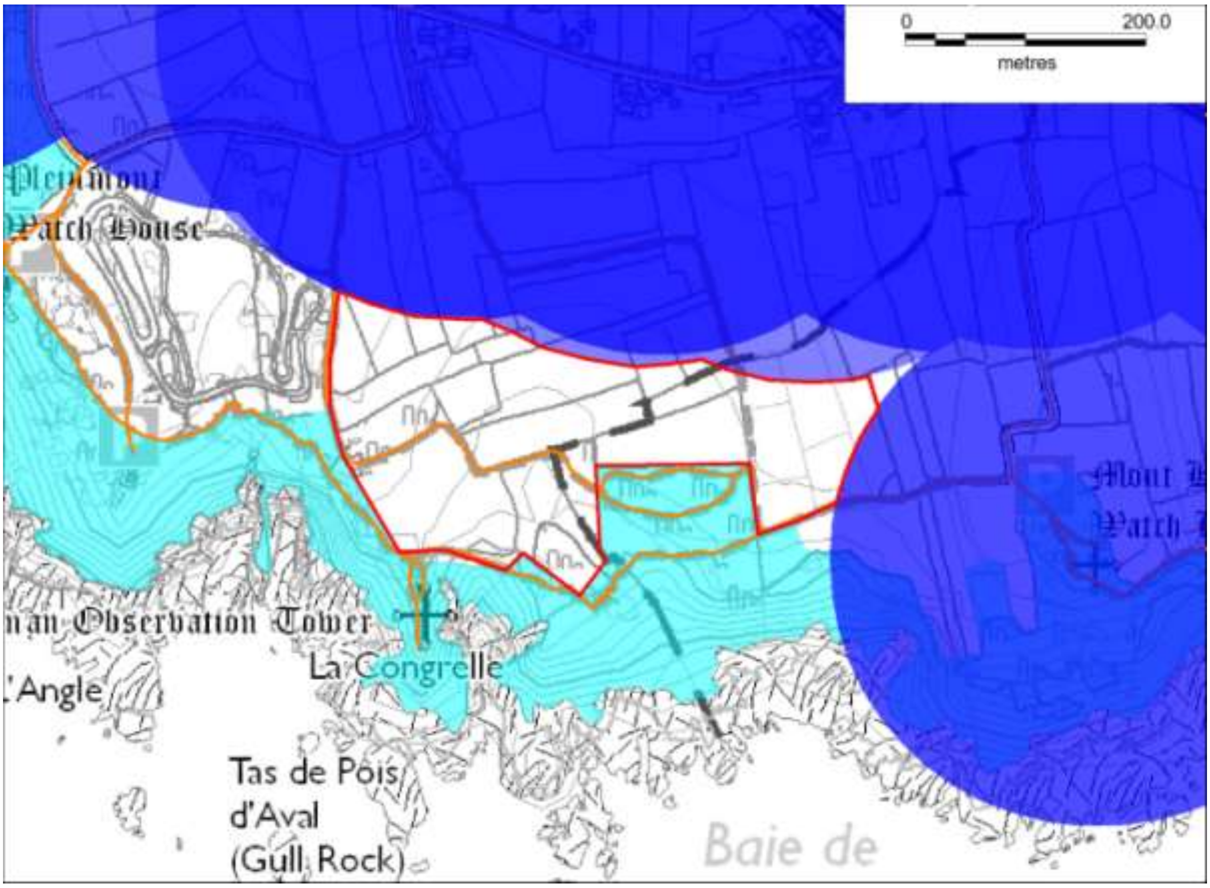

Figure 43: Site at Congrelle with the red boundary shown based on housing and SNCI constriants

As can be seen below, there is sufficient area to develop up to ten 50kW C&F turbines at the Congrelle site. This however would not be advised due to the negative cumulative impacts on both the visuals and noise.

It is therefore advised that no more than three turbines should be installed to minimise impacts by considering the layout and proximity to properties. They have initially been located away from the Cliffside to minimise wind turbulence effects and reduce visual impacts to the nearby footpaths.

Figure 44: Site layout at La Congrelle with three 50kW turbines shown left within the site boundary. The GIS map on the right shows the layout possible to fit up to ten 50kW turbines

Initial analysis has shown that there is enough space at this site to host a 225kW turbine with a 43.5m tip height. This is due to the contours being lower and not allowing interference with the radar ceiling. However, it is unlikely that such a turbine could be installed due to the restricted access to the site. Initial assessments of the area have shown there are narrow roads and tight bends that need to be navigated. This makes it unlikely that a 27m long blade could be transported here without significant difficulty.

4.4.3 Educational and Community projects

As well as the standalone wind sites that have been identified, it was also felt that to further raise the awareness of renewable technologies both educational and demonstration projects should be considered.

After visiting Guernsey Grammar School and speaking to Geography and Environmental Studies A-Level students, it was clear to see their enthusiasm towards renewable energy. Geography and Environmental Studies A-levels both incorporate modules in energy security and renewable energy which could be supplemented by having a renewable energy installation on site. This could enhance the knowledge of all students and staff in the school, allowing direct access to the technology and helping to provide hands on experience with the system to understand how it performs.

As an example of the benefits that can be offered from the installation of a micro turbine in the school environment, Falmouth School has been used as a case study, which installed a Vertical Axis Wind Turbine (VAWT) in 2009. [83]

Falmouth School – Vertical Axis Wind Turbine Student Led Project

Figure 45: Quiet Revolution turbine installation at Falmouth School, Cornwall, developed with staff and student support

Students from Falmouth School in Cornwall were involved in the development and installation of a 6.1m vertical axis Quiet Revolution turbine in 2009.

An information display panel is located in the school foyer to show visitors and pupils how much electricity is being produced and the carbon saving being made.

The turbine generates 7.7MWh/year and saves 3 tonnes of carbon each year.

The school also has a solar photovoltaic array of 210 panels which is used to supplement the understanding and importance of renewable energy.

Community centres and shared facilities could also host renewable energy projects and include all members of the community not just school pupils. Community ran or owned energy projects could help to improve the acceptability and familiarity of wind energy on the island.

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[83] (Falmouth School, 2011) (Falmouth Packet, 2009)

It is worth noting, wind turbines installed in community and educational settings are likely to be micro scale installations that are designed to operate in potentially more urban conditions compared to exposed cliff tops and open fields. As a small installation the electricity generation may be minimal, however the educational benefits could work to outweigh this.

Such a project may present an opportunity for a local wind installer to install a turbine on the school or community facilities' behalf as a short term opportunity for enhancement of technology development.

4.4.4 Further Options

There are several additional options that could be considered for the integration of onshore wind on Guernsey.

4.4.4.1 Social Spaces and Street Furniture

The use of street furniture in public areas such as on road lighting and car parking infrastructure would be used more for raising the public awareness of renewables, than for the sole production of energy. It would demonstrate a positive attitude towards renewable energy integration for visiting tourists and residents alike.

There are a range of small scale vertical axis turbines that have been developed for urban environments. The nature of the turbines means there is a small electricity outputs, although appropriate for the associated lighting installation, whilst being aesthetic and decorative. Several companies design turbines that can be used for branding and marketing in a range of colours, and could be designed to fit into their surroundings. For example, vertical axis turbines positioned in the quayside parking facilities in St Peter Port could promote local events and renewable energy whilst generating electricity for lighting.

Further consideration to such integration should be made to identify ideal sites. However the smaller scale of the turbines should have reduced visual and noises impacts and subsequently require smaller buffering areas and development considerations.

Figure 46: Urban Green Energy Vertical Axis Turbine used as part of car parking infrastructure, advertising space and for lighting

Figure 47: Urban Green Energy PV and wind integration system for street lighting

4.4.4.2 Off-Island Installations

There are several rocky outcrops and small islands around the coast of Guernsey such as Lihou and Houmet Paradis. Although worth consideration, in depth investigation into the access restrictions, geology, effects of rough seas, turbulence, shipping routes and visual implications should be undertake to assess potential feasibility.

4.5 Turbine Selection

There are multiple factors that affect the manufacturer and type of wind turbine chosen. In some cases this selection may be based on specific site parameters such as size or noise constraints rather than optimum energy production.

Guernsey is a very exposed island and can be susceptible to extreme or harsh weather conditions, more so than a typical UK mainland based site. It is therefore important to choose a good quality product with long term reliability. This is especially important as if a turbine were to suffer a fault that requires a specialised technician; the costs would be higher partly from the increased travelling expenses, due to Guernsey’s remote location. A possible form of mitigation could be from the training of some of the local population to provide technical support where possible. This would also have the positive effect through increased public participation and involvement.

The table below shows three turbines selected based on their durability and engagement with the only wind turbine supplier on the island. It is worth noting that, products supplied by a local turbine installer were considered as a feasible option for onshore wind on Guernsey due to the support of local businesses, in addition to the high quality wind turbine manufacture.

4.5.1 ACSA 225kW A27

The Chouet site has been modelled using an A27 225 kW turbine produced by ACSA. The A27 is a redeveloped Vestas V27 which has been in production since 1992. As with many manufacturers, the trend in recent years has been to increase the physical size of wind generators due to the cubed relationship between swept area and energy yield. ACSA, a Spanish company bought the rights to reproduce the V27 under their own name and offers one of the few remaining turbines of this height and large capacity.

Table 13: Specification details of ACSA A27 225kW

Specification Sheet	
Model	ACSA A27
Max. Power	225 kW
Hub Height	30 m
Tip Height	43.5 m
Annual Yield @ 8.4 m/s	872 MWh/year
Guernsey Homes Powered	134
Annual Carbon Savings	495 Tonnes
Noise	44.6 dBA at 5 m/s and 100 m
Method of Installation	Crane

Figure 48: ACSA A27 wind turbine[84]

4.5.2 C&F 50kW and 20kW

The chosen C&F turbines are all direct drive offering the advantage of lower noise levels due to the omission of a gearbox, as well as typically lower maintenance requirements due to fewer moving parts. The A27 on the other hand does utilise a 2-speed gearbox, although the design has proven to be reliable over the last 20 years.[85]

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[84] (World Wide Wind Turbines, 2013)

[85] (ACSA, 2011)

Table 14: Specification details for C&F 20kW and 50kW turbine options

Specification Sheet	Option 1	Option 2
Model	C&F 50e	C&F 20
Max. Power	50 kW	20 kW
Hub Height	25 m	20 m
Tip Height	35 m	26.6 m
Annual Yield @ 8 m/s	228 MWh/year	93 MWh/year
Guernsey Homes Powered	37	15
Annual Carbon Savings	135 Tonnes	56 Tonnes
Noise	37 dBA at 5 m/s and 60 m	35 dBA at 5 m/s and 60 m
Method of Installation	Crane	Hydraulic Tilt Installation

Figure 49: The C&F 50e 50 kW wind turbine[86]

4.5.3 Alternative Options

As not all turbines are suitable for all sites, the array of turbine sizes chosen are based what was felt to be most appropriate for each specific site. To provide a better understanding of what is technically possible, multiple turbines of differing capacities have been demonstrated on the site at Chouet.

Particularly in the micro scale range, there is a wide variety of wind turbines available which would be suitable for installation on Guernsey. Such alternative manufacturers include Endurance Wind

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[86] (C&F, 2013)

Power, a Canadian Company offering the 50 kW E-3210.[87] One of the major factors for selecting a certain turbine and supplier would be discussing delivery to the island as these costs are expected to be higher. Depending on the time scale of the project, just as the turbine for an offshore wind farm has been selected based on predicting future standards, onshore turbines may also further develop. The final turbine selected could therefore differ from those shown in this report.

4.5.4 Carbon Savings

The calculated carbon savings have been based on Greener Guernsey Government figures for Energy Policy, where the carbon intensity of electricity to the consumer has been estimated to be around 0.60kgCO_2 per kWh. This assumes the displacement of GEL's on island generation, more so than offsetting electricity from the French interconnector.[88]

The number of homes powered from the generated energy has been calculated based on figures published in the Guernsey Facts and Figures 2012 handbook.[89]

4.6 Economic Appraisal

Onshore wind devices have proven to be a popular investment, specifically on mainland UK where there are multiple financial support mechanisms. On Guernsey this is not the case, so it is important to understand the economic performance of an onshore wind turbine where the only income stream is from the GEL buyback price.

4.6.1 Exporting all generation

All values have been calculated from the initial estimation of wind speeds using the supplied wind data from the Met Office, as well as the standard assumptions used in table 15. Land rent has been based on a value of zero for these scenarios, as although land ownership is unknown, it has been assumed from initial research to be state owned. Further investigation is required to fully understand the land ownership of each site so communication could be started to negotiate land fees if necessary.

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[87] (endurance, 2013)
[88] (Greener Guernsey, 2013)
[89] (States of Guernsey Policy Council, 2012)

Table 15: Assumptions used for the cash flow models of turbines located at Chouet

Assumptions Used	
Operating life	20 years
Landowner Rent	£0
RPI	3.0%
Cost of Capital	4.5%
Discount Rate	7.5%
Tax on Profits	0.0%
Energy Price Rise	5.0%
Buy Back Price	9.89p/kWh
Electricity Price	17p/kWh

Table 16 summarises the main financial features for both the macro and micro solutions identified for Chouet. This has initially been based on the main assumption of 100% of the generated electricity being exported to the grid, generating an income solely based on the GEL buyback price.

Table 16: Financial performance of wind turbines at Chouet

Project Info	A27 225kW	C&F 50kW	C&F 20kW
CAPEX	£1,000,000	£280,000	£120,000
OPEX	£26,125	£7,000	£3,000
IRR	8%	7%	7%
NPV	£9,335	-£9,136	-£10,029

As there are currently no support mechanisms to provide stable revenue stream over the project life, the only income is from this buyback price. Over the project period however, there is no set price contract such as a PPA, like in the UK. As a result, prices cannot be guaranteed, and may change based on the marginal cost of generation. This further adds to the risk of a project making it potentially more difficult to fund if debt financed.

These initial findings show the variations that typically occur between macro and micro scale turbines, as although the larger A27 has a much higher CAPEX; due to the cubed nature of calculating energy from the wind, it offers a significantly greater performance and therefore income.

All project scenarios have been shown to have a positive IRR, yet only the A27 turbine has been capable of producing a positive NPV as well. NPV could be made positive by lowering project costs to increase revenue. Maximising economies of scale during installation and consulting a wind installer for more accurate budget costs could improve project economics.

It is possible to view the negative NPV as an unfeasible investment opportunity, as it suggests the investment holds less financial value in the future compared to its real value today. However, considering positive IRR in addition to all aspects, such as environmental sustainability, energy security and carbon savings will provide a wider project value that just economically.

