6.5.3 Sir Charles Frossard House: Central Hub of the States of Guernsey

Sir Charles Frossard House is the official headquarters of the States of Guernsey as a whole. Situated on the south-western edge of St Peter Port, it serves not only as an administrative hub but also as a public facing service provider with plans in the pipeline to move more services to the building in the future. Figure 69 shows the building in its current form.[147]

Figure 69: Sir Charles Frossard House

Currently gas oil is the major fuel used for heat generation on the site, with almost 38,000 litres purchased in 2012. This totals almost 105 tonnes of carbon emissions from heat generation alone for the year:[148] a considerable amount for just one building in the States property portfolio. Figure 70 shows the breakdown of fuel purchases over 2012.[149]

[147] (BBC News, 2013)
[148] Based on an emissions factor of 2.762kgCO_2/l for gas oil (Environment Agency, 2012)
[149] (States of Guernsey, 2013)

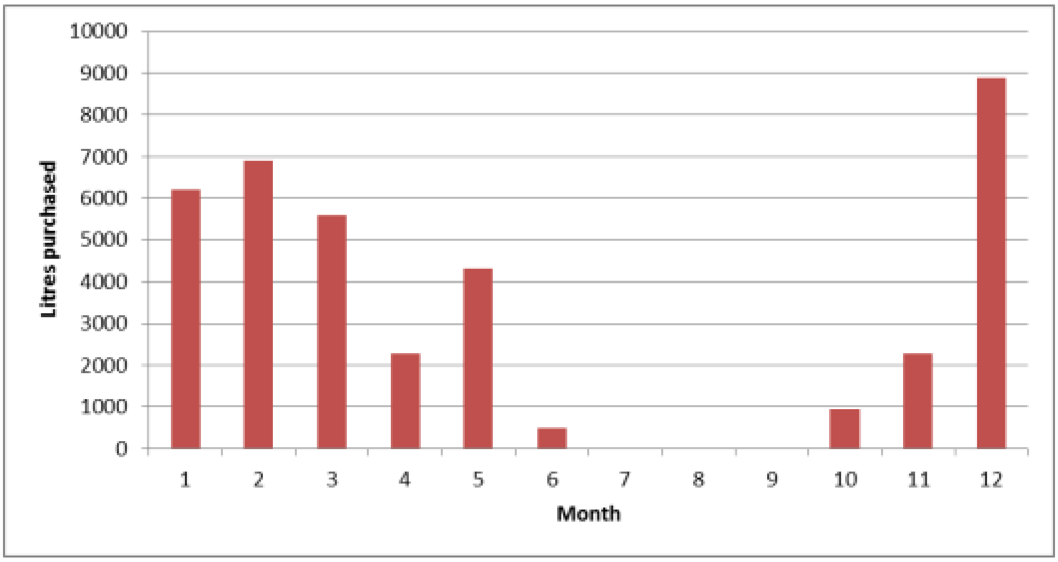

Figure 70: Gas oil purchases in 2012 for Sir Charles Frossard House

It is estimated that, assuming purchase levels matched rates of consumption, in order to fulfil the level of heating required a boiler rated at around 375kW would be required regardless of the primary fuel. Because of the sheer scale required a heat pump system would need an investment so high that return on investment would probably not be achieved in operational life. Dependent on research into the resource, a biomass chip heating system is more viable to meet the heat demand of the building, whilst also keeping biomass-based activities within the States.

It is estimated by Carbon Mixer that in order to match the oil demand seen in 2012, a total of 135.1 tonnes of wood chip would be required over the year. Based on average wood chip prices in the UK, this is equivalent to an annual spend of £13,510; a saving of £8,576 compared to oil.[150] With an estimated initial capital investment of around £45,000, this would be paid back in less than five and a half years. However due to the resource already being in the States' hands ready for processing, operating costs may be lower, decreasing the payback period further.

The rate of savings seen for this example project shows the benefits of having an invest-to-save fund within the States of Guernsey's finances. After the initial investment has been recouped through lower energy costs, further savings could also be directed to this budget, enabling the government to carry out more major works across all their activities.

[150] (Biomass Energy Centre, 2011)

6.6 Conclusions

Guernsey not only has great potential for sustainable heat and energy efficiency integration within its housing stock, but based on the information found, it is apparent that the island needs to start considering its heat use and retention much more than it does at present. The States of Guernsey currently have no policies, incentives or indicators relating to the sustainable and efficient generation and utilisation of heat, as well as building regulations and practice not enforcing the same high standards expected in the UK at present. However, this gives the government a huge opportunity and a blank slate to formulate a policy framework that effectively addresses these issues. This must start with identification of the people most vulnerable through building performance ratings and fuel poverty indicators.

Energy efficiency measures should be prioritised over heat generation, particularly in the short term, to economically utilise any further generation installed whether low carbon or otherwise. Guernsey Housing Association's recent developments prove that through extensive deployment of products that improve heat retention, very little heat is required at all, meaning that the source of what little heat is generated is much less of an issue. However, some energy efficiency measures required to improve Guernsey's older building stock are very expensive to install, thus incentives are required to develop the industry and increase demand of these technologies.

Despite encouraging these measures, the States of Guernsey must lead by example in all aspects of sustainability and energy management. If the States themselves do not enforce energy efficiency standards and deploy renewable heat generation on their own property portfolio, how can they expect others on the island to do so? This factor extends far beyond renewable heat, equally applying to transport and micro-generation of electricity.

Macro heat generation is a possibility on Guernsey in the form of Geothermal energy, but the resource available and the method in which it could be utilised needs to be assessed before progress can be made on the matter. However, the island and the States need to make connections between current challenges: the island has an apparent issue with an excess of waste wood as well as being a heavy importer of oils for heat generation. Therefore why not heat a number of public buildings with biomass chip boiler systems offsetting fossil fuel consumption and reducing the amount of wood being stockpiled?

Overall, seeking methods of generating and managing heat sustainably in Guernsey isn't simply down to reducing carbon emissions, but a method to drive the island towards indigenous production as well. Reducing the amount of energy the island uses through energy efficiency will mean reduced dependency on oil imports, whilst deploying renewable heat technologies will allow Guernsey to make use of the resources it does possess, ensuring that the nation becomes more fuel secure, whilst showing itself as a modern, proactive society ready for the future.

7 Electric Transportation

7.1 Opportunity

From consideration of the previous electric vehicle (EV) work conducted by the University of Exeter for the States of Guernsey, a further study was deemed appropriate to establish the true viability of EVs for use in Guernsey. Much work has already been performed on the issue of feasibility, allowing this report to concentrate solely on devising a strategy to bring increased EV uptake to fruition.

As it stands, Guernsey, as an island, presents an incredible opportunity for the development of an innovative transport network. However, without policy mechanisms or incentives to facilitate the adoption of EVs, limited investment has restricted uptake. Furthermore, without conclusive evidence of issues with the existing transport infrastructure, the Department of Transport are hesitant to commit to a substantial revision of existing transport policy and expenditure.[151] Following a press release on the 23rd of May 2013, the States of Guernsey defined their key transport objectives as:

'To facilitate safe, convenient, accessible and affordable travel options for all the community, which are time and energy efficient, enhance health and the environment and minimise pollution.'[152]

This forms part of a strategic review of transportation, with a focus on addressing the transport concerns of Guernsey's residents.

The existing transport strategy renders Guernsey wholly dependent on the volatile future price of fossil fuels. Therefore, radical change is required to diversify and secure Guernsey's transport future. As a critical instrument for the delivery of this goal, EVs offer an ideal platform with the additional benefit of reduced driving-related emissions. Despite the presence of a dedicated EV converter on Guernsey, and a range of mainstream EV suppliers, the lack of support and infrastructure has resulted in very low vehicle penetration. Guernsey does however have significant potential to be a self-sufficient, world-leading, and environmentally conscious nation, through the use of low-carbon technologies. Therefore, the aim of this study is to present a key strategy to securing the future of transportation in Guernsey.

[151] (Environment Department: Traffic and Transportation, 2013)
[152] (Environment Department, 2013)

7.2 Introduction

7.2.1 Electric Vehicles

EVs are all-electric vehicles where a battery is the only stored energy source. They are based on a simple drivetrain with a large electric motor that drives the wheels either directly or through a gearbox. Most EVs are lightweight and use stored electrical energy very efficiently. They provide an energy efficiency advantage in comparison with traditional vehicles over a short distance, with figure 71 illustrating efficiencies of 80-95% compared to a typical petrol/diesel vehicle's 20-25%, where much of the stored energy is lost as heat.[153] EVs also present drivetrain efficiencies more than twice that of typical hybrids.[154]

The total CO_2 emissions due to driving an EV are typically around 30% less than the average new petrol/diesel vehicle,[155] however this is ultimately dependent on electrical energy mix. Unlike typical internal combustion engines, electric propulsion systems can be driven by energy from renewable sources, with dramatically reduced environmental effects. These key advantages, amongst others, have led to increasing deployment of EVs worldwide, with major producers selling around 40,000 vehicles in 2011.[156]

Figure 71: Efficiency comparison of electric and internal combustion engine powered cars

[153] (POST, 2010)
[154] (IEA, 2011)
[155] (Environment Department, 2013)
[156] (Low Carbon Innovation Coordination Group, 2012)

7.2.2 Potential developments

Research into successful EV strategies indicates that for a system to work effectively, a holistic approach must be adopted. Based on this work the following key objectives can be defined as follows:

- To establish a consistent supply of electric vehicles on the island with required supportive services (e.g. vehicle servicing and maintenance of infrastructure)
- Assessment of grid resilience and infrastructure upgrades to suit public and commercial demand for EV charging points
- To construct a policy framework as a means to streamline the purchase and operation of an EV infrastructure for Guernsey, including necessary financial support to stimulate market demand
- Delivery of an all-encompassing strategy to reduce transport emissions; including the use of car-sharing schemes, optimisation of public transport and other low-carbon approaches
- To improve the public perception and acceptability of EVs through demonstration of their desirability, convenience and performance. This social change could be catalysed through improved education and awareness of the benefits of a unified transport strategy for the future

7.3 Drivers for change

Transport systems and infrastructure are vital services supporting the mobility demand of residents and businesses for social, domestic, commercial and pleasure purposes; the life-line of any nation. Complacency with current transport services may be effective at reducing short term expenditure; however the importance of forward thinking and commitment to improving transport infrastructure should be taken seriously, as the impact to road users can be significant and via multiple channels if the efficacy of current infrastructure continues to decline.

On-going use of traditionally fuelled vehicles and a lack of mass transit infrastructure, especially without vehicle standards and regulation, have resulted in a currently over-burdened road transport network. To highlight the limitations of the existing paradigm, the main drivers for change have been categorised into economic, social and environmental factors.

The cost of Guernsey's traditionally fuelled transport infrastructure is sensitive to volatile and increasingly influential externalities, exposing road users to high future motoring costs.

7.3.1 Economics

Road based transport in Guernsey is a major source of expenditure and therefore represents a significant component of the Guernsey economy. Road transport also accounts for a large proportion of the total energy spend (figure 72), alongside other liquid fuel imports for the power station.

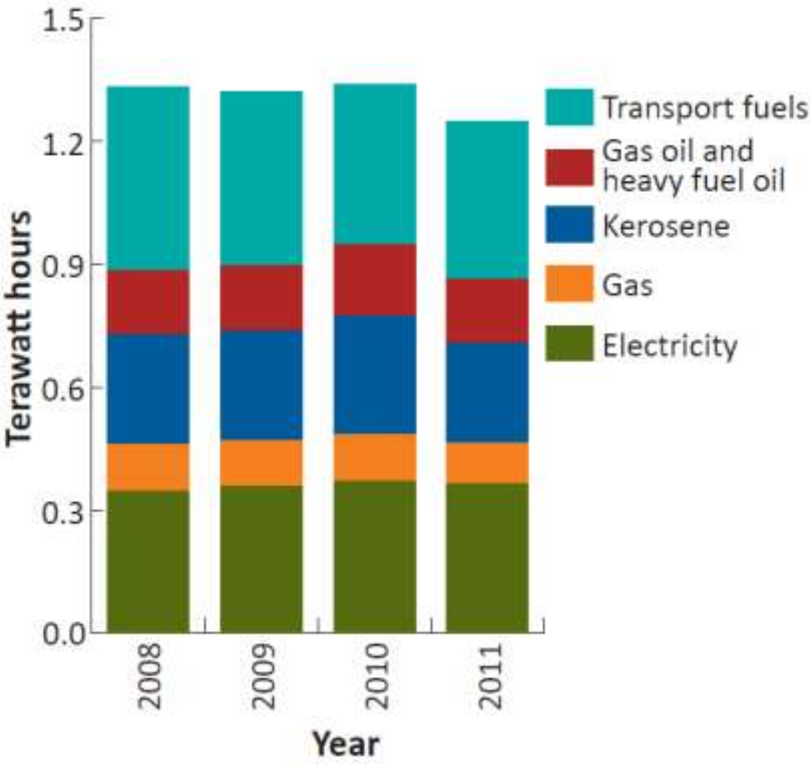

Figure 72: Proportion of Total Energy Spend[157]

7.3.2 Fuel security

Dependence on imported fuel renders the driving population extremely vulnerable to the volatile price of oil, with the potential for major shocks to the Guernsey economy, impacting a large number of residents. This is further compounded by the number of active drivers in the Bailiwick, with 40,106 taxable vehicles on the roads at the last count,[158] and a population of 62,915.[159] These figures highlight the large proportion of the population who are directly subject to changes in fuel pricing. Given that there are currently only 34 vehicles[160] which are not entirely dependent on imported fuels, Guernsey is therefore highly susceptible to any fuel supply disruptions.

[157] (The States of Guernsey, 2012)
[158] (Environment Department: Traffic and Transportation, 2013)
[159] (The States of Guernsey, 2012)
[160] (Environment Department: Traffic and Transportation, 2013)

7.3.3 Social

The existing transport system and road infrastructure in Guernsey is paradoxical in nature as it primarily delivers substantial socio-economic benefits, yet results in growing externalities which affect the social well-being of the people of Guernsey. Transport infrastructure supports the mobility of residents, tourists and commercial freight movements across the island. Continuing increases in mobility demand, with little investment into developing a more substantial road infrastructure, have resulted in highly congested roads giving rise to comparatively long journey times.[161] In 2002, the States of Guernsey Advisory & Finance Committee identified that the urban roads of Guernsey were already overcrowded.[162] Since then, the number of registered vehicles in Guernsey has significantly increased[163] indicating that congestion is clearly still an issue to be addressed.

Figure 73: Traffic Congestion in Guernsey[164]

Modern society has become highly dependent on vehicles to complete routine tasks, and congestion can present a significant social barrier. Congestion increases the likelihood of collisions between other road users, including more vulnerable cyclists and pedestrians. It increases the required time for journeys, resulting in less time for employment related activities, which ultimately impacts on national gross domestic product (GDP), as well as contributing to driver and occupant stress levels with implications for health and well-being.

[161] (Environment Department: Traffic and Transportation, 2013)
[162] (The States of Guernsey, 2012)
[163] (Environment Department: Traffic and Transportation, 2013)
[164] (Sustainable Guernsey, 2012)

The States of Guernsey Consultation Document[165] defines the major transport concerns of the surveyed population as follows:

- Vehicle numbers
- Vehicle size
- Congestion

Further work to quantify the need for change in the current transport system should include a benchmarking approach alongside the monitoring of congestion levels at peak times relative to baseline levels. Assessment of average journey times and their effects should also provide useful data. Until benchmarking can be used to quantify these levels against baselines for comparable situations (similar island economies, or the UK), the use of this data is limited and will not yield an accurate assessment of Guernsey.

The increased use of public transport, the utilisation of alternatively-fuelled vehicles, and the increased use of pedestrianised zones could act to alleviate various societal issues in Guernsey.

7.3.4 Environment

The lack of any significant monitoring or standardised system in Guernsey, for environmental regulation, greatly impedes the decision making process with regard to environmental issues. However, analysis of the position of Guernsey relative to EU member states suggests that the current motoring performance of the island is among some of the most environmentally unsound in Europe, with Guernsey presenting the third most polluting state per unit area[166,167] (figure 74). As well as a representing a key emissions indicator, this comparison is also suggestive of a high traffic road transport density on Guernsey supporting previously stated congestion considerations.

[165] (Environment Department, 2013)
[166] (The States of Guernsey, 2012)
[167] (European Commission, 2012)

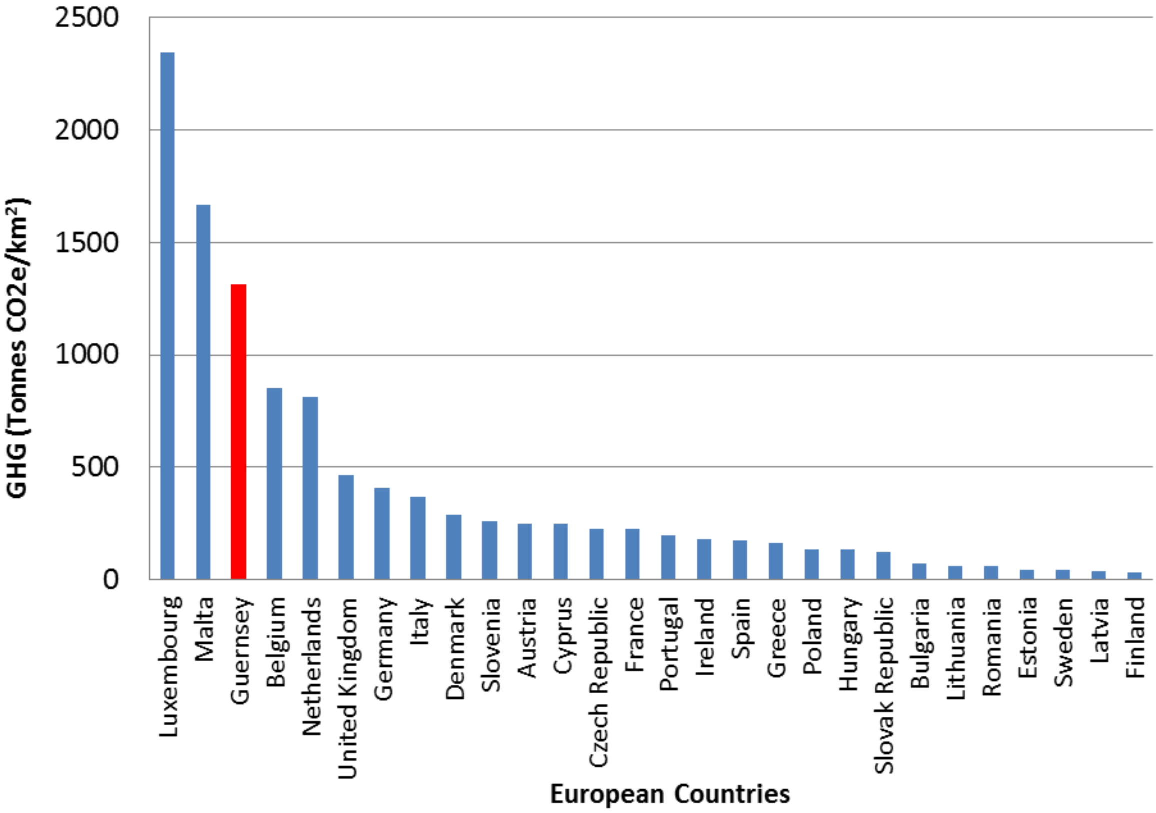

Figure 74: Comparison of Guernsey's Road Transport Emissions with EU Member States (GHG per unit area)

Whilst these figures alone are sufficiently significant as to indicate the need for major change in Guernsey's transport system, this need is further supported by the States of Guernsey Advisory and Finance Committee's[168] own comments, as follows:

'...monitoring confirms that the main source of atmospheric pollution in Guernsey is now undoubtedly motor vehicles working inefficiently in low gear on our overcrowded urban roads. Peak pollution levels in the morning and evening rush hours are regularly twice background levels than those found on Saturdays, Sundays and Bank Holidays when commuter traffic is minimal...'

In order to fully understand the levels of pollution present in Guernsey, it is recommended that a further study be undertaken to assess air quality, allowing for accurate benchmarking with worldwide standards. However, this desk-based study has highlighted some key indicators to suggest that the existing system is in need of major changes.

7.3.5 Moving forwards

To fully address the challenges of transportation, Guernsey should take swift action to secure its mobility future. Both policy and technical measures to assist this transition are discussed in detail,

[168] (States of Guernsey Advisory and Finance Committee, 2002)

including the stimulation and support of an extensive electric vehicle network. Further to private motor vehicles, all transport sectors are addressed to provide a holistic transport strategy.

7.4 Electrical grid

The most important consideration of any electrical transport network is the electric grid; encompassing both the generation fuel source mixture used to generate electricity and the integrity of the grid to support the increased charging demand. It is vital that the generation mix for Guernsey be taken into account when assessing the viability of electrifying transport.

A driver for the shift to EVs is that of secure mobility, which cannot be guaranteed by simply shifting to a reliance on imported electricity in combination with imported liquid fuel. Therefore it is of the utmost importance that if the widespread adoption of electrified transport is planned, both the mix of imported electricity and the source of generation must be substantially improved as to offer a resilient, diverse and thus secure supply. The energy mix must be sufficiently low carbon as to offer a genuine overall improvement on emissions and fuel consumption.

The electrical interconnector between France and Jersey currently enables Guernsey to import 82.1% of its current electrical demand, primarily sourced through nuclear generation (figure 75) with the balance provided by indigenous generation.[169]

The current energy mix mainly comprises nuclear generation, which on face value has low carbon intensity. However, consideration of the entire lifecycle of nuclear generation must be included when discussing the implications of this fuel source.

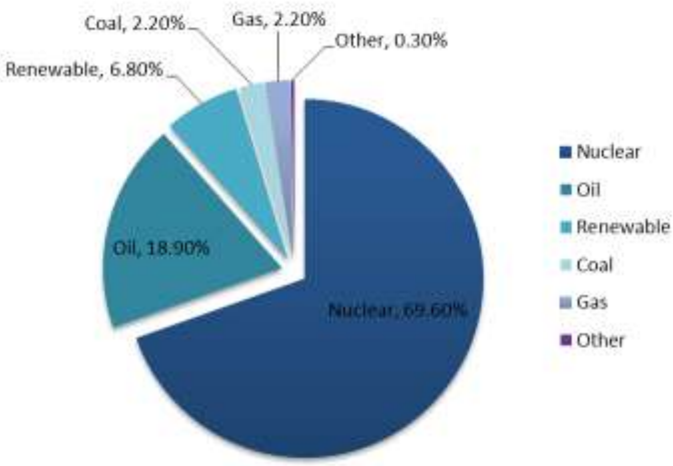

Figure 75: GEL generation mix (2011/12)

[169] (GEL., 2012)

Despite significant emissions reductions of up to 68% for EVs when compared with traditionally fuelled vehicles, large scale electrification of transport will clearly result in an increased electrical demand which may not always be supplied by the 16MW[170] capacity for French imports. Use of on-island fossil-fuelled generators may be required to supply peak demand, simply transferring tail-pipe emissions to generators with only a small reduction in overall carbon intensity. However, a slight gain in well-to-wheel efficiency (raw fuel products to motive power) could be gained through instant uptake of EVs as the round trip efficiency of using the island's diesel generators is greater than that of a conventional car engine.

For the maximum benefit of electrified transport to be realised, and to improve security of supply as the total electrical demand further exceeds the limited capacity of imports, additional long-term investments in both small and large scale distributed renewable generators are required to displace current fossil fuel consumption, irrespective of its origin. The 4th interconnector planned between France and Guernsey[171] may improve the capacity for nuclear imports to alleviate fuel security issues, albeit a questionable fuel source in terms of lifecycle environmental damage. However, this leaves Guernsey exposed to a fuel deficit should reliance be placed on the interconnector and it fails.

Additionally, Guernsey would be at the mercy of French energy security and policy, and as such it is advisable that indigenous renewable generation is developed as a more secure, long-term alternative. Other aspects of this report detail the viability of extensive renewables deployment in the region, creating a suitable climate for a large scale roll out of EVs and associated infrastructure.

7.5 Vehicle Supply

7.5.1 Available vehicles

The supply of vehicles in Guernsey is provided by a series of car dealerships, principally Peugeot, Renault, Nissan and Toyota. From consultation with these dealers, it has been established that a growing supply of EVs are available on Guernsey, with these dealers currently developing key facilities for both servicing and maintenance. The electric vehicles in table 26 are available for purchase:

[170] (GEL, 2012)
[171] (GEL., 2012)

Table 25: EVs Available for Purchase in Guernsey

Car Dealership	Franchises	Currently Available Vehicles	Current Supply/Service Situation	Typical Cost
Freelance Motors Guernsey	Nissan	 Leaf	– Several sold to date – Full servicing available	£23,625[172]
	Renault	 Zoe	– Several sold to date – Full servicing available – Free home charging point installation with vehicle purchase	£17,983 +£70 /month for battery rental[173]
	Toyota	 Auris Hybrid	– All hybrid types sold on a regular basis – Full servicing available – Franchise still training for pure electric vehicles	£13,995[174]
		 Prius Hybrid		£21,845[174]
		 Yaris Hybrid		£14,995[174]
Motor Mall Guernsey	Mercedes	 Smart fortwo Electric	– Can supply and service but none on-site and none sold to date – Petrol Smarts are extremely popular and sold regularly	£17,705[175]
	Mitsubishi	 i-MiEV	– Can supply but none on-site and none sold to date – Deemed too expensive to justify sales	£28,990[176]
	Peugeot	 iOn	– 1x vehicle available for test drive but unpopular and none sold to date	£21,250[177]

[172] (Nissan, 2013)
[173] (Renault, 2013)
[174] (Toyota, 2013)
[175] (smart, 2013)
[176] (Mitsubishi, 2013)
[177] (Peugeot, 2013)

7.5.2 Barriers

From stakeholder consultation, the principal barriers to the widespread uptake of EVs on Guernsey are capital costs and public concerns regarding range and performance anxieties.[178]

7.5.2.1 Capital costs

Thus far the uptake of EVs has been limited to those with the available funds to overcome capital barriers. This has led to a small fleet of 34 EVs[179] in use across Guernsey,[180] which is minimal in comparison to the number of traditionally fuelled vehicles. Any policy should address the capital costs of purchasing a vehicle and provide adequate support to remove the onus on vehicle dealers to deliver cheaper EVs. Existing EV procurement policy in other countries includes capital grants to reduce the up-front cost of vehicles; examples of which can be found in Canada, Japan, the UK, the USA, France and Belgium.[181]

Certain vehicle manufacturers already incentivise the purchase of EVs by offering the installation of home charging points free of charge to their customers.[182] Such a scheme is currently in place in Guernsey, but this has not yet been sufficient to drive a real uptake.

7.5.2.2 Perceived Performance

One of the key perception issues linked with EVs relates to their performance in comparison with traditionally fuelled vehicles. This is predominantly due to the compact lightweight nature of typical EVs, and their perception as solely small, low-powered, and short-range vehicles, best suited for use as milk floats.

However a typical electric motor can provide instant torque at virtually any revolutions per minute (rpm) and therefore the driving force of the motor is available instantly when the accelerator is pressed. In addition to this torque stays virtually constant to a high rpm. These key factors allow for EVs to actually offer a higher deliverable performance when compared with internal combustion engine vehicles, which do not develop peak torque until many thousand rpm and once reached this torque drops off quickly.

Therefore one of the best ways to demonstrate the performance of electric vehicles and overcome common misconceptions is to demonstrate their participation in high performance motorsport. At present, despite the Motor Sports Association (MSA) recognising electric vehicles for participation in

[178] (Environment Department: Traffic and Transportation, 2013)
[179] (Environment Department: Traffic and Transportation, 2013)
[180] (Environment Department: Traffic and Transportation, 2013)
[181] (Tesla Motors, 2013)
[182] (Renault, 2013)

official motorsport events such as sprints and hill-climbs,[183] Guernsey's thriving motorsport events see virtually no electric vehicle participation. Therefore there is significant potential for the future promotion of EVs in this area.

Figure 76: MSA Registered Electric Sprint Vehicle[184]

7.6 Infrastructure

The minimum range of all EVs available for purchase in Guernsey significantly surpasses the typical daily range requirement of residents. For example, the Peugeot Ion, which has the lowest typical range of 93 miles from fully charged[185] could theoretically drive approximately 4 times around the perimeter of Guernsey following the main roads (figure 77). For general social, domestic and pleasure usage, the range of electric vehicles is therefore not seen as a barrier hindering mass uptake of the technology; moreover it is the perceived limitation of range that is causing concern.

[183] (Dragon Electric Vehicles, 2012)
[184] (Dragon Electric Vehicles, 2012)
[185] (Peugeot, 2013)

Figure 77: Maximum Journey Distance around Guernsey[186]

For commercial usage, including delivery services, breakdown recovery services, and taxis which travel substantially greater miles due to the nature of their business, the range of electric vehicles is seen as a potential barrier which can be mitigated through the strategic placement of priority fast chargers. During this phase of transport reformation, it would be beneficial to consult with all of these key stakeholders to identify suitable locations for dedicated small-scale charging infrastructure around the island. GEL has indicated that there are no significant engineering challenges to overcome to enable the installation of rapid charging points throughout the island.[187] However, any developments would need to be in the interest of shareholders (States of Guernsey, and GEL customers) following pressure from the Guernsey Government.[188]

In addition to diversifying, securing and decarbonising the transport system, EVs offer a fantastic opportunity to have integrated energy storage capabilities on the island without the need for costly

[186] (Google, 2013)
[187] (GEL, 2013)
[188] (GEL, 2013)

capital expenditure on dedicated energy storage facilities. Although currently still very much in infancy, an island wide vehicle-to-grid (V2G) system could be used to balance the intermittency of any future developments of renewable energy delivering power to Guernsey. With a V2G system in place, power could be drawn from the battery storage of vehicles on the island temporarily relieving the requirement to consume fossil fuels to supply the demand (figure 78). Through adjustment to the electricity tariffs supplied by GEL, the time at which vehicles are connected to the grid can be manipulated to provide this capability, and to incentivise charging during times of low demand.

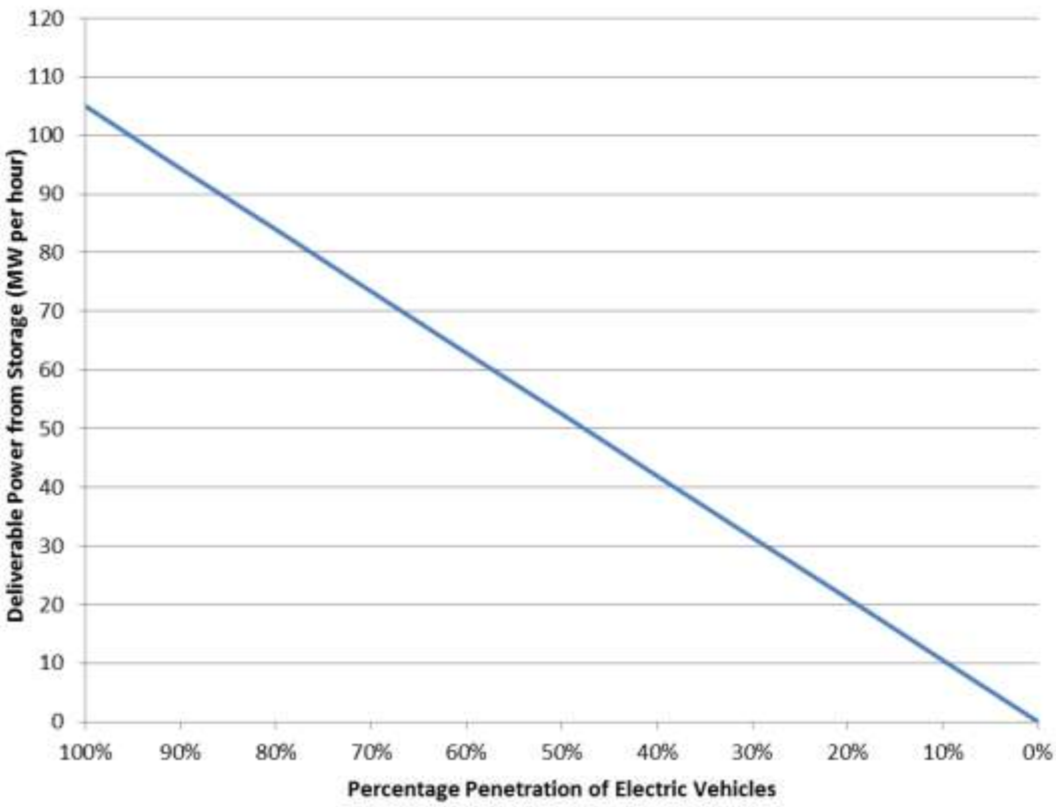

Figure 78: Vehicle Storage Potential

7.7 Transport Reformation Strategy

A wide range of policy instruments could play a role in promoting electric and low emission vehicles (LEV) for Guernsey, including; public vehicle procurement (e.g. government fleets, public transport), differential treatment (e.g. preferred access to key urban areas), and financial incentives for the purchase of electric vehicles or for investments in recharging infrastructure.

It is recommended that the States of Guernsey develop a Sustainable Transport Policy to promote more sustainable travel options such as car-sharing, increased public transport use, walking, cycling, and the increased uptake of LEVs. This has already started in the Transport Strategy Consultation Document. The key aim of this strategy would be to reduce transport energy demand, improve energy security, reduce congestion and diminish carbon emissions, alongside the promotion of walking and cycling to maximise key health benefits.