4.6.2 On site use and exporting

The smaller scale turbines could also be used as a source of onsite generation for local landowners, such as farmers. This could provide multiple benefits from reducing electricity imports by using electricity generated directly from the turbine, as well as selling any excess generation to generate an income from the Buy Back price. The financial results from this can be seen in the table 17 for both the 50kW and 20kW turbines:

Table 17: Summary of economic performance for C&F 20kW and 50kW turbines on south coast sites

Project Info	C&F 50kW	C&F 20kW
CAPEX	£280,000	£120,000
OPEX	£7,000	£3,000
IRR	12%	11%
NPV	£123,495	£45,276

By using onsite generation to displace a proportion of electricity demand from the grid, this can significantly improve the financials of such projects. Not only does the IRR increase, but also the NPV rises to become a positive value.

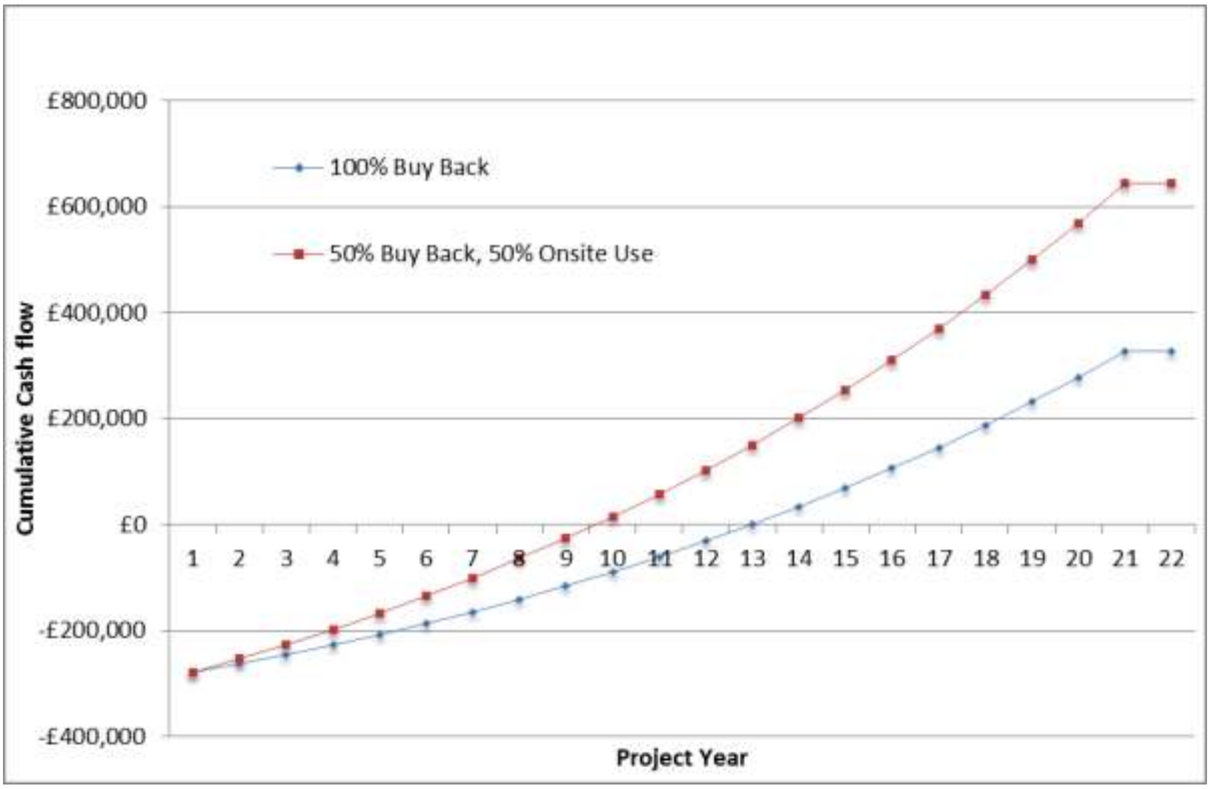

Figure 50: Cumulative cash flow comparison for a 50kW C&F turbine firstly based on both exporting all generation. The second model has been assumed as 50% own consumption and 50% exported

The payback rate would also improve by reducing from approximately 13 years to around 9.5 years for the C&F 50kW turbine (Figure 50). This is due to the savings made from offsetting the higher cost of electricity on Guernsey at around 17p/kWh compared to 14.5p/ kWh on mainland UK.[90]

If a project of this scale and type were to be seriously considered, then it would be advisable to undertake a full economic study to better determine the viability of such a project. This would need to include the most up to date values from the initial capital costs of installing onshore wind, to the revenue achievable through exporting back to the grid. The importance of this is emphasised due to the vulnerability of not having a secure support mechanism. However from initial studies, there does appear to be a small case for installing wind on Guernsey due to the great resource available. This potentially means capacity factors as high as 44% could be achieved, resulting in more energy being generated per installed kilowatt than UK wind farms which are closer to 27% as a long term average.[91] If used as a demonstration project, proving the financial success of onshore wind could be just as important to some as the educational benefits it may provide.

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[90] (Sust-it, 2013)
[91] (Environmental Change Institute, 2005)

4.7 Acceptability of Onshore Wind

Understanding the acceptability of onshore wind by the residents of Guernsey is a complicated task. There are currently no onshore wind devices on Guernsey, further increasing the difficulty of evaluating what would be the best solution overall. Throughout research undertaken throughout this study, it has been identified that there is an important need for renewable energy on Guernsey, but this needs to be partnered with enhancement of public acceptance.

Consultation with stakeholders, including the Government, local businesses and interested parties, throughout a development of a wind development is key to ensuring a balance can be found between an acceptable project and technical and economic benefits. Thorough consultation should be undertaken throughout all stages of the project to keep the public involved in the projects which is likely to enhance public acceptability.

There is scope on Guernsey to incorporate micro scale wind turbines in schools and community facilities. These installations could be used as a teaching tool for students and for all Guernsey residents, by encouraging involvement and input in project development and direction. Additionally, having micro wind installations around the island would enhance familiarity with renewable energy to allow it to become more common place in Guernsey.

Should offshore wind developments proceed, onshore wind installations could provide an accessible demonstration of the wind energy technology to aid the understanding of the technology. This could work to support offshore wind farms and could improve public perception of wind energy overall. There is the potential that there is a large amount of resistance to onshore wind developments. However with an honest development process partnered with education and the support of local businesses, onshore wind energy is a future opportunity for Guernsey.

4.8 Summary

From studies undertaken into the potential for onshore wind on Guernsey, several opportunities for development have been identified within the constraints presented by the island. The five identified sites offer development options for Guernsey that require a balance of responsible development, education and public involvement to actively pursue onshore wind energy.

The most viable site is at Chouet due to the flexibility for various turbine options. It is worth noting that the opportunity to install a large turbine on Guernsey should be considered as a serious asset to the island. When partnered with micro wind installations on the south coast and educational installations, a large turbine could act as an educational tool to support offshore wind developments. Although a strong statement, developing under best practise standards and with the best interests of the island in mind, the project could be appropriate for Guernsey.

Thorough consultation with all stakeholders is vital and could depict the success of the project, and the future of onshore wind developments.

4.9 Conclusions

From initial work undertaken, it has been shown that there is the potential to develop an onshore wind project; the first the island. This however has been based mainly on a technical approach, with many areas still requiring further assessment if considered seriously. Such areas would include the need for and EIA, further noise and visual impact assessments and consultation with local residents to allow their input and discuss potential benefits.

It must be understood that developing such a project further will prove to be a challenge. However on the other side, first hand experiences with a local school have shown the enthusiasm present in the younger generation towards renewable energy and the need for it. Finding the balance between responsible development, education and public involvement is vital for the future of onshore wind. In depth consultation with stakeholders especially the airport radar and the public could depict the success of the project.

It is worth noting that current planning policy is restricting of the development of onshore wind, so expected changes due in 2015[92] could present welcome changes that could be more appropriate to wind developments. Following guidance such as set by Cornwall Council[93] could pave the way to the first onshore wind turbine on Guernsey.

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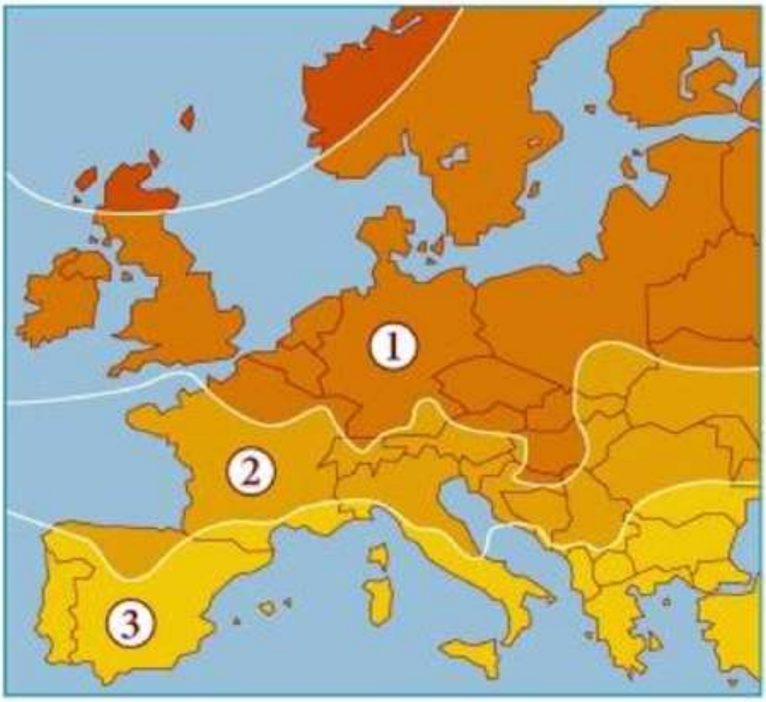
[92] (States of Guernsey, 2013)
[93] (Cornwall Council, 2013)

5 Solar PV in Guernsey

5.1 Opportunity

The Channel Islands have an abundant solar resource. It is important that Guernsey considers solar photovoltaics (PV) to harness this resource, help improve security of supply and insulate against rising fossil fuel prices. Solar PV is a key technology that, because of its maturity, can be deployed now and have immediate effects on Guernsey's electricity mix. Solar PV is a technology that can be implemented on a variety of scales from small, residential sites to large-scale macro sites.



Zone	Average solar radiation on collector surface (kWh/m² day)
1	2.4 to 3.4
2	3.4 to 4.4
3	4.4 to 5.4

Figure 51: Average Solar Radiation on collector surfaces in Europe

Through modelling using the software PVGIS it was calculated that Guernsey's solar resource was 16% better than London, receiving 4.15kWh/m^2/day of solar irradiation. Figure 51 shows the superior level of irradiation experienced by Guernsey compared to the UK and much of Northern Europe.

5.2 Methodology

This section of the report will look at the different scales at which solar PV can be implemented throughout the island: residential, commercial and macro. The generation and economic performance will be assessed for each scale. Feasibility studies will be carried out to show the potential for certain PV developments. Another focus of this section is to look in depth at planning, policy and potential barriers to solar PV developments. The goal is to highlight to RET the best pathways increase solar PV capacity on Guernsey.

5.3 Policy

Current policy framework in Guernsey does very little to promote the increased implementation of solar PV and renewables. Unlike the UK there is no type of FiT and the export tariff is equal to the marginal cost of generation governed by GEL; this currently stands at 9.893p per kWh exported. This means that there are very few incentives to encourage the use of solar PV. The export tariff is considered later in the financial sections of the feasibility studies where it is shown to have some economic benefit, particularly on installations where a substantial amount of the generation is exported.

The States of Guernsey currently have no forthcoming plans for the introduction of solar PV-specific support mechanisms. Due to the nature of the light-touch governance, low population and pressure on capital reserve on the island there is a reluctance to levy an additional charge on consumers to fund any such mechanisms and let the industry grow organically.

Some support for renewables and help towards the implementation of solar PV is briefly highlighted in the Strategic Land Use Plan,[94] compiled by the Strategic Land Planning Group, which covers important aspects including sustainable development, climate change and planning.

With no specific policy coming in to support the implementation of solar PV, other ways of increasing solar penetration in Guernsey will be considered in this report.

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[94] (Strategic Land Planning Group 2011)

5.4 Planning

Planning is responsible for protecting, developing and aiding the sustainable development of the physical environment of Guernsey. This includes the built environment, countryside and all open spaces on the island. Planning legislation aims to achieve quality development that regards the historic heritage of Guernsey and makes a positive contribution to the built and natural environment.

Planning laws and regulations in their current form have very little support for renewables. These laws are currently being revised in the Development Plan review by the States of Guernsey planning department. Obtaining planning permission is currently not streamlined, presenting a hurdle that developers have to overcome. The new regulations will include increased support for renewables and in particular solar PV, to be introduced by summer 2015. The new framework will be loosely based on EU directives and UK planning laws as well as complying with The Strategic Land Use Plan. Planning approval relies significantly upon the location of the development as well as the visual impact. Planning regulation is changing in the next few years to have mechanisms that deal with the specific requirements of each individual development.

In the 'Land Planning and Development (Exemptions) Ordinance 2007'[95] Guernsey's Planning Section of the Environment Department has an exemption specifically for the installation of solar panels.

The section on the exemption for solar panels states that planning permission is not necessary if the installation adheres to the following conditions:

Roof Mounted:

- It is installed parallel to the plane of the roof slope
- It projects no than 30cm from that plane
- The plane is not installed on any roof facing a highway

Ground mounted:

- When mounted on the ground, no part of it is located forward of any elevation of the dwelling-house that faces a highway
- It does not exceed 2m in height
- Does not exceed an area of 10m^2
- It is not located more than 30m from the dwelling – house

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[95] (States of Guernsey 2007)

All exemptions are subject to a number of important general conditions:

- The development must be within your domestic curtilage
- There is a limit on the total area of development. No more than 50% of the curtilage, excluding the ground floor of the dwelling, may be covered
- Exemptions to do not apply to protect monuments and buildings unless the contrary is specifically stated in the exemption
- These exemptions do not apply to building regulations

In addition there may be conditions of previous permissions that affect exemptions, these need investigating before any development takes place.

The use of ground mounted PV installations will only be looked at in detail for the airport case study. Land is a valuable resource in Guernsey and the airport is one of the only locations where a ground-mounted installation would be a viable option. This reports focus will be primarily based on commercial and domestic roof mounted installations in addition to a detailed case study of the proposed airport development.

If a solar proposal does not meet to the criteria previously mentioned in the exemptions document, a planning permission application will be required. Solar panels facing a public highway is a particular piece of legislation which requires a planning permission application and could potentially have an impact on widespread deployment. The States of Guernsey Planning Department have said that this particular barrier to solar developments is being reviewed and is likely to change in the next 18 months. The Department aims to make the legislation surrounding this more flexible in addition to reducing fees for cases where planning permission is required.

5.5 Residential PV

5.5.1 Current situation on Guernsey

The potential contribution of residential solar PV capacity to Guernsey’s overall energy mix should not be underestimated. If half of the 26,000 residential properties on Guernsey had a standard 4kW system installed, the annual generation contribution would be approximately 57.2GWh,[96] which is the equivalent of 84% of the total electricity generated by GEL in the year up to 31st March 2012.[97]

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[96] (PVGIS 2012)

[97] (GEL., 2012)

The uptake of solar PV installations on residential properties in Guernsey is currently low. The total number of installed systems on Guernsey is not known precisely but is estimated to be about 20, of which the majority, if not all, have been installed by one company.[98]

The past low demand for residential solar PV on Guernsey can be attributed to a number of factors including economic viability, public awareness and the lack of a competitive installation market. The introduction of the UK FiT in 2010 and similar schemes across other EU nations, whilst not directly benefitting the residents of Guernsey, has had an indirect positive effect on the economics of solar PV on the island. The UK is now home to a developed solar PV market which has delivered large cost reductions both in terms of system components and installation costs due to competition between manufacturers and also installers. Companies operating on Guernsey are now able to import system components at much reduced prices compared to 2010, however, due to the lack of a competitive installation market on the island and higher labour costs compared to the UK, the overall system installation price on Guernsey has not seen the same price reductions. This is largely due to high balance of system (BoS) costs, including labour, scaffolding and project management.

At the beginning of 2013, total installed system costs in the UK for a 4kW residential system could potentially be as low as £1.31/Watt.[99] Using a sample of 5 systems installed on Guernsey between 2012 and 2013 with an average size of 3.6kW, the average installed price was £2.67/Watt, with the lowest cost system at £2.17/Watt.[100]

Despite the current low penetration of solar PV in the residential sector, there is plenty of scope for increased installation rates, particularly as system costs reduce further in conjunction with improved market competition, leading to improved economics.

5.5.2 Case study – 4kW system design, performance and economics

In order to analyse the potential performance of a standard residential solar PV system on Guernsey and the associated economics, a case study has been carried out. The case study is based on a 4kW system with an operating lifespan of 25 years installed in 2013. The system performance report, all assumptions and variable parameters used plus the cash flow model can be seen in Appendix B.

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[98] (E-Si, 2013)
[99] (Solar Selections, 2013)
[100] (E-Si, 2013)

The results from the case study are shown in table 18:

Table 18: Residential 4kW solar PV system

Residential PV system case study	
System installed capacity (W)	4000
Electricity generation in year 1 (kWh)	4,437
Discount rate (%)	5.0
Initial CAPEX (£)	8,796
System cost per watt installed (£/watt)	2.20
Net present value after year 25 (£)	2,008
Internal rate of return (%)	6.89
Discounted payback (years)	19.82
Annual energy bill savings delivered (£)	680
CO2 annual emission reduction (kg)	3,921

Due to the lack of a generation tariff on Guernsey, the potential savings delivered by the PV system are very sensitive to the expected change in electricity price over the 25 year period. The analysis assumed that 50% of electricity generated was consumed by the primary load and 50% exported. The base case scenario models an annual electricity price increase of 5.2%, producing savings in addition to the export tariff, delivering a discounted payback period of around 20 years and a NPV of approximately £2,000 by the end of year 25.

5.5.3 Case study – sensitivity analysis

A sensitivity analysis has been carried out to look at the economic impact of changes in some of the key variables modelled in the cash flow analysis.

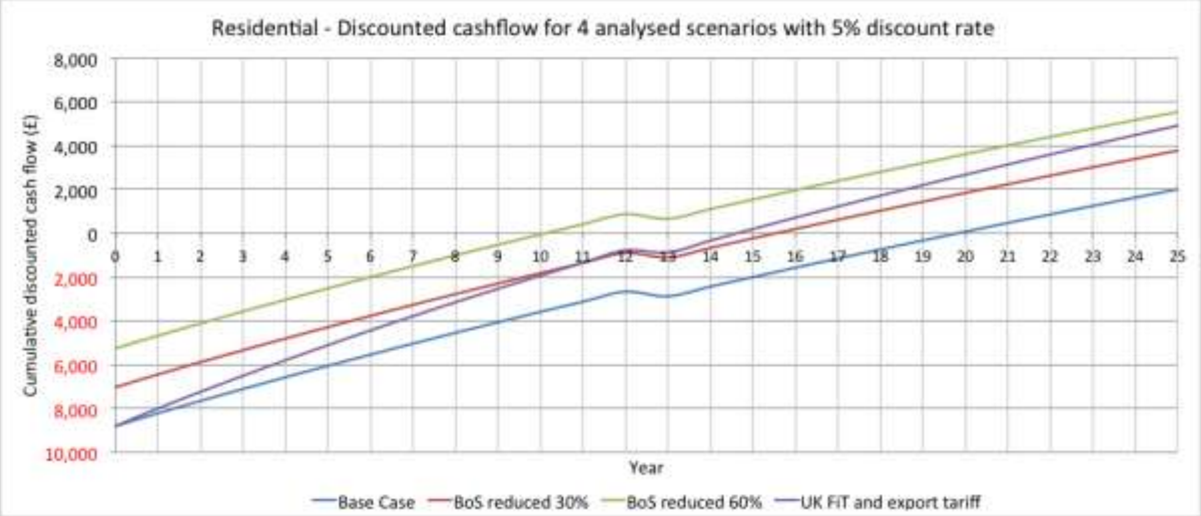

Figure 52: Comparison of scenarios modelling reduced BoS costs and UK support mechanisms against base case

The main difference between total system costs in the UK and Guernsey is the BoS costs, particularly costs associated with project management, labour, scaffolding and planning that are higher on Guernsey. Figure 52 shows the impact of BoS cost reductions on the system payback time. These costs have the potential to fall in the coming years with increased market competition, continued component cost reductions and policy changes more suited to renewable deployment. For comparison, the UK's FiT and export tariff have also been modelled to show the relative impact of reducing BoS costs compared to implementing a generation support mechanism.

This sensitivity analysis shows the positive impact of reducing BoS costs, with a 30% reduction reducing the payback time by over 4 years and increasing the NPV by 88% when compared to the base case. A BoS cost reduction of 60% delivers an initial system cost comparable to the lowest residential PV prices currently seen in the UK, of around £1.30/Watt installed. This delivers a payback period of about 10 years and a good potential return with an NPV of £5,500. If the UK's FiT and export tariff were available in Guernsey with the current installation costs, the system would payback in just under 15 years and deliver a NPV of £5,000; similar to that of a system with a BoS cost reduction of 50% with no additional support mechanisms.

Another key variable to analyse is the potential variability in the electricity price over the next 25 years. Figure 53 shows the impact on the discounted cash flow of different annual electricity inflation rates.

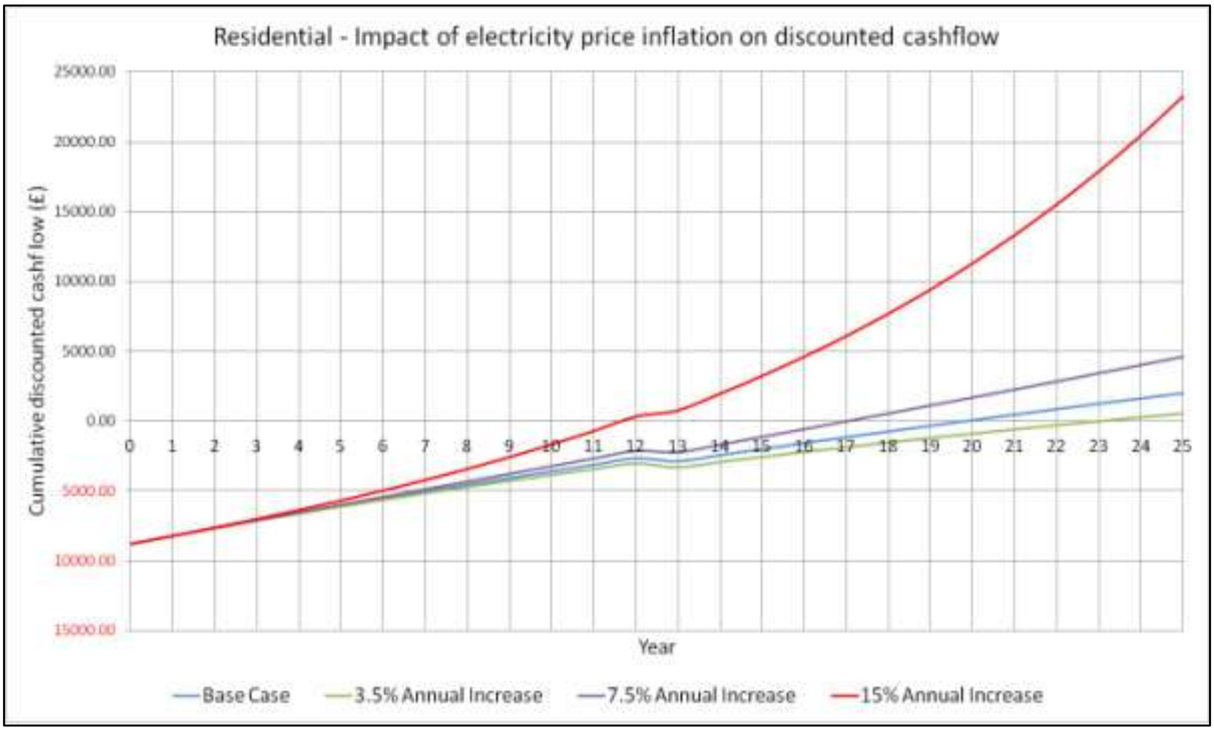

Figure 53: Variation of electricity price inflation for residential PV system

An electricity price inflation value of 3.5% (matching base case general inflation) reduces the economic performance of the system, increasing the payback to 23 years with a NPV of about £500. A 7.5% annual electricity price increase reduces the system payback to 17 years with a NPV of £4,500, improving the economic performance of the system to a level that would probably attract increasing investment on Guernsey. A 15% annual increase in the electricity price makes residential PV an excellent investment in order to insulate the house owner from future rising electricity bills and delivers a NPV of £23,000.

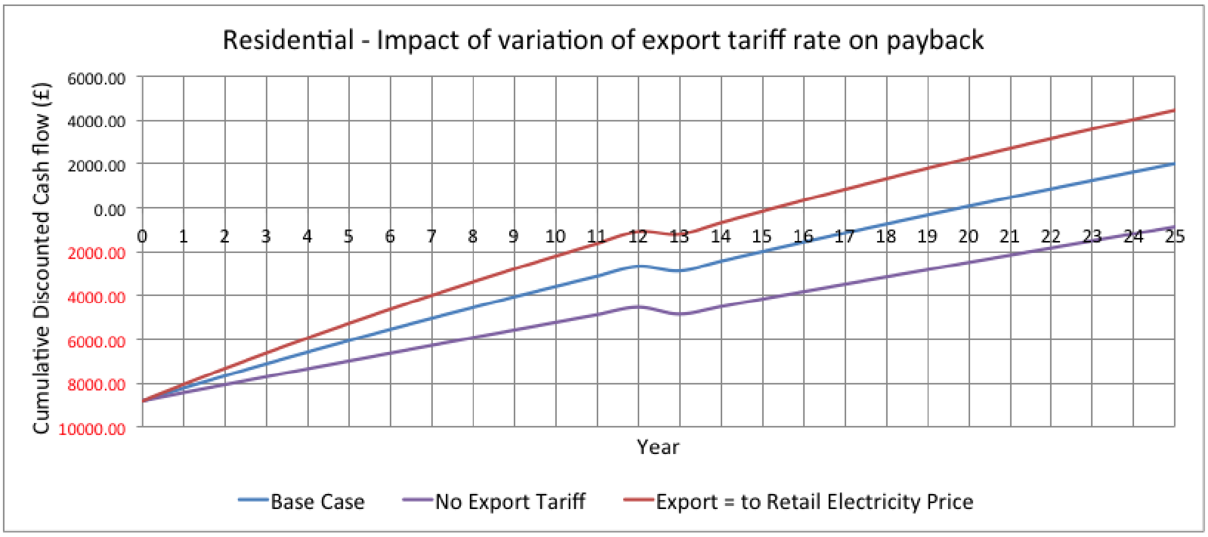

Figure 54: Variation of export tariff rate on residential payback

The sensitivity analysis also shows that the export tariff rate is important when considering the economic performance of the system as can be seen in figure 54. The export tariff in the base case is inflated at 2% per annum.

The lack of an export tariff substantially reduces the economic performance of the PV system to the point that it would not be an attractive investment, with a NPV of about £1,000 after 25 years. An export tariff rate equal to the residential electricity price tariff and inflation helps to significantly improve the payback time of the installation and deliver a NPV of over £4,000 by the end of year 25.

5.5.4 Reducing Balance of System Costs

A key variable that significantly alters the economics of residential PV is the BoS costs. Following a discussion with a local PV installer, it was suggested that the 'Application for new supply, additional load and/or alterations to supply' form that is required to be submitted to GEL when a PV installation is proposed was potentially not suited to this type of electrical installation, potentially increasing installation time and cost.

It is important to make clear that the electrical impact of the installation should be considered particularly for larger installed capacities or if numerous adjacent houses all have solar PV installations but a more flexible approach could be considered. Future self-certification by registered installers and installation of export meters could help increase speed of installation and prevent any export meter installation backlogs if demand increased quickly.

A contributory factor to the current high BoS costs on Guernsey is the high cost of logistics regarding the import of electrical components and associated import duty. The presence of component suppliers on Guernsey would reduce this cost and also potentially speed up installation times further with quick access to components. In the base case residential economic analysis, logistics and import duty accounted for 6.4% of total system cost.

5.5.5 Reducing percentage of electricity exported to grid

Due to the lack of a generation tariff on Guernsey, the payback and NPV of the system are very closely linked to the percentage of electricity consumed by the residential building and the associated electricity bill savings. The base case scenario used in the economic analysis modelled a 50/50 split in electricity consumed and exported to grid.

Two technologies that can improve the amount of electricity consumed by the primary load are ground/air source heat pumps and the use of an electric vehicle.

The use of a ground source heat pump (GSHP) can use electricity generated by the solar PV installation to contribute to space heating within the building, reducing heating costs. This additional use of electricity and increased savings can significantly improve the payback time of the solar PV system.

In the future, a wider uptake of electric vehicles also has the potential to utilise electricity generation that cannot be consumed by the primary load and charge electric vehicle batteries at residential properties. Based on an annual mileage of 4,000 miles for a car on Guernsey, a 2nd generation electric smart car consumes about 0.2kWhs per mile travelled.[101] This would equate to an approximate energy consumption of 800 kWh's per annum to be supplied by the battery, which is less than the annual exported electricity value in the 4kW system case study. Storing the excess electricity for use in an electric car battery would reduce the amount of exported electricity in the residential case study by 36% and increasing the system NPV to £4,000 after 25 years.