This would be in keeping with the States of Guernsey Traffic and Transport Division's stated aim to "facilitate safe, convenient, accessible and affordable travel options […] which are time and energy efficient and enhance health and the environment and minimise pollution".[189] The proposed policy additions and amendments are therefore as follows:

Table 26: Summary of Proposed Policy Mechanisms

Mechanism	Description	Implementation Timeframe
Capital incentives for EVs	A non-refundable grant, in the order of a few thousand pounds, to reduce the purchase price of a qualifying low carbon vehicle.	Prior to 2015
Subsidised installation of domestic EV fast chargers and commercial charging points	A scheme whereby the installation cost of domestic home chargers is partially subsidised by Government funding. This will support the high capital cost of fast charging infrastructure for properties without appropriate access to the electrical network, including kerbside installation for properties without driveways.	Prior to 2015
Government procurement of electric and plug-in hybrid vehicles.	Replacement of Government, public service and transport vehicles with low emission alternatives; including hybrid electric buses electric trams.	Prior to 2017
Congestion Charged zones with preferential access for EVs and smaller vehicles.	A restriction applied to areas of Guernsey, particularly key congestion areas such as St. Peter Port and links with St Sampson, within which vehicular access requires a charge to be paid. Vehicles with emissions exceeding a certain threshold, such as 100gCO_2/km as used by Transport for London[190], could be charged a blanket fee of £15. EVs, vehicles with emissions below the threshold, and smaller vehicles (motorcycles) would have free access.	Prior to 2017
Subsidised on-demand traditionally fuelled vehicle hire	To alleviate range anxiety and resolve genuine restrictions imposed by EVs on overseas travel, the cost of on-demand rental vehicle hire will be subsidised for EV owners.	Prior to 2015

[189] (Environment Department, 2013)
[190] (Transport for London, 2013)

for EV car owners.		
Reintroduce banded Vehicle Excise Duty (Road tax on all vehicles)	To facilitate the implementation of Congestion Charged zones and incentivise the use of LEVs, a banded tax scheme should be re-introduced. The banding levels should be structured such that high emission vehicles are more costly to tax than EVs and LEVs which should pay zero tax. Periodic review of the banding levels should be undertaken to account for the phase out of traditionally fuelled vehicles, as required.	Prior to 2015
Preferential Parking for EVs	Although parking charges are not currently in force in Guernsey, it is recommended that electric vehicles are exempt from any future introduction of charges. Additionally, fast charging points should be made available for commercial vehicles such as taxis.	Prior to 2015
Cycle Hire Scheme	A scheme to promote and support cycling as an alternative mode of transport through development of distributed services and infrastructure around the island. Bicycles, both standard and electric, could be made publically available for hire with the ability to pick up and drop off at any of the docking stations (similarly to the Barclays Cycle Hire Scheme currently implemented in London).	Prior to 2017

7.7.1 Credit-based Vehicle Pricing

Credit-based pricing has been suggested by a number of transport economists as a more acceptable policy for applying automotive transport restrictions than straightforward penalties,[191, 192] and as a means to address transport issues with minimal required government revenue. Researched approaches consider the implementation of revenue-neutral pricing for vehicle use, with the intention of providing transport regulation whilst avoiding both driver inequality and governmental revenue allocation issues.[193] There are two key methods to delivering this pricing mechanism:

- Road tolls or other driver payments can be assigned based on the negative externalities associated with vehicle use, with collected fees returned to all drivers in an evenly distributed fashion, acting as a form of driving allowance.[194] In this approach the typical driver essentially pays nothing across the duration of the scheme, whereas frequent, peak-period or long-distance drivers subsidise others by receiving reduced returns. In simple terms this results in drivers with non-ideal driving profiles subsidising the costs of those with more responsible profiles, providing an incentive to avoid driving in undesirable locations such as congested urban areas, or to avoid driving altogether
- Similar to the existing system of carbon credit trading for emissions, as established by the Kyoto Protocol to address greenhouse gas emissions,[195] a credit-based congestion pricing mechanism may also be delivered as part of a credit trading approach. In this mechanism both drivers and non-drivers are given the option of utilising vehicle credits for themselves, or selling them to other drivers who wish to travel beyond an officially defined individual quota[196] or otherwise cashing them in by returning them to a central pot. This allows for direct benefits or savings for those who utilise public transportation, car-share or reduce their peak-time travel, and penalties for those who do not. Again in this approach the average driver receives no penalty

Research by Kockelman & Kalmanje[197] has demonstrated the potential for a credit-based vehicle policy to alleviate congestion through reduced vehicle use, and to generate benefits across all income groups and vehicle types, with virtually no required government funding.

[191] (Kockelman & Kalmanje, 2005)
[192] (Ch'ng & Tang, 2012)
[193] (Kockelman & Kalmanje, 2005)
[194] (Environment Department, 2013)
[195] (UNFCCC, 2013)
[196] (Kockelman & Kalmanje, 2005)
[197] (Kockelman & Kalmanje, 2005)

7.7.2 Credit-based Vehicle Policy for Guernsey

From consultation with the States of Guernsey Traffic and Transport Division, RET and Guernsey vehicle suppliers, a credit-based pricing strategy is proposed for Guernsey, with the potential to address many of the key transport issues outlined in this study.

The proposed strategy is based on a credit trading approach, would require minimal direct government payments or subsidies to run once initially set up, and could be promoted to the people of Guernsey as a new way to reduce their fuel expenditure.

Under this mechanism, a standardised number of fuel credits would be distributed freely to all licensed vehicle drivers to enable fuel consumption up to a predetermined level, based on an ideal typical annual fuel consumption per driver. These credits would be required to be deposited per unit volume of fuel purchased. This is likely to work best as part of a card-based system, similar to existing fuel loyalty cards, allowing for credits to be utilised as part of both a pay-at-pump approach and for cross-counter transactions.

For the average driver who uses only their allotted credits, there is no penalty for driving. However drivers who exceed this level are required to purchase additional credits, either through an increase in the unit price of fuel or as a separate credit transaction. However the unique advantage to such a scheme is that for drivers who use a fuel volume less than the defined average level, and are left with surplus credits, these can be utilised to achieve fuel expenditure savings, either through a reduction in the unit cost of fuel or by separately cashing in credits for a financial reward. Such a system can be deemed revenue-neutral for the States of Guernsey, as once the physical operating infrastructure has been established, those payments received by conscientious drivers with low fuel requirements would be supplied indirectly by the additional expenditure made by high-consumption drivers.

For continuity and objectivity, taxis and commercial vehicles could be allotted an alternative credit allowance, so as not to unnecessarily penalise key services. In addition, buses, public transport and public service vehicles (e.g. the emergency services) would logically be exempt from such a scheme. Equally the hire cars that are regularly utilised by visitors to Guernsey could each be required to carry a card for fuel credit transactions, in addition to the existing parking time display card. However, further investigation may be required to assess the differences in travel characteristics between tourists and residents, and a tourist fuel allowance defined accordingly.

Such a scheme would present a number of key advantages, as a means to address transport issues. Key advantages may include; Potential reductions in congestion through both reduced overall driving and drivers avoiding the inefficient use of vehicles in low gears on overcrowded roads.[198] In addition, such a credit scheme would encourage the use of both car-sharing and public transport, as well as promoting the use of fuel efficient vehicles which present lower emissions levels and provide a reduced contribution to vehicle pollution.[199] Key advantages would also be present for hybrid vehicle drivers who minimise their fuel consumption through the additional use of electric propulsion, and the drivers of pure electric vehicles[200] who could still own a capable personal vehicle, however with entirely unrestricted usage compared with petrol or diesel vehicles. This scheme would also effectively incentivise the purchase of electric and hybrid vehicles through a driver's ability to financially benefit from the return of unrequired fuel credits.

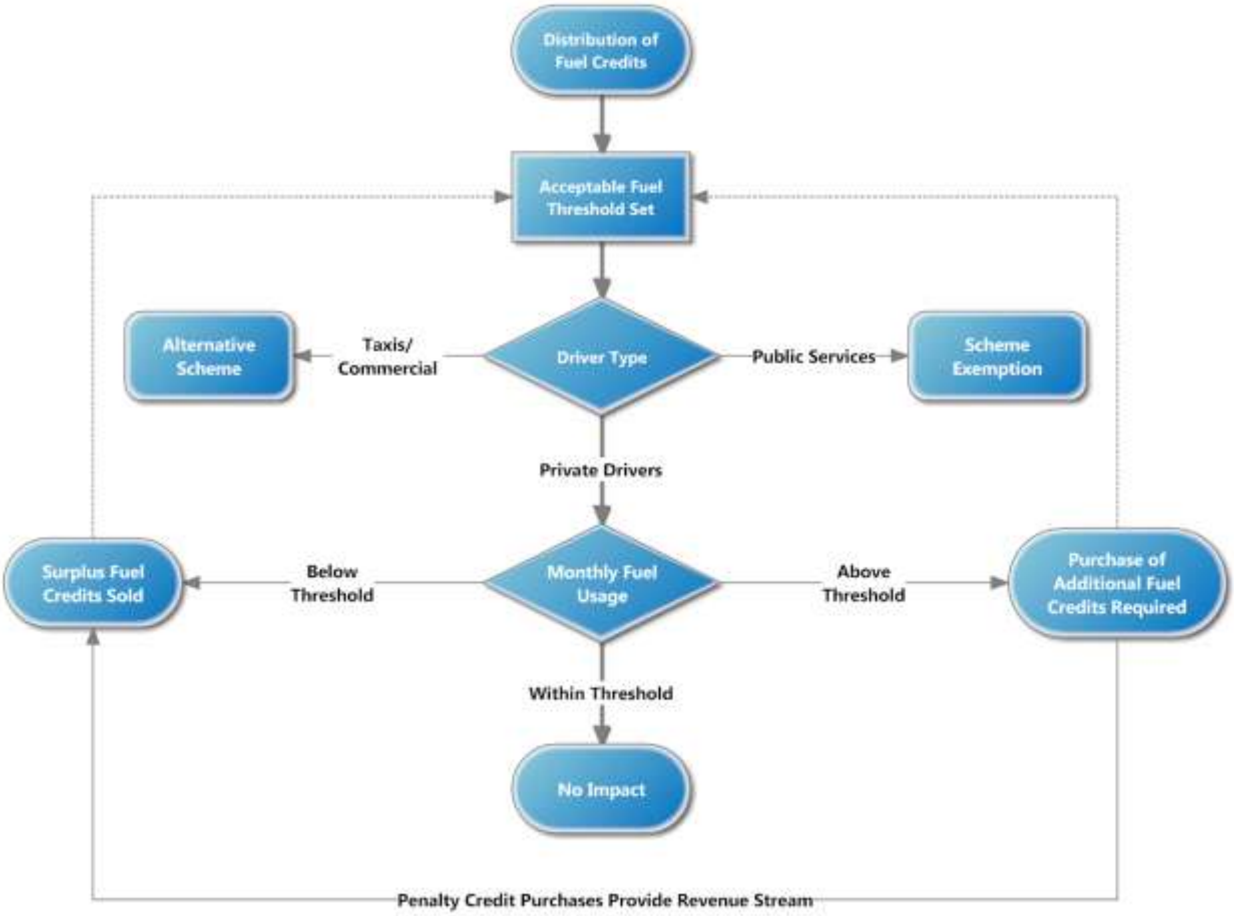

Figure 79: Credit based system flowchart

[198] (Gordon, et al., 2002)
[199] (IEA, 2012)
[200] (Granovskii et al., 2006)

7.7.3 Commercial vehicles

Commercial vehicles (CVs) account for over 20% of the registered vehicles in Guernsey,[201] highlighting the need to ensure that any transport strategy takes them into account. These vehicles have been split into 2 categories for the purposes of this report: light goods vehicles (LGVs) and heavy goods vehicles (HGVs).

7.7.3.1 Light Goods Vehicles

There are already commercial electric LGVs in operation on Guernsey,[202] indicating that there is an existing market for low-emission commercial vehicles. The case study undertaken in a subsequent section of this report uses the Renault Kangoo Electric van as an example LGV, although other electric LGVs are also available for purchase. Consideration must also be given to the use of hybrid LGVs, for instance the Fuso Canter Hybrid 7.5t truck,[203] which has already been used successfully in pilot testing in London and Tokyo. Such a vehicle would be ideal for use on Guernsey, as the hybrid support rates for the vehicle dramatically increase for low-speed, 'urban' driving conditions as commonly encountered on Guernsey. The Canter Hybrid is especially well suited for use in Guernsey, as its high manoeuvrability and small size could reduce the level of potential impacts on other road users. However, a 7.5t capacity would still allow for public service use. Studies have indicated that with no financial incentives, such vehicles only become economically viable in their second lifetimes.[204] As they are not pure EVs, the purchase of hybrid vehicles would not be supported using the proposed capital grants scheme. However, a banded Vehicle Excise Duty (VED) structure and the suggested use of a fuel credit trading scheme would incentivise the use of LGV hybrids.

7.7.3.2 Heavy Goods Vehicles

As stated by the Environment Department in a recent document, 'A Fresh Start', HGVs are vital to the Guernsey economy providing many essential services but are paradoxically seen by some as 'a nuisance'; causing congestion and pollution issues.[205] The use of smaller HGVs has been discussed in this consultation document, but the use of hybrid HGVs should also be considered.

Both the DAF LF Hybrid,[206] and the Mercedes-Benz Atego Hybrid[207] offer the operational benefits of a conventional HGV but with the reduced emissions associated with hybrid vehicles; especially when operating in low gears for a large proportion of the driving cycle.[208] If a Low Emission Zone (LEZ) or a Congestion Zoning system (CZ) was introduced, vehicles such as these with the capability to operate

[201] (The States of Guernsey, 2012)
[202] (Environment Department: Traffic and Transportation, 2013)
[203] (Mitusbishi Fuso, 2013)
[204] (Sharp, 2010)
[205] (Environment Department, 2013)
[206] (DAF Trucks Limited, 2013)
[207] (Mercedez Benz, 2013)
[208] (Environment Department, 2013)

in pure electric mode would become even more attractive as they would be the only vehicles permitted to operate in the LEZ or CZ.

7.7.3.3 Commercial Vehicle Policy

There are numerous mechanisms which could be used to incentivise the use of low emission, or pure electric, commercial vehicles. However, their high capital costs are currently prohibitive. A careful balance between encouraging the further use of commercial vehicles and incentivising cleaner vehicles is required. This could be enforced through a commercial fuel credit scheme, using a similar model as the previously defined private vehicle approach, but with a quota assigned to each business as opposed to each driver. The VED system could also include a parallel structure for commercially registered vehicles, similarly to the VED structure for private users, with the structure providing price reductions or rebates for electrically driven or low emission vehicles. The current system used in the UK encourages the use of more efficient engines in HGVs, with preferential rates for more modern engines.[209]

A CZ or LEZ system, similar to the systems currently used in London[210] and the proposed scheme in Manchester,[211] would prioritise the use of lower emission vehicles. This would encourage commercial vehicle users to consider using LEVs to access urban areas to avoid losing business, but the savings from this scheme would have to be significant in order to recoup the high capital costs of a hybrid or electric CV.

7.7.4 Buses

The relatively small bus network in Guernsey, having only 41 vehicles,[212] covers a comparatively high annual mileage with each vehicle covering over 40,000 miles per annum.[213] As the current fleet is reaching the end of its lifetime, and the States of Guernsey will be looking to replace the vehicles, it would seem like the ideal opportunity to purchase more efficient vehicles.

However, the criteria for selecting buses for use in Guernsey are reasonably strict,[214] requiring standard capacities and the meeting of all-ability access requirements whilst still being small enough to allow them to use the island's road network. The complex contractual agreement between the States of Guernsey and the contractor on Guernsey (HCT) also limits the influence of the States with regard to vehicle selection, lowering the likelihood of simply replacing the current fleet with either an electric or hybrid fleet.

[209] (DVLA, 2013)
[210] (Transport for London, 2013)
[211] (Manchester City Council, 2008)
[212] (Environment Department, 2013)
[213] (Environment Department: Traffic and Transportation, 2013)
[214] (Environment Department, 2013)

The driving profile of buses limits the potential effectiveness of pure electric buses, as high mileage requires rapid refuelling and often at irregular times.[215] This implies the use of a rapid charging point or a battery swap system, both of which are however limited in development.

Hybrid buses have been successfully used in the UK in a variety of locations including Brighton, Oxford and Birmingham,[216] demonstrating that these buses can be used successfully on a commercial basis. The Environment Department raised concerns over the likelihood of finding hybrid buses which are compatible with the requirements for mass transit in Guernsey, however a wide range of vehicles are indeed available.

Whilst financial mechanisms are unlikely to be suitable for the funding of an electrified bus network without substantially increasing the costs to the user, the use of hybrid or electrified buses could form a part of a public procurement scheme to demonstrate the capabilities of low emission vehicles, and offer part of a wider campaign to promote responsible vehicle use. As part of the contractual agreement between HCT and the States of Guernsey, the buses selected by the States of Guernsey would need to be accepted by the contractor. If a CZ or an LEZ was enforced, this would further the case for the uptake of low emission buses and as such could influence the decision as to which buses are suitable. In order to incentivise the use of low emission buses, the CZ or LEZ charges would need to be suitably prohibitive to the operation of conventional buses.

7.7.5 Capital Grant Scheme

To improve the economic viability of purchasing a new EV, overcoming the increased capital cost of compared to a traditionally fuelled vehicle, a capital grant scheme is proposed. Upon purchase of a new and qualifying EV, a non-refundable grant could be paid by the States of Guernsey to fund the purchase of the vehicle. The States of Guernsey could provide a grant similar to schemes adopted by other countries worldwide,[217] hypothecated from increased VED, paid parking and the fuel credit scheme proposed as follows.

7.7.6 Banded Taxation Structure

As a part of a policy-driven approach to supporting EVs, a banded vehicle road tax structure is recommended. This structure will help to raise capital to install EV associated infrastructure, and will also allow for more accurate monitoring of vehicle numbers and classifications. The existing scheme used on the UK mainland grants low-emission vehicles tax exemption, and uses consequently lower rates of taxation for vehicles with lower emissions (for instance Euro 5 HGVs have a lower taxation

[215] (Environment Department: Traffic and Transportation, 2013)
[216] (Stagecoach, 2012)
[217] (Tesla Motors, 2013)

rate than Euro 4). The use of such a scheme for Guernsey could include the separation of EVs from internal combustion engine vehicles to further encourage their uptake.

As there are a wide range of vehicles in use in Guernsey with limited regulations for emissions, the most logical system to use is that of ranking vehicles by engine size and registration type. This originates from the format used to register a vehicle for use in Guernsey; the most pertinent details being:

- Vehicle make/model
- Engine Size
- Fuel type[218]

For vehicles produced after 2001, emissions data is published by the manufacturer which would facilitate the use of a banding structure based on the grams of CO_2 emitted per kilometre.

7.7.7 Off-Island Transport

To address genuine anxieties concerning vehicle range for trips to the mainland, the use of a community fleet of high efficiency diesel vehicles is recommended.

These vehicles would form a community car pool for use by residents who use the ferry system to take vehicles further afield where the range of EVs is likely to become an issue. Such a system allows the residents of Guernsey to have an EV without the imposed range limitations. An on demand car-sharing scheme could provide access to a vehicle for use off the island, in addition to the electric vehicle purchased for day to day use in Guernsey. This would also minimise costs for residents as the cost of the diesel vehicle would be socialised over a large number of shareholders. The Hertz On-Demand system[219] is a good example of a large scale car sharing network, potentially providing a template for a similar scheme in Guernsey. This mechanism is especially relevant as Hertz vehicles already operate on Guernsey.

7.7.8 Rental Vehicles

Given that there are approximately 1750 rental vehicles in Guernsey,[220] principally for use by the tourist industry, it would be senseless to ignore the potential their use as both a marketing tool for EVs and to showcase Guernsey's environmental credentials.

To make optimum use of the rental fleet, co-operation between the States of Guernsey and rental vehicle providers is required. The main rental operation on the island is Hertz Car Hire,[221] as well as

[218] (Environment Department, 2013)
[219] (The Hertz Corporation, 2013a)
[220] (States of Guernsey Transport Division, 2013)

Avis and Europcar, who already include EVs in their rental fleet but have not yet introduced them to Guernsey. By incentivising the use of EVs through the re-introduction of a banded vehicle excise duty and the provision of EV specific parking areas around the island, EVs could become the rental vehicle of choice for tourists visiting Guernsey.

7.7.9 Preferential Parking for EVs

Following the prospective introduction of paid parking in Guernsey,[222] there is scope for providing preferential parking spaces for EVs. The use of such scheme could offer significant convenience benefits to incentivise their uptake and by the same stroke discourage the use of conventional vehicles in favour of travelling via other modes of public and personal transport.

7.7.10 Proposed Policy Mechanisms: Guernsey Electricity Case Study

To illustrate the cost benefit of electrifying a fleet of business vehicles, a discounted cost analysis is presented to demonstrate the difference in cost between the electric and traditionally fuelled vehicles.

GEL runs 19 cars, and 57 light commercial vehicles[223] for which electric substitutes, for example the smart electric drive and Renault Kangoo ZE respectively, could be supplied.

7.7.10.1 Financial Modelling Assumptions

- Capital cost of vehicles as per manufacturers May 2013 prices, excluding UK VAT
- Fuel as per May 2013 prices in Guernsey
- Fuel price inflation: 8%
- Fuel efficiencies of vehicles as per the manufacturers specification
- Consumer Price Index: 4%
- Electricity as per May 2013 prices on the Super Economy Tariff
- Electricity price inflation: 4%
- Battery range as per the manufacturers specification
- Annual mileage per vehicle: 4000 miles
- Battery lease cost as per the manufacturer specification
- Servicing cost of EVs at 50% of the servicing cost of traditional vehicles, rising with inflation

[221] (The Hertz Corporation, 2013a)
[222] (Environment Department, 2013)
[223] (GEL, 2013)

7.7.10.2 Policy Incentive Assumptions

- Capital Grant Scheme: £5000 towards the cost of purchasing an EV
- Re-introduction of a banded VED mechanism with tax exemption for EVs
- Use of fuel credit trading scheme, with credit value of 20 pence per litre of fuel purchased

7.7.10.3 Sensitivity Analysis Variable Ranges

Table 27: Summary of Variable Swing in Sensitivity Analysis

Variable	Low	Best Guess	High
Fuel Price Inflation	6%	8%	10%
Electricity Price Inflation	2%	4%	6%
Annual Mileage	2000	4000	6000
Average Fuel Consumption	-40%	-20%	Manufacturer
Average EV Range	-40%	-20%	Manufacturer
Capital Incentive	£3000	£5000	£7000
Value of Credit	£0.1	£0.2	£0.3
Vehicle Excise Duty	£75	£100	£125

7.7.11 Light Commercial - Renault Kangoo

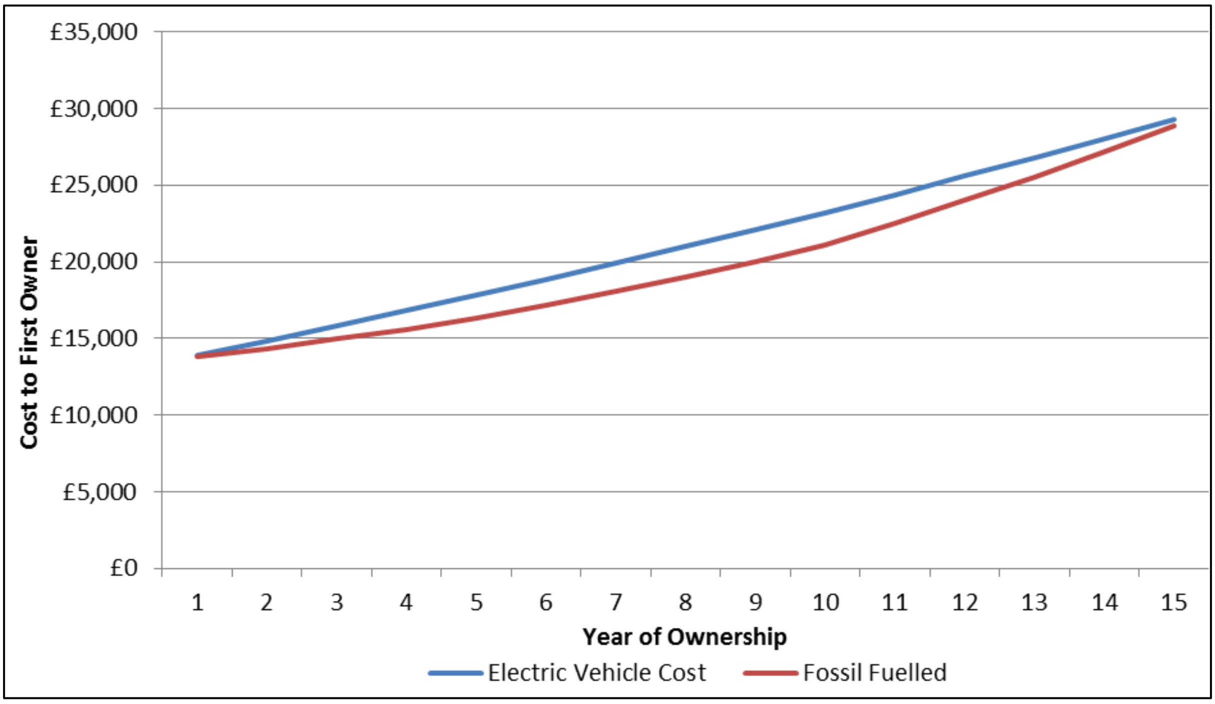

Figure 80: Economic Comparison of Fossil Fuelled vs EV Renault Kangoo under current Policy Conditions

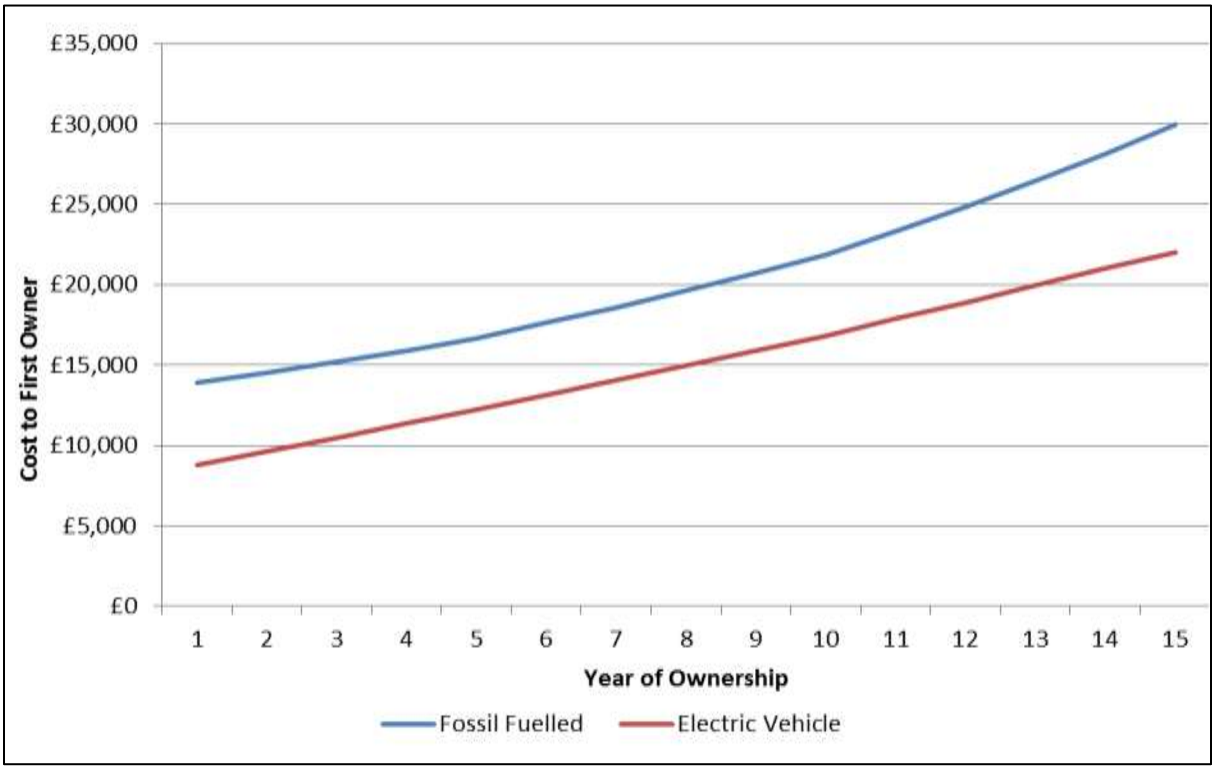

Figure 81: Economic Comparison of Fossil Fuelled vs EV Renault Kangoo with Proposed Policy Mechanisms

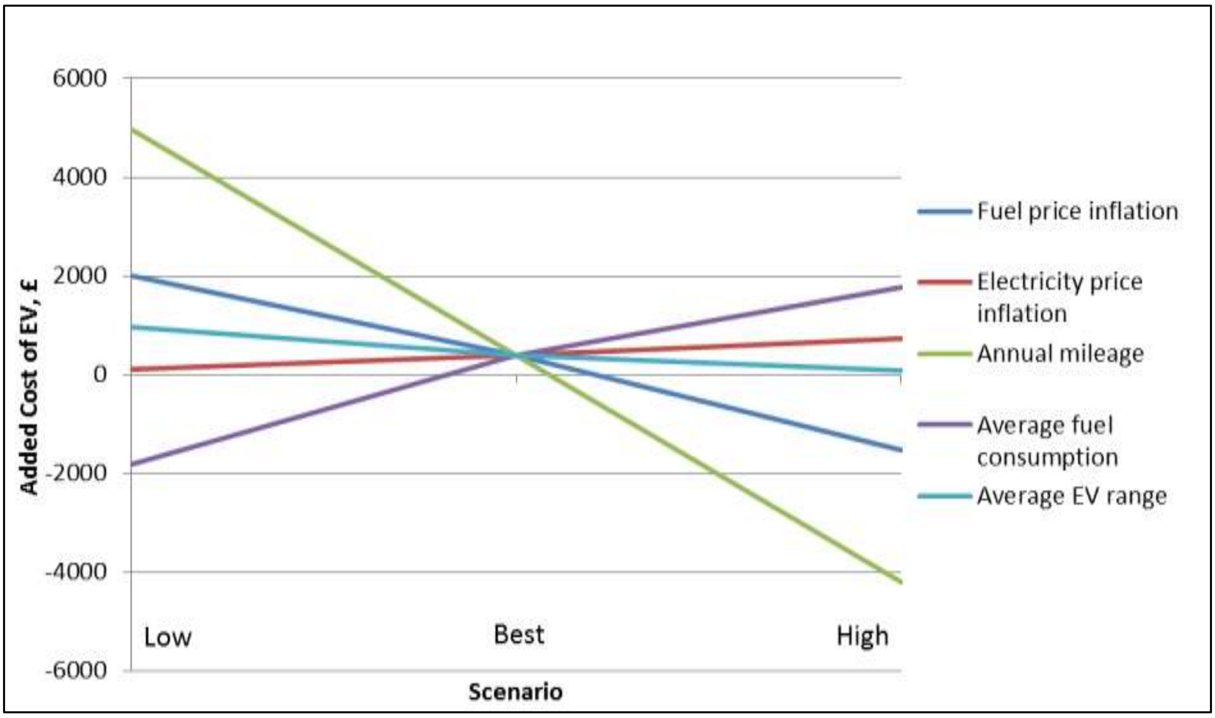

Figure 82: Sensitivity Analysis - Variation in Model Assumptions

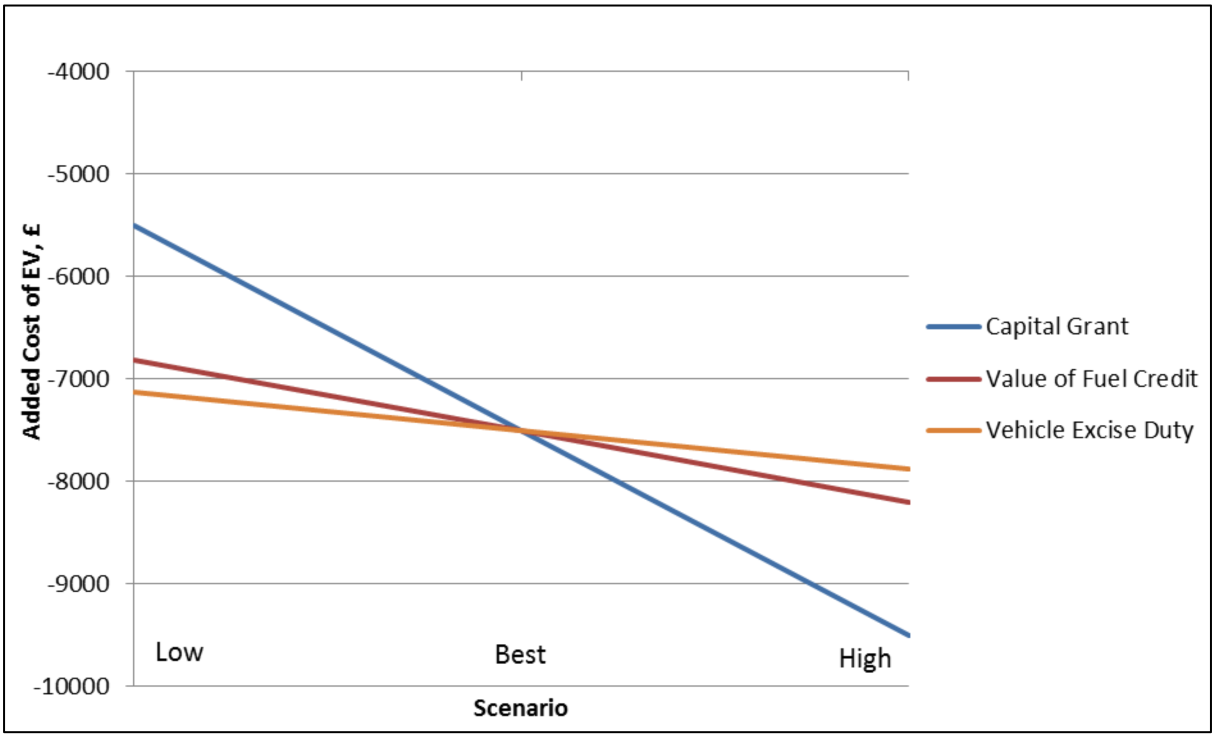

Figure 83: Sensitivity Analysis - Variation in Policy Mechanisms

7.7.12 Car – smart fortwo

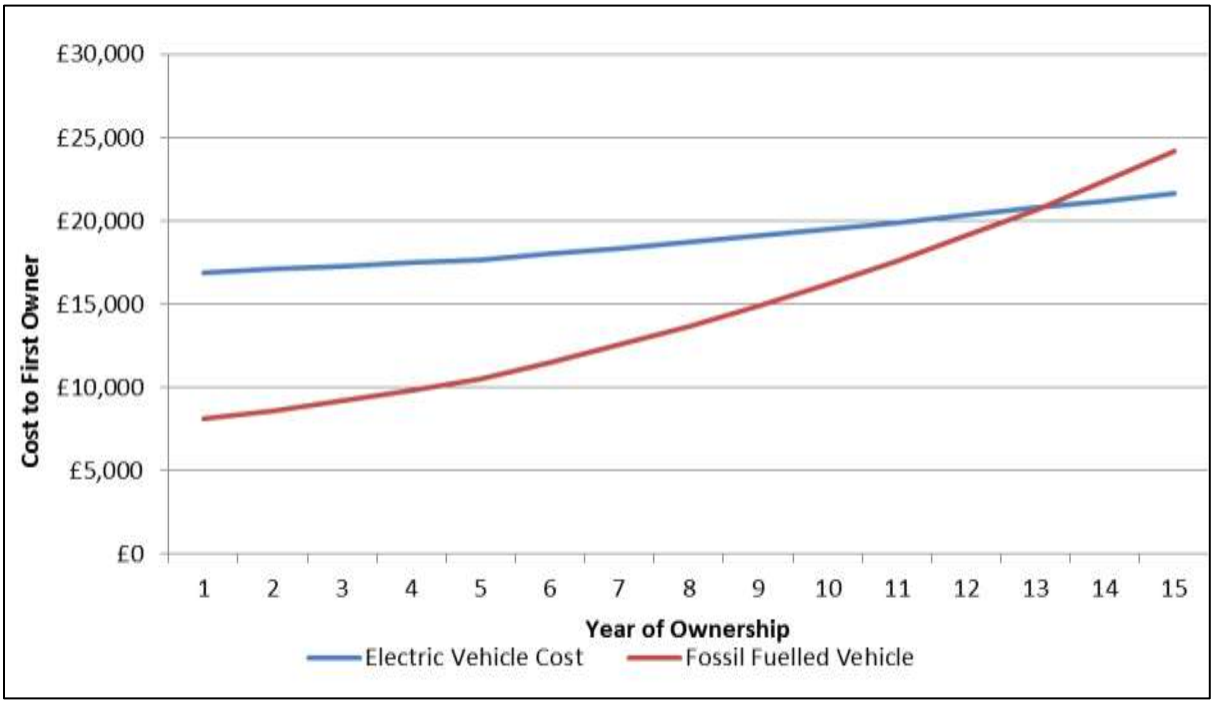

Figure 84: Economic Comparison of fossil fuelled vs. EV smart fortwo under current Policy