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[101] (Autoblog Green, 2010)

5.6 Commercial Rooftops

5.6.1 Methodology

In the following section of this report the commercial application of PV in Guernsey is investigated by calculating the total potential for PV on commercial rooftops, financial models of average estimated systems for these rooftops.

The potential for commercial rooftop PV was estimated using GIS, courtesy of Digimap, and satellite imagery to identify and then measure commercial rooftops across Guernsey. The locations of these building were marked and the number counted. A sample of buildings, shown in figure 55, was then measured to determine an average size so that an average system could be designed for all commercial rooftops.

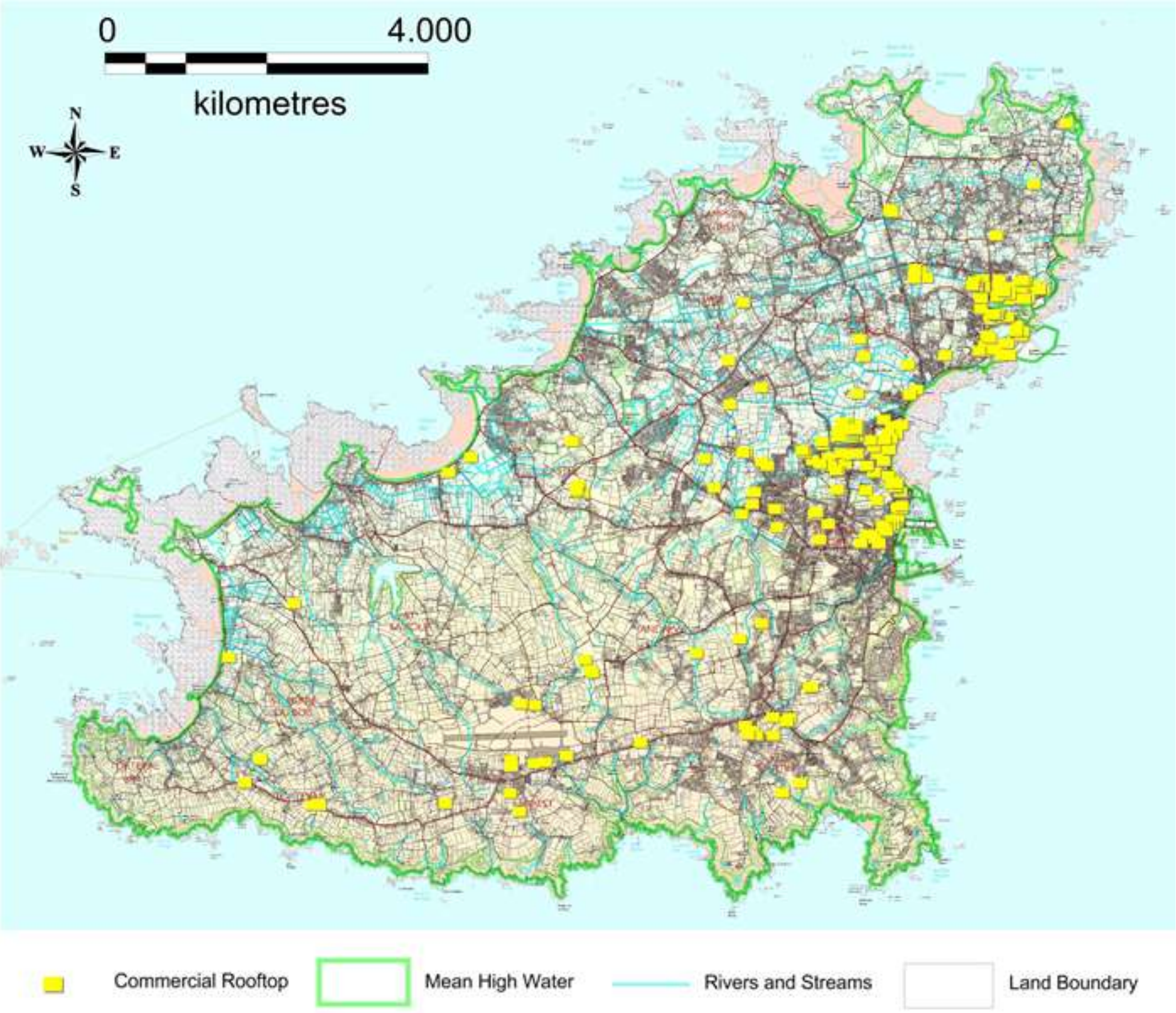

Figure 55: GIS map of locations of identified commercial rooftop sites

Table 19: Results of commercial rooftop potential

Quality	Quantity
Number of Commercial Rooftops Identified	227
Average Commercial Rooftop Size	1990 m^2
Rooftop Available for PV Array	1000 m^2
System for Average Sized Rooftop	34.5 kWp
System Energy Output in Year 1	37.6 MWh p.a.

During site identification only those buildings that could be clearly identified from GIS software and subsequently verified using satellite imagery were recorded as potential sites for PV installations. This means this data does not account for the majority of smaller commercial sites on the island.

A sample of twelve buildings was taken and their roof area calculated using mapping software. An assumption that was applied to this average rooftop area is that 50% of it could be realistically used for solar PV arrays. This is designed to account for the total number of sloped roofs that are south facing and the proportion of commercial properties that have flat roofs where slope is not an issue. From this assumption an average system for a commercial rooftop would be a 34.5kWp system that would produce 37.6MWh per annum. Results regarding Guernsey's commercial PV potential are shown in table 20.

Table 20: Opportunity for commercial PV

Percentage of Buildings Identified	Number of Buildings	Total Power	Total energy generated p.a.	Percentage of Total Electricity Demand	Percentage of Commercial Electricity Demand
5%	11	392 kW	427 MWh	0.12%	0.22%
10%	23	783 kW	854 MWh	0.24%	0.43%
15%	34	1170 kW	1280 MWh	0.36%	0.65%
20%	45	1560 kW	1700 MWh	0.47%	0.86%
25%	57	1950 kW	2125 MWh	0.59%	1.10%
100%	227	7800 kW	8500 MWh	2.40%	4.30%

The results show that the potential for PV installations on commercial rooftops is small but not insignificant.

One area of Guernsey's commercial potential which has not been covered is glasshouses. When undertaking the analysis of the islands commercial rooftop space a large number of glasshouses were identified. The structures themselves could potentially support PV arrays or alternatively the land that they occupy could be used. This area is substantial and although a more detailed analysis would need to be carried out it is likely there is as much potential for PV on glasshouses as commercial rooftops, if not more so.

Although glasshouses present a significant opportunity for PV in Guernsey they also present potential problems. Due to zoning laws, land must be allocated for a particular use and the land glasshouses are situated on must be allocated for agricultural use. Building a PV array on this land would require changing the land use to commercial/industrial which brings significant difficulties regarding planning permission. Although these difficulties are not impossible to overcome once the land use has been changed this opens the door for other, more economical developments.

Although commercial scale PV is feasible in Guernsey it is by no means economical enough to compete with other industries on the island. Therefore unless this land was set aside specifically for PV it is unlikely any would be built on these sites. For these reasons Glasshouses and the land they are situated on have not been included in this study of commercial PV potential.

5.6.2 Financial analysis

The financial analysis of commercial PV on Guernsey is designed to analyse the pertinent variables inherent to potential projects and the effect they have on a projects economic feasibility. Table 21 shows the factors defining the base-case scenario for financial analysis on commercial PV.

Table 21: Base case variables for financial analysis

Factor	Quantity
Inflation	3.50%
Project Discount Rate	6.50%
Electricity Price (£)	0.161126
Electricity Price Inflation	5.20%
Export Tariff Inflation	2%
Import Duty	3.30%
Electricity consumed by Primary Load	100%

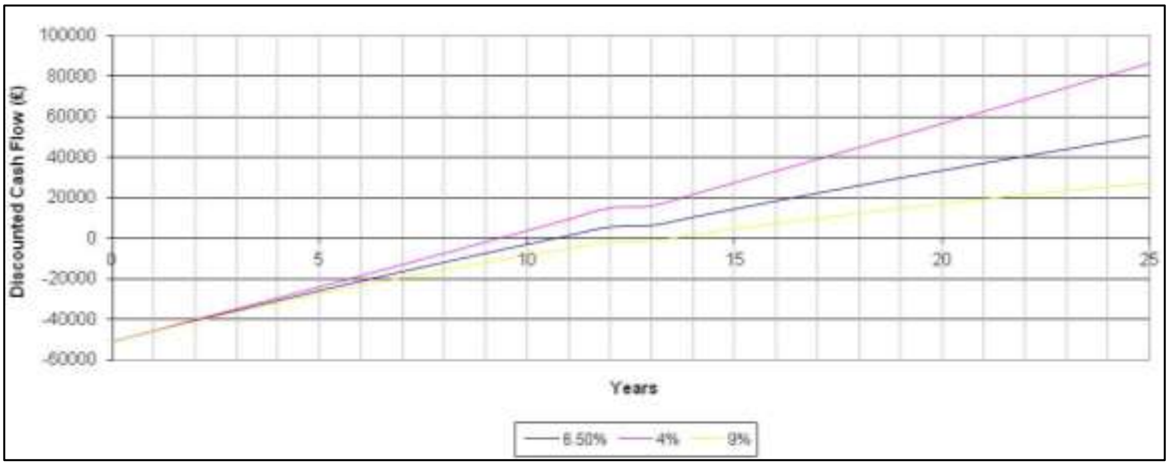

Figure 56: Effect of discount rates on discounted cumulative cash flow

The discount rate applied to the project has a significant effect on the feasibility of the project. As shown in the graph above, when the discount rate is brought down to 4% a project becomes much more economically feasible. A discount rate of 6.5% has been used as the base for calculations on commercial rooftop PV arrays, which is designed to reflect the scale and potential risk of a project.

GEL's customers are divided roughly 80:20 between residential and commercial however the amount electricity consumed by these two groups is roughly 50:50.[102] This highlights the higher levels of average electricity demand in commercial properties and can help to make commercial PV more economical due to more electricity being consumed on site.

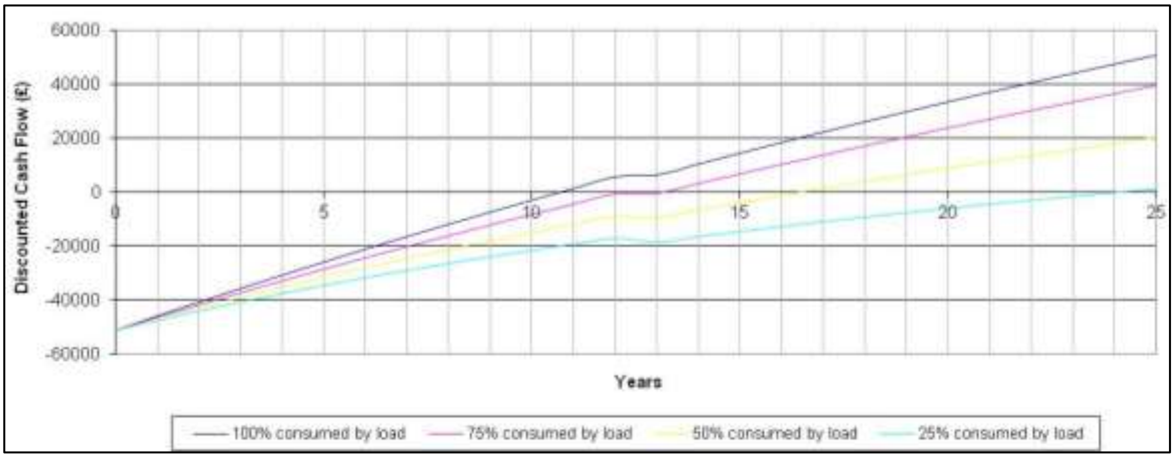

Figure 57: The variation in cash flow when varying the proportion of electricity consumed by the primary load

As shown in figure 57, the variation in discounted cumulative cash flow when varying the proportion of electricity consumed by the primary load commercial projects are significantly more economical when all electricity produced by the PV array is consumed directly. Having on average higher levels

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[102] (State of Guernsey, 2012)

of electricity consumption than households can make commercial PV projects more economically attractive than domestic PV projects.

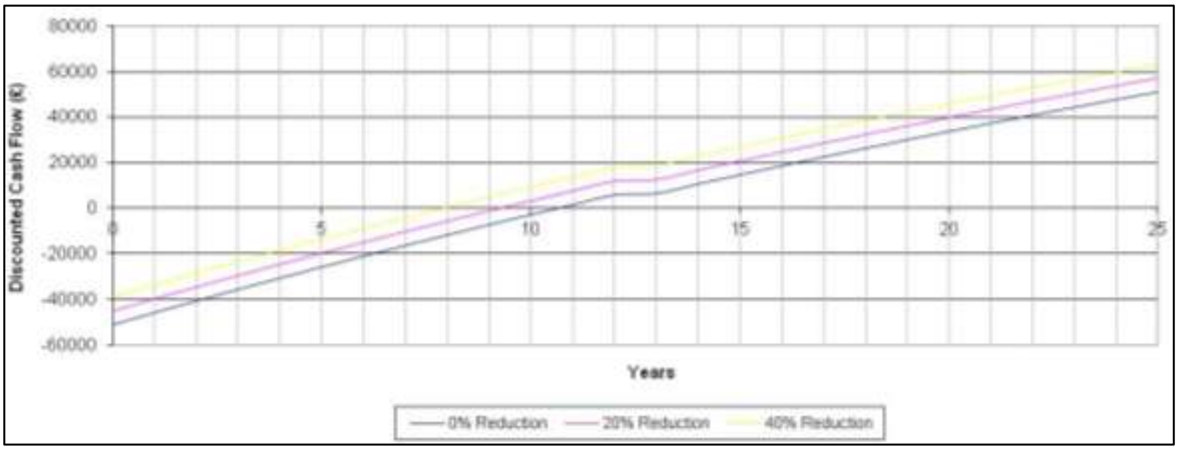

Figure 58: The variation in discounted cumulative cash flow due to changes is BoS costs

As shown in figure 58, reducing the BoS costs greatly improves the economic viability of commercial rooftop PV in Guernsey.

A major factor affecting the return on a commercial rooftop project is electricity price inflation. A base level of 5.2% annual inflation has been used throughout this analysis but by altering this value dramatic increases in profitability can follow.