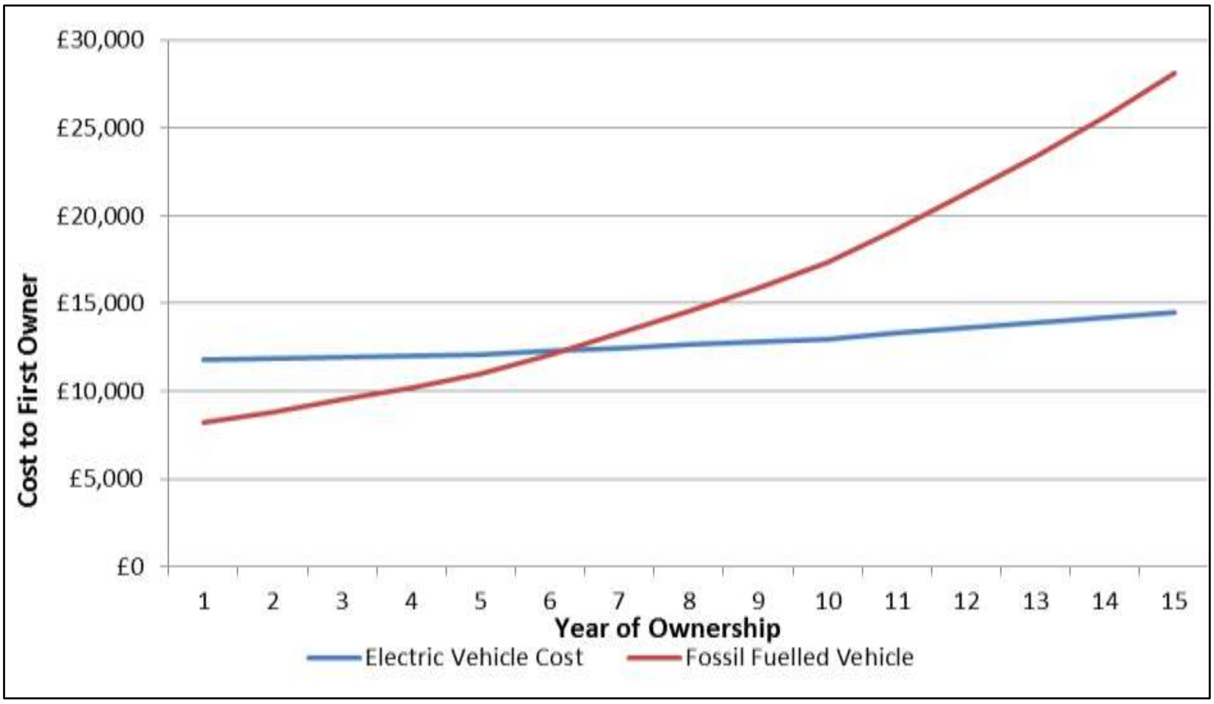

Figure 85: Economic Comparison of fossil fuelled vs. EV smart fortwo, under Proposed Policy Mechanisms

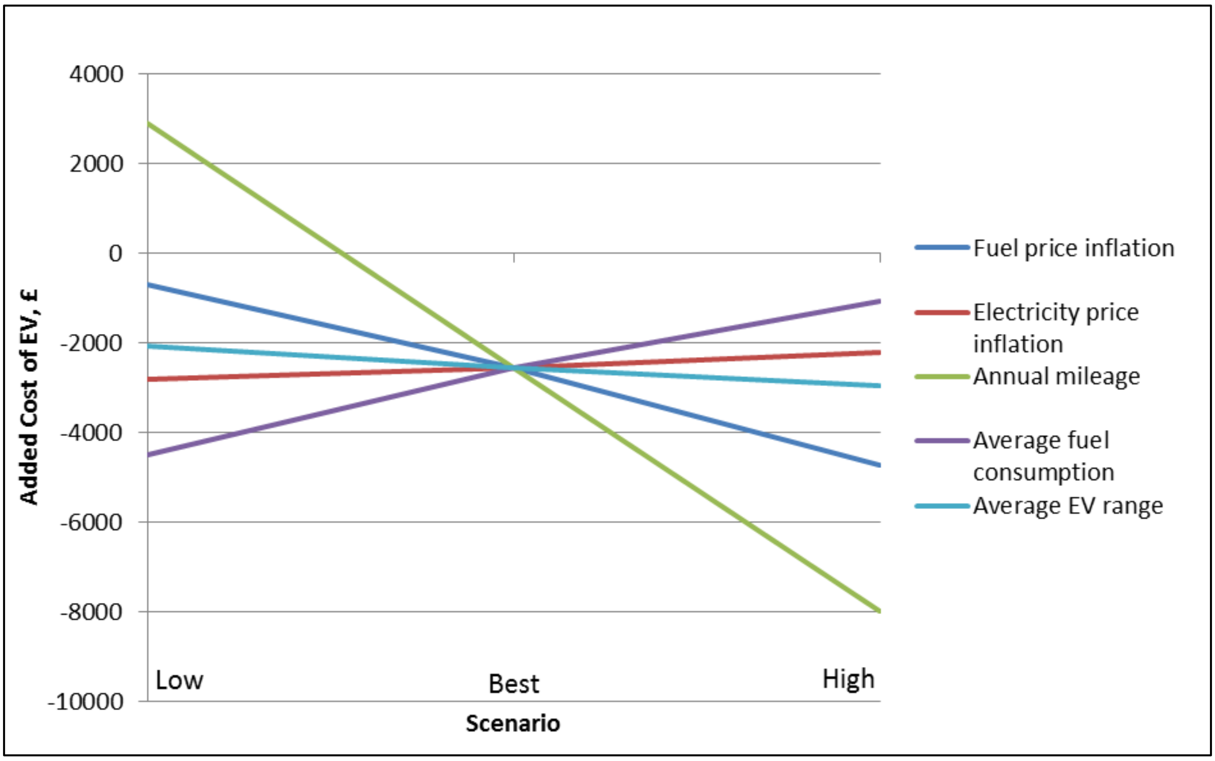

Figure 86: Sensitivity Analysis - Variation in Model Assumptions

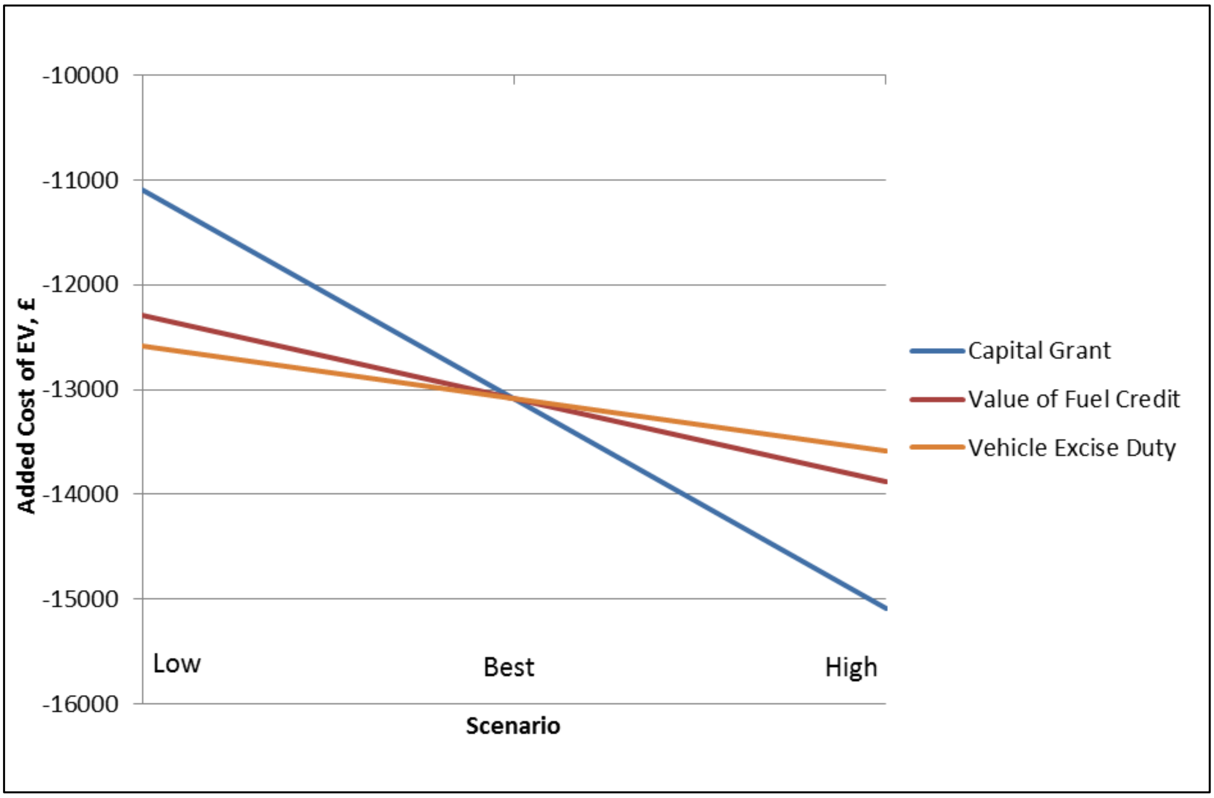

Figure 87: Sensitivity Analysis - Variation in Policy Mechanisms

7.7.13 Analysis

Under current market conditions, both vehicle replacements present an attractive prospect over a typical life of 15 years. The lifetime cost of the traditionally fuelled Kangoo is very similar to the EV Kangoo, and indeed the Smart EV costs less to own over the same time period that its fossil fuelled equivalent. However, this modelling does not include the cost of replacement battery traction packs as this is highly dependent on user driving characteristics. Additional modelling could however include this as part of a complex driving simulation to further inform policy.

The significant difference in trend with regards to the ownership cost with time (figure 80; figure 84) is given by the different strategies adopted by each of the manufacturers. Renault provide battery rental on a fixed monthly lease agreement[224] whereas for the smart the battery is required to be purchased, owing to a higher initial purchase price and no requirement for monthly repayments.

With the addition of the proposed policy mechanisms, both EV alternatives become substantially more cost effective than their fossil fuel counterparts (figure 81; figure 85); as required to provide a powerful enough incentive to overcome the present barriers to deployment. The Kangoo becomes significantly cheaper from the date of purchase, and the smart fortwo electric becomes cheaper to own than a conventional smart after 6.5 years rather than 13 years without the subsidies.

[224] (Renault, 2013)

At present, conversion of the GEL fleet is financially attractive however consideration should be given the specific choice of EV replacement vehicle. Certain vehicles, for example the Renault Kangoo ZE but not the Smart fortwo electric, present economically viable or equal alternatives for higher vehicle turnover rates of typically 5 years as used by businesses for fleet vehicles. However, upon introduction of the proposed policy mechanisms, conversion of the entire GEL fleet is considerably more cost competitive that fossil fuelled vehicles, even for high vehicle turnover rates.

The sensitivity analyses (figures 82-83; 86-87) suggest that all variables impact on the economic viability of converting a fleet vehicle to electric. The most sensitive variable affecting the cost effectiveness of the change is the annual mileage of each vehicle; vehicles with a low annual mileage (2000 miles) become less cost effective to replace with EVs than those with a higher mileage (6000 miles). Further work is required to accurately assess the mileage covered by each fleet vehicle to confirm the economic viability of a conversion to electric.

Additionally under best guess scenario conditions, the sensitivity of the economic viability of converting to electric is low for variations in each of the proposed policy mechanisms. This suggests that the Government may be able to use a lower capital grant than first anticipated to achieve the same goal, thus reducing capital expenditure.

7.8 Summary

The initial goals of this study were to identify barriers to electric vehicle deployment, highlight ways in which these can be overcome, and present a methodology to ensure the success of electric vehicles in Guernsey.

Throughout the duration of this project, several changes of scope occurred. This was predominantly due to fundamental differences identified between the initially defined scope and later stakeholder consultation. This consultation took place with both RET and the States of Guernsey Transport Division. Based on the outcome of these discussions, it became apparent that conclusive evidence was required to prompt any future changes to the existing transport system.

Data obtained from desk-based studies highlighted issues with the current transport system in Guernsey, with regards to key economic, social and environmental transport externalities. On obtaining sufficient evidence to conclude that there are indeed issues with the transport system in Guernsey, the following tasks were undertaken:

- Research of key transport issues
- Key stakeholder consultation
- Consideration of EV perception
- Assessment of EV supply, servicing capabilities and infrastructure
- Development of an appropriate transport policy framework to address a wide range of transport issues, including key EV deployment barriers
- Economic assessment of the potential for GEL to purchase a fleet of electric vehicles
- Delivery of an all-encompassing strategy to promote EVs

7.9 Conclusions

To improve the sustainability of Guernsey's existing transport system and overcome negative transport externalities, whilst promoting electric vehicles, a series of key strategy recommendations are proposed. The focus of this proposal is a substantial reduction in the use of conventionally fuelled vehicles, alongside improvements in motoring economics and fuel security, supported by reductions in associated environmental impacts.

To deliver these goals, whilst overcoming associated barriers, the following strategy mechanisms are strongly recommended to ensure Guernsey's sustainable transport future and to incentivise the use of low-emission vehicles:

- Further studies to establish accurate emission levels across the island
- Re-introduce VED (road tax) to facilitate monitoring of vehicular emissions and to generate additional funding for capital grant and credit-based fuel trading schemes
- Introduce a grant scheme to reduce the capital cost of purchasing a new EV
- Introduce a credit-based fuel trading scheme, which can be sold as a means of reducing fuel prices, to incentivise more conservative usage of fuel
- Develop substantial electrical generation capacity from distributed renewable sources to reduce reliance on energy imports, and to meet increases in EV power requirements
- Dissolve perceived performance and range limitations through public procurement of GEL and States of Guernsey fleet, and promotion of EV motorsport
- Introduce a community car sharing scheme consisting of high efficiency conventionally fuelled vehicles/hybrids for overseas trips, and as a means to overcome EV range limitations
- Designate priority parking for EVs in urban car parks
- Incentivise car hire companies to provide EV hire cars as already instituted by Hertz in Oxford and Birmingham
- The future deployment of smart grid technology to facilitate vehicle-to-grid capabilities to support energy storage in the future.

8 Energy Storage

8.1 Opportunity

Many forms of renewable energy are inherently intermittent or unpredictable. This can magnify the operational challenges of meeting electricity demand because their output varies with the available resource and cannot be ramped up as required to meet demand. Effectively system operators must 'take what they can get' and provide some form of backup generation at least equal to the size of the renewable installation. The load following properties of Energy Storage (ES) can be used to smooth the output by storing up energy when excess electricity is available, and releasing it during times of high demand.

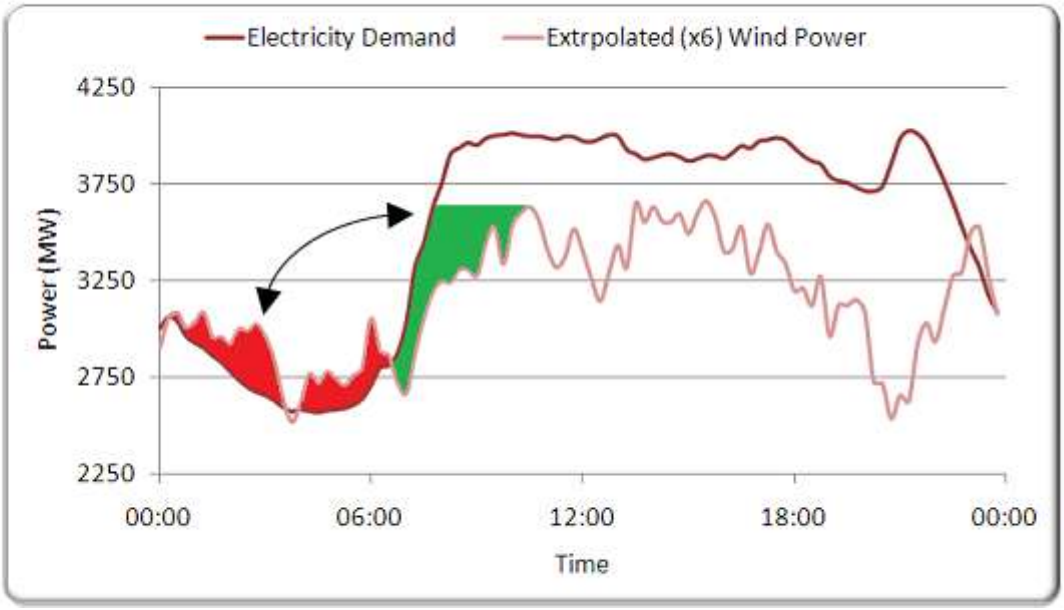

Figure 88: Fundamental principle of energy storage [225, 226]

Energy storage is an enabling technology which can facilitate a greater deployment of renewable energy technologies into the existing grid infrastructure. It can improve the flexibility of both the scale and location of renewable energy technologies, and can defer the need for network infrastructure investment or excess generation capacity. It can also greatly improve the economics of renewable energy by allowing energy produced during off peak hours to be stored and sold at a premium during times of peak demand, known as energy arbitrage.

[225] (Connolly, 2010)

Furthermore, by avoiding repeated power cycling of generators which are intended for base load production and by reducing the need for 'spinning reserve', ES optimizes the efficiency and productivity of existing fossil-fuel generation. Diesel generators are more efficient when operating at high load factors. Modelling has shown that storage can be cost-effective even in the absence of renewable energy because it is able to reduce costly diesel consumption.

In the past, storage was only feasible either on the large scale with pumped hydro or small scale with lead-acid batteries. However recent technological advances could allow storage to be used for a much greater range of applications than have previously been considered, including distributed generation levelling or Uninterrupted Power Supplies (UPS).

8.2 Scope

The scope of this report is to consider new unexplored potential for energy storage in Guernsey and to provide updates on technology advances since previous work carried out in 2012. The technical performance, current level of commercialization and applications for Guernsey are considered for each of the major technologies. In addition, the future trends and strategy for implementation are analysed.

RE 2012 recommended a "detailed stochastic financial analysis" to determine what level of any storage capacity is necessary for a given level of renewable generation and demand prediction.[227] The HOMER[228] modelling system can be used to model a range of different storage technologies with chronological analysis to identify which are the best options. The inputs include the current form of generation and typical load profiles, data which is available from GEL.

8.3 Grid infrastructure and RE integration

GEL is responsible for the management of both generation and distribution of electricity on the island, including investment in energy storage technologies to strengthen the existing grid. Electricity is generated using diesel and gas turbines, but is also imported via a subsea cable link with Jersey and France. The 90kW, 60MW rated cable provides a minimum of 16MW base load supply.

High deployment of wind, solar and wave would require either considerable back-up generation (which Guernsey already has) or the use of ES systems. Ideally the ES power rating should match the renewable technology rating. In the UK, the National Grid estimates it will need 4.5GW of storage – which is around 10% of the average electricity demand.

[227] (University of Exeter, 2012)
[228] Hybrid Optimisation Model for Electric Renewables

Minimum demand load is likely to increase beyond projected figures due to shift from gas and oil heating to electricity and potential uptake of electric vehicles. This will allow more RE to be generated, but there will likely be increases in infrastructure investment which may detract from energy storage.

8.3.1 Cable link connection

If Guernsey adopts a large amount of RE generation, export of electricity to France and the European grid could be one economically viable option. Currently electricity imported from France is cheap compared to generation by fossil fuels on the island, and is largely made up of hydroelectricity and nuclear. Presently there is only exchange of generation support between Guernsey and Jersey, but potential exists to export to France if cable is upgraded. This would allow better balancing capability and increased stability via the pool of generators made available via the cable.

However a two-way cable connection would have a high capital cost, be susceptible to damage or outages which could have detrimental effects on Guernsey's economy, and could leave Guernsey vulnerable to changes in the cost of importing.

8.4 Pumped Hydro

8.4.1 Overview

Pumped hydro storage is a mature and widely used energy storage method. Pumped hydro plants have long life times, with the possibility of operating for up to 100 years with the appropriate engineering. There is unlikely to be any major improvements in either the efficiency or the price of pumped hydro plants in the future since they are a mature technology at the end of their learning curve. Pumped hydro systems have a visual and environmental impact due to creation of reservoirs, this must be assessed in more detail as the main focus of this study was technical feasibility.

8.4.2 Operation

Pumped hydro works by pumping water from a lower reservoir to an upper reservoir converting cheap or unwanted electrical energy into stored gravitational potential energy of the water in the upper reservoir.

Pumped hydro typically has around 80% round trip efficiency,[229] although this varies on factors such as the design and length of the penstocks and possible evaporation of water from the reservoirs. An advantage of pumped hydro is that it has a fast response time, reaching full power in under a minute.

[229] (Alstom, 2012)

8.4.3 Commercialization

Pumped hydro currently provides 99% of bulk storage technologies with 14 countries currently having pumped hydro plants.[230] A salt water pumped hydro as suggested in this report has been constructed in Okinawa Japan. This is currently the only salt water plant in operation but plans for two other salt water plants have been announced.

The 'Spirit of Ireland' project has been planned; this plan proposes to block two valleys in the west of Ireland to create a lake 2km by 2km. This project would be the largest water based energy storage project in the world if it is constructed, A 300 MW salt water plant is planned in Lanai, Hawaii.[231]

The salt water plant in Okinawa faced engineering challenges due to the corrosive nature of salt water. To prevent pollution of the water table an EPDM[232] sheet is used to line the upper reservoir, below the liner there will be gravel with pipes installed which can measure pressure and detect leaks in the liner

Fibreglass reinforced plastic (FRP) to construct the penstocks. FRP has two main properties that make it suitable for use in salt water pumped hydro, it does not get corroded by salt water and it is considerably more difficult for sea animals to attach themselves to the FRP than to a steel pipe. The turbine usually made from carbon steel changed to stainless steel with corrosive coating and a breakwater in the sea to reduce the flow of the water reduces velocity of the flow of water coming out of the penstock.

8.4.4 Costs

The costs of pumped hydro schemes can vary greatly due to geological, geographical and site conditions but a good estimate for a pumped hydro scheme is between £2000-3000 per kW,[233] but can be as low as £500 and as high £5000 per kW[234] Of the capital costs the construction of reservoirs normally costs 50% and the power house costs around 28%. The operational costs range from £0.03 to £0.1 per kWh.

8.4.5 Applications for Guernsey

The key requirement for pumped hydro is a difference in height between the two reservoirs, this rules out much of the island due to large flat areas, other sections of the island are also ruled out due to the high population density of the island.

[230] (The Economist., 2012)
[231] (Knight Pesold Consulting, 2010)
[232] Ethylene Propylene Diene Monomer
[233] (IRENA, 2012)
[234] (DECC, 2012)

A possible area for pumped hydro storage would be in the south coast of Guernsey, this area is mainly high steep cliffs of up to a hundred meters, and this creates a good head height for the pumped hydro plants. Even in the south of the island it is not possible for the reservoir to be the size of a conventional pumped hydro project and may become more expensive per KW from the lack of economies of scale. With the aim of reducing cost sites with naturally occurring geological features such as valleys near the sea which can be block of at one end to create an upper reservoir were surveyed. Three sites were located and scoped for technical feasibility.

Figure 89: Location of scoped sites

Table 28: Site specifications

Site	Energy Stored	Estimated Cost (at £3000 per kW)
Site 1	6 MW hours	£2.1 million
Site 2	8 MW hours	£2.9 million
Site 3	1.2 MW hours	£0.45 million

All of these sites had suitable geography for the creation of an upper reservoir and good head height, with site 3 having the highest head. In the costing it is assumed that the stored water will be released over 8 hours each day and the powerhouses are suitable sized for that capacity.

A possible problem with the construction of a pumped hydro plant is public opinion, GIS mapping was conducted to find if the site would be suitably located to not cause too much disturbance to houses nearby.

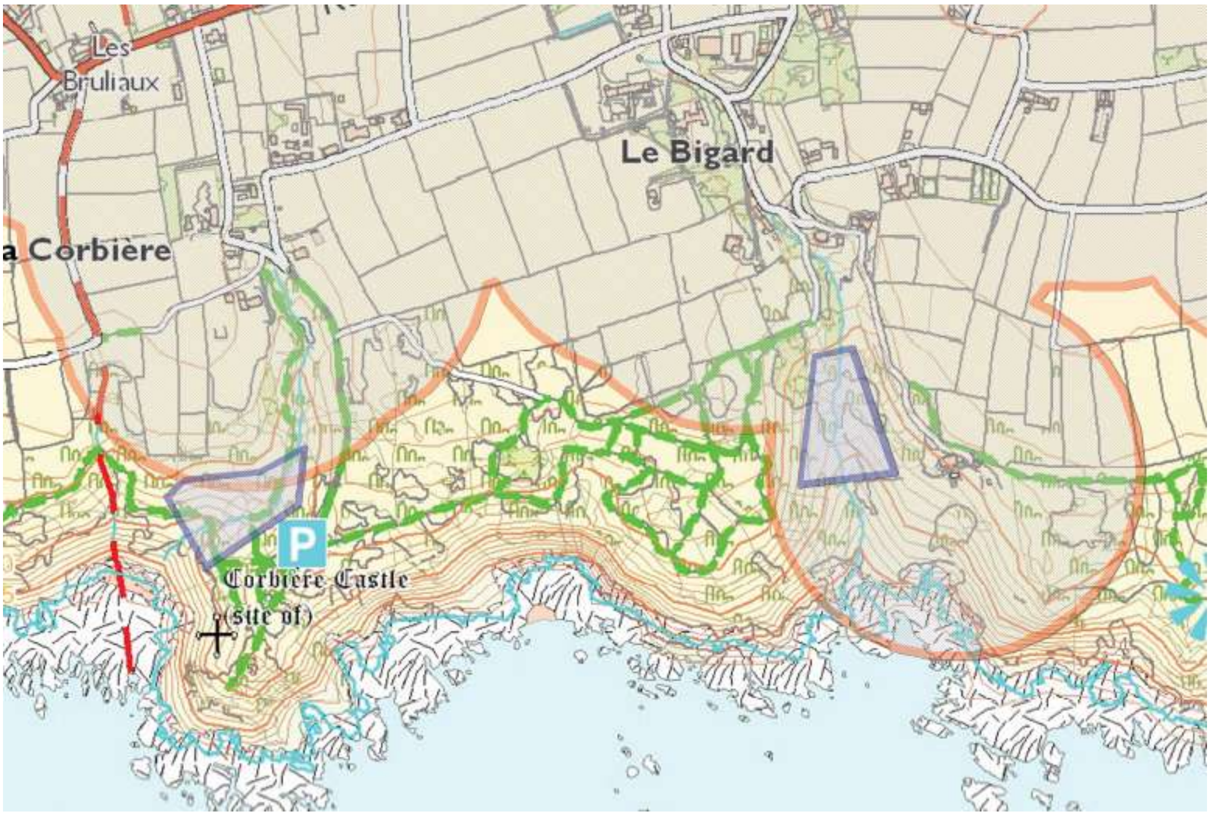

Figure 90: Site 1 (left) and 2 (right) with 200m house buffers

GIS for site 1 and 2 shows that they are both within a 200m radius of the proposed reservoirs, and from site visits it has become clear that some of the nearby resident would be able to see the reservoirs from their home.

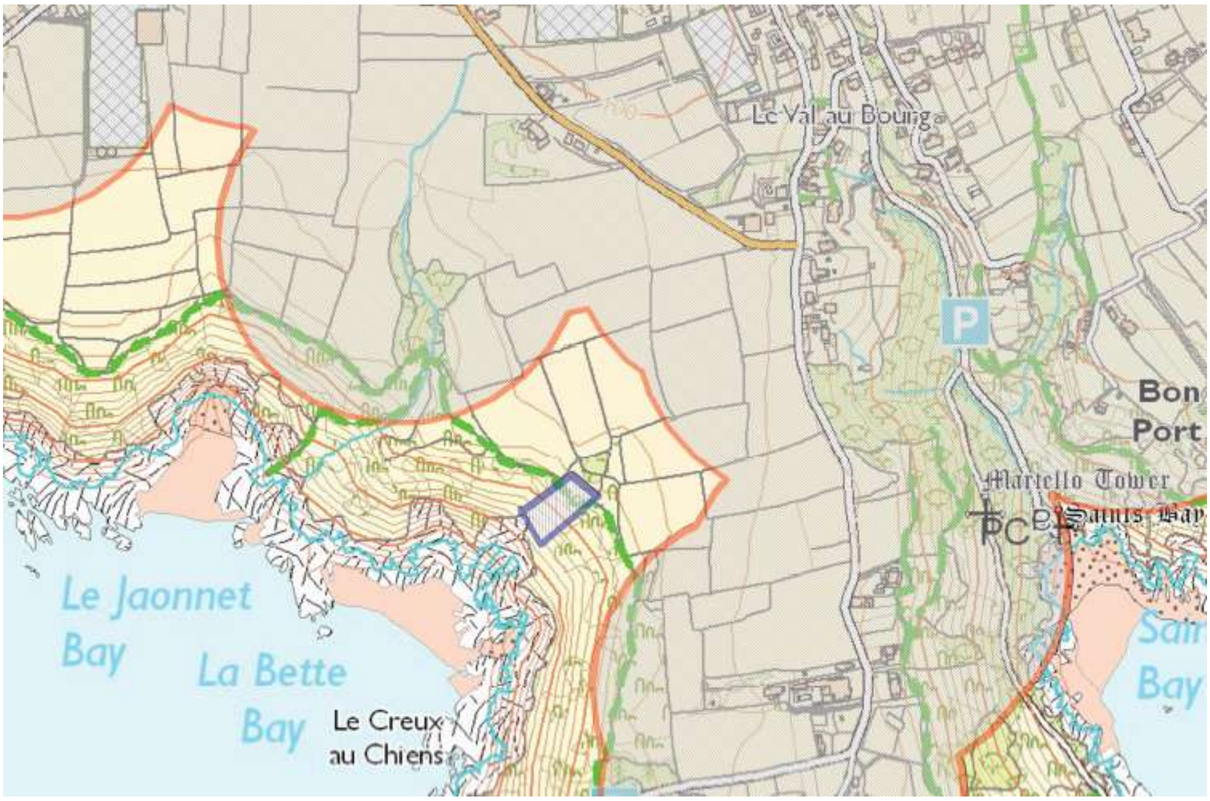

Figure 91: Site 3 with 200m house buffers

Site 3 however is not as near to houses as the other two sites, this makes it a more suitable location from a social point of view. A site visit showed that it is not likely to be visible from any nearby houses.

A simple economic analysis of site 3 was undertaken as it seemed the most suitable, in this is was assumed that the pumped hydro plant would be used to full potential each day, which could be possible with enough installed renewable energy generation and that the pumped hydro would replace diesel generation. Figure 92 shows when payback would be achieved:

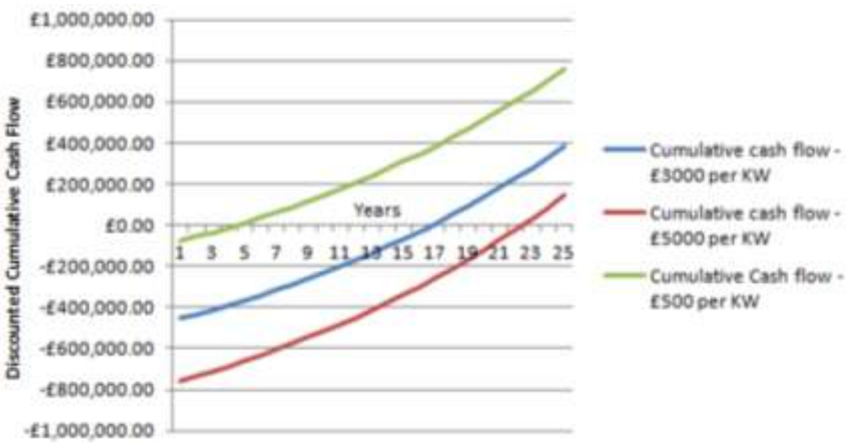

Figure 92: Discounted cash flow analysis for a range of capital costs for site 3

IRR for the best guess of £3000/kW was around 5% with a NPV of £37,000 and as shown by the scenarios in figure 92, payback varies from 4-22 years. The calculations assumed the pumped hydro was used every day year apart from the 41 days per year required for maintenance; this estimate was taken from Okinawa's running time and maintenance. It is assumed the plant replaces diesel generation and the price for diesel generation used was the low price scenario from the offshore wind cost analysis.

8.5 Compressed Air Energy Storage

8.5.1 Operation

Compressed air energy storage (CAES) stores excess energy as pneumatic energy which can be released at a later time when energy demand is high. There are two methods of generating energy from the stored air a hybrid system where fuel is added to the expanded air to generate electrify in a gas turbine or an adiabatic system where no fuel is added.

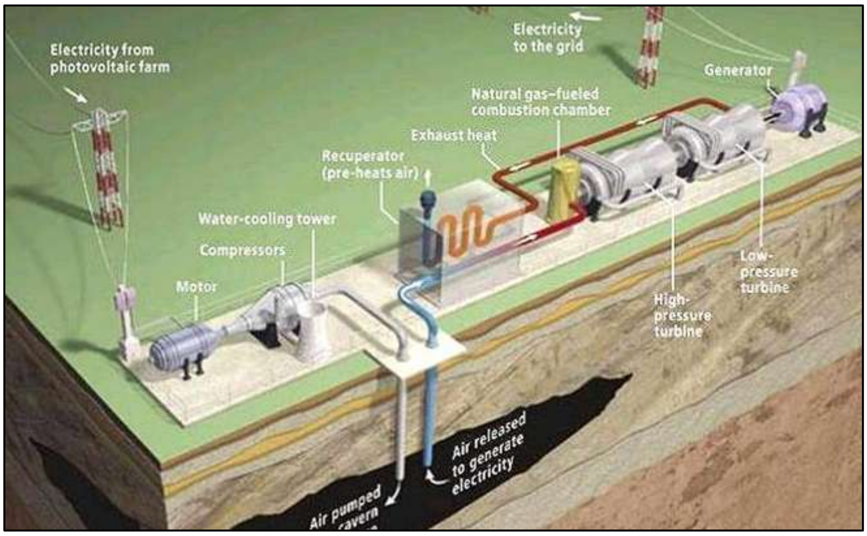

Figure 93: Operation of CAES plant[235]

8.5.2 Overview of Commercialisation and Applications

There are very few utility-scale compressed air energy storage plants worldwide, although smaller city wide plants had been in operation as early as the 1900's. The first large utility scale compressed air energy storage plant was constructed was a 230 MW plant in Huntorf, Germany. A second plant was constructed in Alabama in 1991.

[235] (Climate Tech ,2007)

8.5.3 Costs, shortcomings and Limitations

CAES would require an underground salt cavern, underground aquifer or rock storage cavern. On Guernsey these structure do not exist and therefore compressed air energy store is unlikely to be possible.

CAES is a reasonably cheap form of energy storage, with capital costs ranging from around £490/kW for storage in rock to £275/kW in salt caverns or aquifers.[236]

8.6 Flywheels

8.6.1 Operation

Flywheels store energy in the form of rotational energy, the most advanced fly wheels operate at between 20,000 and 50,000rpm. Flywheels operate on a short time scale as the efficiency of storage decreases the longer energy is stored, usually storage is in the range of seconds to minutes. Flywheels can be constructed with both mechanical and magnetic bearings, using magnetic bearing round trip efficiency can achieve 85% round trip efficiency, the magnetic bearing loose significantly less energy to friction compared to the mechanical bearings.

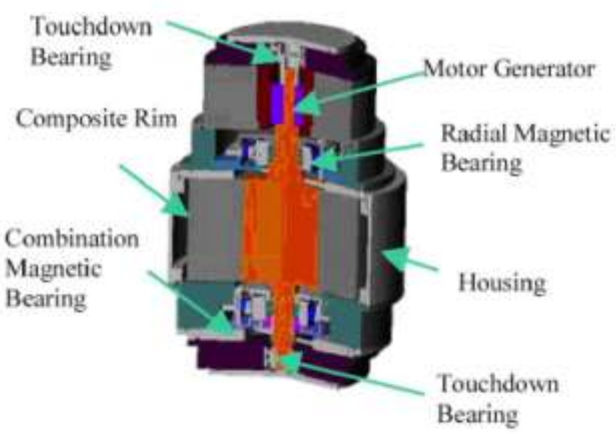

Figure 94: Components of a flywheel[237]

8.6.2 Overview of Commercialisation and Applications

In Stephentown, New York the world largest fly wheel system has been installed in 2012 with a power of 30MW to be used in voltage regulation, flywheels have a large range of applications including use in transport and small scale storage for industries and laboratories. When used for UPS flywheels have a longer lifetime the batteries.[238]

[236] (Bradshaw, 2010)
[237] (Climate Tech, 2007)
[238] IRENA. (2012)

8.6.3 Costs, shortcomings and Limitations

Flywheels costs vary between £500-5000/kW depending on the design of the system. A flywheel with magnetic bearing and in a vacuum will have high efficiency but will be considerably more expensive than a fly wheel using mechanical bearings.

The main limitations and shortcomings for fly wheels is there power is normally reasonably low, they do not store energy for very long and they have a high cost if high efficiency is to be reached.

8.7 Cryogenic Energy Storage

Cryogenic Energy Storage (CES) uses low temperature liquids for grid energy storage applications. It is based on mature technology from the air separation and medical industries, with standard equipment and established supply chains.

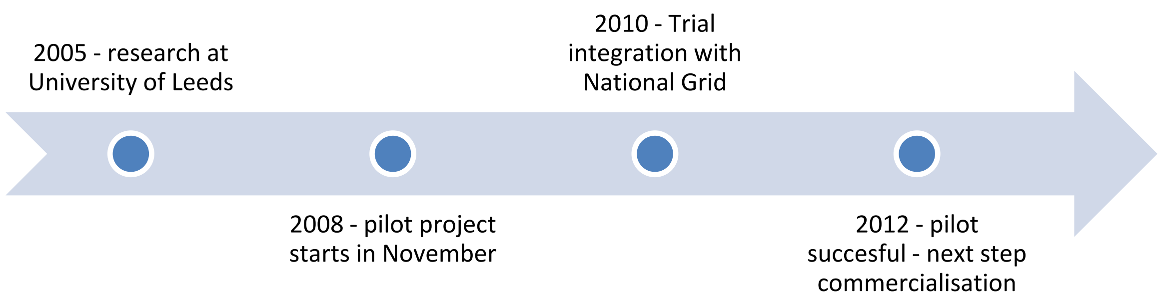

Figure 95: Timeline of CES Development

8.7.1 Operation

Electricity is used to cool air to below -196 so that it liquefies, taking up one-thousandth of its original volume. It can then be stored easily in large vacuum-insulated tanks at atmospheric pressure at reasonably low cost. The liquid air can then be pumped at high pressure into a heat exchanger where it expands through a turbine to generate electricity. Unlike pumped hydro and CAES, the technology has no major geographical constraints and is environmentally benign.

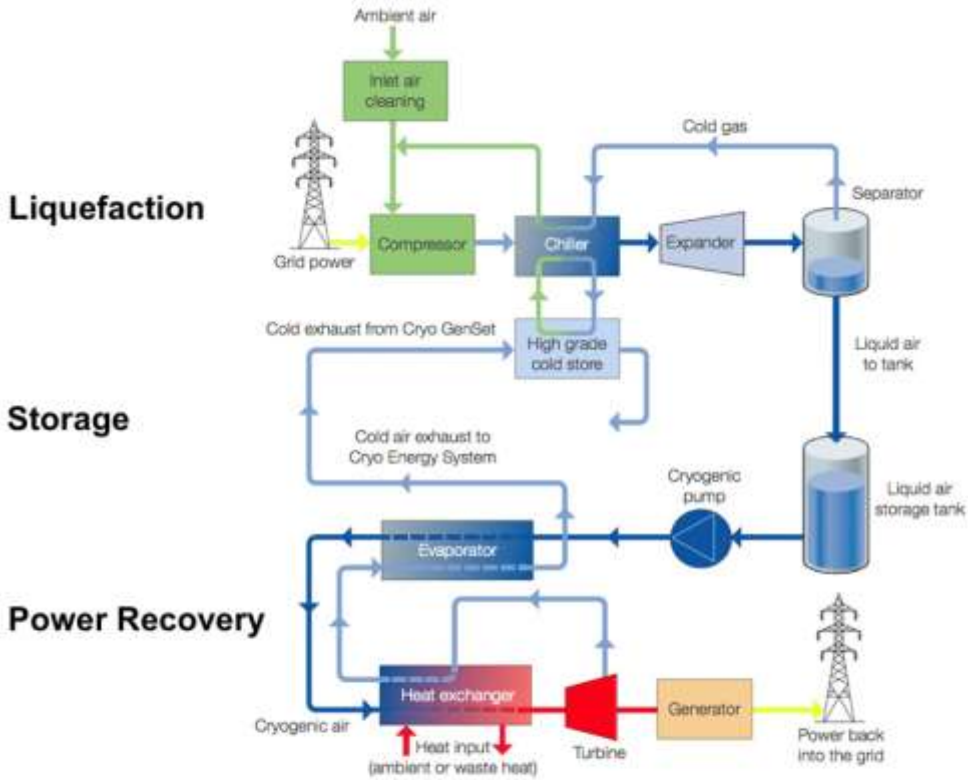

Figure 96: Basic operation of CES plant[239]

The storage medium has high energy density when compared with other liquid energy storage options, as shown in table 30:

Table 29: Energy densities of different storage mediums

	Energy density, KJ/litre
Liquid Nitrogen at ambient pressure	620
Compressed hydrogen gas at 200 bar	1918
Compressed air at 200 bar (CAES)	143
Water with 100m head (pumped hydro)	1

The basic cycle has an efficiency of around 25%, though this can be improved to around 70% by the use of a low-grade cold store and a low-grade heat source, such as waste heat from a power station; as illustrated in table 31:

[239] (Highview, 2012)

Table 30: Thermodynamic cycle efficiencies

Thermodynamic Cycle	Efficiency
CES at ambient	72%
CES at 100 degrees Celsius	80%
Rankine Cycle at 100 degrees Celsius	25%
Super Critical Steam Cycle	70%

This shows that the cycle is efficient at converting low grade waste heat to power at low temperatures.

8.7.2 Commercialization

The main developer in the UK is Highview Power Storage, who were established in 2005 to develop utility-scale energy storage systems. CES is expected to be a major new industry, potentially worth £1bn and 22,000 jobs in the UK.

Highview Power Storage currently operates a 300kW; 2.5MWh pilot plant hosted by SSE[240] at Slough Heat and Power since 2010 with full integration to National Grid network. They are also working on two multi-MW projects which are through to the feasibility stage of DECC's Energy Storage Technology Demonstration Competition. One of these projects is for a system up to 6MW and 30MWhs, in collaboration with National grid. Highview give the estimated capital cost of a completed plant between £590-$1240/kW installed.

8.7.3 Applications for Guernsey

Within the next few years, as the technology approaches commercial maturity, there is good potential for CES to be integrated within Guernsey's existing electric grid and generating infrastructure. Vale power station could possibly be a site for a commercial-scale demonstration project.

The technology has shown potential for use as short term operating reserve (STOR). In the UK this is defined by the ability to offer a minimum of 3MW for at least 2 hours when instructed by the National Grid to cope with demand being greater than forecasted. Highview's pilot plant was trialled as a STOR facility over a 2 week period, achieving 94.6% availability. During 2012, GEL customers lost on average 84 minutes from unintended generation outage, which could be covered by a plant similar to Highview's. The summary data from the STOR trial is shown in the table below.

[240] Scottish and Southern Energy Plc

Table 31: STOR Summary data[241]

Total time on call	2160 minutes	100%
Generating time	245 minutes	10.63%
Recovery time (shutting down and re-starting)	108 minutes	5%
On standby	1800 minutes	84%
Unplanned Outage	7 minutes	0.32%
Availability (either on standby or generating)	2045 minutes	94.6%

8.8 Electric Car Batteries

8.8.1 Operation

With the introduction of electric vehicles into the transport sector comes the opportunity to utilise the on-board batteries as a storage medium. There is the potential to make large-scale battery storage economically viable. They have been estimated to increase feasible wind penetrations by 30% to 65%, depending on the design.

Electric vehicles can be categorised as Battery Electric Vehicle (BEV), Smart Electric Vehicles (SEV) and Vehicle to Grid (V2G). Whilst BEVs act as a load on the grid, SEVs can also communicate with the grid as a form of demand management, so that they begin charging during periods of excess electricity production, or to stop when demand is high. V2G goes a step further by allowing the cars to supply electricity to the grid, so that they can be considered an energy storage technology.

8.8.2 Commercialization and Applications for Guernsey

The technology has unique potential on Guernsey, due to the high availability of cars and short driving distances creating a greater capacity for storage. Based on UK usage statistics, a system of 6000 cars could generate 10MW of power and 150MWh of storage capacity, providing 14.4 hours of continuous supply.

8.8.3 Costs and limitations

It does not make sense to try and compare the cost per kw or per kwh as with other technologies, because the cost of the investment is covered by the consumer. Electric cars are typically more expensive than conventional cars, however this extra cost could possibly covered by soft loans or other incentives schemes as outlined in §7.

[241] (Highview, n.d.)

Significant initial investment would be required for the increased demand on the grid, and the smart grid to facilitate the controlled automatic charging and discharging of car batteries. Smart grids are also not currently a mature technology, although Guernsey is making progress towards getting a smarter grid.

8.9 Vanadium Redox Flow Batteries

Vanadium Redox Flow Batteries (VRFB) are increasingly being used as an energy storage device for kW power scale projects, though to MW and GW scale stationary batteries are still in the research and development stages. They offer several benefits:

- Energy efficiency improvement
- Flexibility of national electricity grids
- Increase the use of renewable energy, during period of high generation and low demand
- Mitigate the requirement for peaking power plants on fossil fuels

In addition, the environmental impacts caused by VRFB are considered lower when compared to other batteries technologies. However there are concerns related to environmental polluting potential of vanadium. Given its high energies capacities, lower cost, easy operation and flexibility, VRFB have already been developed and adopted commercial for load levelling and for renewables support in many countries: Australia, Austria, Canada, Germany, China, the Republic of South Africa, USA and Japan.

8.9.1 Operation

The VRFB are composed of the cell stack, electrolyte tank system, control system and power conversion system (PCS). The battery acts as a dual electrolyte system, in which the redox couple is separated by the use of a cation (proton H+) exchange membrane. The power capacity of the battery is determined by the size of the cell stack, while the energy capacity is related to the volume of electrolyte. Figure 97 shows the structure of a VRFB.

At the discharge period, the separate tanks release the two electrolytes to the cell stack, in which H+ ions cross between the two electrolytes trough the permeable membrane. This entails the self-separation within the solution. The ionic form of the vanadium is then changed as the potential energy is converted to electrical energy. The reversed process is induced during the recharge of the battery.

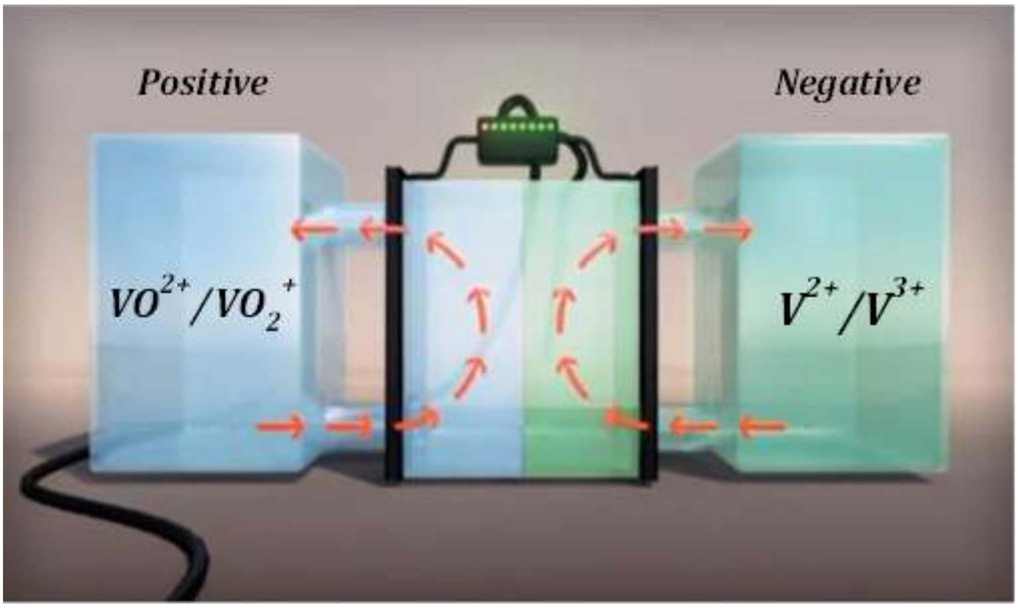

Figure 97: Vanadium Redox Flow Battery Representation

- Characteristic Reaction of VRFB at the positive electrode

$$VO^{2+} + H_2O - e^- \leftrightarrow VO^+_2 + 2H^+$$

- Reversible Reaction of VRFB at the negative electrode

$$V^{3+} + e^- \leftrightarrow V^{+2}$$

- Overcharging: hydrogen and oxygen evolution
    1. Negative Electrode

$$2H^+ + 2\,e^- \leftrightarrow H_2$$

    2. Positive Electrode

$$2H_2O - 4e^- \leftrightarrow O_2 + 4H^+$$

The operation of VRFB requires a high capital cost, due to the cost of the electrolyte and non-triviality of the electrolyte manufacture and of the optimization of vanadyl sulphate solubility. In addition there are some issues related to the decomposition of the charged electrolyte. However, VRFB have a favourable theoretical cell voltage for the overall discharge reaction (approximately 1.26V) and considerable high efficiencies, ranging from 70-90%.

8.9.2 VRFB and other Electrochemical Technologies

Table 32: Comparison of Electrochemical Energy Storage Technologies

Technology	Efficiency (%)	Lifetime (years)	Lifetime (cycles)	Applications	Disadvantages
VRFB	75-80	7-15	10,000	UPS, load levelling, peak shaving, etc	Lowest power density and requires much more parts
Lead-Acid Batteries	75-85	5	250-1,000	Telecommunications and UPS	Extremely sensitive to temperature
Nickel-Cadmium Battery	60-70	10-15	1,000-3,500	Commercial Electronic Products	Suffers from memory effect and high self-discharge rate
Sodium-Sulphur Battery	85-90	15	2,500	Energy management and Power quality	Requires high operation temperatures (270^{o}C)
Super-capacitors	95	Not Specified	1,000,000	Hybrid Cars, Mobile phones and Load Levelling	Low energy density and high capital cost for large scale applications.

8.9.3 Commercialization

The use of VRFB for MW-scale projects have become commercialized in the last two decades, given the improvements in the efficiencies, decrease in the capital and operational costs and improvement in the material durability. For example, 6MWh of VRFB are being used to store energy in 30MW wind farm, in Sapporo Japan. The increase of energy storage from batteries in Japan, made the country reach approximately 250MW of battery storage capacity, used in power quality, load levelling and renewable energy application.

In the case of Europe, given the considerable efficient national interconnected high voltage transmission system, there is a lack of investment in battery technology. An exception is Austria, which is considering a VRFB design for distributed energy and voltage output moderation for wind and PV projects, having already 100kWh of flow battery capacity installed.

8.9.4 Costs

The evaluation of VRFB commercial costs are place and time dependent, being difficult and inaccurate. Table 34 presents the main costs comprised by the installation of VRFB for renewable energy storage.

A significant decrease in the prices of VRFB post the acceptance of the technology is shown by emerging energy technologies experience curve. This decrease is related to reductions in the manufacturing, operational and maintenance costs.

Table 33: Cost for VRFB for renewable energy application

Cost Breakdown	Cost (£/kW)
Cell Manufacture	1,058.4
Electrolyte Materials	46.3
Installation Capital Cost	330.75
Operation and Maintenance	0.006
Energy Storage Capital Cost	66.15
Overall Internal Cost	2,182.95

8.9.5 Applications of VRFB on Guernsey

Given to the versatility of VRFB, it has been used for many energy storage requirements, such as load levelling, telecommunications and integrating renewable resources. Considering the future energy scenario proposed in this report, it is expected that VRFB will be implemented, firstly, as a backup power system for UPS. UPS are usually used, as a solution for systems, in which the secure power for electrical equipment is a priority. In most of the cases lead-acid batteries are installed combined to diesel generators, however given the poor performance and short life cycle of lead-acid batteries, the system has significant dependence on the diesel generator.

The use of VRFB for UPS has the following benefits:

- Low cost for large capacities
- Existing system can be easily upgraded
- Capacity and state-of-charge of the system can be easily monitored
- Easy maintenance
- Flexibility

Considering the current energy scenario in Guernsey, it is proposed the installation of a VRFB with capacity of 5kW in The Princess Elizabeth Hospital. The battery will operate as an initial back up system in case of any failure in the grid. In this case, the battery will be capable to supply the first hours, being shut down when the generator is turned on. The 5kW VRFB can be charged by the grid electricity or by PV panels that can be installed in the hospital. The initial cost of the VRFB system combined to PV panels is estimated in £ 10,900.

Considering the potential of onshore wind turbines installation in the island, it is also proposed:

- Integration of VRFB as an energy storage system, storing the excess of energy produced by the wind turbines, in a low demand period
- Use of energy stored in VRFB for electrical cars

In both cases, a study relying the site and power required for the battery has to be conducted in order to evaluate the suitability of the system.

8.10 Hydrogen Solutions

8.10.1 Operation

The use of electricity from renewables for hydrogen production via water electrolysis can be through:

- ***Alkaline Electrolysis***: uses an electrolyte, usually aqueous potassium hydroxide solution to increase the conductivity of the water. The process has two electrodes (cathode and anode) immersed in a liquid electrolyte and connected to a direct electric current. The total reaction is the sum of two partial reactions (cathode and anode), resulting in oxygen and hydrogen:[242]

Electrolyte	$4H_2O \rightarrow 4H^+ + 4OH^-$
Cathode	$4H^+ + 4e^- \rightarrow 2H_2$
Anode	$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
SUM	$2H_2O \rightarrow O_2 + 2H_2$

- ***Proton Exchange Membrane (PEM) Electrolysis:*** this method does not require any liquid electrolyte; instead a solid polymer membrane is adopted, with the split of the water molecules occurring in its surface. During the process, a voltage is applied, forcing the protons through the membrane, while the oxygen is released as gas. Hydrogen gas is formed by the electrons, which pass in the electric circuit, combining with the protons.

[242] (Riss, T, 2006)

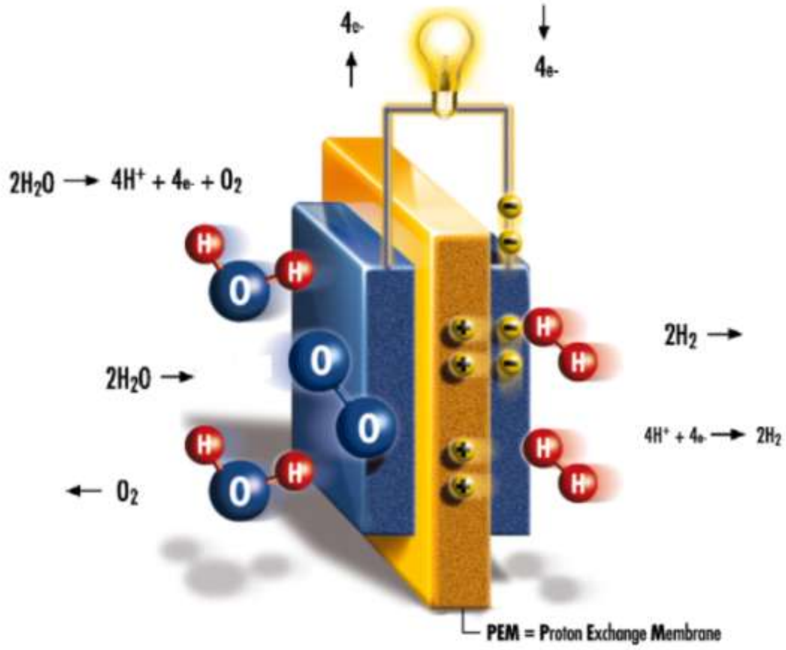

Figure 98: PEM Electrolysis[243]

The hydrogen produced can be stored in its three states forms: gas, liquid and solid. The liquid hydrogen storage is, generally, by cooling it down to cryogenic temperatures. However the storage of liquid hydrogen as a constituent of other liquids has been developed. Hydrogen gas storage is usually operated by steel tanks or lightweight composite tanks. The storage of hydrogen in its solid state is mainly through solid materials, such as carbon and other high surface area materials. Table 35 compares the advantages and disadvantages of each storage process.[244]

Table 34: Comparison of Hydrogen Storage Technologies

Storage Process	Advantages	Disadvantages
Compressed Gas	Low Weight; Well-Engineered and safety tested; Accepted in many countries.	Large volume required; High cost.
Liquid Hydrogen	High Storage Density at low pressures; Commercial adaptability for vehicles Low Weight	General public perception as an unsafe technology.
Solid Hydrogen	Lower volume and pressure; Higher purity hydrogen.	Not commercial available.

[243] (H-TEC Education., 2012)
[244] (Riss, T, 2005)

Due to the advantages of compressed gas, this is considered the main hydrogen storage process in the hydrogen economy, being already installed in many countries. The method adopted for gas storage is composite tanks, due to its commercial viability and easy connection with PEM electrolyser, which produce hydrogen in its compresses gas form.

8.10.2 Cost

The hydrogen production costs from renewables is significantly higher compared to hydrogen production from conventional sources (natural gas and coal).The price of "renewable hydrogen" is mainly affected by the electricity costs. Researches point to a electricity cost from renewables four time less than commercial costs, in order to make renewable hydrogen production commercial viable.[245] In addition studies have shown the requirement of decrease on the price of wind turbines and PV panels. However, the use of optimized designs, such as catalyst and membranes, can reduce 15% of the capital cost. In addition, government support will also improve economic competitiveness of the hydrogen production from renewables.[246] Table 36 compares the cost of hydrogen production from different routes:

Table 35: Cost of hydrogen production

Route	Cost of Hydrogen Production (£/kg)
Natural Gas Reforming	0.68
Natural Gas + CO_2 Capture	0.81
Coal Gasification	0.64
Coal Gasification +CO2 Capture	0.69
Wind Electrolysis	4.40
Biomass Gasification	3.06
Biomass Pyrolysis	2.52
Nuclear Thermal Splitting of Water	1.08

Barriers

Hydrogen technologies still face problems related to high cost and safety. Even with massive production of the fuel, substantial returns on investment cannot be assured. The production of hydrogen requires a high capital cost, due to expensive materials, relatively small systems and labour-intensive fabrication. In addition the technologies require prohibitively high operation and maintenance costs. In terms of safety, there is an inconsistency in the current certifications, codes

245 (Abbasi, T, 2011)
246 (IPHE, 2011)

and standards. However these barriers can be minimized with several measures, such as improvements in fuel cells and in codes for hydrogen installations.[247]

8.10.3 Applications of Hydrogen Technology on Guernsey

The current demand of hydrogen is from the oil refining industry (hydro-treating crude oil), food production (e.g. hydrogenation), metal treatments and ammonia production. However, given the improvements in the efficiency of fuel cells, there is a high probability of this industry contributes for a great part of the hydrogen demand.

The leading micro wind turbine supplier in Guernsey, Kesell Ltd., has officially announced, in 22nd May 2013, the partnership with Relion Fuel Cell. Relion commercializes fuel cell for emergency and backup power requirements for public and private organizations, including telecommunications and infrastructure. The main advantage of hydrogen is its capacity to integrate the three energy sectors (heating, transport and electricity), since it can be used in fuel cell vehicles and combined to others gases producing synthetic fuels.

The several benefits comprised by hydrogen technologies make it a potential energy storage technology for Guernsey. The technology can be implemented in several sectors in the island, for example in potential offshore wind turbines. Given the continuous electricity production by the offshore wind turbines, there will be periods, when the demand will be lower than the potential electricity produced. In this case, electrolysers can receive the excess of electricity produced. The electrolysers will produce oxygen, which can be released into the air, and hydrogen. However the best approach for Guernsey is to wait until further studies relying the storage and transport of hydrogen.

[247] (FredomCAR, 2009)

8.11 Summary

The limitations and opportunities for a range of technologies have been considered from a technical and financial perspective, as well as possible timescales for deployment. The technologies have been broadly categorised as short term solutions which are nearly commercially viable and long term solutions which are not yet mature.

Several potential barriers to the deployment of energy storage have been identified.

- The industry is not financially motivated to optimize grid assets and reduce their costs – particularly so in Guernsey where currently the cable link negates the need for energy storage for meeting demand
- The 'gas turbine boom' has meant there is currently significant excess capacity on Guernsey
- The costs are high because of the immature market, and because the true value of energy storage has yet to be accurately quantified
- The value of grid security and of energy storage is not properly understood and quantified

Electric utilities such as GEL are ideally positioned to test, evaluate and deploy these technologies and ultimately receive the financial benefits. Policy must recognise the true value of storage and create a competitive incentivised environment with support for commercial demonstrations.

8.12 Conclusions

A problem identified with ES in the UK is that although it has been shown to bring benefits to the electricity system as a whole, it may be too expensive for any "discrete part of the value chain to realise a sufficient return on investment". However this would not be an issue in Guernsey where generation, transmission and distribution are entirely managed by GEL. Because of this, GEL is well placed to ensure the thorough integration of ES with the existing generation capacity and grid infrastructure. There could be great potential for GEL to link with developers of novel energy storage technologies for pilot scale projects at the Vale power station.

Energy storage may become vital if the RE capacity extends beyond 20% of total electrical supply; however the possibility of a two-way connection with France may negate the need. Despite this, case studies have shown that even when RE is not considered there may be a financial case for energy storage as a way of reducing the use of diesel fuel.

In the short term pumped hydro seems to offer some potential from a technical perspective, however further EIA and public consultation would be necessary and may affect the outlook for the technology. VRFB and CES are promising technologies which we recommended GEL and the RET of Guernsey watch closely for future developments

Guernsey faces many decisions including the choice of technology and when to implement. It is unlikely there will be a single 'silver bullet' solution that will emerge; instead we recommend Guernsey adopts a diverse portfolio of distributed energy storage technologies to make full use of each resource.

9 Environmental Scoping

9.1 Opportunity

This section aims to determine the key impacts that the renewable energy technologies, described in the previous chapters of the report, will have on the physical, biological and human environments of the Bailiwick of Guernsey. Methods to establish the baseline environment will also be identified and can be used to enhance the development and positive effects of the renewable energy projects in addition to providing important data needed for the EIA process.

9.2 Marine and Offshore Projects

These projects include tidal stream, tidal barrage and offshore wind installations which will affect a range of the area's marine features. The need for a converter station also means that these technologies may impact various onshore receptors.

The Regional Environmental Assessment (REA), carried out by the Commerce and Employment Department in 2011,[248] can be used as a baseline for the scoping process of the marine environment. However, plans to extend the 3 mile Territorial Zone to 12 miles will mean further data collection in these areas will be required.

9.2.1 Geology

The different types of foundations involved in the tidal and offshore wind projects will all have a significant impact on the seabed, especially during the construction process. Drilling and impact piling involves material displacement of the bedrock and therefore data on the geology as well as topography of the seabed must be collected to determine the extent of these impacts. Onshore converter stations and subsea cabling will also involve land based effects such as erosion and heating of the soil.

9.2.2 Hydrodynamics

The permanent turbine structures will remove energy from water flows and can disrupt current regimes. The consequential effect of this can create additional problems concerning sediment transportation and deposition which can have significant impacts further away from the actual structures. With regards to tidal barrage installations, this impact is of particular concern due to the size and operation of such a technology.

[248] (Guernsey Renewable Energy Commission, 2011)

Detailed assessment of flow regimes and sediment movements will be required to review the impact that the offshore structures will have with respect to erosion and deposition of silt and materials.

9.2.3 Ornithology

Off shore devices present a collision risk to birds, by building a structure in a previously open area an obstacle is created. Surveys to find flight paths to feeding grounds and migratory routes should be carried out so devices are not placed in frequently used areas.

Figure 99: Herring gull and nest at Lihou Island

Off shore devices "represent an underwater collision risk to diving birds. Fixed structures under the surface pose little risk due to their ease of navigation; however, the energy converters, anchor chains and cabling are highly mobile and so harder to navigate"[249] Surveys to determine the key feeding grounds should be carried out to minimise the risk.

9.2.4 Marine Mammals

Off shore devices cause a potential obstacle to the mammals and risk harm to both the animal and the devices "The deployment of structures in a previously clear area brings the risk of collision and/or entanglement of animals; primarily the larger fish, the seabirds, and the marine mammals."[250] The tidal stream devices are most likely to cause harm to marine mammals, surveys that find the species present and the key migratory routes so the devices are not located in a place where there is a high chance of collisions occurring.

[249] (Grecian, et al., 2010)
[250] (Boehlert, et al., 2008)

9.2.5 Fish and Seabed Ecology

The buoys, mooring lines, cables and off shore devices themselves will create structures in the environment that did not previously exist. This will have a "minimal impact on phytoplankton and most zooplankton, but positive effects on abundance (through aggregation) of other species (e.g., krill, mysids, and fishes)"[251] this will in turn lead to an increase in predators that would not normally exist in the area. The interactions between the off shore devices and these predators may cause environmental issues.

Tidal stream devices cause a potential collision risk, surveys to find the key habitats and any migratory routes should be carried out so projects are not located poorly.

In order to connect the generated electricity to shore an off shore cable will be needed. During the transmission of electricity this cable will have an electromagnetic field. "The current state of knowledge regarding the electro-motive force (EMF) emitted by undersea power cables is too variable and inconclusive to make an informed assessment of any possible environmental impact of EMF in the range of values likely to be detected by organisms sensitive to electric and magnetic fields",[252] due to the lack of knowledge in this area surveys should be carried out to identify the life forms such as elasmobranches fish in the area of the cable and whether or not they use electromagnetic signals for navigation.

9.2.6 Seascape and Visual Impact

After several meetings with different bodies of the States of Guernsey, the value of the seascape was highlighted as a major issue and it was emphasised that any developments that can have significant visual impacts are unlikely to be approved. It is likely that marine renewable energy technologies developments will have an effect on the visual and seascape amenity in rural areas around the islands such as areas of high landscape quality such as the coastline of Guernsey (Cliffs, Western Bays and Northern Shores).[253]

From the construction to the decommissioning phase, the developments will have a significant effect on both seascape character and visual resource. The visual impacts are likely to be more significant during the construction phase of the development where the presence of large cranes and vessels is essential for the installation of the proposed structures. It is important to carry out a visual impact assessment and to increase public awareness by presenting the visual impacts on the different stages of the development.

[251] (Boehlert & Gill, 2010)
[252] (Centre for Marine and Coastal Studies, 2003)
[253] (Guernsey Renewable Energy Commission, 2011)

The visual impact of tidal power devices will depend on the type of technology. A tidal barrage development is likely to have a higher visual impact due to its larger more prominent structure. A tidal stream development will have minimal visual impact due to most of its components being under water.

9.2.7 Heritage and Culture

Marine technologies are likely to have a potential effect on the historic environment of the island both offshore and onshore. Around the coastal waters of Guernsey, there are around 800 hundred shipwrecks scattered throughout the area with historical value, dating from Gallo-Roman period to the twentieth century.[254] Onshore, there are many sites of archaeological importance around the coasts of Guernsey such as forts and castles, which means that they are sensitive receptors to visual impacts from the installations.