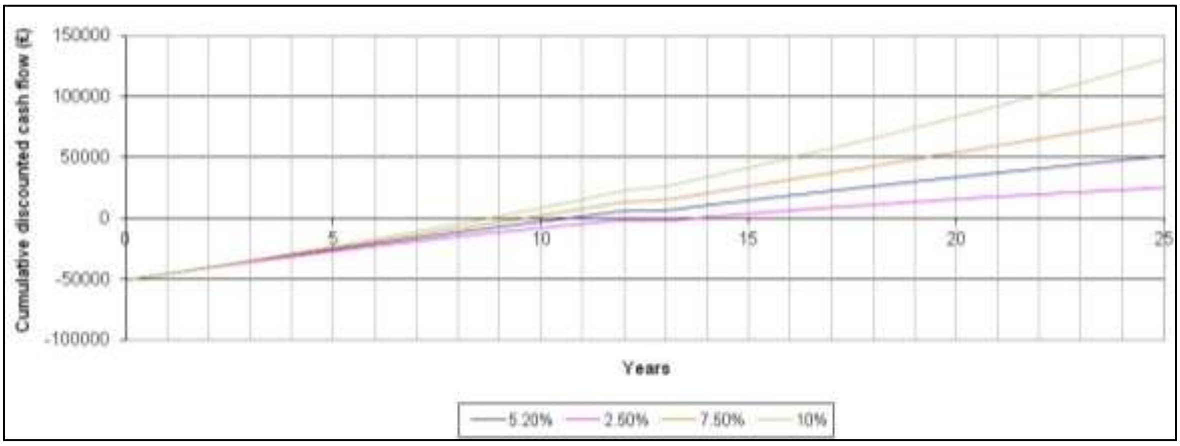

Figure 59: Variation in discounted cash flow caused by changes in electricity price inflation

As shown in this graph if annual electricity price inflation were to rise to 10% then the return on the initial investment on PV panels is significant. As shown in this financial analysis commercial PV has potential economically in Guernsey. It may not be able to provide a significant proportion of Guernsey’s electricity supply but it can still have an impact and exists as a fairly economically viable option.

An issue with solar PV development on commercial roof spaces is that most commercial properties in Guernsey are owned by landlords. With the current legislation, or lack thereof, the majority of profit made by solar PV installations is due to savings on energy bills. Landlords do not use the commercial properties, do not benefit from the reduction in energy bills and as such there is nothing to incentivise them to invest in solar PV systems. This is an issue that needs to be addressed if commercial solar PV arrays are to be encouraged.

5.7 Macro - Airport Case Study

5.7.1 Scope

After a meeting with RET, it was decided that large-scale solar farm developments in Guernsey would not be favourable option due to the space restrictions and planning barriers. Aesthetics in Guernsey are very important due to the population density the maintenance of the ‘Guernsey brand’ of fields, cows and picturesque countryside. This is why it was decided that analysis of one site in particular would be more beneficial. After meetings with RET, Simon Dudson of the Little Green Energy Company and the airport director, Collin La Ray it became clear that significant amount of discussion and investigations had gone into the development of a solar installation at the airport.

There are some main reasons why the airport would be a good location for a solar development:

- Visual impact is not a major concern as it is located within the airport boundary
- Solar PV at the airport could present a good public relations opportunity to convey to visitors the Guernsey Government’s potential commitment to renewable energy
- There is a surplus of space without having to change the land use, making planning simpler

5.7.2 Previous Work

Previous analysis of this project includes a generic 500kWp output calculation, identification of possible constraints and issues and very rough cost estimates. We intend to improve on this by creating a site-specific 500kWp design and performing a much more in-depth cost analysis.

5.7.3 Design

500kWp was identified as a suitable size for a PV system at the airport because, based on 2011 consumption figures, all the generation would be used on site and it would comfortably fit in the designated area. As safety at the airport is of the utmost importance the constraints on the site are very stringent.

Table 22: Pertinent airport PV descriptors

Configuration	25 groups of 80 modules
Layout	3 rows of 7 groups and 1 row of 3 groups
Module	2000 x SolarWorld 250W Monocrystalline
Inverter	25 x SMA Tripower 20000TL (20kWp)
Mounting	On piles, banked in rows of 2

The spatial constraints for the area around the runway are very specific. There is a strict exclusion zone 150 metres from the centreline of the runway, in which only equipment needed in the interest of navigation or safety can be sited, for example, a directing sign, with the condition that they collapse easily when struck by, for example, an aircraft during an emergency landing. This is shown by the red line in figure 60.

One of the reasons why the airport is an attractive site for a large PV array is the simplicity of the planning process due to the lack of need for officially changing the use of the land. This is why the site under consideration does not include the larger area to the North, shown in purple in figure 60. Although it is owned by the airport, this land is classified as agricultural, meaning that if solar PV were to be installed here there would be an issue with change of land use legislation.

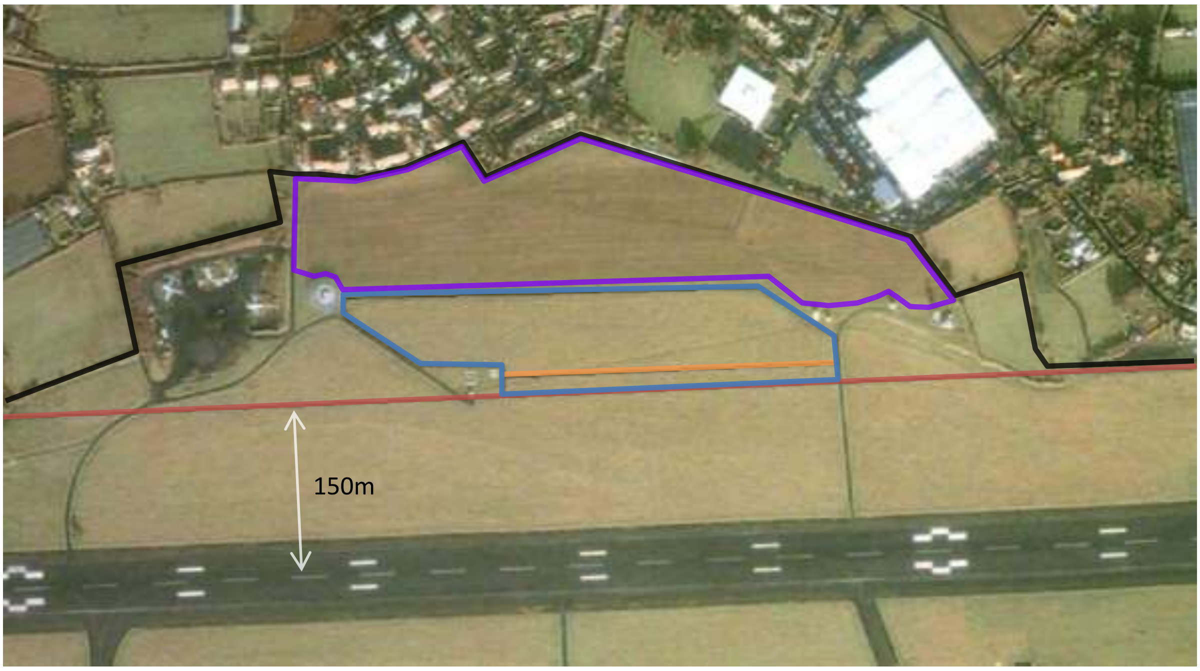

Figure 60: Site area constraints

The site constraints are also three-dimensional in that no object can cut a plane with a 1 in 10 slope from the runway centreline as well a plane with a slope of 1 in 7 from the 150m line. The designed array has a maximum height of 3m meaning that the tallest point cannot be closer than 21m to the 150m line, shown by the orange line in figure 60.

Glint and glare was raised as a potential issue with the PV array. Firstly if sunlight is reflected from a solar panel, it means that some solar radiation is not being absorbed so it is in their interest to minimise reflection. Most modern solar panels have a slightly rippled surface with an anti-reflective coating to help achieve just 4% reflection of normally incident light rays.[103] Secondly, determined using simple geometric analysis, the flight control tower is too low and far away for reflection to be an issue. The angle required for the sun to reflect into the tower is 1.4˚ from horizontal. For this to occur, the sun would have to be incident from an angle of 88.6˚ on to the 37˚ inclined panels, which cannot happen as the maximum solar angle is 64˚.[104] Further analysis needs to be performed to determine the potential effect on incoming aircraft.

The site is also ideal because of its close proximity to electricity substations in the residential area nearby. However, there is a need to consult with GEL to determine whether the capacity of the grid in the area would need reinforcement prior to connection. The airport has recently completed the installation of a new radar tower. To save money, the power supply cable for the existing one could be used to connect the PV array to the substation. Further analysis should be performed to determine the viability of this option.

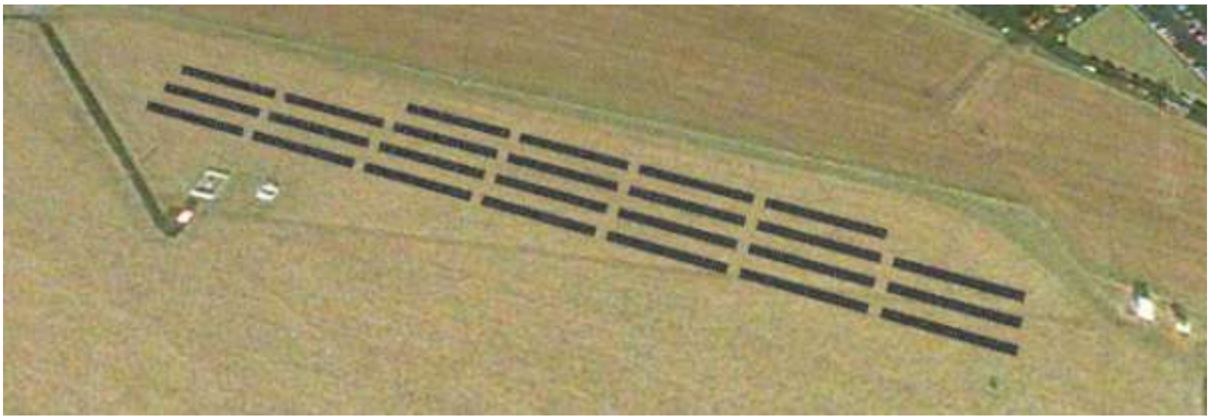

Figure 61: Airport PV array arrangement

The PV array is designed in a modular layout. There are 25 20kWp inverters each with four strings of 20 250kWp panels. This means that, during maintenance and inverter replacement, only 20kWp of the array need be offline at any one time. The modular nature of the design also allows construction

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[103] (Delplanque 2011)
[104] (PVGIS 2012)

to take place over a length of time rather than all at once if need be. It also appears that 25 20kW SMA[105] inverters (£89,000)[106] would cost less than one 500kW SMA inverter (£112,000).[107]

5.7.4 Financial Analysis

There is a large amount of capital that is ready to be committed to this project so the financial analysis of it is important. Pertinent base case scenario financial figures are shown table 19 and a break-down of the assumptions, costs and financial models are shown in Appendix B. Using a discount rate of 6.5% and an electricity price inflation figure of 5.2% p.a., the project is somewhat attractive with a payback period below the stipulated maximum of 15 years.

Table 23: Pertinent Airport Financial Figures

Guernsey Airport PV System Case Study	
System Installed Capacity (kWp)	500
Electricity Generation in year 1 (kWh)	545,700
Discount Rate (%)	6.5
Initial CAPEX (£)	683,500
System Cost Per Watt Installed (£)	1.37
NPV after 25 years (£)	634,100
IRR (%)	13.4
Discounted Payback (years)	11.1
Annual Energy Bill Savings in year 1 (£)	75,600
CO_2 Emission Reduction per Annum (kg)	483,200

Modelling the initial cost and financial performance of such a project is particularly difficult due to the large amount of variables so best, base and worst-case scenarios have been modelled in figure 62. Payback times could potentially vary from 7.2 to 19.3 years. Appendix B shows the break-down of the assumptions for each case.

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[105] System Mess und Anlagentechnik (SMA)
[106] (Solar E-Store 2012)
[107] (PVPower 2012)

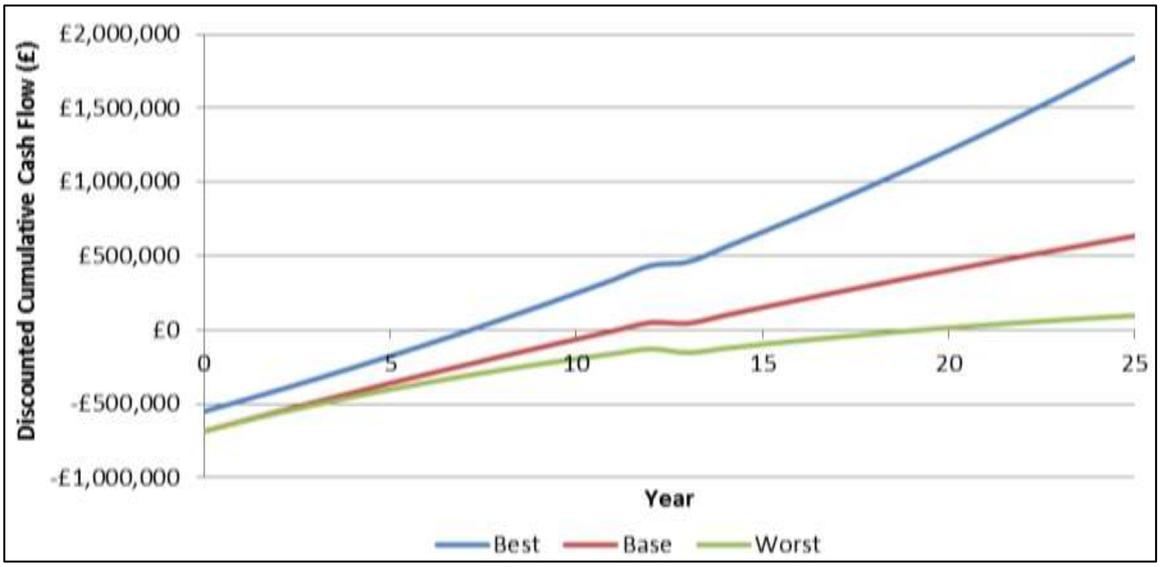

Figure 62: Airport Best to Worst Case Scenarios

The project's most sensitive economic variables are the electricity inflation rate and BoS costs, the former of which is extremely difficult to define as it is likely to be a bit above normal inflation of around 3.5% but between October 2011 and October 2012 there was an increase of 12.5%.[108] It makes a significant difference because it affects the amount of savings that are made each year. Figure 63 shows sensitivity to electricity inflation rate between 1% and 12.5%:

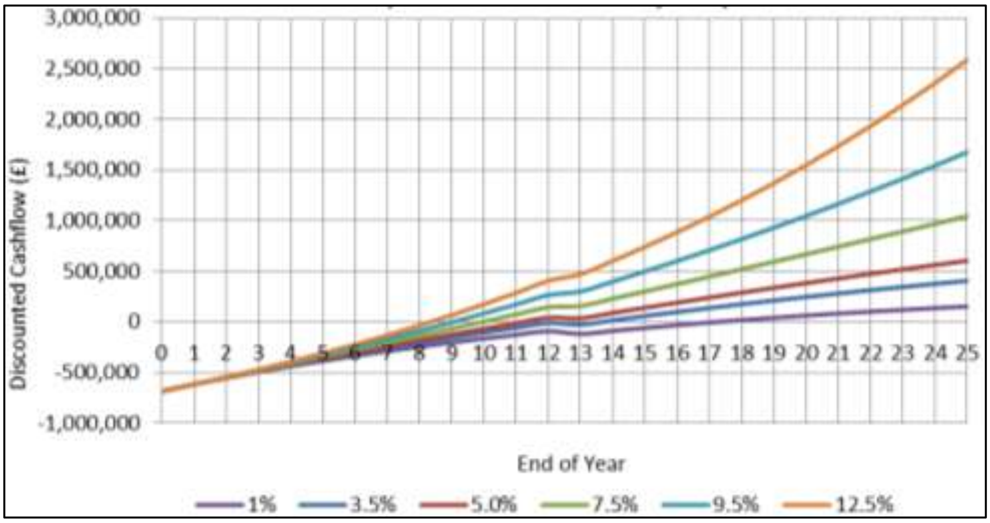

Figure 63: Airport Electricity Inflation Rate Sensitivity

Another variable with a significant effect on the financial attractiveness of the system is BoS costs (see figure 64). These costs are significant because they can be reduced the most easily, for example, through reductions in import duty and labour costs, but will also reduce naturally at inverters reduce in price.

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[108] GEL tariff documents

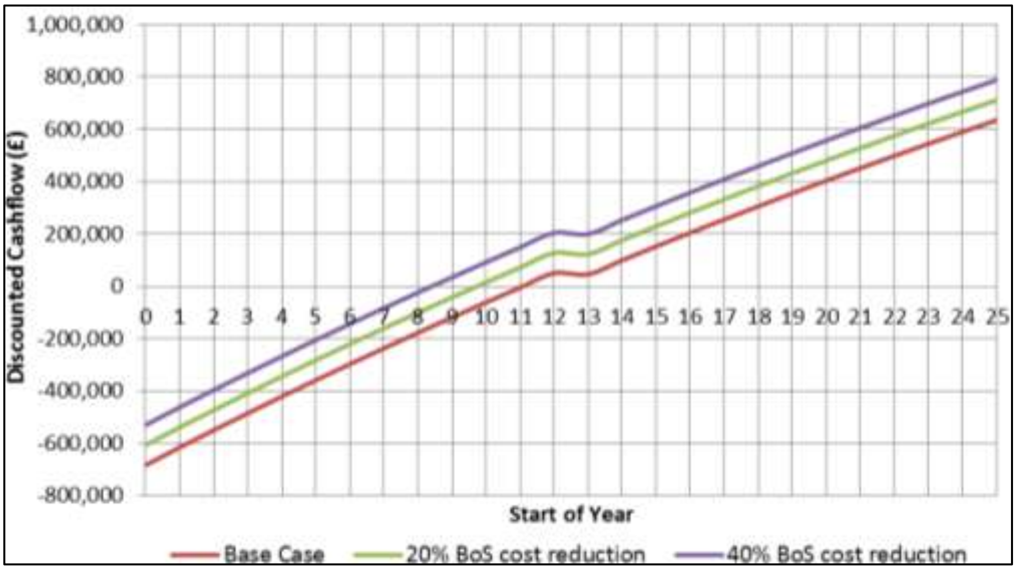

Figure 64: Airport BoS Costs Sensitivity

5.7.5 Conclusions and Recommendations

A large-scale solar PV system at the airport is an attractive project for several different reasons and should go ahead and when it is installed, inverter and module costs will have reduced. Before then, an effort should be made to identify ways to reduce BoS costs to further reduce the initial capital cost. It is suggested that analysis should be performed to determine the viability of using the old radar tower's grid connection.

5.7.6 Future Work

Further analysis into the effect of glint and glare on aircraft needs to be performed. Also, there is potential for a 760kWp array to fit in the same area, which would provide a lower levelised cost of electricity. If a larger array is desired, the agricultural land to the North could be used so further research is needed into the legislative and economic impacts of this.

5.8 Barriers and additional information

Solar photovoltaic technology in Guernsey is influenced by many factors that can act as barriers to successful development. These factors can be classified into three categories: social, economic and legislative.

5.8.1 Social Barriers

Renewable energy on Guernsey currently has a very low profile with minimal development of any on the island. The inhabitants of Guernsey's lack of exposure to solar PV could be a primary cause of the general lack of awareness of the benefits of solar PV for residents and larger businesses. This lack of exposure is due to the effects of the other barriers listed in this section, primarily economic. PV is often seen as not economically viable and hence there is no motivation to install. However this may no longer be the case due to recent system cost reductions.

To increase awareness of solar PV and to allow the population to become more informed about the technology, a range of programs could be considered. Chief amongst those would be the development of the airport PV project. This 'flagship' installation would be in a very high profile location and could act as an educational tool if information about its performance was freely available to the public and schools. Further installations could be developed in schools to allow pupils to get first hand understanding of the technology and how it can benefit them and their school. A solar PV installation in schools could also act as a catalyst to begin teaching other topics along similar themes, such as energy efficiency etc.

5.8.2 Economic Barriers

For all solar PV projects, the economic performance is a key consideration when assessing the viability of any investment. In the EU the presence of Governmental subsidies helps to make solar PV attractive to potential investors. In Guernsey however there are no such financial incentives to attract solar PV investment. As such, the economic viability of the technology in Guernsey is uncertain. Under ideal conditions and with the application of thoughtful informed design that mirrors the user's electricity habits solar PV could be seen as an attractive investment.

However, this is to ignore the fact that any financial projections are based primarily on informed guesswork and therefore the financial performance of a theoretical installation could actually be far poorer than originally projected. Due to this level of uncertainty over several very influential financial parameters there is a reasonable degree of risk to be taken on when making any investment into solar PV.

An area which affects the financial performance of a project but does not contain any risk is the initial CAPEX. In Guernsey the basic wage of labourers and skilled tradesmen is higher than in the UK. This means that any solar PV installation will cost more to design and install in Guernsey. Couple the effect of increased wages with the higher prices to be paid to ship PV components to Guernsey and it can be seen that potential solar PV customers in Guernsey are at a distinct disadvantage compared to their UK neighbours.

The higher BoS costs experienced in Guernsey are a considerable barrier to developing solar PV on the island. To limit or reduce BoS costs, larger installations could be put out to tender to secure the cheapest possible installation. It is very likely however that this approach will favour UK installers as they will be able to offer cheaper installations compared to Guernsey installers. This will mean that Guernsey's solar PV industry will potentially not benefit from any such installations.

To help reduce BoS costs for all scales of installation it is essential that the solar PV industry in Guernsey matures. This will allow indigenous installers and suppliers to create a more streamlined and cost effective supply network to customers, reducing the BoS costs involved. A more sizeable and established Guernsey solar PV industry will allow installations to be completed with the potential for less delay, hence reducing cost to the customer.

There are other methods of reducing BoS costs by simply making an installation quicker to complete. These are restructuring and simplifying the over-complicated and time consuming processes of acquiring planning permission and completing all necessary electrical load applications. In addition to this, unlike in the UK,[109] Guernsey has no system of self-certification for electrical installations[110] and hence all solar PV installations on the island currently have to be certified by an engineer from GEL.

Subsequently the installation process on Guernsey is somewhat bloated and drawn out, which increases costs; all of which are passed on to the final customer as BoS costs. Guernsey could adopt the self-certification system employed in the UK and assess the need for load applications on a case by case basis rather than assuming a load application is always required. These two simple steps would reduce BoS costs.

5.8.3 Legislative Barriers

Planning legislation in Guernsey is somewhat strict and conservative in nature. This is understandable considering how densely populated the island is and how highly the inhabitants

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[109] (Department for Communities and Local Government, 2010)
[110] (Environment Department: Traffic and Transportation, 2013)

value the traditional aesthetic appeal of Guernsey. However, this does mean that it is not really geared towards enabling renewable energy resources to be exploited. In regards to solar PV, the Strategic Land Use Plan states that the *"the panel is not installed on any roof slope facing a highway".*[111] This rule also applies for all ground mounted systems. This law prevents a large amount of potential developments coming to fruition and should be of many pieces of legislation subjected to consideration ahead of the finalisation of 2015's new planning legislation.

The laws concerning designated land use in Guernsey are very particular and exacting. This makes securing a change in land use, for instance from agricultural to industrial to create a ground mount solar farm, a difficult and unlikely prospect. Nonetheless, if a change in land use was granted, a solar PV installation would probably not be the most lucrative option for exploiting this land and other developments (commercial, industrial) would most likely be preferred. To counter this, special dispensation could be given to renewable energy technologies concerning land use change, provided certain criteria are met which would ensure the development's impact would be minimal. These criteria would have to be considered by the Guernsey Planning and Building Department.

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[111] (Guernsey Planning and Building Department, 2009)

5.9 Summary

The island of Guernsey has an abundant solar resource which, as of yet, has not been utilised to any significant degree. The proposed planning law changes could provide a boost to solar PV by helping to alleviate difficulties faced by potential PV developers and consumers. Following the dramatic price decrease in components over the past few years, the economics of residential installations are likely to improve, whilst not achieving the cost per Watt of comparable systems in the UK. Due to the lack of any financial support mechanisms in Guernsey, proposed developments are far more sensitive to the higher initial capital cost experienced in Guernsey. To improve the economics of a project, it is desirable to minimise the costs.

The existing export tariff is not sufficient to make export of generation desirable and as such all generation should be consumed on site to maximise return on investment. This is demonstrated very clearly in the economic assessment of the airport case study.

The airport is an ideal site for a large scale solar PV development; it can comfortably accommodate a 500kWp array with the potential for expansion to 760kWp without further infrastructural change.

Utilising residential and commercial roof top space could potentially offset a large portion of the island's generation if large scale deployment were to occur.

Table 24: Unit cost for each case study

System	Cost per watt (£)
Residential	2.20
Commercial	1.48
Raymond Falla House	2.32
Airport	1.37

The estimated cost per Watt figures for all case studies are summarised above. These can be compared to the average UK figure of £1.40 per Watt for all scales of development. It can be seen that there is significant potential for cost reduction in Guernsey.

5.10 Conclusions

- Removal of legislative barriers to solar PV development and increased gearing towards renewable energy development is required in the current Development Plan review
- Change in land use legislation to prioritise renewable energy development should be considered
- All scales of development are very sensitive to BoS costs. BoS costs should be a target area for reduction, in particular the non-system costs such as labour and logistics
- A reduction in BoS costs could be achieved by creating an imbedded indigenous installation and supply network. In addition to this, streamlining the system of self-certification and modifying the rigid electrical requirements to be met would cut the installation timescale
- Residential systems frequently export a proportion of generation to the grid. Reducing this by coupling a solar PV system with other technologies, primarily heat pumps and electric vehicles can dramatically improve the payback period and NPV
- Due to difficulties in defining the realistic potential of commercial PV in Guernsey, a small sample was assessed to attempt to quantify a hypothetical contribution to the island's energy mix
- Further study is required, particularly into incentivising landlord involvement. Landlords own most of the commercial properties in Guernsey and are therefore a key demographic to target
- The airport solar PV proposal is currently financially attractive and should be considered for development in the near future. It could potentially reduce the airport's electricity expenditure by £75,000 per year and deliver a NPV of £634,000 over the 25 year lifetime of the project
- Solar PV in Guernsey is faced with additional barriers to the selection highlighted above
- A lack of awareness of the potential benefits of solar PV could be addressed via educational programs and public and business involvement into future developments

6 Heating and Energy Efficiency

6.1 Opportunity

As an island nation with no direct energy connections except for an undersea electricity cable to France via Jersey, Guernsey relies heavily on imported fuels, mainly in the form of oils, for heat generation whether for domestic, commercial or industrial means.[112] This makes the country significantly vulnerable to global market fluctuations of which the costs are either passed onto the consumer or absorbed by the energy provider. This was particularly prevalent when the undersea cable failed in 2012, causing GEL to generate 100% of the island's demand from red diesel and heavy fuel oil at a significant loss to the company.[113] In order to reduce this risk, Guernsey must find methods to generate energy, whether thermal or electrical, indigenously, reducing its dependency on resources not found within its own boundaries.

When considering sources of renewable energy, it is common for most people to think of renewable sources of electricity first rather than renewable sources of heat. This train of thought has also been seen within national governmental policy, with the development of long-term renewable heat subsidies in the UK being the first in the world despite only being introduced in 2011.[114] With the States of Guernsey looking to deploy a wide range of renewable and sustainable technologies, renewable heat must also be considered at macro and micro scales.

However, in order for renewable sources of heat to be utilised to their full potential, it is important to investigate and ensure that Guernsey's building stock is of a good thermal efficiency and retention. This widens the scope of the heat and energy efficiency project considerably, putting the extent in which the States of Guernsey have control over the condition of the national building stock into the spotlight. Although the measures to rectify inefficient properties are fantastically straightforward, if the methods of physical and social identification don't exist, improvement cannot be achieved in a structured and targeted manner.

This section aims to explore the opportunities available to Guernsey and the States to deploy renewable forms of heat, as well as look at the challenges the country faces in order to bring its building stock up to a standard that can retain sustainable heat generation including through legal, regulatory and fiscal means.

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[112] (GEL., 2012)
[113] (BBC News, 2012)
[114] (Department of Energy and Climate Change, 2013)

6.2 Energy Consumption in Guernsey

6.2.1 The Heating Fuel Mix

Figure 65 shows the total fuel mix for Guernsey between 2008 and 2011. In 2011, fuels used exclusively for the generation of heat (gas, kerosene and other oils) made up around 36% of total energy consumption; outstripping both electricity and transport fuels.[115] However, electricity consumption has seen an overall increase in recent years, a rise assumed to exist through the increase in uptake of electrical heating.[116] Therefore energy consumption for heating purposes makes up a higher proportion than is currently measurable.