Figure 100: Castle Cornet at St Peters Port

For each marine installation there is a variety of individual aspects that need to be considered with regards to the potential impacts on the historic environment that depend on the location of the development. The historic issues to consider are heritage sites in the area that require individual studies due to their complexity in order to avoid any potential damage to the archaeological sites.[255]

9.2.8 Socio-economics and Recreation

The offshore wind and tidal structures will create exclusion zones that will prohibit commercial and recreational activities in that area. Consultation with the Fisheries Department found that commercial fishing is a large industry for Guernsey with shellfish being the largest and most valuable species. Therefore it will be important to examine and identify relevant employment sectors as well

[254] (Walls, 2011)
[255] (Huddleston, 2010)

as specific fishing areas to determine if the renewable energy projects will displace income from these commercial activities. The development of these technologies will also create positive impacts on the local environment through direct employment as well as the introduction of new skills and labour.

Recreational fishing, water sports and diving are also popular in the sea around the Bailiwick of Guernsey and impacting these will have social consequences as well as an effect on retail industries on the island. These activities, combined with Guernsey's admired coastal landscape and seascape are also important drivers for the tourism industry and could be affected from the proposed developments. Identifying population numbers and tourism and leisure activities can ensure minimal impacts on these aspects of Guernsey's human environment.

Figure 101: Recreational fishing at St Peters port

9.2.9 Navigation and Shipping

Tidal and offshore wind technologies will upset marine navigation networks and shipping routes by requiring exclusion zones that prevent ships from coming within a certain distance. This can cause issues if these zones fall within high traffic areas especially between islands. During construction and decommissioning there will likely be a large increase in ships transporting installation and removal equipment and although is a temporary issue, will cause the most significant disruption of shipping and navigation activities. Due to the size of the proposed installations, this also requires very large marine vessels and will greatly increase the risk of boat traffic collisions. Further problems arise from the fact that these vessels will most likely be too large to access St Peters port and may require the use of one in Northern France.

Identification of the shipping routes taken as well as the number and sizes of the vessels in question need to take place as well as plotting the expected exclusion zones so they can be added to marine navigational charts in the future.

An analysis of the proposed increase in shipping traffic would need to take place in order to identify the impacts on the area as well as potential issues with docking that an increase in boat traffic may cause during the construction and decommissioning phases.

9.2.10 Aviation and Telecommunications

As discussed previously, the airports radar communication system may be a significant barrier to the development of the offshore wind turbines as they utilise large turbines that can interrupt radar signals, creating hazards to nearby flight paths. Larger turbines may also create problems with regards to interfering with microwave links.

Microwave links for the Bailiwick will need to be identified alongside the areas of radar cover. Analysis can also be carried out to identify the possible use of materials in the turbine blades that reduce or prevent radar detection.

9.3 Onshore Projects

The onshore renewable energy technologies include pumped storage, onshore wind and commercial PV. These installations will have a different range of environmental impacts on the area compared to the offshore and tidal systems.

9.3.1 Geology

It is unlikely that PV installations will have any effect on the geology of the site and therefore impacts caused by the construction and operation of pumped storage technologies and onshore wind turbines will be of most environmental concern. Concrete foundations and onshore works could create problems with regards to excess erosion and physical damage to the soil. Underground cables may also lead to issues such as localised heating of the soil due to transfer of electricity. It is also important to assess the rock type and structure of the site before carrying out any material displacement near the coast, as this may lead to landslips such as that seen in figure 102:

Figure 102: Land slip at Moulin Huet Bay on Guernsey coast

9.3.2 Hydrology

The construction and operation of the onshore developments may have potential impacts associated with surface and ground water features of the site. These include contamination of local drinking water and alterations to the natural drainage capabilities of the area. A detailed assessment of the underwater storage and the effects on nearby streams and banks will also be required to minimise the effects of erosion and ensure there is no risk of flooding to the site.

9.3.3 Air Quality

As renewable energy projects there is potential for a positive impact to local air quality due to the displacement of fossil fuel combustion. However, the increased transport as well as the embodied energy of the turbines, panels and other structural material will involve higher production of chemical emissions. Due to the small size of the islands, there is a high population density and local communities will likely be near to construction and transportation activities. Therefore a review of the development process as well as air quality monitoring will be needed to analyse how these may impact nearby residents.

9.3.4 Ornithology

Onshore developments are likely to have some impact on the birds, unlike offshore where some technologies are submerged; all onshore technologies present a collision risk.

Figure 103: Ducks at an intertidal zone on Moulin Huet Bay

Surveys should be carried out to determine the seasonal use and the species present at the proposed sites. The most disruptive periods in a developments lifespan are likely to be during the construction and decommissioning of project. They periods should not coincide with the most sensitive times such as the breeding season. Surveys should be carried out to assess the distribution and abundance of birds and there food sources across the whole island, this data will make the siting of onshore developments easier as it will rule out sensitive sites before resources are invested in them. More detailed surveys are required once a site is selected with a particular technology installed.

Any migration routes for bird should be assessed; with these routes assessed it will be possible to locate any onshore projects in a way that has minimal collision risk.

9.3.5 Terrestrial Mammals

Installing onshore technologies is likely to create a change in the habitat in the area where they are located. A change of environment will affect the inhabitants; surveys should be carried out to determine the species present in each type of habitat. Surveys in combination with the abiotic factors mentioned earlier will be required to assess how changes will affect the habitats of terrestrial mammals.

For onshore wind projects bats are key terrestrial mammals to consider. Surveys should be carried out to detect their presence at potential sites; this will allow turbines to be situated in places that minimise the chance of a collision.

9.3.6 Flora

Site specific surveys should be carried out to assess the flora, excavations for the installation of equipment and the cabling for grid connection are likely to be the biggest causes of damage to flora. When creating access for the sites hedges may need to be removed or pruned, the likely effects of these changes should be measured.

Figure 104: Bluebell population in Fauxquets Valley

9.3.7 Landscape and Visual Impact

The installation of onshore wind developments can affect the visual amenity of locations representative of both static views; e.g. residential properties and sequence views, e.g. roads and footpaths.[256] Visual disturbance will be more significant during the installation phase of the development as equipment and machinery have to be transferred to the potential site. Therefore by conducting a complete landscape character assessment, the description, classification and evaluations of the existing landscape resources likely to be affected by developments during construction and operation phases can be achieved.

PV installations will create a visual impact on the surrounding area as a result, largely from the solar reflection on the panels. Sunlight can be reflected by solar panels and thereby have the potential to create a potential irritation to nearby residences if the panels are not screened by vegetation or

[256] (MRE, 2012)

buildings from the residences and are orientated towards such properties.[257] Therefore, it is proposed that an assessment of potential visual effects arising from the installation be conducted.

9.3.8 Heritage and Culture

Although Guernsey has a small total land area it contains a significant amount of archaeological sites and remains buried underground.[258] In addition, there is a list of buildings protected by the Environmental Department for their historic, architectural, and traditional or other interest value. There are also numerous monuments and historical towers and forts that represent an important feature of Guernsey's heritage therefore will be a sensitive receptor to the impact of the proposed technologies. To assess the full extent of these impacts, further site specific studies are required in order to identify the locations of all these sites in relation to the renewable energy structures as well as to assess how the development will affect the island's historical environment.

Figure 105: Historical site on Lihou Island

9.3.9 Socio-economics and Recreation

It will be important to review local land uses and employment sectors to assess the economic impact of the proposed projects with potential beneficial effects arising from further employment generation and the introduction of more labour and skills. For example, Guernsey has an important agricultural industry which is also largely associated with the island's culture and the renewable energy installations could potentially disrupt this activity.

[257] (Dulas, 2011)
[258] (Walls, 2011)

Figure 106: Guernsey dairy cow

The coastal and inland landscape with various nature reserves and coastal paths mean that these islands are also popular locations for recreational activities such as hiking, horse riding, cycling and bird watching. These features are associated with generating local income through the tourism industry and an assessment into how they will be affected by the proposed installations will require a review of these activities.

9.3.10 Traffic and Access

Onshore renewable energy installations would result in an increased use of onshore traffic as well as increased use of the ports during the construction and decommissioning phases. This will cause issues with congestion especially due to the small size of the roads on Guernsey which will create difficulties regarding access to site locations.

Traffic data should be obtained and a swept path analysis needs to be undertaken for any HGV's used in the construction and decommissioning phases of any onshore wind installation. These time periods will also involve increased noise levels due to the larger numbers of vehicles in the area and these impacts will need to be assessed through establishing the background noise levels as well as the timings of specific goods deliveries.

9.3.11 Aviation and Telecommunications

Similar to the offshore wind turbine installations, desktop analysis of designated telecommunication sites and aviation flight paths will be needed to ensure that the onshore turbines do not interfere with these receptors. The commercial PV developments will not require further assessment into these impacts due to the height of the potential installation.

Figure 107: Radio tower in central Guernsey

9.4 Summary

The construction, operation and decommissioning of the proposed offshore and onshore renewable energy projects will all have a wide range of potential impacts on the physical, biological and human environment. The major concern that needs to be considered with the development of these projects is the visual impact of the installations which would in-turn; affect the heritage and culture of the island. It is important in all cases to carry out detailed studies and surveys, which are shown in the Terms of Reference in Appendix C, to establish the baseline environment to aid in the EIA process.

Table 36: Severity of different impacts of each technology

Receptor	Technology					
	Offshore Wind	Tidal Barrage	Tidal Stream	Onshore Wind	Commercial PV	Pumped Hydro
Physical Environment						
Geology	High	High	Medium	Medium	Low	Medium
Hydrology	Low	Medium	Low	Medium	Low	Medium
Hydrodynamics	Medium	High	Medium	Negligible	Negligible	Medium
Air Quality	Low	Low	Low	Low	Low	Low
Biological Environment						
Ornithology	Medium	High	Low	Medium	Low	High
Marine Mammals	Low	Low	Medium	Negligible	Negligible	Low
Terrestrial Mammals	Negligible	Low	Negligible	Medium	Low	Medium
Fish	Low	Low	Medium	Negligible	Negligible	Low
Benthic Ecology	Medium	High	Medium	Negligible	Negligible	Medium
Flora	Low	Medium	Low	Low	Low	Medium
Human Environment						
Landscape/Seascape/Visual	High	High	Low	High	High	High
Heritage & Culture	Medium	Medium	Low	High	Medium	High
Navigation & Shipping	High	High	High	Negligible	Negligible	Medium
Traffic & Access	High	High	High	Medium	Low	Medium
Recreation	Medium	High	Medium	Low	Low	Low
Aviation & Telecommunications	High	Low	Low	Medium	Negligible	Low
Socio-economics	Medium	Medium	Medium	Medium	Medium	Medium
Noise & Vibration	Medium	Medium	Medium	Medium	Low	Medium

Impact Severity Key: High, Medium, Low, Negligible

9.5 Conclusions

The human environment is likely to be the main barrier to the development of these projects and continuous consultation with relevant authorities will be important to gather the necessary data to identify the baseline environment. This will then allow an accurate assessment of the various impacts mentioned above as well as providing the opportunity to develop clean renewable energy technologies while simultaneously enhancing the surrounding environment.

10 Policy, Legislation, Regulation and Licencing

10.1 Opportunity

A package of policy instruments are suggested that consider the economic and social factors on Guernsey, remaining compatible with the aspiration of renewable energy development, and sustainability, whilst protecting a reputation for light touch governance.

Three key areas of policy and legislation are presented:

- Marine licensing through development of the draft Ordinance. Considering positive and negative experiences observed in other jurisdictions, in order to deliver a framework that is fit for purpose from the outset, and not subject to significant amendment. Stability of the licensing process from first implementation will reduce the perception of political risk for renewable energy developers
- Access to renewable energy incentive mechanisms in partnership with EU member states, through the joint project provision in the Renewable Energy Directive (RED) 2009
- Energy management motivation for demand reduction and embedded generation, through government backed financing of efficiency projects for commercial and domestic applications. Energy performance certification coupled to a flexible rate of landlord tax is proposed to drive a reduction in energy consumption of buildings

10.2 Introduction

Guernsey relies heavily on the financial sector for economic activity, which is incentivised through a light touch and low taxation framework. Stemming the haemorrhaging public finances by balancing tax receipts with expenditure is already an emotive issue, notwithstanding incentivising the deployment of renewable energy through increased cost of energy to consumers, or more punitive taxation. There are island wide fears that erosion of the existing competitive business environment could lead to significant loss of revenue for Guernsey, if banking operations were to be relocated, since figure 108 shows that the economic spectrum is polarised by dependence on financial institutions to a worrying extent:

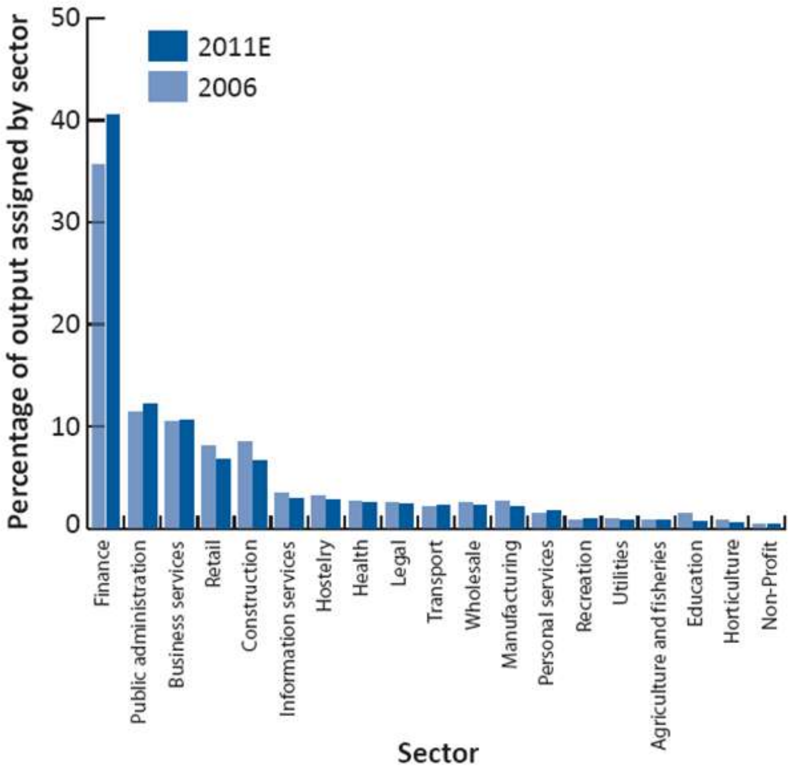

Figure 108: The One Legged Stool[259]

Coupled with acutely limited land area for development and the associated planning pressures, it seems unlikely that large onshore renewable energy developments such as solar PV or wind would be socially or economically acceptable, particularly in the absence of subsidy. It is plausible that larger offshore projects may attract support from other EU incentive mechanisms, however smaller domestic or commercial implementations are likely to remain economically unattractive. This excludes commercially immature renewable technologies from participation in the market, leaving

[259] (SOG 2012)

energy efficiency and large offshore wind as the most politically and economically acceptable options.

A two-pronged approach is suggested, focusing on the two areas most likely to bear fruit; the development of offshore wind and investigation of subsidy eligibility, and a campaign of adopting energy efficiency in all sectors.

Marine licensing is currently under development with the drafting of a new Ordinance, which would extend the jurisdiction of the planning department to the territorial waters of Guernsey. Even with a suitable licensing framework in place, development is only likely to occur if combined with access to subsidies for renewable energy technologies, which are at this time still progressing along their learning curves and not yet mature enough to compete in the market.

Incentive mechanisms are necessary for renewable technologies to transition from technology push to creating a market pull as the levelised cost of electricity decreases over time with economies of scale, and learning from experience. Renewable technologies such as offshore wind were expected by some industry commentators to become competitive with central grid generation as soon as 2020,[260] however more recent experience of costs suggest that this will not occur until around 2030.

Despite the economic barriers to renewable energy deployment, institutional barriers in the planning framework for onshore renewables such as solar PV are compounding the disappointing penetration of embedded generation. Renewable energy planning applications could be assisted in Guernsey by adopting the pragmatic approach embraced by other jurisdictions such as Cornwall Council in order to streamline the application process.

Financial support for renewable energy development such as soft loans, direct subsidy or public procurement is presented in the economics section of this document. A carbon tax was also considered, however without a suitable rate of around £50 per tonne, behavioural change is likely to be limited. Furthermore, the probable effects on the precarious island economy resulting from such a levy mean that these options seem incompatible with the holistic vision of sustainability, encompassing environmental, economic and social balance.

[260] (Elliot 2003)

10.3 Marine Licensing & Draft Ordinance

10.3.1 Introduction

Licensing refers to any permission, consents and permits under marine development. It is a fundamental process of marine planning that successfully implements renewable installation from pre-application to operation. The aim of this document is to be an aid for the Guernsey planning, policy and legal team, that lists, warns and recommends actions or legislation that may be of benefit to Guernsey.

The scope of work will investigate existing failures of marine licensing, using case studies to present the failures, reasons for failure and where possible; measures to avoid them. The scope will include measures to streamline the marine licensing and planning process. Key suggestions are provided that will be of benefit to the developer and regulator alike. Lastly, sea restriction and precautionary safety zones are considered, with difficulties experienced in the suspension of navigational and fishing rights and possible measures to remedy them.

10.3.2 Case Study: Marine and Coastal Access Act 2009

The Marine and Coastal Access Act (MCAA) passed in 2009, was the first piece of holistic legislation for the marine environment in the UK. It aim was to ensure healthy biodiversity in the sea by placing systems for delivering sustainable development of marine and coastal environments.[261] The document had a broad scope of aims but one of its main mechanisms for delivering its objectives was the Marine Management Organization (MMO). The MMO is the marine planning authority acting on behalf of the UK Government.[262] One of its main functions is providing marine licensing and enforcement of marine legislation.

10.3.2.1 Biodiversity

The central theme of the Act is considered to 'uphold biodiversity' yet there is no legal binding in the Act or in the MMO obligation to maintain biodiversity in a development. The legal obligation is loose and is expressed as to 'have regard' to biodiversity. A meaningless legal expression and in layman terms can be translated into 'consider'.

Therefore a new marine development is not legally bound to maintain biodiversity. The void in the MMO is filled by the obligations of significant EU laws. For Guernsey, outside of EU law, it may be suggested to adopt a 'precautionary principle' ecosystem approach to management, avoiding damage to biodiversity based on a robust evidence-based methodology.

[261] (Part 1 Marine and Coastal Access Act 2009)
[262] (s2 Marine and Coastal Access Act 2009)

10.3.2.2 Marine Spatial Planning

Marine planning is a complex process as there a number of uses for any given area. Therefore it is appropriate to have congruent marine planning documents that successfully protect the existing environment and the interest of others while enabling development. The failures are the lack of enforcement to comply with the conditions of the planning documents. Public authorities in dealing with consents must only make their decisions 'in accordance' with them unless relevant considerations indicator otherwise.

The document then identifies why the public authorities may choose to ignore them, thereby giving the authority the chance to evade the marine planning documents. The marine plans may still exert some pressure and perhaps encourage consent but are still able to evade them and thus undermine the marine spatial planning.

10.3.2.3 Marine Conservation Zones

Marine conservation zones are becoming an increasing necessity to uphold biodiversity with the expansion of offshore renewables. Protected zones can either be strictly exclusive preventing all forms or extraction and construction or circumstantial to the level of protection needed. The UK has opted for the latter known as Marine Conservation Zones (MCZ). Logical as a blanket policy, a one-size fits all approach, would not distinguish between the levels of protection needed, if any.

However the flaw is that in order for an area to be a designated MCZ it requires scientific proof that the area is of high biodiversity. Only then is the area assigned as a MCZ with the appropriate level of protection. It is the 'precautionary principle' in reverse: it is not an area of biodiversity unless proven otherwise. The burden of responsibility is then on the conservation agencies to provide scientific evidence that the area must be protected. Collecting such data is expensive and consequently existing records are scarce.

10.3.3 Case Study: Marine Scotland

The Scottish Government has a target of 100% electrical demand to be met by renewables by 2020.[263] To fulfil its objective it is reliant on a portfolio of both onshore and offshore technologies and the means to facilitate their development. Consequently Marine Scotland has considered the existing challenges and consent framework to the offshore industry and then recommend a number of actions to assist development. Key initiatives that have been implemented in Scotland would further facilitate offshore development in Guernsey.[264]

[263] (Marine Scotland 2012)
[264] (Marine Scotland 2012)

10.3.3.1 Create a Licensing Manual

Create a licensing manual that summaries the process to be followed by developers. The document should provide guidance on what the regulator is expecting to see in an application; providing developers with direction and advice for the whole licensing process from pre-application to post-consent. This would include the roles and responsibilities of the team and organizations involved in the consenting and licensing process and their individual roles made clear. Its aim is to aid both the developer and regulator alike. It will be a simple-terms manual and to be considered a live document. To be reviewed or updated should amendments be required.

10.3.3.2 Access to Information

To support developers at pre-application, the commission will provide access to key information. This would include access to national datasets and detailed site-specific information such as baseline environmental receptors. This will assist developers in determining the level of data collection required needed for an informed impact assessment.

10.3.3.3 Planning Permission not Required

Planning permission is not required for an application for offshore installations. The marine licensing consent is the means by which authority is given. Therefore the planning and licensing can be considered as one.

10.3.3.4 Onshore Ancillary Planning

For offshore installations there is normally some form of onshore ancillary equipment that is essential to the generators. Therefore planning permission is required to the relevant onshore Planning Authority. Consequently delays can occur while permission is sought although the offshore installation has been granted. This has been rectified in Scotland by planning permission granted for any development that is ancillary to the offshore installation.

10.3.4 Safety Zones and Sea Restrictions

10.3.4.1 Safety Zones

Safety zones are provisions around offshore installations that prohibit entering or remaining in that area. They are for the benefit of the installation and the vessel. Safety zones for offshore installation are normally 500m when the development is being constructed, refitted or decommissioned[265] and 50m when the site is operational.[266] As offshore wind is the only marine technology at commercial deployment these provisions are written to suit accordingly. Foresight would suggest alternate

[265] (The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007)
[266] (The Electricity (Offshore Generating Stations) (Safety Zones) (Application Procedures and Control of Access) Regulations 2007)

safety provisions for wave and tidal devices. Wave installations are generally constructed in deep water. The mooring can extend beneath the sea some distance from the structure itself. This would present a navigational and fishing hazard that the standard 50m zones would fail to avert. Consequently operational safety zones would need to be enlarged to cater for these alternative marine technologies.

10.3.4.2 Navigation Rights

Navigational routes in respect to renewable installations have been extinguished or suspended should they pass over all or some of the development. As long as they are constructed away from essential sea-lanes the safety zones will have relatively little impact. Should a proposal however interfere with recognized sea-lanes, essential to international navigation, the application should be refused. This is common sense and UK legislation has guaranteed this.[267]

10.3.4.3 Fishing Rights

Difficulties have arisen from the prevention of fishing. It is an individual matter, as the implications will differ depending on the size of the local fishing industry affected. Nevertheless prevention of fishing rights is a hot topic and requires due consideration. Ownership by the Crown, and persons deriving title from the Crown is subject to public rights in tidal or navigable waters, to fish and to navigate. These can be removed or limited by legislation and has been done to some extent. However the removal of rights by legislation can infringe human rights. The public rights in respect to navigation "is not to be regarded as a right to sail in every square inch of the surface of the sea"[268] and therefore must hold true for public rights to fish. But infringement of them can potentially give rise to compensation claims against developers.

The UK has tried to side step the issue by removing navigational rights but not fishing rights in the safety zones. As the UK is further subject to EU law, where Guernsey is not, member states have equal access to fishing grounds. Removing the right to fish would infringe on the rights of the EU and the UK. So in principle a fishing boat is entitled to deploy its net or lines over the location of the renewable energy installation but not to pass over it itself. Thereby curtailing the exercise of fishing rights but not the fishing rights themselves. Nevertheless the ambiguity remains in the infringement of rights, therefore the right to compensation. As Guernsey is within its own jurisdiction and exempt from of EU law it would be better to grapple legislation properly with the public rights to navigate and to fish.

[267] (Energy Act , s99 2004)
[268] (Crown Estate Commissioners v Fairlie Yacht Slip Ltd 1977)

10.3.4.4 Compensation

The potential loss of fishing grounds is a subject of most concern. As the fishing industry is the most likely affected by offshore installations.[269] There is a conflict, caused by the fear of negative impacts, to hinder offshore developments. Although there is a consensus that exclusion zones could benefit the ecosystem. The safety zones are believed to have similar effects to exclusions zones: providing breeding or nursery grounds allowing species freedom to spawn and mature.[270] Prevention of fishing access can become lost profits, affecting present and future livelihoods. Compensating can be a method, albeit controversial, to resolve these issues. From the point of view of fishermen, compensation hand-outs are seen as short–term thinking,[271] not securing fishing futures. If used as a mitigating measure it raises many questions such as who are entitled and the adequacy of compensation. Once individual compensation is awarded a bandwagon clamour may ensue. Should the conflict of interest not be settled or resolved by any other means compensation is an option. However longer-term alternatives should be considered such as creating a common fund allowing fisheries to diversify or fund island community initiatives.[272]

10.4 Access to Incentive Mechanisms of Other Nations

Given that there is little appetite to establish indigenous subsidy for renewable energy for the reasons already presented, an alternative solution must be found to bolster the appeal of Guernsey to developers.

With this in mind, possible options were investigated for accessing RE support from outside of Guernsey. It transpires that mechanisms were established by the EU to facilitate the achievement of legally binding commitments made by Member States (MS) with regards to RE generation as a proportion of total primary energy consumption. The legal framework to enact such support is laid out and presented in the RED 2009 ("the Directive"). The RED outlines several ways in which MS can cooperate to attain their goals. The possible options available to Guernsey for economic and energy security benefits are discussed in further detail.

10.4.1 Joint Projects between EU Member States and Third Countries

10.4.1.1 The Idea

There is an option that Guernsey could access renewable energy subsidies from within the EU as Joint Projects (JPs), as documented in the RED.[273]

[269] (Karen A. Alexander* 2013)
[270] (Karen A. Alexander* 2013)
[271] (Karen A. Alexander* 2013)
[272] (Karen A. Alexander n 2013)
[273] (The European Parliament and the Council of the European Union 2009)

The Directive, requires EU MS to achieve an overall share of final energy consumption sourced from renewable energy, of at least 20% by 2020, as well as a 10% overall share for RE in transport. This builds upon the 20-20-20 targets previously laid out in the 2008 EU Climate and Energy Package by *inter alia*, improving the legal framework through the creation of co-operation mechanisms.[274]

The JP scheme is one of four such co-operation mechanisms covered by the Directive that permits under-performing MS to achieve their targets by allowing the surplus renewable generation produced in another country to count towards their total.

Article 9 of the RED relates to JPs between MS and third countries, whether EU MS or not. It allows MS to co-fund new RE projects, with third countries, within the territory of the third country. The MS imports the renewable generation, which counts towards its targets. The third country receives part funding for the RE project and the output is eligible for full subsidies and support that cover that specific technology in the partner MS.

The RED does not rule out the involvement of private companies or financiers.

10.4.1.2 The Entry Criteria

All parties involved must agree to outline terms of interest in a bilateral agreement such as a Memorandum of Understanding (MoU) or equivalent. Subsequently, an Inter-Governmental agreement is established between the MS and the third country, enabling the following qualifying action in establishing a JP recognised by the Commission:[275]

1. A Notification has to be sent to the Commission, this includes;
    - A complete detail of the proposed project
    - The quantity of electricity that is planned to be exported to the MS
    - The projected period in whole calendar years in which this will take place
    - The quantity of electricity that will be consumed domestically
    - The corresponding financial agreement, pending confidentiality status

2. Proof of consumption within the EU, occurs when;
    - A nominated equivalent amount has been recognised as ‘passed through’ the network ‘by all responsible transmission system operators’ involved
    - A nominated equivalent amount has been registered on the EU side of an interconnector

[274] (European Commission 2013)
[275] (Bistola and Pause 2012)

- The nominated capacity and electricity production have to coincide temporally

3. Other prerequisites;
   - The generated electricity is produced by new or upgraded plant that has become operational after the 25th of June 2009
   - The exported electricity cannot have received other forms of support from any other support schemes
   - The period of transfer cannot exceed 2020 but the JP can exceed 2020
   - Once the Commission has received the Notification of the JP then the JP cannot be amended or withdrawn without consent from all parties

10.4.2 Candidate Partners

Guernsey would fill the role of the third country under this option of JP. The MS in question would have to be a country that is under-performing in their targets, that is relying on co-operation mechanisms to achieve them or has previously shown an interest in JP, of which there are potentially nine:

1. Belgium
2. Bulgaria
3. Denmark
4. Italy
5. Latvia
6. Luxembourg
7. Malta
8. Netherlands
9. UK

The following appraisal outlines key factors in assessing suitability for a JP partnership with Guernsey:

10.4.2.1 Belgium

- Was reportedly one of six MS that were below their target in 2010[276]
- Is perceived as being increasingly vulnerable to the euro-crisis which leads to investor uncertainty[277]

Possible JP partner

10.4.2.2 Bulgaria

- One of six that were below target in 2010
- Had an infringement case brought against by the Commission for 'non-transposition of the Directive'[278]
- Is currently suffering from an overloaded grid due to a rapid increase in wind and solar capacity and a decrease in domestic consumption[279]

JP ruled out

10.4.2.3 Denmark

- One of six that were below target in 2010
- Recent reports apparently suggest that they will be in surplus RES by 2020[280]

JP ruled out

10.4.2.4 Italy

- One of six that were below target in 2010
- Is currently suffering from a highly unstable economy, which is not congruent for a medium to long-term partnership
- Like Denmark, will be in surplus by 2020

JP ruled out

10.4.2.5 Latvia

- Was greater than 1% below its first interim target of 2011-2012, indicative of failing to stay on track with its own projections, and therefore is likely to miss its 2020 target[281]

[276] (EWEA 2010)
[277] (Index Mundi 2013)
[278] (European Commission 2013b)
[279] (Bauerova 2013)
[280] (European Commission 2012b)

- Although currently enjoying a growing economy has been plagued with recent instability
- The delivery of electricity would be subject to the negotiation of a minimum of four separate Transmission Network Use of System (TNUoS) agreements
- Like Denmark and Italy, will be in surplus by 2020

JP ruled out

10.4.2.6 Luxembourg

- Good economy, good support for RE
- Imports 50% of its electricity, 50% of its gas consumption used to generate electricity[282]
- Has an MoU with Lithuania and has had 'more concrete negotiations' with Germany
- Any new imported electricity from RES would require the commissioning of a new interconnector, the cost implications coupled with the fact there are already in talks with Germany, their major energy supplier, lessen the likelihood of a JP with Guernsey[283]

Possible JP partner

10.4.2.7 Malta

- One of six that were below target in 2010 and like Latvia did not hit its first interim target
- Was one of three MS given a special mention by the Commission with regards to countries that have to make additional effort to achieve their target[284]
- Crucially as an island without connection to the European grid cannot participate in any JP

JP ruled out

10.4.2.8 Netherlands

- One of six that were below target in 2010
- Was one of three MS given a special mention by the Commission
- Need to increase renewable energy from 4% in 2010 to 14% by 2020[285]
- Will at the current rate miss the 2020 target without an additional €24billion of investment[286]
- Has relatively weak support for RE yet wants to enable the cross-border trade of energy[287]

Preferred JP partner

[281] (European Commission 2013b)
[282] (European Commission 2011)
[283] (European Commission 2013a)
[284] (European Commission 2012a)
[285] (Government of the Netherlands 2010)
[286] (Rabobank 2012)
[287] (Government of the Netherlands 2010)

10.4.2.9 UK

- Has a strong long-term policy of support for RE, existing mechanisms and a proven system for earning Renewable Obligation Certificates (ROCs), currently 2 for offshore wind
- Has a relatively stable economy
- Was one of three MS given a special mention by the Commission
- Seemingly appeared to be under-performing in 2009[288]
- Has looked into JPs and has already signed an MoU with Ireland

Preferred JP partner

10.4.3 Preferred JP Partners

Of the EU countries requiring additional action, the top two MS most likely to be motivated to undertake a JP with Guernsey are the Netherlands and the UK, given economic stability, long term support for renewables in the form of a feed in tariff and lack of grid constraints.

10.4.3.1 Appetite for JP in the UK

The UK could be a highly likely candidate for entering into a JP as it is already considering doing so with Ireland, who are both in the process of finalising an Inter-Government Agreement.[289]

A 2010 DECC commissioned report to look into the possibility of establishing JPs complete with subsea connector cables between the UK and Norway or Iceland concludes that an inter-connector link to Iceland is cost effective but too risky for private investment.

The report also suggests that for continental Europe:

"linking two offshore wind farms to create an interconnection could be the most cost effective approach and provide a cost effective 'back up' interconnector"

but goes on to dismiss the suggestion as it would not benefit UK's targets as electricity generated from RE has to come from new capacity i.e. new plant or upgraded plant.[290]

This however would not be the case if an interconnector were proposed for an as yet un-built wind farm off the coast of Guernsey and say, the proposed Navitus Bay Wind Parks off the coast of Bournemouth only 125km to the North;[291] a proposal that is worthy of further consideration.

[288] (Lorentz 2012)
[289] (Department of Energy & Climate Change 2013)
[290] (Sinclair Knight Merz 2010)
[291] (4C Offshore 2013)

10.4.4 Qualification for Statistical Transfer

Under protocol 3 of the *European Accession treaty law, 1994*, EU legislation may be adopted voluntarily. This may enable Guernsey to become a signatory to the terms of the RED 2009, which makes provision for nations participating in the 2020 renewable energy target to statistically transfer renewable energy generation to other nations, and to exploit the incentive mechanisms in the country to which the energy is transferred. The result of this is that if Guernsey could demonstrate that 20% of its electricity could be obtained from renewable sources, then a statistical transfer outlined in articles 6 of the RED could become available.

As outlined in the offshore wind section a single offshore wind farm offers the potential to make a significant contribution to meeting Guernsey's demand for electricity. One single project of this scale may provide to statistical transfer under article 6 of the RED 2009.

10.5 Government-Backed Energy Services Company

Given the unusual way the Guernsey energy market operates, in that it is effectively a state owned monopoly, many of the traditional policy mechanisms designed to promote energy efficiency or renewable energies are not applicable to this market. In addition the aversion to levying any type of tax means that direct government subsidy seems an unpopular option. On this basis a policy based on the ESCo model is most plausible to encourage greater uptake of energy efficiency measures and renewable technology market penetration within Guernsey.

ESCos engage in developing, installing and financing comprehensive, performance-based projects on the condition that they will be able to take a portion of the savings (figure 109) made from a lower energy usage over a given period, typically 5–10 years.[292] The ESCo model has worked widely for private sector large-scale developments but does not lend itself so readily to domestic scale applications without government support.

The UK's Green Deal is a government backed ESCo scheme, which aims to provide a framework that enables private firms to offer energy efficiency improvements to consumers at no upfront capital cost, and recoup payments through the energy bills.[293] The Green Deal removes the complexity of energy monitoring associated with the typical ESCo model via a deeming process carried out by a domestic energy advisor.