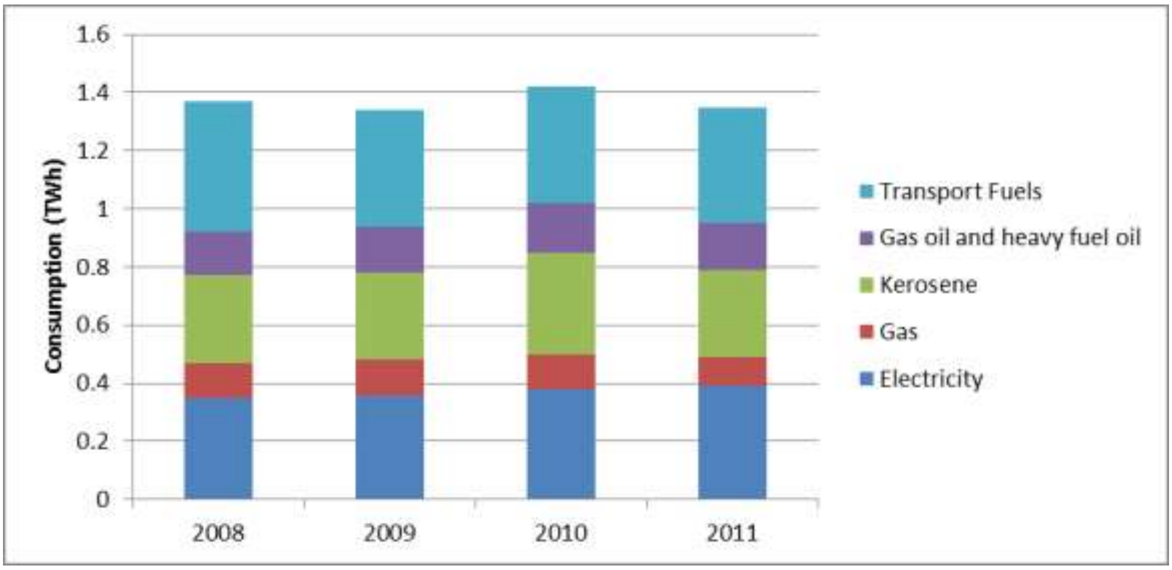

Figure 65: Fuel mix of Guernsey 2008 - 2011

75% of the measured heating fuels are accounted for by kerosene, gas oil and heavy fuel oils. It is unsurprising that gas (in the form of liquefied petroleum gas) only makes up the other 25% of heat consumption due to its high price. Standard domestic consumers pay 17.89p per kWh of gas compared to an equivalent 6.7p per kWh for domestic heating oil. [117, 118]

Despite the low uptake of gas in Guernsey, the island possesses a relatively extensive mains gas distribution network, shown in figure 66, having used some form of gas since the 19th Century. Therefore the infrastructure is available if a switch to cheaper natural gas were considered. Currently no plans are in progress, but three potential routes have been identified:

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[115] (States of Guernsey Policy Council, 2012)
[116] (States of Guernsey Policy Council, 2012)
[117] Domestic heating oil price quoted for standard 1000 litres on 15th May 2013 (Channel Island Fuels, 2013)
[118] (Guernsey Gas, 2013)

- Switching to importing liquefied natural gas (LNG) over liquefied petroleum gas (LPG)
- Sourcing a site suitable for pressurised gas storage
- Constructing a natural gas connection to France's infrastructure[119]

Despite this potentially reducing the price of gas in Guernsey in the short term, especially if shale gas is considered economically viable in the UK and Europe, the strategy still makes the island reliant on imports and fluctuations in the global market. Therefore it would be more beneficial to make savings through increased thermal efficiency of the building stock and low carbon means of heat generation.

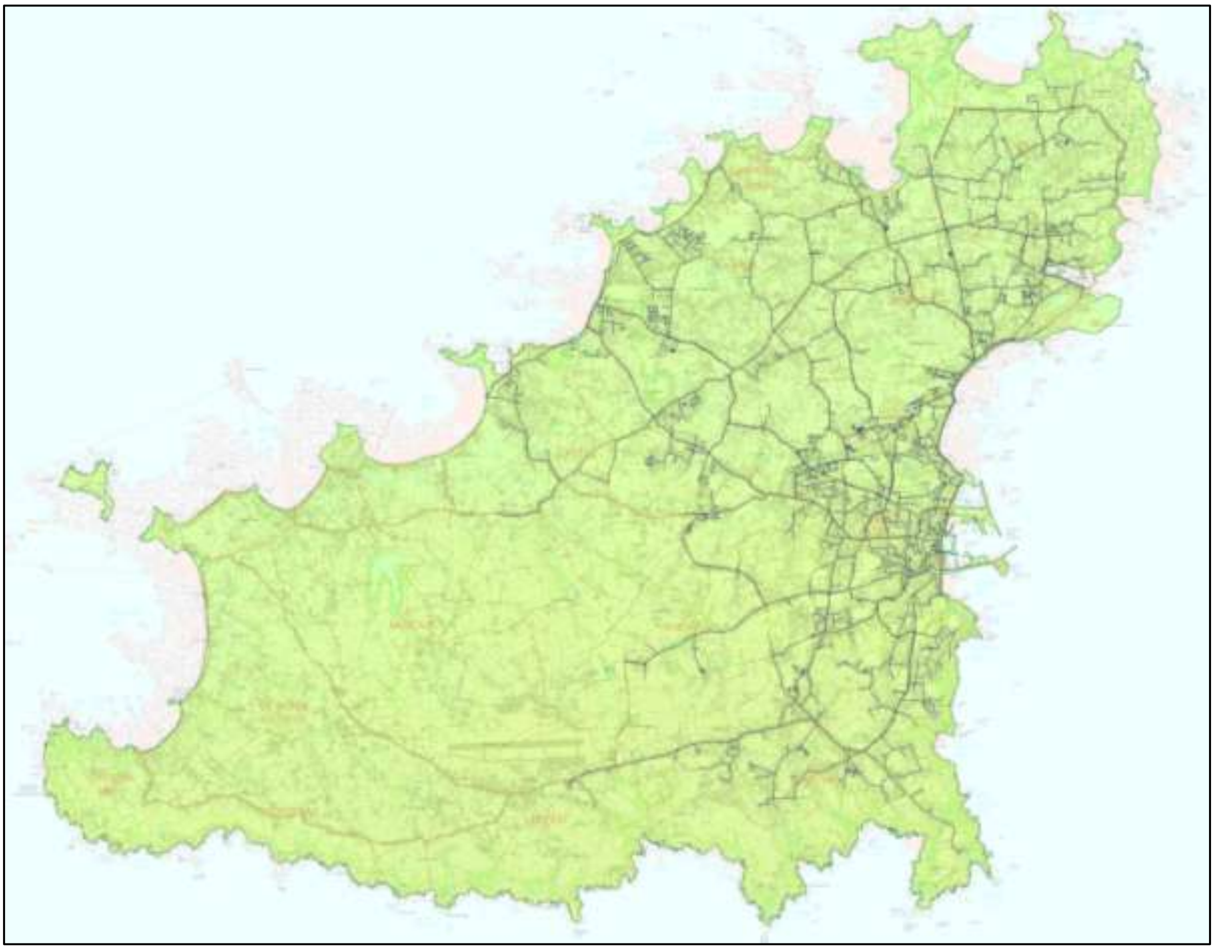

Figure 66: Gas distribution network in Guernsey

6.2.2 Fuel Poverty

Although Guernsey does not have a fuel poverty indicator or equivalent is it import to mention the prevalence of fuel poverty and the fact that does not get noticed. In the UK fuel poverty is defined as when a household "spends more than 10% of its income on fuel to maintain a satisfactory heating regime (usually 21°C for the main living area and 18°C for other occupied rooms)."[120] In a 2005-2006 the States of Guernsey completed a household expenditure survey. Within this the average spent on

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[119] (Morris, 2013)
[120] (Department of Energy and Climate Change, 2013)

fuel, light and power was £25.18 per week. This accounts for 3.3% of the total £748.58 weekly expenditure, but it is important to mention that this is only an average. There will be households whose energy bills will account for a substantial proportion of their weekly expenditure and with the rise in fuel bills the amount of people who are struggling to pay fuel bills will only increase. Indeed, the "European power industry fears fuel poverty [will] increase significantly in the next 20 years."[121] This shows that having an indicator such as fuel poverty, if not considered important by the state now, will be in years to come.

6.3 Energy Efficiency

6.3.1 Island Perception

In the twelve days that the University of Exeter were in Guernsey, it was apparent from the people asked that the building stock on the island was largely inefficient and poor at heat retention. This was a view also shared by RET. Around a third of properties on the island are of pre 1919 construction, indicating a large proportion of solid wall builds, and in turn a lack of insulating measures installed. However, due to there being no standard indicator of building energy efficiency on the island, these assumptions cannot be set in stone.

6.3.2 Measuring Building Energy Performance

In order to convert Guernsey's perception of their buildings' energy performance into a scientific statement, the efficiency of the island's dwellings needs to be measured. Heat loss surveys can be carried out, but to make these activities worthwhile and comparable, a standard measurement unit or rating needs to be implemented within policy and regulations nationally.

The UK addresses this challenge through the Energy Performance Certificate (EPC), an example of which is shown in figure 67. The EPC generates a rating from A+ to G depending on the energy efficiency of the building, and is valid for ten years. An EPC must be available to present whenever a building is constructed, sold or rented.[122] Alternatively, the States of Jersey commissioned a heat loss survey of every building on the island in 2011, with the results being publically available in map form.[123] If Guernsey implemented similar systems into their own housing policies, awareness of building efficiency would increase dramatically as properties changed hands, potentially making energy performance a more influential factor in the Guernsey housing market.

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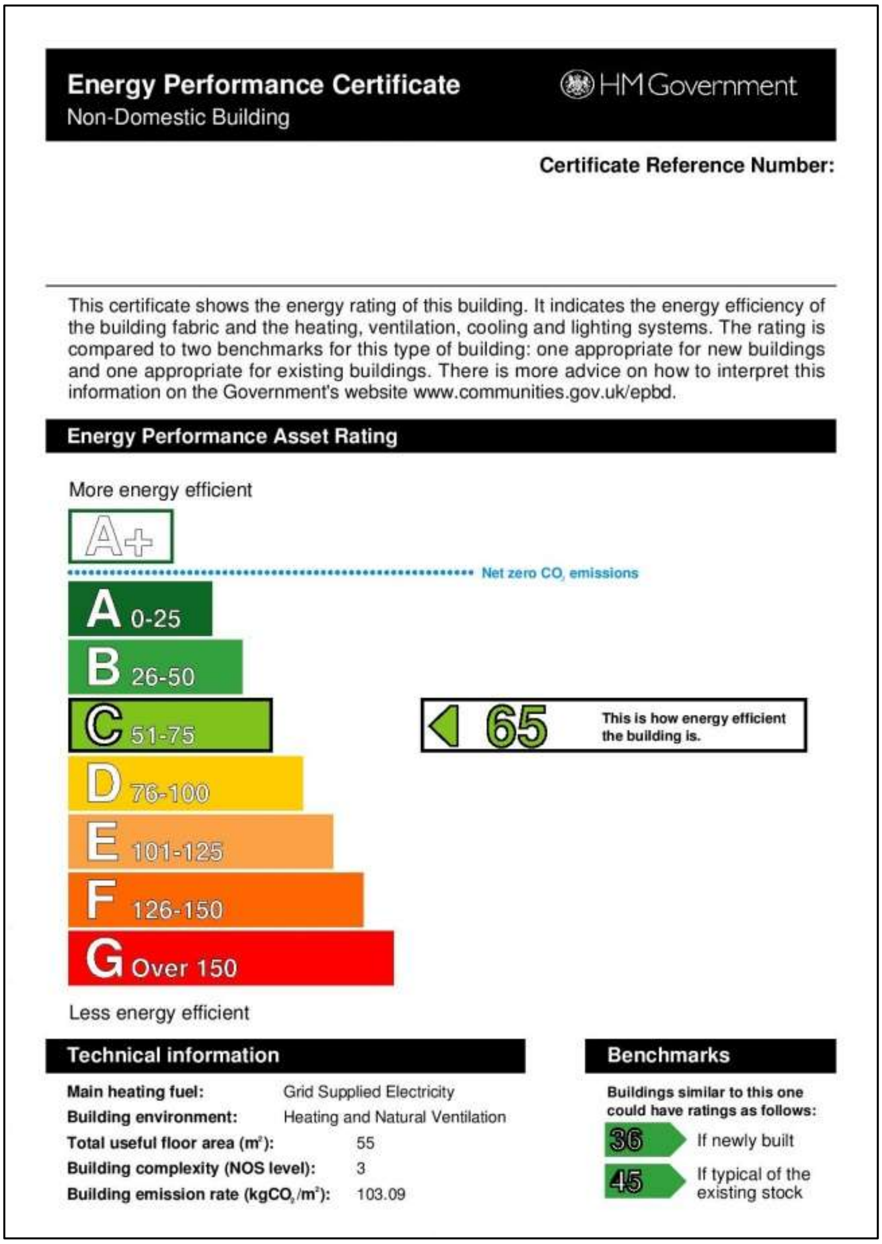
[121] (Sustainable Guernsey, 2013)
[122] (Housing and Local Services, 2013)
[123] (States of Jersey, 2011)



Energy Performance Certificate
Non-Domestic Building

HM Government

Certificate Reference Number:

This certificate shows the energy rating of this building. It indicates the energy efficiency of the building fabric and the heating, ventilation, cooling and lighting systems. The rating is compared to two benchmarks for this type of building: one appropriate for new buildings and one appropriate for existing buildings. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Asset Rating

More energy efficient

A+

Net zero CO_2 emissions

A 0-25
B 26-50
C 51-75
D 76-100
E 101-125
F 126-150
G Over 150

65 This is how energy efficient the building is.

Less energy efficient

Technical information

Main heating fuel:	Grid Supplied Electricity
Building environment:	Heating and Natural Ventilation
Total useful floor area (m^2):	55
Building complexity (NOS level):	3
Building emission rate ($kgCO_2/m^2$):	103.09

Benchmarks

Buildings similar to this one could have ratings as follows:

36	If newly built
45	If typical of the existing stock

Figure 67: UK Energy Performance Certificate

6.3.3 Promoting Efficiency through Regulation

The key factor in determining the designed thermal efficiency of new buildings, whether domestic or non-domestic, in Guernsey is building regulations. Guernsey Technical Standards L1 and L2 regard the Conservation of Fuel and Power in dwellings and non-dwellings respectively, therefore these are the key standards when studying thermal efficiency.

The current Guernsey building regulations were introduced in 2012; the UK building regulations from 2002 were used as a guide to create them (including part L) despite the most recent UK regulations being released in 2010. The Guernsey building regulations contain some guideline levels with regards to energy efficiency, mainly regarding the U-values of the external surfaces. However minimum requirements have changed significantly between the 2002 and 2010 regulations. In the Guernsey regulations a dwelling can be built with minimum requirements of 0.35W/m^{2}K for a roof and 0.7W/m^{2}K for a wall or floor.[124] Compared with the UK 2010 regulations of 0.2W/m^{2}K for a roof, 0.3W/m^{2}K for a wall and 0.25W/m^{2}K for a floor the standards are much lower, leading to a lower building thermal efficiency.[125] In addition the most recent UK regulations also state a requirement of a consideration of carbon emissions of the building, setting target carbon dioxide emissions rates (TERs) for each new build. This sets a minimum level of CO_2 emissions in comparison with the floor area of a new building.