[292] (Vine 2005)
[293] (Guertler 2011)

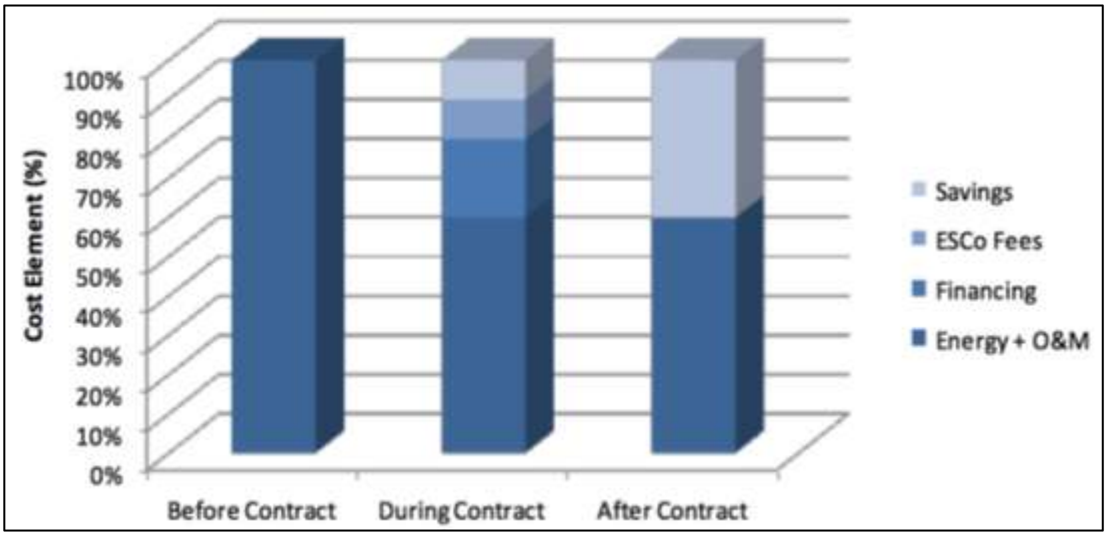

Figure 109: ESCo model

10.5.1 How a Government Supported ESCo Model Might Work

- Households, property landlords or commercial enterprises can install a package of energy efficiency measures, renewable heat or renewable energy technologies at no upfront cost[294]
- This capital is raised either from a government backed fund or the private sector
- The repayment for the measures is made through a service charge on the consumer's energy bill. This charge is tied to the household rather than the occupant taking the onus off the homeowner to pay for measure in the instance that they move, allowing for a repayment period in line with the lifetime of the low carbon technology installed
- At the centre of the Green deal measure is the "Golden Rule" whereby the expected fuel savings are greater than the payback obligations. In this way the householder is able to save money as soon as the low carbon technologies are installed.[295] A rule similar to this would be required to ensure the policy is made attractive to consumers
- The measures must be taken in accordance with advice from an accredited domestic energy advisor and installed by an accredited ESCo

10.5.2 Energy Efficiency Measures

The policy should be designed to encompass all green technology measures; however, a preference should be given to those that offer the biggest savings in both financial and carbon terms; aka the low hanging fruit.

[294] (Guertler 2011)
[295] (DECC 2010)

In creating the policy, a process is needed to prioritise the low hanging fruit, thereby creating an order of preference. Not all of these will be applicable to a development and so it would be the role of the accredited domestic energy advisor to tailor action plans to each consumer.

A suggested order of preference is given below with the most cost effective measures at the top of the list. A more detailed breakdown of energy efficiency and sustainable heat measures are given in the Heat and Sustainability section of this document.

1. Energy efficiency
2. Solar thermal
3. Heat pumps
4. Solar PV
5. Small scale wind

10.5.3 Who Would Invest?

There are two investor options for such a policy; if the principal financier was the government a greater incentive could be given by offering loans at rates comparable to government bond rates (~3%), alternatively the investment could come from a market driven source of finance (as with the Green Deal), at present lending rates between 7.67-7.96% are typical with the Green Deal programme.[296]

There are residents of Guernsey that already have considerable investments in other renewable energy projects and so might be interested in operating as an ESCo. Under the ESCo model numerous finance sources have emerged from the private sector these include banks, leasing companies and insurance funds. Local availability of financing at reasonable terms is essential for a mature, well-functioning ESCo market.[297]

10.5.4 Repayment Mechanism

A key advantage of the ESCo model for Guernsey is that there is that GEL operates as the sole energy company, thereby reducing the potential complexity otherwise associated with such a system. In addition GEL already operate a similar scheme in which electrical goods can be acquired and paid back through hire purchase agreements secured on fuel bills. As this mechanism is already in place it should not require fundamental change in existing arrangements to provide such an ESCo type

[296] (The Green Deal Finance Company 2013)
[297] (Goldman, Hopper, and Osborn 2005)

service. After presenting this idea, GEL indicated that this is something they feel could be accommodated, given authorisation from the regulator; historically the OUR.[298]

Currently GEL's sole mandate is to supply energy at minimum cost to the consumer, whilst maintaining island energy security. Such aims do not accommodate the provision of demand reduction as part of the solution to energy supply, without explicit change to the mission statement authorised by the regulator.

10.5.5 The "Golden Rule" Type Measure

The "Golden Rule" stipulates that the expected financial savings from energy efficiency measures should be equal to or greater than the service charge that is added to the fuel bills, taking into account opportunity cost and changes in interest rates and energy prices.[299] This rule ensures that the householder will not be worse off as a result of investment.

10.5.6 Accreditation

10.5.6.1 Accredited Domestic Energy Advisor

In order for a government backed ESCo model to work some kind of standardised assessment methodology for buildings would have to be adopted. In the UK the EPC was introduced in 2007 as a response to EU directive of 2002, which states that a common approach to rating the energy efficiency of buildings should be introduced by member states. This process is carried out by qualified and/or accredited experts, whose independence is to be guaranteed on the basis of objective criteria.[300] EPCs give banded ratings for buildings taking into account the specific issues associated with each building. The development of standardised methods to report project characteristics, cost and savings can be an important tool for policy makers.[301] The regulator would be the body responsible for administering the accreditation process.

10.5.6.2 Accredited ESCos

The ESCos will need to be accredited as part of any government based ESCo model, this will allow for competition within the ESCo market and assurances of the quality of the installations made. Again, the regulator would be the governing body that would oversee this accreditation process.

[298] Office of Utility Regulation
[299] (Booth and Choudhary 2013)
[300] (EU 2002)
[301] (Goldman, Hopper, and Osborn 2005)

10.5.7 Risks Associated With a Government Backed ESCo Model

10.5.7.1 Assessment Risk

A failure to implement an effective energy assessment regime could lead to measures not performing as anticipated, this could lead to a failure for measure to meet the "Golden Rule" post installation.[302] A solution to this could be a well-planned energy saving estimation tool that takes into account realistic guidelines such as a bottom up, engineering based, housing stock energy model that is able to handle uncertainties, using a combination of statistical calibration and probabilistic sensitivity analysis.[303]

10.5.7.2 Consumer Confidence Risk

Another potential risk is that there is a lack of consumer confidence in the scheme, either due to high interest rates or inappropriate government assurances. Again the government-invested scheme supplies more attractive returns and appropriate policy design could reduce perceived risk.

10.5.7.3 Rebound Effect Risk

Another risk to such a measure is the so-called Jevons Paradox, which questions whether improvements in technical efficiency will actually reduce energy consumption by the amount predicted within the deeming process.[304] It has been demonstrated that consumption often increases as a direct result of the installation of energy efficiency measures. Options for combat these effects are limited but mandatory consumer education measures could help to mitigate them.

10.5.7.4 Limitations of Measures Applicable Under the Golden Rule

The interest rate of any such a scheme has a powerful bearing on what measures can meet the golden rule, the lower it is the wider the ranger of measure that can be installed under the scheme.[305] Under a government backed scheme, a much broader range of technologies could be installed and consequently a greater potential energy saving and reduction in demand could be attainable.

10.5.8 The Energy Services Company Model for Guernsey

The Sarnia Scheme could be a plausible option for an internal push towards green technologies for Guernsey because it does not require a significant investment from the state. With limited set-up and administration costs, the proposed scheme is one of the support mechanisms that could most effectively be applied to an energy market based on state intervention.

302 (Guertler 2011)
303 (Booth and Choudhary 2013)
304 (Sorrell 2009)
305 (Guertler 2011)

Improving the energy efficiency of buildings and introducing low carbon technologies could have a significant impact on the living standards of the homeowner, if a policy such as this was to be implemented provisions should be made to encourage development for all demographics within Guernsey society but specifically those considered to be in poverty or in especially adverse living conditions. It is suggested that the rate of landlord tax could be linked to the potential for energy efficiency improvements in the commercial building or housing stock, which could be implemented as a net zero gain policy instrument, with winners and losers. Another benefit generated through encouraging investment in a growing green technology sector could be the creation of local jobs for installers.

When designing their own government backed ESCo policy Guernsey should look to the Green Deal and aim to build on the lessons learnt from the successes and failures of its implementation. In so doing they could design a successful policy that could see their carbon emissions fall along with their energy dependency whilst improving the living conditions for Guernsey residents.

10.6 Summary

If renewable energy is to gain a foothold in the Bailiwick of Guernsey, without direct subsidy, it would seem that a streamlined consenting process is required, and the availability of economic support, possibly as joint projects. As outlined, a Government backed ESCo similar in nature to the Green Deal in the UK could play a key role in reducing the barrier of cost to energy management in business and domestic applications and bring demand side benefits with improved energy security and higher standards of living.

As a key enabler of offshore renewables, it is vital that the Marine licensing framework is fit for purpose from its first implementation; observing the lessons of experience as presented here. The case studies undertaken highlight the failure to protect biodiversity, and lack of legal rigor afforded by the MCAA 2009, whilst Marine Scotland Licensing demonstrates initiatives that are likely to be of benefit to Guernsey, such as comprehensive guidance and resources for developers and a streamlined consented process encompassing both offshore and onshore works. Safety zoning requires buffering appropriate to each different technology, with fisheries likely to experience the greatest impact from any development, although single payment compensation to individuals may not be a suitable long term solution.

Once marine licensing is available to offshore developers, EU renewable incentive mechanisms may be accessible in accordance with the RED 2009. Should Guernsey develop a joint project with an EU Member State, such as the UK or the Netherlands, policy instruments such as tariff or quota mechanisms may become available as if operating within the territory of the partner country. Inter-governmental agreement is required from an early stage, with notification and proof required by the European Commission.

In the UK, a previous study undertaken on behalf of DECC, explored possible JPs with other countries and performed cost-benefit analysis for establishing a sub-sea interconnector. The findings of the report concluded that an interconnector between two offshore wind farms would be the most cost effective. Alternatively, a less immediate option might be access to statistical transfer under the 2009 EU RED as a de facto MS. This would require Guernsey to wield its membership of the European Economic Area (EEA) through the 1994 Accession Treaty, and first comply with the RED 2009 renewable energy targets, bringing its share of renewable generation into line with other EU countries.

For island energy management, due to the nature of the Guernsey energy market, the Sarnia Scheme offers one of the most plausible options for increased uptake of energy efficiency and smaller scale renewable technologies that are closest to commercial maturity. It is proposed that capital expenditure could be financed by central Government and secured on consumer electricity bills, to enable installation of energy management measures, whether by private or public sector contractors, at no upfront cost. Such a scheme is most likely to be successful if the Government are the principal financier, as it could offer more attractive returns for the consumer.

Arguably, the Sarnia Scheme may prove easier to manage than examples in other countries due to the existing level of state intervention coupled with comparative simplicity of the energy system on the island. In order for such a scheme to be successful, lessons should be observed from the successes and failures of the UK's Green Deal policy. At present, the utility regulator does not provide GEL with a mandate to include incentivising demand reduction, without which the Sarnia Deal could not be implemented.

10.7 Conclusions

An opportunity exists to establish the Marine Ordinance as a powerful licensing framework to enable offshore renewable energy development to proceed in an appropriately managed manner. If implemented without delay, with deference to lessons of experience, marine renewables promise to grow an additional leg on the economic stool, contribute to greater island energy security, and offer an overall net positive result for Guernsey.

Guernsey has the possibility of securing a future supply of sustainable electricity with cross-border incentives and co-finance being an available option now. As long as arrangements are put in place in the short term that open up communications with the EU and Member States notifying them of their interest in initiating talks for a potential JP then there is a possibility that Guernsey could be generating and exporting RE onto the European by 2020 and beyond. In addition to intergovernmental dialogue, it is suggested that an interconnector between the proposed Navitus Bay Wind Parks off of the coast of Bournemouth and an as yet un-built Guernsey Wind Farm should be explored. Further legal exploration of Protocol 3 and the 1994 Accession Treaty with regards to Guernsey's position within the EEA should also be conducted to ascertain future eligibility to participate in statistical transfer of RES-E under the RED 2009.

The Sarnia Scheme would potentially enable Guernsey to address energy security and fossil fuel intensity of the island whilst reducing consumer bills, at very low cost to the States. A simple expansion of the mission statement by the regulator for GEL to also include demand side management could lay the foundations for such a scheme.

11 Economic Modelling

11.1 Opportunity

Guernsey's electrical demand has been increasing yearly, due to a slowly increasing population and increased electrification of energy sources. Total island consumption in 2011 was 380GWh peaking at around 85MW.[306] A large proportion of the power supply originates from France. It is transferred through the CIEG link via Jersey costing between 5 or 6 pence per kilowatt hour. This 55 MW connection reserves Guernsey's right to draw a baseload of 16 MW at all times; unless Jersey require the power which is very rarely the case.

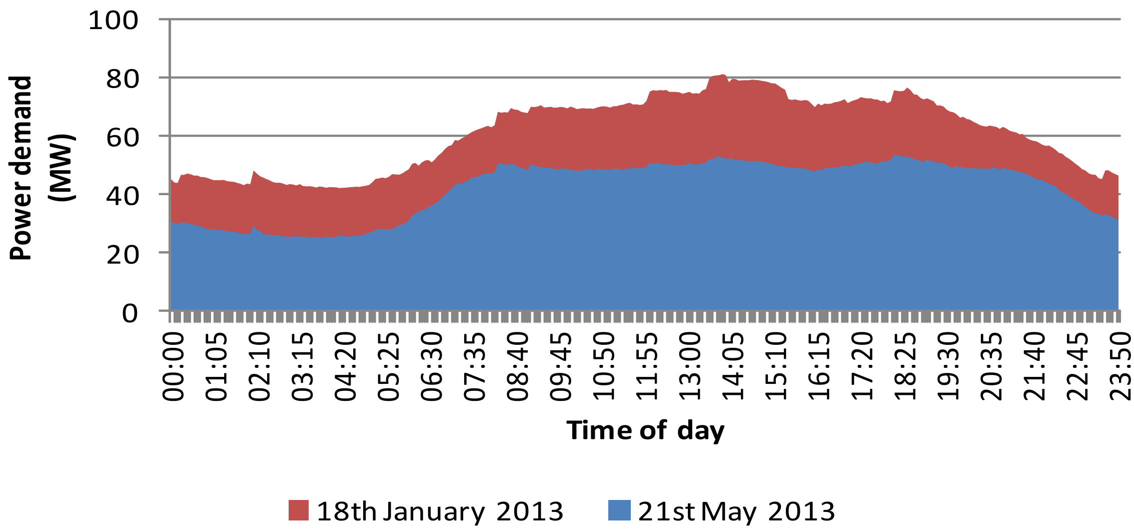

Figure 110: Typical Guernsey power demand profile using 18th January and 21st May 2013 as exemplars for seasonal variations[307]

As displayed above for different seasons, imported electricity is not sufficient to meet the island's daily load. Consequently, it is GEL's responsibility to ensure their diesel powered generators procure the remainder of demand: the marginal cost of which is close to 14 pence per kilowatt hour. It is this stark contrast in prices combined with the supply ratio of imports to diesel generation which impacts consumer prices.

As a state monopoly, GEL aims to provide affordable energy. It does so through a merit order prioritising cheapest supply. In the tax year of 2011/2012, the vast majority of electricity supplied was imported; only 20% was locally generated. This allowed GEL to distribute the elevated cost of diesel power across all consumers at an average price of 13 pence per kilowatt hour. However, the supply interruption caused by the failure of the CIEG link forced Guernsey to be entirely self-

[306] (Dorey, 2013)
[307] (Le Page, 2013)

sufficient for the majority of the following 2012/2013 year. Indeed, only 28% of supply was imported that year.[308] In order to maintain affordable prices and public credibility, the subsequent increase in tariffs did not proportionally match that to GEL causing the state monopoly to operate at a loss.

Furthermore, the Chamber of Commerce has suggested several of the slow speed diesel generators will be reaching the end of their economic life by 2017, reducing the generating capacity by 40MW.[309] From a technical point of view it is likely the machines will still be operation a few years subsequent to this, however it's no compensation for the resultant strain it places on the remaining supply options. As such, this chapter of the RE 2013 report aims to identify the costs associated with the potential development of renewable energy to meet security of supply and sustainability issues.

11.2 Levelised cost of electricity

The levelised cost of electricity (LCOE) represents a "break-even" value that a power provider would need to charge in order to justify an investment in a particular energy project. It is quite a crude tool in that it is only indicative and based on 'best guess' approximations of total costs and revenue streams.[310]

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{el}}{(1+i)^t}}$$

LCOE : Levelized costs of electricity in Euro/kWh
I_0: investment in Euro
A_t: annual total costs
M_e: electricity output in yeat t in kWh
i: interest rate (discount rate)
n: economic lifetime in years
t: year of operation (1, 2,…n)

Figure 111: Equation to calculate the levelised cost of energy[311]

However, the real value of LCOE lies in its ability to provide a direct comparison between technology choices to inform investors. The case of sustainability for RET is a compelling trait in evaluating Guernsey's future energy investments. As such, offshore wind energy, solar PV and direct

[308] (Sexton, 2103)
[309] (Dorey, 2013)
[310] This tool would be complemented by a sensitivity analysis to evaluate the probable range of each LCOE. For example: offshore wind power CAPEX was defined as £3.5million per MW which is in fact the high end of the range beginning at £3 million.
[311] (Kost, Schlegl, Thomsen, Nold, & Mayer, 2012)

interconnection to France have been analysed in relation to already existing diesel generating capacity. Figure 112 displays the results:

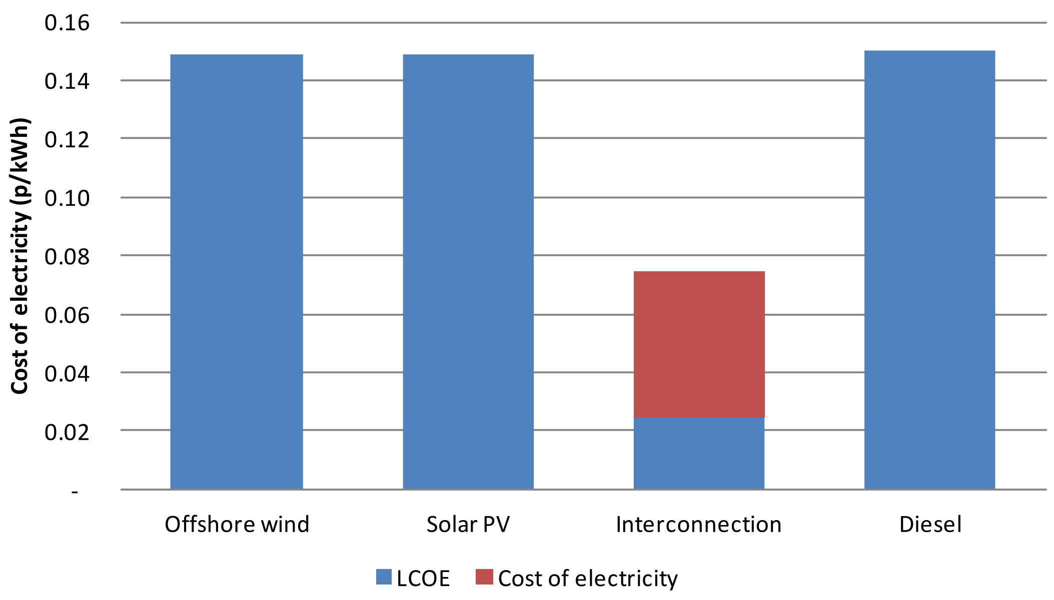

Figure 112: Comparison of the levelised costs of electricity of different power technologies

Clearly, as the technologies stand today offshore wind power and solar PV are on a level playing field with diesel. This is largely due to the expensive fossil fuel costs required for importing the petroleum product; the future of which is subject to a high level of volatility and unpredictability. That being said however, the unpredictability of the wind resource cannot be factored into the LCOE equation and despite being completely free it is offset by a high capital expenditure of £3.5 million per MW. It is important to note that these figures were derived on a 'per MW' basis and make no attempt to quantify economies of scale. As explained in the offshore wind energy chapter, both 30MW and 100MW plants have been considered. As such, it is likely the investment required would be smaller on a per megawatt basis for the larger developments.

Solar PV is comparable to offshore wind in terms of lifespan and resource, but would be more beneficial to individual house owner than as a means of centralised generation in Guernsey. As such, driving down the capital expenditure would not be as heavily based on economies of scale but rather market deployment of the technology and its associated services.

Furthermore, GEL's buy-back tariff of electricity as it stands today is not sufficient to meet the LCOE for any of the generating technologies considered above. Its current value of 9.983 pence per kilowatt hour is based on the marginal costs of electricity production and would be insufficient to incentivise RET uptake. Consequently, any large scale energy investment would need to be owned by

GEL to ensure appropriate revenue streams in the same way that the island's diesel generators are currently operated.

Contrastingly, an interconnector provides the cheapest cost of predictable electricity over the longest time span. In terms of sustainability, importing power from France would be carbon neutral and originating in a politically stable country much larger than Guernsey. Purchasing agreements can be organised on the long term market and facilitate securing a good price for energy. Indeed, according to Sally-Ann David of GEL the import prices are forecasted to remain constant up to 10 years ahead. Beyond that, the unforeseen cost of nuclear decommissioning may cause price spikes; assuming there are any.

11.3 Interconnection

Guernsey's chamber of commerce have assessed the viability of a 100MW interconnector directly to France. It would be able to provide 100% of Guernsey's power demand and cost between £70-100 million. The time horizon of the investment will dictate the 'transport cost' per unit which would be significantly cheaper than that of any generating capacity investments; between 1 and 1.5 pence per kilowatt hour.[312] Consequently it would render the electricity supply both secure and affordable, key qualities held high GEL's priorities. Furthermore, it could entirely reduce dependence on carbon-emitting diesel generation.

Consequently it could be argued that building such an interconnector would displace the need for RET altogether. The view held by RE 2013 agrees with this argument, but believes it should by no means be used to overlook the potential for renewable energy in Guernsey: an interconnector could provide long term strategic benefits of developing a new industry through export capacity. Short term securing of supplies could lead to long term energy independence coupled with revenue generation. Moreover, allowing for exports would render the business case for RET in Guernsey attractive as generators access foreign subsidies.

Recent news articles confirming a £70 million investment in transmission capacity between the France and the Channel Islands[313] is directly in line with this view held by RE 2013. Bolstering Guernsey's import capacity from 16MW to 60MW should drive down local prices as it will influence the supply ratio.

[312] (Dorey, 2013)
[313] (Channel Online, 2013)

11.4 Connecting renewable energy to the grid

During the CIEG link failure, Guernsey's electricity system demonstrated resilience and security complying with GEL's mandate; however, the issue of sustainability was called into question. The clean and carbon neutral nuclear energy imported was no longer available, diesel power contributed to Guernsey being the third largest greenhouse gas emitter per unit area in the European Economic Area and GEL's financial losses cannot be sustained in the long term. Moreover, despite being small in magnitude power blackouts experienced during the disruption had not previously occurred in 12 years[314] and localised voltage drops known as brownouts also increased occurrence at times of diesel generation.

Brownouts affect data parks' ability to store information. Due to Guernsey's large financial sector, these data parks are accountable for 20% of the island's energy supply.[315] According to Allianz insurance, 30 minute power losses can cost medium to large scale industrial clients an average of £10,400 each. Power disruptions to Guernsey's largest economic asset could therefore have detrimental impacts.

It is important to note that the paragraphs above do not imply that the introduction of renewable energy would solve these issues. On the contrary, the intermittent nature of RET introduces an element of uncertainty around forecasted resource outturn predictions. Grid balancing services, known as ancillary services (AS), will need to be introduced into the system to maintain stability.

However, these need not be expensive: prices range between 0.4 and 2.4 £/MWh across European countries and can easily be distributed within the system operating costs.[316] Furthermore, GEL's current Merit Order has developed the company's expertise at balancing grid components for frequency stability. As such, the resultant grid management costs of incorporating renewable energy onto the grid would be negligible and address security concerns.

11.5 Financing large scale wind energy

11.5.1 Impact from Offshore Wind deployment

A flexible financial modelling tool[317] has been created to explore the impact on prices based on a synthesis of the modelling work of RE 2012 and RET for Offshore Wind. This technology is currently closest to maturity for which there is greatest scope for deployment in Guernsey. Table 38 below

[314] (David, 2013)
[315] (Dorey, 2013)
[316] (Kuzle & Sabolic, 2011)
[317] Available for the Renewable Energy Team of the States of Guernsey

lists the variables chosen for the spreadsheets. Discussion of the capital and operating costs used is available in §3.

Table 37: variables used in economic modelling

Flexed variables	Low	Central	High
General Inflation	2.5%	3.5%	5.5%
Oil Price Inflation	3%	5.5%	7%
Annual Increase in Electricity Demand	-1%	2%	3%
Annual Increase in French Energy Prices	3%	5.0%	6%
Inflation Rate for GEL Electricity Price	1%	4%	5%
Decommissioning cost	£150,000.00	£-	£200,000.00
Displacement ratio (Imported electricity: diesel generation)	20:80	50:50	80:20
Fixed variables			
Project Operating Life	20 years		
GEL Electricity Price 2012	0.135 £/kWh		
Discount Rate	10%		
Repayment Period Required	15 years		
Debt Share	75%		
Interest on loan	4%		

Important to note, is the fact that this is a relatively simplistic form of modelling and that while the most accurate information available has been used, there is still uncertainty surrounding a number of external factors such as the development of the European electricity market. Consequently, the results should be considered a rough guide rather than an accurate prediction.

11.5.2 Mix of energy source displaced

Predicting with any accuracy how the current fuel sources for Guernsey's electricity will be displaced by generation from offshore wind is beyond the scope of this report. Nevertheless this is likely to be a significant consideration; therefore a range of displacement scenarios have been modelled to illustrate the sensitivity of the financial impact on electricity prices to this factor. These displacement ratios are highlighted in table 38 above.

Figure 113 shows that, only under the worst economic scenario is a 30MW offshore wind farm unlikely to return a positive NPV. This implies for the least favourable interest rates, highest capital costs, lowest price of fuel displaced and the lowest generation from wind farm to all occur simultaneously. Yet should the majority of the displaced supply originate from diesel, even in the worst case scenario will the project reach a positive NPV. This suggests that the likely outcome of investing in offshore wind will result in a saving on the costs of supplying electricity, in turn reducing the burden on end-user bills.

In the worst case, a negative NPV of no more than £50million would need to be socialised across the consumers; approximately £2.5million a year for the 20 year lifetime. However this is based on a scenario where the rise in fuel prices is much lower than predicted, meaning that any increase in price as a consequence should not be greater than that which might be anticipated at present rates of energy cost inflation.

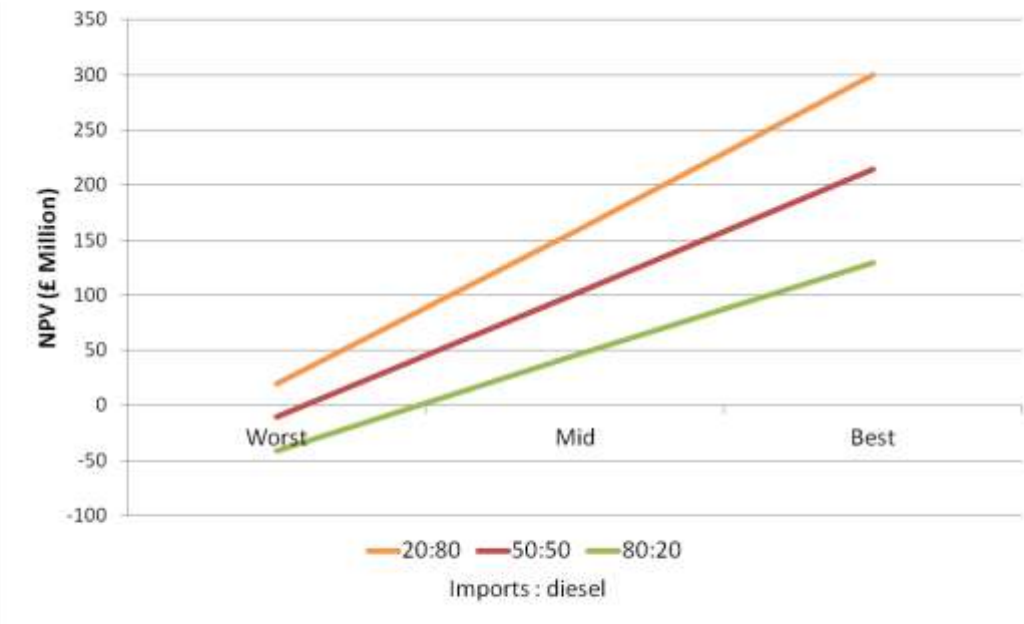

Figure 113: Graph showing impact of fuel displacement on NPV of 30MW wind farm

11.5.3 Increase in cost of electricity imported from France

So far the modelling results have assumed that the cost of imported electricity from France via Jersey remains stable and increases only with inflation given the long term contracts negotiated by GEL. Beyond this, it is not unlikely for the misrepresented cost of nuclear decommissioning or the building of new replacement power stations to cause unpredictable price fluctuations. An increase of 3p per kWh from 2023 was modelled purely to illustrate what a significant increase in the cost of imported electricity might do to the NPV of the wind project. As might be expected, this increases the viability of the wind project (Appendix D) but not to an extent that makes a marked difference to the curves of the graph in figure 113.

11.5.4 Privately financed generation and subsidy level required

The modelling detailed above only considers scenarios with GEL investing into 30MW projects as the larger 105MW project would create revenue via exports which have not been considered. An alternative set up to this would be for an independent generator to develop one of the sites.

A report by SKM[318] into offshore grid connection suggested offshore wind farms were economically attractive should the IRR exceed 12%. It is based on this assumption that the UK's Renewable Obligation quota mechanism aimed to create a market for 'clean' energy generation by forcing suppliers to source a certain percentage of their electricity from renewable energy sources. This percentage is quantifiable in terms of the tradable commodity of the Renewable Energy Certificate (ROC) and changeable year on year. Thus competition is created between conventional generators for ROCs at the risk of having to pay a punitive price for not meeting targets.

Given GEL's monopoly status in Guernsey, adopting a quota mechanism to incentive the uptake of RES-E would be turned upside down: competition would occur between 'clean' generators driving the down the cost of the clean energy certificate, in turn removing the threat of having the pay a punitive price. Given the size of the island's energy industry it can be concluded that a quota mechanism would not be successful in promoting the independent deployment of renewable energy. As such, it has not been accounted for in the economics modelling.

GEL's current buy-back price is unlikely to favour wind power investments. Thus, it could be concluded that unit revenues should be boosted to incentivise investment. Subsidies to this effect would facilitate offshore wind power development in the short to medium term until the technology matures and beyond which point they could be gradually removed. The level of subsidy required per kilowatt hour has been calculated below.

The tables below set out the average pence per kWh that would need to be paid to generators to make the projects viable at an IRR of 12%. Determining the level of subsidy Guernsey would need to offer can be determined by establishing the viable price GEL could pay for this (i.e. the buyback tariff) and then finding the difference between the two values.

[318] (Sinclair Knight Merz, 2010)

Table 38: cost of electricity likely from the 30MW offshore wind project developed by private investor

	30MW		
Case	**Worst**	**Mid**	**Best**
NPV	£107,700,000	£105,700,000	£103,200,000
IRR	11.9%	12.0%	12.0%
Payback (years)	7.4	7.5	7.8
LCOE	£0.11	£0.09	£0.08
GEL buying Price (£/kWh)	£0.095	£0.095	£0.095
Additional Subsidy Required (£/kWh)	**£0.15**	**£0.10**	**£0.05**
Total price of electricity from offshore wind (£/kWh)	£0.25	£0.20	£0.14

Table 39: cost of electricity likely from the 105MW offshore wind project developed by private investor

	100MW		
Case	**Worst**	**Mid**	**Best**
NPV	£377,000,000	£369,900,000	£361,000,000
IRR	11.9%	12.0%	12.0%
Payback (years)	7.4	7.5	7.8
LCOE	£0.11	£0.09	£0.08
GEL buying Price (£/kWh)	£0.095	£0.095	£0.095
Additional Subsidy Required (£/kWh)	**£0.15**	**£0.10**	**£0.05**
Total price of electricity from offshore wind (£/kWh)	£0.25	£0.20	£0.14

Referring to tables 39-40, the linear costs and output of the projects mean that the price per kWh is the same for both scales of offshore wind. This economic modelling is based solely on the price paid for electricity rather than the cost of imports and diesel generation displaced. In all cases a subsidy is required, but it is interesting to note that in the best case the price GEL must pay for the energy is the lower end of the current cost paid for diesel generation. This suggests that in the best case if wind generation were to replace predominantly diesel-generated electricity no subsidy would necessarily be required.

The subsidy levels required based on the relatively high buying price of 9.5p/kWh are considerable, ranging as they do from 50% to 100% of the buyback price. As it is the electricity supplier that amasses the cost of the subsidy; it is eventually recouped through being distributed evenly across all other end-user bills. In the UK, such increases in the cost of electricity are therefore distributed across over 27 million customers and therefore represent a negligible increase in per unit price. Contrastingly, in Guernsey the cost of subsidies would be shared between approximately 30 thousand customers and would therefore represent a greater rise per paying consumer. It must not be forgotten that GEL's mandate is geared toward affordability.

Avoiding subsidies may be possible based on an export price. A 105MW wind farm for example would, certainly much of the time, supply more electricity than Guernsey can use. For this to be viable, an agreeable price must be reached. Jersey's preferential access to French imported electricity and subsidies available to both French and UK wind farms mean that the price of electricity these three countries pay for 'low carbon' electricity would be substantially lower than the price identified through this modelling as necessary to attract independent generators. Consequently these potential buyers are unlikely to pay a sufficient price for the wind generation and therefore only by offering some kind of subsidy could private developers be incentivised to develop large-scale offshore wind projects.