It is unclear as to the reasoning behind the adoption of UK 2002 regulations in Guernsey, the Royal Institute of Chartered Surveyors say the following:

> ***"The values in its Part L documents are not the same as those in England and Wales, as Guernsey has a more temperate climate and the carbon intensity of its fuel is different to that of the mainland."***[126]

However as oil is the main heating fuel on Guernsey the carbon intensity of heating is higher, thus invalidating the reasoning for the standards of housing being more relaxed than in the UK.

Obviously the building regulations only set out minimum requirements and individuals can build their homes to a greater standard of thermal efficiency, there is still an allowance for lower building standards. Therefore building regulations in Guernsey should be updated to at least the same standard as UK regulations, this will aid an increase in energy efficiency which should be an island priority. In addition, Guernsey should also give thought to the carbon emissions of each building in the way the UK does in the 2010 regulations, aiding a reduction of the carbon footprint of the country.

6.3.4 Incentivising Efficiency Measures

Currently in Guernsey there are no policies regarding energy efficiency or renewable heat technologies. Because of this, uptake has been extremely low. In the UK, inefficient properties account for 43% of the greenhouse gas emissions and due to the similarity of properties in both type and age this figure will be fairly accurate for Guernsey also.[127] This shows how energy efficiency should be a priority of the state above the development of renewable energy technologies. As there

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[124] (Environment Department: States of Guernsey, 2012)
[125] (HM Government, 2010)
[126] (Royal Institute of Chartered Surveyors, 2012)
[127] (Barker, 2013)

is little point in generating energy from a renewable source when it is being use in inefficiently , in both commercial and domestic properties.

Even though these energy efficiency measures have been recognised as important by many civil servants and local stakeholders there are still barriers to installation, the primary being the cost. 33% of the properties on Guernsey were build pre 1919 which is indicative of solid wall properties. Insulation on a property is one of the measures that have the greatest impact but the cost of installing on a solid wall property is costly. In a telephone conversation with Zeev King, owner of Blast it, the only insulation company on the island, said that demand for cavity wall insulation (CWI) has been high in his 8 months of installing. He has made the active decision to focus on cavity wall due to the sheer cost of solid wall insulation (SWI). The prices quoted by Mr. King were £14 per square metre for CWI and £110 for SWI. The difference it startling and stresses the need for policy that removes or reduces the need for up front capital.[128]

In order to facilitate this without a grant scheme a loan scheme could be introduced in the form of a government backed Energy Services Company (ESCo) model, similar to that of the Green Deal in the UK. The scheme would work with GEL as they have existing schemes whereby customers can purchase electronic equipment on finance and pay the balance through their electricity bill. As this structure has already been established, adding extra services and products should not be as complicated as creating a whole new sector of the business. The policy would work as described in §10.

In order for this policy to work the Golden Rule or an equivalent will have to be set. This in itself will prioritise the energy efficiency measures over the renewable energy technologies as they will tend to have a greater impact on the energy bill than the renewable heat of electricity generators.

6.3.5 Case Study: Guernsey Housing Association

Guernsey Housing Association (GHA) is a not-for-profit company providing social rented housing and partial ownership for the residents of Guernsey. It was set up in 2002 and currently has built/refurbished 418 homes which have been rented or leased to local people. The States of Guernsey are heavily involved with the GHA; the States' Housing Department sponsor the association as part of the States Corporate Housing Programme. In developments the land for the builds has been supplied by the States, normally brownfield sites, and a proportion of the dwellings built are given over for the state to allocate.[129] There is a large demand for affordable housing in Guernsey, mainly because of the high house prices on the island, with an average in excess of

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[128] (King, 2013)
[129] (Guernsey Housing Association, 2013)

£400,000[130] compared with the average UK house price of approximately £160,000[131] it is easy to see why there is a need for affordable housing.

Eligibility for housing with the GHA falls under some requirements; must be a resident of Guernsey, there are income and savings restrictions and if someone is eligible for States housing they are not eligible for housing under the GHA's allocation. Of the housing built by the GHA 70% is to be rented, the other 30% being partial ownership; the State nominates 66.6% of the 70% rented under its social housing and the rest is rented by GHA. The GHA houses are built to lifetime home standards; a set of criteria which adds to the comfort and convenience of the home and supports the changing needs of individuals and families at different stages of life.[132]

The houses which are built by GHA are of particular interest to this study due to a high standard of thermal efficiency designed into the properties such as those show in figure 68:

Figure 68: GHA Rue Clouet development

The dwellings are constructed mainly from SIPs (Structurally Insulated Panels) which allows fast construction along with high insulation properties. The recent building work is designed to Passivhaus specifications, which is one of the highest standards of energy efficiency in the world.[133] Each dwelling has an overall U-value of 0.13W/m^{2}K which is far better than minimum building regulation standards. The fewer number of air changes a building has; the less heated air it will lose in a given time. GHA has set a target for this with a maximum of 2m^3/hour per square metre, with a

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[130] (Policy Council: States of Guernsey, 2013)
[131] (Land Registry, 2013)
[132] (Lifetime Homes, 2013)
[133] (Building Research Establishment, 2013)

lowest measured 1.43m^3/hour per square metre in a GHA building; the building regulations in Guernsey states a maximum of 10m^3/hour per square metre is allowed.

The level of thermal efficiency in the dwelling leads to a maximum heat demand of 2.5kW in the one bed flats and 3.3kW in the largest 3 and 4 bed houses. This heat is generated through the use of solar thermal panels (an example shown in figure 68), typically 1 panel on 1 and 2 bed dwellings and 2 panels on 3 and 4 bed dwellings, combined with electric heating. The heat from the solar panels is stored in an accumulator tank, and when the heat in the tank drops below a set temperature the electric heating is used increase the temperature; the solar panels meet the majority of the heat demand in this set up.

The heat is then supplied to the home through a heat exchanger system meaning the water used in the home is kept separate from the water used in the solar panels. Heat is distributed through a minimal number of radiators; a one bed flat only requires one radiator in the whole dwelling due to the level of insulation on the properties. All these measures to make the properties thermally efficient combined with the integration of solar thermal technologies, means that the annual energy bill of a one bed flat is approximately £400. This is especially beneficial in social housing as the occupants are among the most vulnerable on the island; saving money on fuel bills therefore allows greater financial flexibility on their part.[134]

The addition of the efficiency measure does add to the total cost of the dwelling; however it is not overly significant. It is difficult to calculate exactly the increase in cost which is entailed by these developments; there is the additional cost of the higher building quality, but the way in which the dwellings are built (using SIPs panels) means that they are also constructed faster than standard buildings. A faster build time means that there will be earlier rental income, generating more revenue. Therefore GHA believe that building the dwellings to this quality adds just 3% to the overall build cost.

Another benefit of this type of development is that it has brought more specialised industry to Guernsey. By introducing new building techniques and technology to the island GHA have built up a skilled installer industry which could expand further if these types of development, and other eco-builds, were to increase in number.

Heat pumps were considered for the buildings but not installed again due to high thermal efficiency. Peak heat demand of the buildings is 3.3kW whereas the smallest air source heat pump (ASHP) available was rated at 6kW (there are small rated ones now available). It would therefore be cost

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[134] (Roussel, 2013)

and energy inefficient to install this technology. District heating was also considered, but was discounted due to the infrastructure required and the matter of responsibility of the system. When heating is centralised someone needs to be responsible for the generation. The maintenance of the district heating system itself would then also be a continuing expense. It was decided therefore that it was not viable for this type of system.

There are drawbacks to this type of development, the main problem which has been identified by GHA is that the occupants do not use the dwelling as efficiently as they can. Such problems are a failure to understand how the building works; examples include occupants opening windows frequently. This will negate the effects of insulation and also the attempts to reduce the air-flow through the building. GHA do attempt to educate the occupants, however they only have limited resources to do so, but an increase in education would almost certainly be beneficial.

6.4 Island Resources

6.4.1 Biomass and Waste

Until June 2010, wood waste in Guernsey was generally disposed of through controlled open burning.[135] However, since a change in legislation there has been a growing problem with waste wood with much of this being stockpiled on the site of Mont Cuet landfill.[136] With an estimated 9000 tonnes of waste wood being created each year by the island, this produces a huge resource for means of heat generation in Guernsey.

Assuming 50% of this waste wood was available and safe to burn as chips in commercial and domestic buildings, the annual energy resource would be around 13.4GWh based on 85% boiler efficiency.[137] This value is equal to and has the potential to offset around 25% of the oil and gas consumption on the island in 2011, so long as the appropriate technology was installed in buildings. It is important to note, however, that if this resource were not appropriate for heat generation, solid biomass would not be a fuel recommended to the States of Guernsey to adopt as it would require further island imports. Therefore further research into the full resource and the building stock it could sustain would need to be undertaken before making any move on the matter. This in turn makes the resource better suited for States use only as consumption and production would be an entirely internal process.

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[135] (This Is Guernsey, 2010)
[136] (SLR Consulting Ltd, 2011)
[137] Average calorific value of wood chips in the UK is 3500kWh/tonne (Biomass Energy Centre, 2011)

6.4.2 Geothermal

Harnessing geothermal energy is heavily dependent on geographical location. Currently economically viable geothermal energy is located on fault lines where there is tectonic activity which creates significantly warmer bed rock on the fault and the surrounding areas. Guernsey is not on a fault line however the rock type in Guernsey is mainly granite with some sand, gravel and clay throughout the island.[138] The dominant rock type, granite is a non-porous which lends itself well to hot rocks generation if the appropriate temperatures are available at the correct depths.

In terms of electricity generation from geothermal energy there are several types of technology that could be used. Dry steam and flash steam both require high temperatures of the water/steam that is emitted from the pipe and directly turns the generator however Guernsey does not have this resource as it is not located close to a fault line and there is no evidence on high ground temperature. Another technology is the binary cycle; this requires temperatures as low as 74 degrees which is much more achievable for a site off a plate boundary.[139] But in depth resource assessment studies are required in order to see if geothermal energy generation is possible.

At a site where the temperatures are high there is potential for thermal and electrical energy production however if the required temperate are not available there is still the potential for large scale heat generation. However this would require a large infrastructure in order to distribute the heat accordingly. There are few buildings such as the hospital, prison and leisure centre that have heat demands throughout the year so could benefit from geothermal energy. If the heating generated is in excess of local demand then a district heating development would have to be considered. This would involve massive civil engineering works across the country in order to utilise the generated heat effectively.

An example of Geothermal that is not on or near a fault line is planned in Cornwall, with the United Downs hot rocks project. The project has been estimated to produce 55 MW of thermal energy, and 10MW of electrical power (net power output of 7MW) at a depth of 4.5km. Estimated capital cost is in the region £50million.[140] This project shows that the resource, if available, is viable economically. With the advantages of this form of energy generation focused on the minimal visual impact as the site will look like an industrial unit after construction. The construction process involves drilling two holes to a depth of approximately 5-6km, at this depth the rock will have to be fracked in order for the water to flow from one of the pipes to the other to create the cycle. Depending on the specific

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[138] (Kagal, 2008)
[139] (Law, 2011)
[140] (Department of Energy and Climate Change, 2013)

type of granite the rock may have natural fractures and therefore these will be primarily used over the laborious process of creating new fractures.

6.5 Leading By Example

Based on the group structure proposed between RE 2012 and RET, it is apparent that the States' mind-set lies predominantly at arm's length from central governmental activities: in manpower terms, much of the focus lay in varied levels of wind generation and PV, whilst those technologies most suited to States applications such as demand-side management and transport were neglected. With the States of Guernsey being a major organisation on the island irrespective of its governmental status, in order to prove to others that sustainable technologies are worth pursuing, they must first implement measures themselves to prove commitment to their own policies and ideas.

In the UK, DECC encourages the implementation of energy efficiency measures and practices through the Carbon Reduction Commitment (CRC). The CRC submission is a mandatory scheme for any organisation in the UK that consumes more than 6000MWh of electricity per year from their corporate estate. These organisations must then submit an annual report of their energy consumption (for all fuels) and purchase their resulting carbon emissions at a current rate of £12 per tonne. The focus on energy efficiency rather than renewable incentive also means that renewable electricity generation is still initially included in this purchase at the national grid average: the scheme encourages the organisation to use energy as effectively as possible rather than creating a false picture through indigenous generation.[141]

The CRC purchase, although the monetary value is on the whole an insignificant expenditure compared to these companies' usual cash flow, nonetheless stamps a fiscal value on energy consumption, emissions and efficiency, meaning companies are more likely to find ways to minimise their purchase and thus their carbon emissions. Currently the States of Guernsey are undergoing spending cuts over a much wider scope; however a heavier focus on energy efficiency could have a far greater impact in the long term than other measures.

6.5.1 Financial Transformation Programme

Since 2009, the States of Guernsey have been conducting a spending review across all their departments and services. The primary aim is to reduce net revenue expenditure by £31 million in the five years that the programme will run. "Reducing States energy consumption and creating a proactive States-wide approach to energy management conservation" is one such measure being

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[141] (Department of Energy and Climate Change, 2013)

implemented to reach this target, although specific details as to how this is being achieved are not readily available to the general public.[142]

The States of Guernsey are also reviewing their extensive property portfolio, with the aim of relocating some departments and services into larger central hubs rather than dispersing them across the island. It is expected that more common services would be moved to the current central States hub of Sir Charles Frossard House in St Peter Port, however the building itself is considered to be relatively inefficient and in great need of refurbishment.[143] The government's workplace transformation programme aims to tackle these issues, although new construction hasn't been ruled out where appropriate, opening up more opportunity for integration of sustainable heat technologies.[144]

6.5.2 Invest To Save

At present, the States of Guernsey have a capital reserves fund, used for large States projects such as recent expansions to the island's airport. The fund is in very high demand from all departments, and its allocation is made in conjunction with the States Strategic Plan and Government Service Plan. Major improvements to States properties such as the integration of renewable energy technologies are likely also to be competing with this fund, however these will be competing with more socially and economically important projects such as those involving healthcare and education, therefore slow progress may be made on energy and environmental matters within the government.[145]

Many local authorities in the UK operate an invest-to-save fund. This is a pot of money used to purchase measures and technologies that will save that organisation more money in the long run. Energy efficiency products are very applicable to this as the savings are reaped through energy bills. If the States established a budget of this ilk within their own finances it would enable them to make the necessary changes to their property portfolio without competing with other services perceived to be more important.[146]

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[142] (States of Guernsey Treasury and Resources Department, 2012)
[143] (BBC News, 2013)
[144] (Hackley, 2013)
[145] (Hackley, 2013)
[146] (HM Government, 2012)