11.5.5 Support mechanisms

However, in Guernsey's case, the subsidies need not be generated nationally. Economic modelling has not been performed for the viability of wind farms with access to the UK support mechanisms in terms of either ROCs or the Contracts for Difference (CfD) because the farm will not be developed in time to access the former and the details of the latter[319] are as yet still unknown. Should access to foreign subsidies be obtained, developments in the CfD scheme may render large scale offshore wind energy viable in Guernsey. This is examined in more detail in the policy chapter.

11.5.6 Impact of different debt ratios: independent developer

A fixed debt share of 75%, the figure used by RET in their own economic models, has been used throughout the economic modelling. With regards private investment, figure 114 below shows the effect of a range of debt shares from 65% to 85% on the IRR of the projects. The IRR decreases[320] with a greater debt share and consequently the subsidy required increases. This is pertinent because

[319] Specifically the 'strike price' that determines the exact income a generator can expect for their electricity provided they can secure a buyer.
[320] NPV also decreases

offshore wind projects are capital intense and a higher debt share than 75% may be required,[321] however, as can be seen from the graph in figure 114 that sensitivity to this factor is not great.

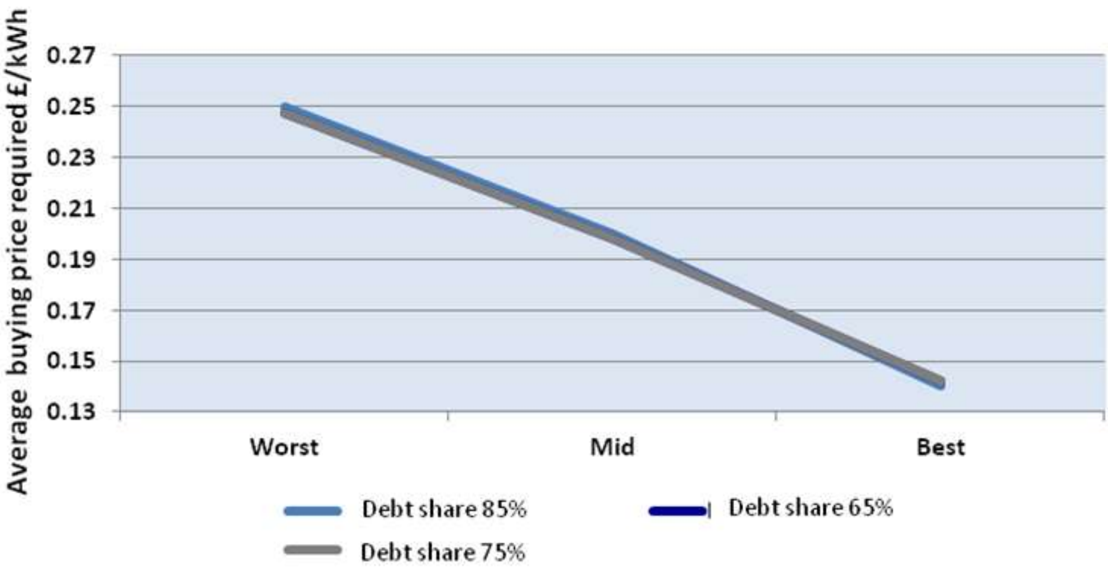

Figure 114: graph comparing average electricity price required for range of debt share

11.5.7 Impact of different debt ratios: GEL as developer

In order for the 30MW projects to return a positive NPV under all scenarios modelled and therefore remove the potential for a negative impact on consumer electricity prices completely, GEL or at least the States of Guernsey, would effectively have to provide all the equity for the project.[322]

11.6 Financing solar PV

This section of the report discusses the financial issues of installing solar PV projects and how this may affect the electricity prices on the island on Guernsey. In order to do this a number of cash flow projections accounting for a total of 1MW PV plant have been constructed.

As solar projects can be greatly variable in both their size and application three different likely situations for Guernsey were considered:

- GEL funding their own utility scale plant to add to Guernsey's energy mix
- A resident installing PV for their own use and possible grid export
- A private energy project developer installing a standalone project in order to make a profit from the generation

[321] (BWEA 2010)
[322] A 6% debt share returns a positive NPV in the worst case scenario

Clearly these three options give rise to very different assumptions and funding options. These differences and the reasoning behind them are discussed in the next section.

11.6.1 Model structure and assumptions

11.6.1.1 General assumptions

A number of model assumptions were used in all of the cash flow scenarios the table 41 states the values and reasons for their selection:

Table 40: solar PV model assumptions

Parameter	Value	Reason
Project lifetime	25 years	Industry Standard
Inflation	3.5%	Figure indicated as used by the States of Guernsey
Construction costs	£1.37M/MW	Figure from the Solar PV research group
Operating Costs	£5000/MW	Typical figure for the minimal maintenance required by such a project
Year 1 Generation Levels	1090 MWh/MWp	Figure found by the Solar PV research group based on the irradiation levels on Guernsey
Discount rate	8%	Typical

11.6.1.2 GEL funded project

In the case of the GEL funded project the two main variables were the way in which the project was funded and the estimated value of the produced energy. Historically, GEL would charge customers around 0.5% for future capital expenditure so as not to incur any debt in accordance with the State's policy of 'Save to Spend'. However with the commercialisation of GEL, recent regulatory reforms suggest charging current customers for future investments they may not benefit from as irrational and as such left GEL short pocketed and in need of external debt financing to support its latest generator acquisition. It is with this in mind that the three financial scenarios were modelled; one on the old system where the CAPEX was funded with equity, one on the new debt funded system and one at 50% debt and equity for comparison.

As the 100% debt funded scenario was most likely to be the way forward for GEL a further investigation using this assumption was made. Here the value of the produced electricity was modified. For all three runs it was taken that the value of the produced energy was equal to the cost of the obtained energy that it displaced. This is variable depending on load and production profiles the solar generation could displace the high cost diesel generation or the low cost imported energy.

With this in mind the three runs consisted of; a mixture of 80% imported and 20% generated energy (the typical energy mix), a 50% split of imports and generation and a 20% import 80% generation (it was felt this may be likely as any power on the grid should displace the expensive generation first). This method is similar to that used for the offshore wind energy modelling.

11.6.1.3 Resident projects

The Resident project cash flows were based on the evidence we had seen during multiple meetings in Guernsey and our background knowledge of PV systems:

- PV's high CAPEX is a hurdle
- The States of Guernsey are not pro-tariff if it could lead to a rise in electricity costs

With this in mind a cash neutral way for the government to help reduce the CAPEX for any Guernsey resident wishing to install a PV system themselves was found. The proposed solution was a form of soft loan. The States would pay for half of the upfront cost of the project by supplying the resident with a low interest loan that was repayable only after the initial investment of the resident had been met. This allowed for a fast payback to the consumer making the idea more attractive and the fact the loan would be paid back to the states made the idea cost neutral.

Two different levels for the loan interest rate were considered one at the estimated rate of inflation (3.5%) and one at 1% above inflation to allow for the Sates to recuperate some of the administrative cost of the loan. In either case, the investor payback period could be reduced to approximately six years.

11.6.1.4 Private developer project

The final form of project we investigated was that of a private renewables developer aiming to make a worthwhile investment from installing photovoltaic technology on the island. From previous countries' experience and due to the small nature of Guernsey's market it was decide that there should be an investigation into the level of subsidy needed to give an attractive 10% IRR. The subsidy was assumed to work like the UK feed-in-tariff and the value of the generation was taken to be the cost of energy at a 20% generated 80% imported rate as this is how GEL calculates its buyback value.

It is assumed that the developer uses "equity" to fund this project as the finance of a development company can be very complex.

11.6.2 Analysis of cash flow models

11.6.2.1 GEL funded project

Table 42 shows each iteration of the funding dependant cash flows showing the indicative NPV and IRR of the projects.

Table 41: Indicative NPVs and IRRs given different GEL financing methods

Scenario	NPV	IRR
100% Equity Funded	£159,000	9.07%
50% Equity 50% Debt Funded	£15,000	8.14%
100% Debt funded	£-65,000	7.12%

Note that the negative NPV of the 100% debt funded is relatively small compared to the initial investment and is negative due the optimistic 8% discount rate. Also an NPV of £15,000 for a project of this size and timescale is fairly negligible but again this has been discounted with the 8% figure. Below are time cash flow graphs for the projects:

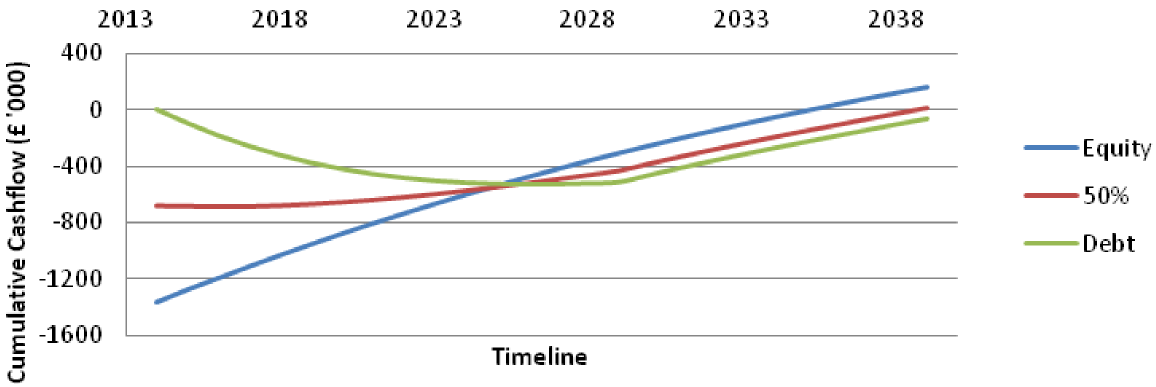

Figure 115: Solar PV cumulative cash flow

The variable energy mix displacement results are shown in table 43:

Table 42: indicative NPVs and IRRs given varying supply displacement scenarios

Scenario	NPV	IRR
80% Import 20% Generation	£-65,000	7.12%
50% Import 50% Generation	£188,000	10.63%
20% Import 80% Generation	£589,000	17.25%

IRR's over 10% are seen as favourable by most for action and an IRR of 17.25% is notably high. Note any positive NPVs in this section represent a saving for GEL customers and hence a possible passed on lowering of their bills.

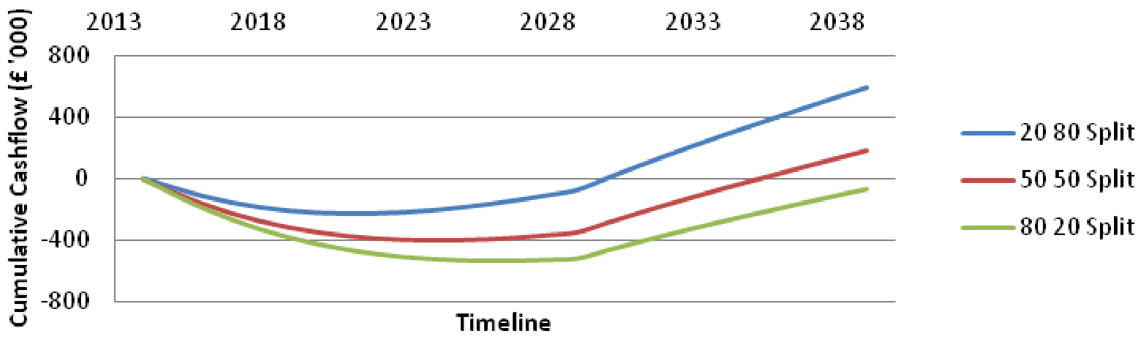

Figure 116: Solar PV cumulative cashflow varying energy displaced

11.6.2.2 Resident project

The results of the two scenarios for soft loan rates are shown below:

Table 43: Impact of soft loan interest rates

Scenario	NPV	IRR
Loan Rate at Inflation (3.5%)	£285,000	12.16%
Loan Rate at Inflation +1% (4.5%)	£180,000	10.78%

Both return good IRRs but importantly give NPVs that represent a substantial improvement over an 8% investment opportunity. The cash flow chart is shown below:

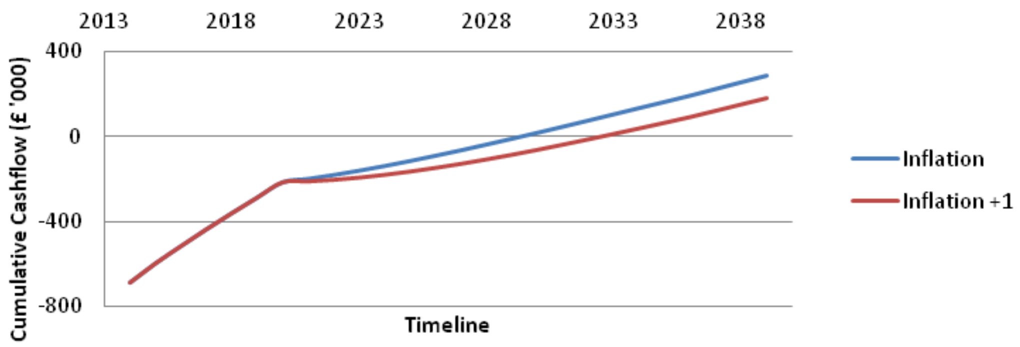

Figure 117: Cumulative cash flow varying soft loan rates

11.6.2.3 Private developer project

Assuming that the private investor uses equity to fund the investment a subsidy of 4.67p/kWh generated would be required to provide a 10% IRR and would lead to an NPV of £828,000 for the project.

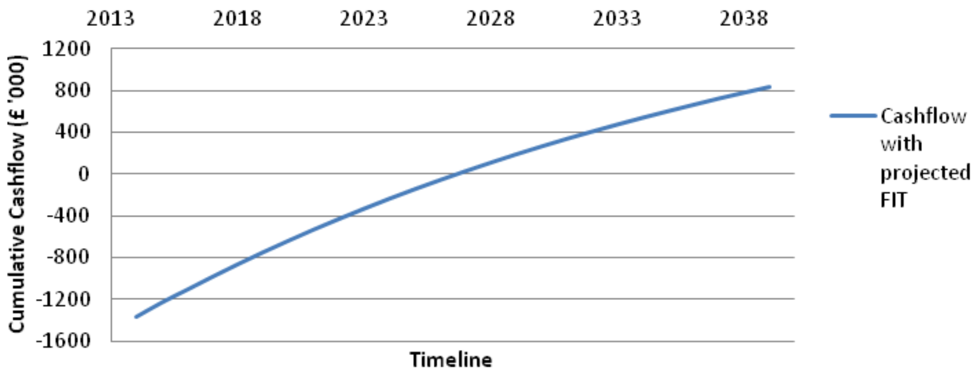

Figure 118: Cash flow with Feed in Tariff support

11.6.3 Cash flow findings for solar PV

11.6.3.1 GEL funded projects

Although the more likely 100% debt finance projects had a negative NPV at an 8% discount rate and standard energy displacement it appears to be very close to grid parity on Guernsey. In fact when the displaced energy mix is skewed more toward the diesel generation the project soon becomes profitable and as displacement of the more expensive diesel will take place whenever possible it is likely that GEL building PV projects are unlikely to add to consumer bills and could in fact contribute toward lowering them although the level of this contribution may be drowned out by the general rise in electricity prices.

11.6.3.2 Resident projects

It is clear that with a soft loan from the states of Guernsey to help with the Capital expenditure residents of Guernsey could find that installing their own projects financially viable and, under the conditions of this cash flow; they could enjoy similar IRR values as some installations in the UK.

However the generation values used in the model are favourable given the assumed correct azimuth and pitch, also micro generation may prove to have a higher capital expenditure per kilowatt than that used in the calculations. However, this would likely be balanced out by the fact that much of the generation would not simply have the GEL buyback value but rather the value of the displaced electricity the resident would have used. On Guernsey this can be up to 50% higher than the buyback price and hence would contribute very favourably to the cash flow scenario.

11.6.3.3 Developer projects

The subsidy level suggested by these cash flows is not dissimilar to those found in the UK and does give a good IRR for such a project. However, the problems with planning and relatively few viable development areas on the island may lead to developers having relatively low penetration and hence the subsidy may end up paying only one or two projects where the administration and set up fees could render it a fairly expensive system.

11.7 Conclusions and recommendations

The overall impression gathered by the RE 2013 team in Guernsey suggests there is interest in renewable energy as a sustainable, carbon neutral and domestically secure source of power. Yet these views are heavily counterbalanced by the intermittency and expensiveness of the technologies.

While interconnection would prove the cheapest option to secure long term clean power and provide a founding platform upon which Guernsey could develop its energy industry, events such as the failure of the CIEG link of 2012 emphasise the need for domestic resilience. The introduction of renewable energy could facilitate this process but their economics are not currently favourable in Guernsey.

The effect of large-scale deployment of RE on local energy prices will be dependent on a number of factors. Most pertinently the exact mix of RET deployed, the mix of energy displaced, the financing methods and agreements and finally the level of incentive available are all likely to influence end user unit costs.

As such, the economics team's recommendation suggests designing a pathway which focuses on interconnection in the short term and generation technologies in the medium to longer term when the capital costs of currently state-of-the-art technologies are driven down. Secondly, it is clear subsidies will heavily impact consumer prices and are opposed by both GEL and the state. Consequently, supporting generation through access to foreign subsidies in exchange for green credentials will boost revenue and incentivise investment. Finally, it may be possible to instigate the uptake of smaller scale solar PV by reducing the upfront capital cost of the purchaser through the use of soft loans paid back over the lifetime of the installation.

12 Recommended Energy Strategy to 2050

12.1 Opportunity

Guernsey has the opportunity to analyse the success and failures of energy strategies developed by other countries; then incorporate the most effective solutions to minimise risk and cost. Guernsey is also blessed with a variety of significant renewable energy resources and is very lucky to have such options at its disposal.

12.2 Other Island Case Studies: Jersey

12.2.1 Opportunity

Both Guernsey and Jersey are signatories of the Kyoto Protocol, through the UK, and therefore have a target of 80% emissions reduction by 2050 (compared to 1990 levels).[323] The Islands are also particularly vulnerable to changes to patterns of temperature, rainfall, sea levels and storminess associated with climate change[1] as well as the risk of nearby French nuclear plant failure. The risks to Jersey and Guernsey associated with Climate Change are explored in the 'Turning Point'[324] and 'Planet Guernsey'[325] studies respectively. The 'Jersey Stern Review' into the economic impact of climate change on Jersey, overseen by the Energy Partnership, is due to be completed by 2020.

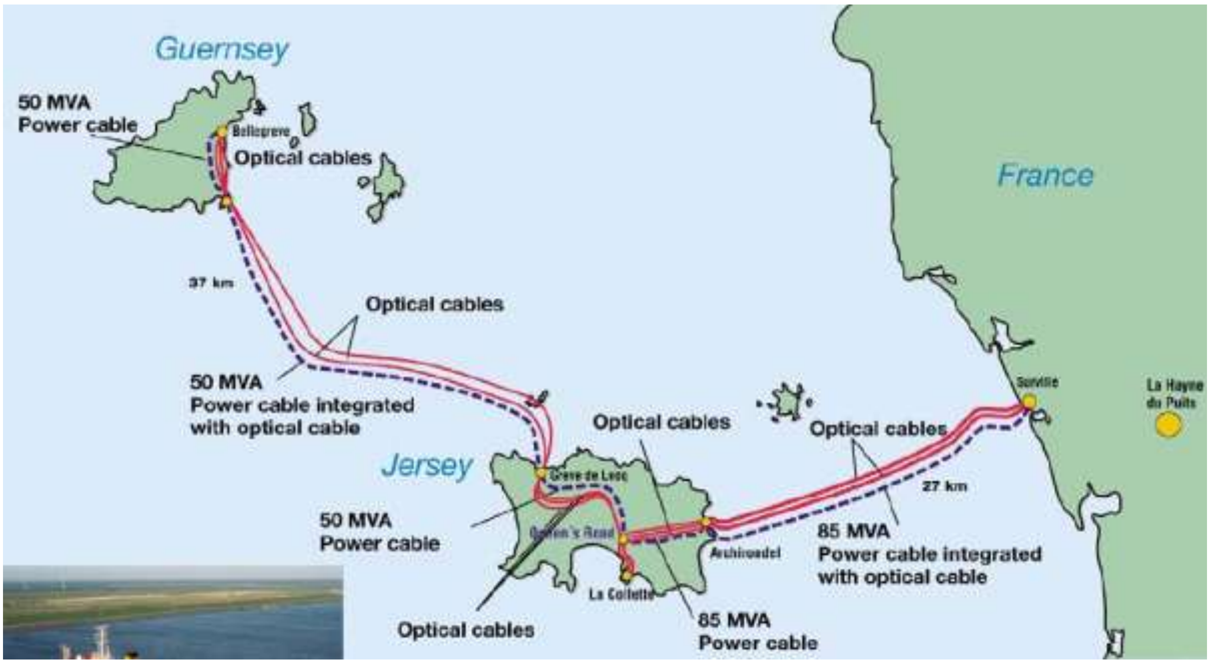

Figure 119: Channel Islands Electricity Grid Project

[323] (States of Jersey, 2012)
[324] (Eco-Active, 2009)
[325] (Casebow, 2007)

Jersey has been connected to France since 1984 and, since November 2000, Guernsey was added through the CIEG joint venture to import electricity from France; guaranteed to be low carbon until 2023. Increasing electricity imports contributes to Jersey's carbon reduction as carbon accounting is based on produced, rather than consumed capacity. The 28% reduction on 1990 levels achieved by 2012 was largely due to the switch from local hydrocarbon based electricity generation to imported electricity.

However, any reliance on imports leaves both Jersey and Guernsey susceptible the cost and impact of interruptions in global supply, international price volatility and local breakdowns in the supply chain, such as the cable failure in 2012.[326]

Guernsey is only guaranteed 16MW from the interconnector, and otherwise relies on expensive hydrocarbon based fuel, especially for peak demand, for which there is limited storage space. This reduces energy security and therefore encourages demand reduction and the investigation of alternative fuel sources.

12.2.2 Jersey's Pathway to 2050

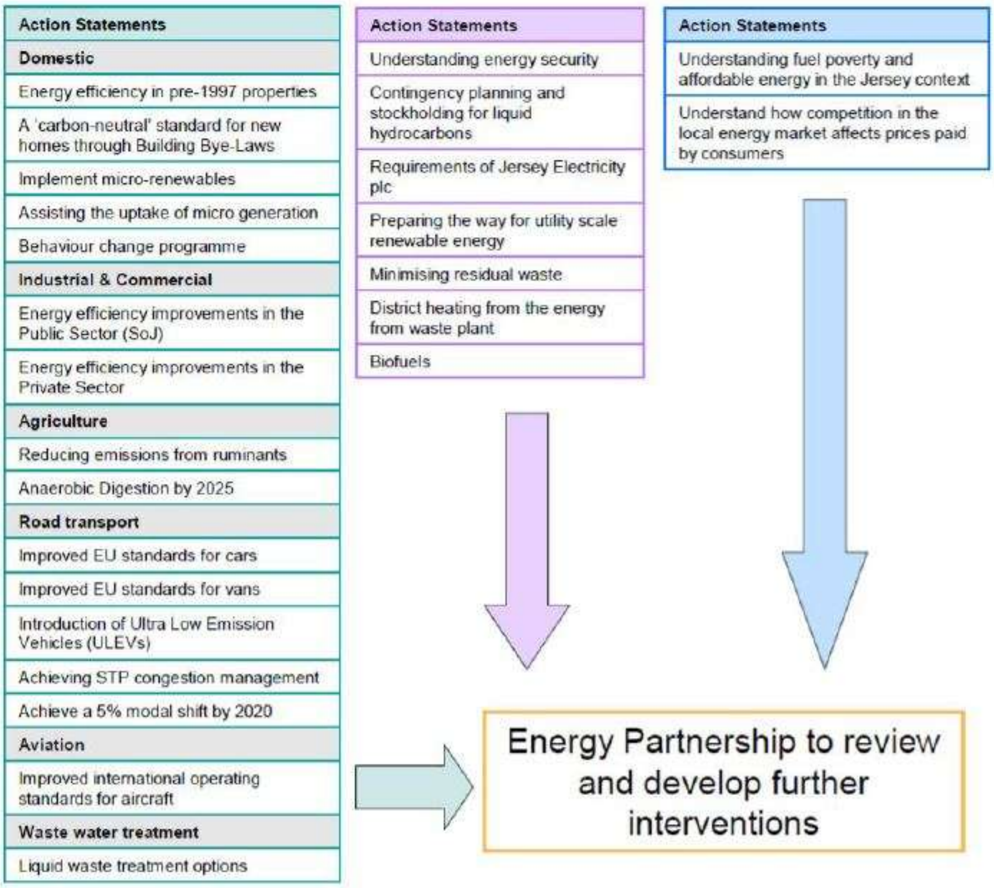

Figure 120: Jersey's pathway to 2050 outlined in the Energy Plan 2012

326 (ABB, 2000)

The 2012 Energy Plan expresses Jersey's strategy to 2050 and highlights three policy focus areas: energy demand reduction (green), increasing energy security through utility scale renewable energy projects (purple) and investigations into energy affordability and fuel poverty (blue) (figure 120).

A compromise between energy security, affordability and sustainability is needed to avoid increasing fuel poverty due to the cost to islanders of increasing stockholdings or deploying renewables.

12.2.2.1 Energy Efficiency

In order to meet the emissions reduction target Jersey must reduce energy consumption by 10% between 2012 and 2015 and 15% by 2020. Initially this is to be achieved through increasing energy efficiency and promoting sustainable transport.

Energy efficiency in the domestic, industrial and commercial, and agricultural sectors is projected to contribute 30, 20 and 5%, respectively, of total emissions savings to 2050.

86% of buildings were constructed prior to the 1997 Building Bye-Laws and so are less energy efficient, 50% of these use hydro-carbons (oil or gas, or solid fuel) for space and water heating, the remaining use electricity. The Energy Partnership is working to define local fuel poverty, identify vulnerable groups and develop strategies to provide affordable warmth.

The Energy Efficiency Service was established in 2009 and is overseen by Jersey Energy Trust with advice from the UK Energy Saving Trust. A free advice service and two grant-funded States-run schemes are offered: the 'Home Energy Scheme' and 'Community Buildings Programme'.[327] The former is allocated on income and/or age based criteria, the later provides energy efficiency assistance to charities and not-for-profit organisations serving vulnerable community members. The Eco-Active Business (EAB) service has a self-assessment toolkit for environmental improvements with the aim of increasing EAB's from 150 to 500 between 2012 and 2020 and increase by 500 in each subsequent decade to 2050. The EAB's are required to reduce demand by 10% per decade between 2020 and 2050.

In 2011 the Building Bye-Laws were updated to include energy performance certificates and encourage incorporation of low carbon systems. The Island Plan 2011 and Energy Plan 2012 aim for a 60% improvement on 2011 standards by 2014 and a 'carbon-neutral' standard for new homes, in respect to heating, by 2018. From 2030 hydrocarbon fuelled space and water heating with micro-renewable systems supported by electricity back-up will be employed with a pilot scheme from 2015-2020.

[327] (States of Jersey, 2012b)

59% of emissions from the agricultural sector are from enteric fermentation, this is to be reduced by 30% by 2030 through improvements in diet, genetics and husbandry. The other 41% is from slurry of which 50% will be used in Anaerobic Digestion (AD) by 2020 increasing to 100% by 2030. The potential for food waste to be treated in this way is also being investigated. Targets will be set for liquid waste by 2015 with an appraisal of treatment options by 2020.

In 2011 a new £120m Energy from Waste (EfW) plant began operating.[328] The potential for district heating from the EfW plant is being explored as part of the review of the Solid Waste Strategy completed by 2014. A feasibility study for the local production of biofuels from waste vegetable oil is due by 2020.

By 2020 all new cars and vans registered with Driver and Vehicle Standards should comply with the EU emissions standards of 95g/CO_2/km and 147g/CO_2/km respectively and by 2030 all vehicles should conform to this standard with a shift to ultra-low emissions vehicles, in line with the UK Carbon Plan 2011 of 10% of new cars by 2020, 30% by 2030, 60% by 2040 and 90% by 2050. Jersey's Sustainable Transport Policy aims to reduce peak time travel by 15% by 2015 and to reduce annual mileage by 5% by 2020 through encouraging school and workplace travel plans, cycling, walking, use of public transport and working from home. Jersey aims for early compliance with the International Air Transport Association target of 50% reduction in emissions by 2050, relative to 2005 levels, by achieving 15% by 2020 and 50% by 2030.

12.2.3 Opportunities

In future Jersey can use its financial and administrative expertise and infrastructure to participate in carbon markets by administering the international financial instruments and vehicles required due to the cost of negative externalities.

12.2.4 Summary

Research due to be completed by 2025 is being conducted into the comparative risks and costs associated with reduced security of supply and the deployment of an on and off shore renewable energy infrastructure including any impact on affordability.

In order to engage government, industry, business, Non-Government Organisations and communities an Energy Partnership is being appointed to include stakeholders from each sector to advise, coordinate, monitor, review, develop and commission new policy interventions as appropriate.

[328] (ECO-ACTIVE, 2011)

Jersey aim to meet their emissions reduction targets by: reducing demand, using low-carbon and renewable sources - where they can be justified on the ground of energy security and sustainability encouraging synergies with dual benefits such as AD.

12.3 Other Island Case Studies: Samsø

Figure 121: Samsø Island in Denmark[329]

The introduction of a scheme for turning islands into the pinnacle of RE technologies development is everything but new. In 1997, following the RE development scheme in the country, the Danish government initiated a contest for turning one of its islands into "Denmark's renewable energy island." Boroughs and municipalities were invited to put forward proposals and compete against each other. A small landmass by the name of Samsø won the contest. The Danish island, with an

[329] (Fauziah, 2012)

estimated population of 4,300 people and a territorial extension of 114km^2, was expected to convert all its energy supply into 100% renewable energy within 10 years, but completed in 8 years.[330]

This island does not stand out for its energy usage. Samsø's electricity demand is approximately 27GWh, and the main energy-consuming sector is agriculture.[331] Figure 122 shows the number of employed islanders per sector. The RE projects (wind farms, district heating plants and renewable energy installations in private buildings) also have an important role in the employment sector for the area.

	1995
Farming, fishing and extraction of minerals[1)]	401
Public administration	80
Social- and healthcare[2)]	361
Teaching[3)]	140
Production companies[4)]	220
Trade, hotels and restaurants[5)]	300
Transportation, post and telecommunication	180
Services	100
Building and construction[6)]	120
Financing and business services	100
Occupation in total	**2002**

Figure 122: Employed individuals in Samsø[332]

12.3.1 The renewable energy project

By 1997, the island was entirely dependent on oil and coal, which were imported from the mainland[333]. Since 2003, Samsø has been self-sufficient and by 2009 the island achieved 140% self-sufficiency on RE. 11 Onshore wind turbines generate 100% of the islands electricity demand. 70% of the heating demand is generated through renewable energy sources (mainly solar power and biomass); the remaining 30% is produced through oil burning, but compensated by 10 offshore wind turbines, with a generating capacity of at least 2 MW each.

330 (Saastamoinen, 2007)
331 (Dua, Manwell, & McGowan, 2008)
332 (Jørgensen, 2007)
333 (Alves, Costa, & Carvalho, 2000)

Name	Year Erected	No. of Turbines (1 MW)	Total Annual Production	Total Price (USD)	State Guarantees	Owners
Tanderup	2000	3	7,600 MWh	$3.6M	$0.12/kWh for first 12,000 full load hours and $0.086/kWh for first 10 years	Wind cooperative owns one, and the other two are privately owned.
Permelille	2000	3	7,600 MWh	$3.6M	$0.12/kWh for first 12,000 full load hours and $0.086/kWh for first 10 years	Wind cooperative owns one, and the other two are privately owned.
Brundby	2000	5	12,700 MWh	$6M	$0.12/kWh for first 12,000 full load hours and $0.086/kWh for first 10 years	All five are owned by private investors.

Figure 123: Samsø's onshore wind farms[334]

12.3.2 Key points in the project

The most important points highlighted by the project are the following:

- Cuts in consumption and increased efficiency in terms of heat, electricity and transport by the introduction of the most up to date technologies and adjusting people's behaviour towards energy use
- Expansion of district heating supply systems combined with local sourced biomass resources
- Expansion of individual heating systems, through use of heat pumps, solar heating and biomass plants
- The construction of onshore wind farms to cover electricity production
- Gradual conversion of the transport sector from petrol/oil power to electrical and hydrogen powered means of transport

12.3.3 Program focus

The project did not receive any important economic benefits or direct assistance from the government. The solution was to participate in local meetings, and bring up the RE project in them, as well as supporting the island's local opinion leaders. The method taken by Søren Hermansen, project leader, to convince the Samsingers was to approach the people not only as citizens, but also as consumers, household owners and property owners.

[334] (EDIN, 2011)

12.3.4 Design of the program

The plan was based on a vision that the project should be approached by a bottom-up method and assuring citizen involvement right from the start of the project. It was a rather loosely organised project, where the ideas and methods evolved along the way.[335]

As mentioned previously, a key factor for the success of the program was Hermansen's support from the island's opinion leaders; as people started to get involved and become more active, others started to follow. To incentivise public involvement, invitations were made to citizens for participation in the development and planning of the work, choosing technologies, make financial investments. The aim of these actions was to make citizens feel involved and have "ownership" of the developed solutions.

The involvement of the local media was used in favour of the program; through it, a good level of communication was accomplished, that included regular releases with progress and status reports about the project.

12.3.5 Investment and job creation

A total investment of €53.3 million + €4 million in public subsidies was needed to achieve the program's goal of energy self-sufficiency. Regarding citizen's involvement, the onshore wind farms include 5,400 shares, owned by 450 Samsingers. Between 1998-2007, this investment generated a number of jobs equivalent to 20 times the employment creation rate of 1997. All of this reflects in a GDP per capita figure of approximately US$791,000 in Samsø.[336]

12.3.6 Progress timeline

- 1997: Samsø Energy and Environmental Agency creation
- 1998: Samso Energy Company Established
- 2000: 11 onshore wind turbines erected in 3 different locations
- 2003: 10 offshore wind turbines erected in the south coast of Samsø
- 2004: New renewable energy heating plant to supply heat for 6 villages through district heating
- 2005: 100% of electricity and 70% of heat demand through renewable energy resources achieved
- 2007: Samsø energy Academy created

[335] (Saastamoinen, 2007)
[336] (Saastamoinen, 2007)

- 2021: 50% of local cars consist of electric vehicles. 30% reduction in heat consumption in private buildings/ 5% reduction for business
- 2030: 100% electricity or gas a propellant for ferries. 80% of local cars consist of electric vehicles
- 2050: 100% of local cars consist of electric vehicles. 35% reduction in heat consumption in private buildings/ 10% for business

12.3.7 The product

- Onshore wind farms → Electricity generation of ~28GWh/yr (630 households per turbine). When excess is generated, the electricity is exported to the mainland
- Offshore → Generation of ~77.5 GWh/yr and designed for offsetting the CO_2 footprint of oil fuelled transportation. Exported to the mainland
- District heating plants → 6.8 MW between the 4 woodchip & straw existing heating plants, including 2500m^2 of solar powered panels

12.4 Lessons for Guernsey

Samsø's success and failures in the projects' life can be of great value for the implementation of an RE scheme in the States of Guernsey. Territorial extension, as well as population density is extremely different in the two scenarios. Economic activities also pose as a crucial difference between the two isles and reflect in energy demand: energy demand per capita in Samsø lies around 2.6 kW[337] per capita compared to the one of Guernsey.

On the other hand, although Samsø (before its energy independence) and the States of Guernsey share some similarities, such as reliance on imports of oil derivatives for electricity generation and an electricity interconnector with continental land, there is a key factor that renders the application of the same energy plan unwise: land availability. Guernsey is highly populated and the implementation of onshore RE projects is virtually impossible due to this factor.

The conclusion, then, lies on the lessons learned from the Danish project. The two main lessons learned from the Samsingers project are a bottom-up approach with citizens' involvement right from the beginning of the project and the creation of citizens' ownership of project initiatives and final solutions. This is reflected in the achievement of the plan's goal two years ahead of time and the erection of multiple wind farms as well as new district heating plants to produce 70% of the total heat consumption through RE technologies.

[337] (Saastamoinen, 2007)

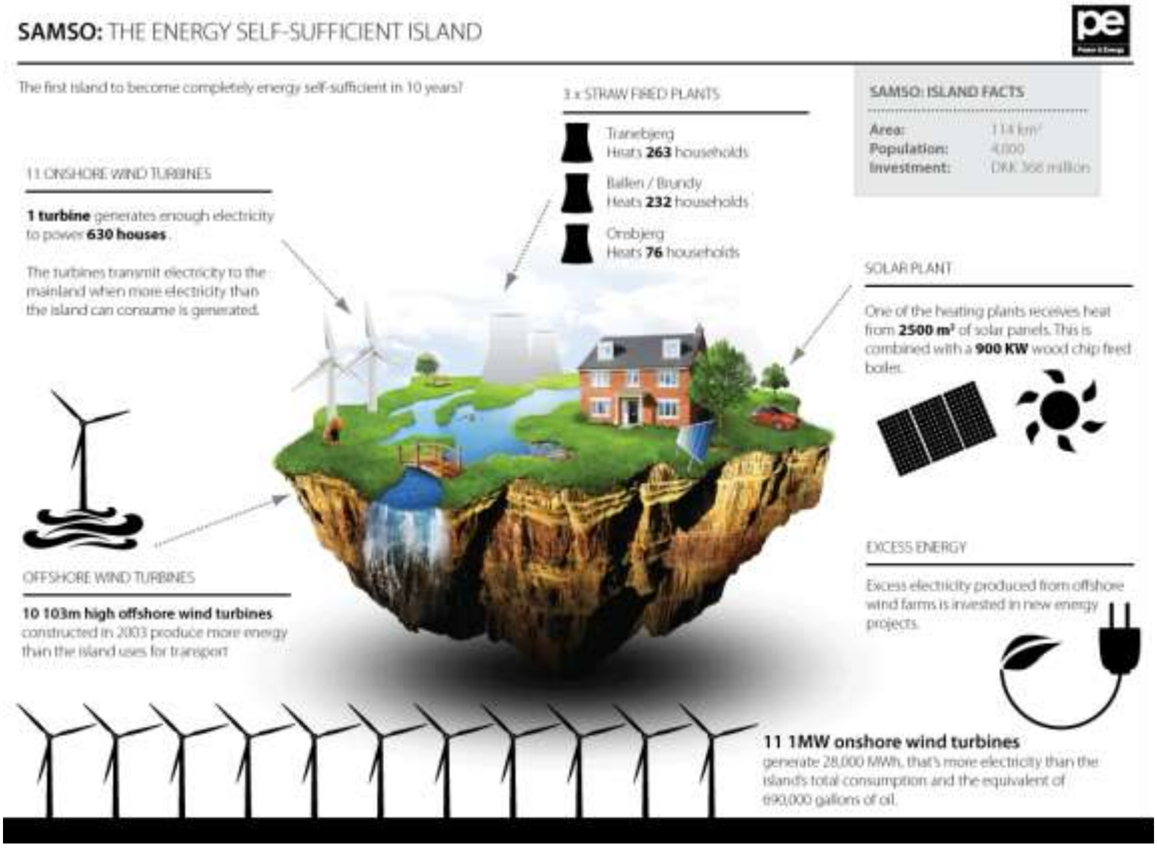

Figure 124: Samsø's energy representation

12.5 Expected Impacts of Shale Gas

The shale gas boom in the USA has dramatically decreased natural gas prices, helping to boost the economy both low energy prices and the resulting employment opportunities. Indeed, it is estimated that over 1 million manufacturing jobs could be created over the coming decades.[338] In combination with low consumer energy bills, this is an attractive solution and one that should be explored to identify the possible implications on energy strategy.

12.5.1 Shale Gas Extraction Concerns

Social and environmental concerns have been raised with regard to shale gas extraction to include:

- Will burning shale gas hinder progress toward achieving UK and European carbon emission reduction targets
- Will investment in shale gas reduce investment in renewable energy technologies
- Will drilling for shale gas cause earth tremors
- Will the extraction process contaminate the environment and / or drinking water supplies

[338] (PwC, 2011)

Until these questions are answered, it is predicted that European shale gas extraction shall be somewhat limited.

12.5.2 UK and European Shale Gas Extraction

There are a number of critical differences between the USA gas markets and those applicable to Guernsey:[339]

- Europe is more densely populated
- Drilling infrastructure is inferior to the USA
- Mineral rights: The USA is unique in that the landowner owns the rights to the minerals beneath ground level. This is not true for gas in many parts of Europe
- Differing environmental regulations

Based on this, it is not expected that the Guernsey and rest of Europe will experience the same financial and employment benefits as seen by the USA.

In conclusion the price of gas in Guernsey is likely to remain unaffected by the shale gas resources in Europe and the USA.

12.6 Recommended Pathway to 2050

It is impossible to accurately predict the trajectory of the numerous inter-twining trends that will occur in the energy sector over the next 40 years as price shocks and market-shifting innovations are both likely to occur. However, based on the assumptions and resultant conclusions in each section of this study, this chapter outlines one strategic pathway to a diverse and secure energy portfolio in 2050.

There are, of course, a wide range of possible pathways; each with different economic, environmental and social impacts. The path taken will be largely dependent on the relative weight assigned to drivers such as carbon reduction, price security and energy independence, and other influences such as cultural heritage and visual impacts. All these shape Government policy, which is a natural starting point.

12.6.1 2013 – 2020

Policy initiatives should be established as soon as possible to address low-hanging fruit at minimum cost to the State. Proposals such as the *Sarnia Scheme* outlined in §10 to increase energy efficiency

[339] Reports by Deutsche Bank and KPMG

at zero capital cost to electricity customers should be initiated in the very near-term to make future energy transitions as effective as possible.

Other schemes such as the fuel-credit trading system can also be implemented relatively quickly to increase the use of high-efficiency cars and encourage a shift away from cars to travelling by bike and foot. This not only reduces reliance on imported fuel but helps to solve the social and environmental challenges that significant car use forces on residents.

The first large-scale renewable energy solution, now financially viable, is a 500kW solar PV array at the Airport. As more large scale renewable energy projects become feasible, more significant efforts to survey the baselines of environmental key performance indicators surrounding possible sites for development are required. This can help strengthen the case for policy reform and aid the smooth development of renewable energy projects as grid parity is achieved, most likely in the period 2020-2030.

12.6.2 2020 – 2030

An onshore 225kW wind turbine at Chouet is a viable investment at the time of writing, with no support structure in place, but previous attempts at onshore wind on Guernsey has encountered opposition from certain demographics. However, a careful approach with lots of public engagement and community finance options could mean that, by 2020, this is a socially accepted project.

In addition to generating clean power for a relatively small number of homes, an onshore wind turbine could help educate and relax the public about the possibilities of an offshore wind farm. The costs of offshore wind are decreasing rapidly and the economics are likely to become quite favourable by this time; with plenty of opportunity to progress through planning, stakeholder consultation, environmental impact assessments and other prior requirements.

Further work should be done to progress the development options for the offshore wind sites identified. Consultation with DECC should continue regarding joint finance with a view to benefitting from the UK's support scheme for offshore wind, which would be the FiT CfD during this period.

If accessing UK financial support is successful then the significant tidal stream resource should be pursued to provide a reliable, and in some cases constant, clean energy source with no visual impact. If access to this support is not available then the exploitation of both resources is still possible but is likely to be delayed until experience pushes costs further down the learning curve.

Large scale development of renewable electricity generation infrastructure should ideally be coupled with large scale energy storage solutions. The technical feasibility of pumped hydropower has been indicated, but further research and consultation is required to ensure that the development has no significant negative ecological, visual or other environmental impacts. However, even then, the energy capacity and power rating is likely to be too small to entirely complement the possible offshore wind and tidal stream developments so other options such as an interconnector become attractive.

A direct interconnector to France allows the export of excess renewable electricity, reducing the need for large scale storage solutions such as pumped hydropower. In addition, the interconnector would have a significant positive impact on energy security as it increases import capacity, bypassing Jersey.

The cleaner electricity portfolio with enhanced security also strengthens the case for displacing conventional vehicles with electric ones, the cost of which will have decreased with performance continually improving. This could be driven through policy incentivising the uptake of electric vehicles, such as the continued use of the fuel credit trading scheme, low-cost capital loans and greater charging infrastructure.

12.6.3 2030 – 2040

The increasing use of electric cars is likely to increase base load demands and whilst it should be possible to cover this through the new interconnector, additional security and export potential could be gained through developing a geothermal power plant. Alongside generating around 10MW of electrical power, a heat distribution network could also utilise the recoverable heat. However, the additional cost to consumers when the existing interconnectors are likely to suffice may result in opposition.

Similarly, energy security could be further increased through the use of vanadium flow batteries and cryogenic energy storage solutions, but consumers may fight any resultant increase in energy cost if they view the interconnectors as secure enough. Indeed, such energy storage solutions may not be required at all if electric vehicle uptake is significant and a smart grid is developed.

12.6.4 2040 – 2050

A smart grid allows the batteries in electric vehicles to be used to balance the grid in a number of ways and provides a superb synergy with variable electricity sources. Although it is anticipated that this is a long term goal, RET should pursue it and carefully track smart grid developments around the world.

A number of hydrogen-based solutions could also become attractive as developments are made in its storage and/or transport as it can be used as a viable method of energy storage that can complement all uses of energy: electricity, heating and transport.

12.7 Closing Remarks

This report has showcased a range of opportunities and explored energy solutions that can create a diverse, secure and low carbon energy system over the coming decades, as illustrated by figure 125.

Figure 125: A comparison of the current and potential diversity in energy solutions now and in 2050

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14 Appendix

14.1 Appendix A - Tidal

14.1.1 Victoria Marina: rough order calculation

Assumptions:

Surface area = 16,000m^2

Tidal range = 5m (approx)

Tidal period = 12.4hrs

t_g (half tidal period) = 6hrs

Density sea water = 1023kg/m^3

g = 9.81ms^{-2}

Revenue = £45/MWh (approx)

Available winter only:

Assume turbine efficiency: 0.3

14.1.2 St Saviour Reservoir: calculation

Assumptions:

Head = 19m

Large body of water implies zero velocity at surface

Internal pipe diameter = 0.25m

Bernoulli, head form:

,

Therefore rearrange to give:

However this is the potential capacity; in reality the flowrate will be determined by the treatment works. This has a nominal capacity of 10 million litres per day or $0.12m^3s^{-1}$, but will vary according to demand. As stated, unrestricted flowrate is estimated to be $0.95m^3s^{-1}$.

Reviewed potential:

14.1.3 Havelet Bay: rough order calculation

Assumptions:

Surface area = $450,000m^2$ Wall length = 2.8km Cost/km = £72,200,000/km

Tidal range = 6m (average) Total cost = £202,160,000

Tidal period = 12.4hrs

t_g (half tidal period) = 6hrs

Density sea water = $1023kg/m^3$

g = $9.81ms^{-2}$

Revenue = £45/MWh (approx)

–

Assume turbine efficiency: 0.3

By comparison, La Rance has a basin area of 22.5km^2 which is 50 times greater than the area indicated for Havelet. An area this size would give a flowrate of 3125m^{3}s^{-1} with the tidal range at Havelet.

14.1.4 Cobo Bay: rough order calculation

Assumptions:

Surface area = 8,100,000m^2 Wall length = 10.5km Cost/km = £72,200,000

Tidal range = 6m (average) Total cost = £758,000,000

Tidal period = 12.4hrs

t_g (half tidal period) = 6hrs

Density sea water = 1023kg/m^3

g = 9.81ms^{-2}

Revenue = £45/MWh (approx)

Assume turbine efficiency: 0.3

14.1.5 Beaucette Marina: rough order calculation

Assumptions:

Surface area = 14,400m^2

Tidal range = 6m (average)

Tidal period = 12.4hrs

t_g (half tidal period) = 6hrs

Density sea water = 1023kg/m^3

g = 9.81ms^{-2}

Revenue = £45/MWh (approx)

Assume turbine efficiency: 0.3

14.2 Appendix B - Solar

14.2.1 References for variable values and assumptions

General inflation and electricity price inflation based on data from Economic Modelling group.

Electricity price tariffs and export rate based on GEL rates from 1st October 2012 [340]

Module performance and cost based on a Solarworld Plus SW250 Mono Black Solar PV Module [341] [342]

SMA 3600TL-21 inverter price £820.00 [343]

SMA 7000TL Sunny Mini-Central inverter price £1,595.62 [344]

SMA 11000TL-10 inverter price £1,726.00 [345]

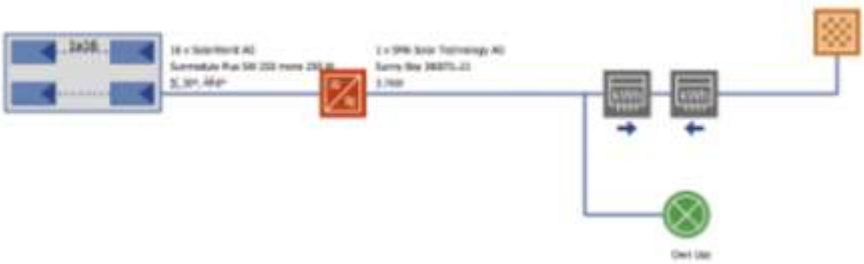
SMA 20000TL inverter price £3,551.75 [346]

All other prices calculated using information provided by IRENA [347] and e-Si [348]

[340] (Guernsey Electricity, 2012)
[341] (Urban Energy, 2013)
[342] (Solarworld, 2013)
[343] (Urban Energy, 2013)
[344] (Solar Trade Sales, 2013)
[345] (UK Solar Shop, 2013)
[346] (Solar E-Store 2012)
[347] (IRENA, 2013)
[348] (E-Si, 2013)

14.2.2 Residential PV case study PV Sol system report

Demand profile of residential building has not been modelled.



Location:	GUERNSEY AIRPORT	
Climate Data Record:	GUERNSEY AIRPORT	
PV Output:	4.00	kWp
Gross/Active PV Surface Area:	26.83 / 26.88	m

PV Array Irradiation:	35,502	kWh
Energy Produced by PV Array (AC):	4,436.8	kWh
Energy to Grid:	4,436.8	kWh
Direct Use of PV Energy:	0	kWh
Energy from Grid:	17.1	kWh
Yield Reduction Due to Shading:	0.9	%

System Efficiency:	12.4	%
Performance Ratio:	83.7	%
Inverter Efficiency:	93.1	%
PV Array Efficiency:	13.4	%
Specific Annual Yield:	1,105	kWh/kWp
CO2 Emissions Avoided:	3,921	kg/a

The results are determined by a mathematical model calculation. The actual yields of the photovoltaic system can deviate from these values due to fluctuations in the weather, the efficiency of modules and inverters, and other factors. The System Diagram above does not represent and cannot replace a full technical drawing of the solar system.

14.2.3 Residential PV case study economic variables for base case

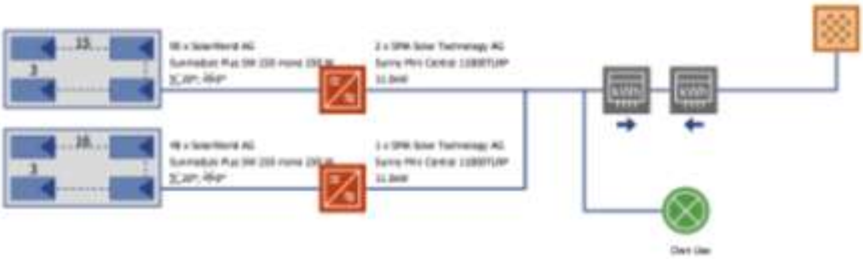
Table 44: Financial Model for PV Case Study – Residential Base Case

Variable	Value
Inflation	3.5%
Project discount rate	5.0%
Electricity price (£/kWh)	0.176815
Electricity price inflation per annum	5.2%
Export tariff (£/kWh)	0.0983
Export tariff inflation per annum	2.0%
Import duty	3.30%
Transmission use of System Charge per kWh	0
System Specification	
Number of panels	16
Panel rating (W)	250
Panel performance degradation 1st year	3.00%
Panel performance degradation 2nd-25th year	0.70%
System rating (W)	4000
Number of inverters	1
Inverter lifespan	12.5
System performance	**(kWh)**
Energy generated by system	4,436.8
Energy consumed by load	2,218.4
Energy exported to grid	2,218.4
System costs	**(£)**
Module cost	145.20
Inverter	820.00
Total initial inverter cost	820.00
Inverter replacement	820.00
System design	523.60
Site preparation and installation	2,014.00
Project management and procurement	285.60
Module support/mounting	1,224.00
Wiring	544.00
Logistics	400.00
Additional cost / contingency	500.00
BoS costs	6,311.20
Import duty fee	162.07
Module cost	2,323.20
Total system cost	8,796.47
Cost per watt installed	**(£/watt)**
System cost per watt	2.20
Module cost per watt	0.58
BoS cost per watt	1.58

14.2.4 Residential PV case study 25 year base case cash flow

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Totals
Capital Expenditure (£)	8,796	0	0	0	0	0	0	0	0	0	0	0	0	1,239	0	0	0	0	0	0	0	0	0	0	0	0	**10,036**
Cumulative Capital Expenditure (£)	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	8,796	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	10,036	**10,036**
New Capital Allowances in Period (£)	352	0	0	0	0	0	0	0	0	0	0	0	0	103	0	0	0	0	0	0	0	0	0	0	0	0	
Total Capital Allowances in Period (£)	0	352	352	352	352	352	352	352	352	352	352	352	352	352	455	455	455	455	455	455	455	455	455	455	455	455	**10,036**
Annual Output from System (kWh)		4,437	4,304	4,274	4,244	4,214	4,184	4,155	4,126	4,097	4,069	4,040	4,012	3,984	3,956	3,928	3,901	3,873	3,846	3,819	3,793	3,766	3,740	3,713	3,687	3,662	**99,822**
Electricity Supplied to Grid (kWh)		1,418	2,152	2,137	2,122	2,107	2,092	2,078	2,063	2,049	2,034	2,020	2,006	1,992	1,978	1,964	1,950	1,937	1,923	1,910	1,896	1,883	1,870	1,857	1,844	1,831	**49,111**
Electricity Exported to Load (kWh)		3,018	2,152	2,137	2,122	2,107	2,092	2,078	2,063	2,049	2,034	2,020	2,006	1,992	1,978	1,964	1,950	1,937	1,923	1,910	1,896	1,883	1,870	1,857	1,844	1,831	**50,711**
Energy Bill Reduction (£)		534	400	418	437	456	477	498	520	543	568	593	619	647	676	706	738	771	805	841	878	918	959	1,001	1,046	1,093	**17,142**
TUoS charge (£/kWh)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Export Tariff Revenue (£)		139	216	214	213	211	210	208	207	205	204	203	201	200	198	197	196	194	193	191	190	189	187	186	185	184	**4,921**
FiT generation revenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Fixed Operating Costs (£)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Cash flow (£)	8,796	139	216	214	213	211	210	208	207	205	204	203	201	1,039	198	197	196	194	193	191	190	189	187	186	185	184	**5,114**
Cumulative cash flow (£)	8,796	8,657	8,441	8,227	8,014	7,803	7,593	7,385	7,178	6,973	6,769	6,566	6,365	7,404	7,206	7,009	6,814	6,619	6,427	6,235	6,045	5,856	5,669	5,483	5,298	5,114	
Additional Savings (Non-cash flow) (£)	0	534	400	418	437	456	477	498	520	543	568	593	619	647	676	706	738	771	805	841	878	918	959	1,001	1,046	1,093	**17,142**
Cash flow and Savings (£)	8,796	673	616	632	650	668	686	706	727	749	772	796	821	392	874	903	933	965	998	1,032	1,069	1,106	1,146	1,188	1,231	1,276	**12,028**
Cumulative Savings and Cash flow (£)	8,796	8,123	7,507	6,875	6,225	5,558	4,871	4,165	3,438	2,689	1,918	1,122	302	694	180	1,083	2,017	2,981	3,979	5,012	6,080	7,187	8,333	9,520	10,751	12,028	
Discounted Cash flow (£)	8,796	641	559	546	534	523	512	502	492	483	474	465	457	208	442	434	428	421	415	409	403	397	392	387	382	377	**2,068**
Cumulative Discounted cash flow (£)	8,796	8,155	7,597	7,050	6,516	5,993	5,481	4,979	4,487	4,004	3,530	3,065	2,608	2,816	2,375	1,940	1,513	1,092	677	269	134	531	923	1,310	1,691	2,068	

14.2.5 Generic commercial case study PV*Sol system report



Location:	GUERNSEY AIRPORT
Climate Data Record:	GUERNSEY AIRPORT
PV Output:	34.50 kWp
Gross/Active PV Surface Area:	231.38 / 231.87 m

PV Array Irradiation:	299,582 kWh
Energy Produced by PV Array (AC):	37,614 kWh
Energy to Grid:	37,614.2 kWh
Direct Use of PV Energy:	0 kWh
Energy from Grid:	34.1 kWh
Yield Reduction Due to Shading:	1.5 %

System Efficiency:	12.5 %
Performance Ratio:	84.3 %
Specific Annual Yield:	1,089 kWh/kWp
CO2 Emissions Avoided:	33,305 kg/a

The results are determined by a mathematical model calculation. The actual yields of the photovoltaic system can deviate from these values due to fluctuations in the weather, the efficiency of modules and inverters, and other factors. The System Diagram above does not represent and cannot replace a full technical drawing of the solar system.

14.2.6 Financial Model for PV Case Study - Generic Commercial

Table 45: Financial Model for PV Case Study – Commercial Base Case

Variable	Value
Inflation	3.5%
General interest rate	
Project discount rate	6.5%
Electricity price (£/kWh)	0.161126
Electricity price inflation	5.2%
Export tariff (£/kWh)	0.0983
Export tariff inflation	2%
Import duty	3.30%
Transmission use of System Charge per kWh	0
System Specification	
Number of panels	138
Panel rating (W)	250
Panel degradation 1st year	3.00%
Panel degradation 2nd-25th year	0.70%
System rating (W)	34500
Number of inverters	3
Inverter lifespan (years)	12.5
System performance	
Energy generated by system (kWh)	37,614
Energy consumed by load (kWh)	37,614
Energy exported to grid (kWh)	0
System costs (£)	
Module cost	145.20
Inverter	1,726.00
Total initial inverter cost	5,178.00
Inverter replacement	1,726.00
System design	1,991.44
Site preparation and installation	9,319.84
Project management and procurement	1,087.48
Module support/mounting	6,000.00
Wiring	2,400.00
Logistics	2,000.00
Grid Connection	0.00
Additional cost / contingency	2,000.00
BoS costs	29,976.76
Import duty fee	1,109.31
Module cost	20,037.60
Total system cost	51,123.67
System cost per watt (£/W)	1.48
Module cost per watt (£/W)	£0.53
BoS cost per watt (£/W)	£0.80
System fixed operating costs (£)	10

14.2.7 Commercial rooftop base cash flow model

End of year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Totals
Capital Expenditure (£)	51,124	0	0	0	0	0	0	0	0	0	0	0	0	7,824	0	0	0	0	0	0	0	0	0	0	0	0	**58,948**
Cumulative Capital Expenditure (£)	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	51,124	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	58,948	**58,948**
New Capital Allowances in Period	2,045	0	0	0	0	0	0	0	0	0	0	0	0	652	0	0	0	0	0	0	0	0	0	0	0	0	
Total Capital Allowances in Period	0	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,045	2,697	2,697	2,697	2,697	2,697	2,697	2,697	2,697	2,697	2,697	2,697	2,697	**58,948**
Annual Output from System (kWh)		37,614	36,486	36,230	35,977	35,725	35,475	35,227	34,980	34,735	34,492	34,250	34,011	33,773	33,536	33,301	33,068	32,837	32,607	32,379	32,152	31,927	31,704	31,482	31,261	31,042	**846,271**
Electricity Supplied to Grid (kWh)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Electricity Exported to Load (kWh)		37,614	36,486	36,230	35,977	35,725	35,475	35,227	34,980	34,735	34,492	34,250	34,011	33,773	33,536	33,301	33,068	32,837	32,607	32,379	32,152	31,927	31,704	31,482	31,261	31,042	**846,271**
Energy Bill Reduction (£)		6,061	6,185	6,461	6,749	7,050	7,365	7,694	8,037	8,396	8,771	9,162	9,571	9,998	10,444	10,911	11,398	11,906	12,438	12,993	13,573	14,179	14,812	15,473	16,163	16,885	**262,672**
TUoS charge (£/kWh)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Export Tariff Revenue (£)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fixed Operating Costs (£)		345	357	370	383	396	410	424	439	454	470	487	504	521	540	558	578	598	619	641	663	686	711	735	761	788	**13,438**
Cashflow (£)	51,124	345	357	370	383	396	410	424	439	454	470	487	504	8,346	540	558	578	598	619	641	663	686	711	735	761	788	**72,386**
Cumulative cashflow (£)	51,124	51,469	51,826	52,195	52,578	52,974	53,383	53,808	54,247	54,701	55,171	55,658	56,161	64,507	65,047	65,605	66,183	66,781	67,400	68,041	68,704	69,391	70,101	70,837	71,598	72,386	
Additional Savings (Non-cashflow) (£)	0	6,061	6,185	6,461	6,749	7,050	7,365	7,694	8,037	8,396	8,771	9,162	9,571	9,998	10,444	10,911	11,398	11,906	12,438	12,993	13,573	14,179	14,812	15,473	16,163	16,885	**262,672**
Cashflow and Savings	51,124	5,716	5,827	6,091	6,366	6,654	6,955	7,270	7,598	7,941	8,300	8,675	9,067	1,653	9,905	10,352	10,820	11,308	11,819	12,352	12,910	13,492	14,101	14,737	15,402	16,097	
Cumulative Savings and Cashflow (£)	51,124	45,408	39,581	33,490	27,123	20,469	13,514	6,244	1,354	9,295	17,596	26,271	35,338	36,991	46,896	57,248	68,067	79,375	91,194	103,546	116,456	129,948	144,050	158,787	174,189	190,287	
Discounted Cashflow (£)	51,124	5,367	5,138	5,042	4,949	4,857	4,767	4,678	4,591	4,506	4,422	4,340	4,259	729	4,102	4,025	3,950	3,877	3,804	3,733	3,664	3,595	3,528	3,462	3,398	3,334	**50,992**
Cumulative discounted cashflow (£)	51,124	45,757	40,619	35,577	30,628	25,771	21,004	16,327	11,736	7,230	2,808	1,531	5,790	6,519	10,621	14,646	18,596	22,473	26,277	30,010	33,674	37,269	40,798	44,260	47,658	50,992	

14.2.8 Airport PV case study PV*Sol system report

Location:	GUERNSEY AIRPORT
Climate Data Record:	GUERNSEY AIRPORT
PV Output:	500.00 kWp
Gross/Active PV Surface Area:	3,353.35 / 3,360.47 m

PV Array Irradiation:	4,403,794 kWh
Energy Produced by PV Array (AC):	545,711 kWh
Energy to Grid:	545,711.1 kWh
Direct Use of PV Energy:	0 kWh
Energy from Grid:	498.4 kWh
Yield Reduction Due to Shading:	3.3 %

System Efficiency:	12.4 %
Performance Ratio:	83.2 %
Inverter Efficiency:	96.1 %
PV Array Efficiency:	12.9 %
Specific Annual Yield:	1,090 kWh/kWp
CO2 Emissions Avoided:	483,194 kg/a

The results are determined by a mathematical model calculation. The actual yields of the photovoltaic system can deviate from these values due to fluctuations in the weather, the efficiency of modules and inverters, and other factors. The System Diagram above does not represent and cannot replace a full technical drawing of the solar system.

14.2.9 Airport PV Cost Breakdown - Best to Worst Case Scenarios

	Best	Base	Worst
Inflation	2.5%	3.5%	5.5%
Project discount rate	4.0%	6.5%	9.0%
Electricity price (£)	0.1385	0.1385	0.1385
Electricity price inflation	7.0%	5.2%	3.5%
Export tariff (£)	0.09893	0.09893	0.09893
Export tariff inflation	5.0%	3%	0%
Import duty	3.30%	3.30%	3.30%
System Specification			
Number of panels	2000	2000	2000
Panel rating (W)	250	250	250
Panel degradation 1st year	1%	2%	3%
Panel degradation 2nd-25th year	0.3%	0.5%	0.7%
System rating (W)	500,000	500,000	500,000
Number of inverters	25	25	25
Inverter lifespan (years)	12.5	12.5	12.5
System performance			
Energy generated by system (kWh)	545,711	545,711	545,711
Energy consumed by load (kWh)	545,711	545,711	545,711
Energy exported to grid (kWh)	0.0	0.0	0.0
System costs			
Module cost (£)	145.20	145.20	145.20
Inverter (£)	3,551.75	3,551.75	3,551.75
Total initial inverter cost (£)	57,715.94	88,793.75	88,793.75
Inverter replacement (£)	3,551.75	3,551.75	3,551.75
System design (£)	12,526	19,272	19,272
Site preparation and installation (£)	58,624	90,192	90,192
Project management and procurement (£)	6,840	10,524	10,524
Module support/mounting (£)	35,360	54,400	54,400
Wiring (£)	16,120	24,800	24,800
Logistics (£)	6,500	10,000	10,000
Grid Connection (£)	32,500	50,000	50,000
Additional cost / contingency (£)	19,500	30,000	30,000
BoS costs	**£245,688**	**£377,981**	**377,981**
Import duty fee	**£13,186**	**£15,126**	**15,126**
Module cost	**£290,400**	**£290,400**	**290,400**
Total system cost	**£549,274**	**£683,508**	**683,508**
System cost per watt (£)	1.10	1.37	1.37
Module cost per watt (£)	0.58	0.58	0.58
BoS cost per watt (£)	0.49	0.76	0.76
System fixed operating costs (£)	3	6.5[349]	10
BoS total multiplier	0.65	1	1
IRR (%)	**18.98**	**13.39**	**10.55**
NPV	**£1,838,411**	**£634,115**	**£96,763**
Payback (years)	**7.15**	**11.10**	**19.25**

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14.2.10 Airport base case cash flow model

End of year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Totals
Capital Expenditure (£)	683,509	0	0	0	0	0	0	0	0	0	0	0	0	134,173	0	0	0	0	0	0	0	0	0	0	0	0	**817,682**
Cumulative Capital Expenditure (£)	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	683,509	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	817,682	**817,682**
New Capital Allowances in Period	27,340	0	0	0	0	0	0	0	0	0	0	0	0	11,181	0	0	0	0	0	0	0	0	0	0	0	0	
Total Capital Allowances in Period	0	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	27,340	38,521	38,521	38,521	38,521	38,521	38,521	38,521	38,521	38,521	38,521	38,521	38,521	**817,682**
Annual Output from System (kWh)		545,711	534,797	532,123	529,462	526,815	524,181	521,560	518,952	516,357	513,776	511,207	508,651	506,107	503,577	501,059	498,554	496,061	493,581	491,113	488,657	486,214	483,783	481,364	478,957	476,562	**12,669,179**
Electricity Supplied to Grid (kWh)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Electricity Exported to Load (kWh)		545,711	534,797	532,123	529,462	526,815	524,181	521,560	518,952	516,357	513,776	511,207	508,651	506,107	503,577	501,059	498,554	496,061	493,581	491,113	488,657	486,214	483,783	481,364	478,957	476,562	**12,669,179**
Energy Bill Reduction (£)		75,581	77,921	81,563	85,375	89,366	93,543	97,915	102,491	107,282	112,296	117,545	123,039	128,790	134,809	141,110	147,706	154,610	161,836	169,400	177,318	185,606	194,281	203,362	212,867	222,816	**3,398,428**
TUoS charge (£/kWh)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Export Tariff Revenue (£)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Fixed Operating Costs (£)		3,250	3,364	3,481	3,603	3,729	3,860	3,995	4,135	4,280	4,429	4,584	4,745	4,911	5,083	5,261	5,445	5,635	5,833	6,037	6,248	6,467	6,693	6,927	7,170	7,421	**126,587**
Cashflow (£)	-683,509	-3,250	-3,364	-3,481	-3,603	-3,729	-3,860	-3,995	-4,135	-4,280	-4,429	-4,584	-4,745	-139,084	-5,083	-5,261	-5,445	-5,635	-5,833	-6,037	-6,248	-6,467	-6,693	-6,927	-7,170	-7,421	**-944,269**
Cumulative cashflow (£)	-683,509	-686,759	-690,122	-693,604	-697,207	-700,937	-704,797	-708,792	-712,927	-717,206	-721,636	-726,220	-730,965	-870,050	-875,132	-880,393	-885,838	-891,473	-897,306	-903,343	-909,591	-916,058	-922,751	-929,679	-936,848	-944,269	
Additional Savings (Non-cashflow) (£)	0	75,581	77,921	81,563	85,375	89,366	93,543	97,915	102,491	107,282	112,296	117,545	123,039	128,790	134,809	141,110	147,706	154,610	161,836	169,400	177,318	185,606	194,281	203,362	212,867	222,816	**3,398,428**
Cashflow and Savings	-683,509	72,331	74,557	78,082	81,772	85,636	89,683	93,920	98,356	103,002	107,867	112,960	118,294	-10,295	129,727	135,850	142,261	148,974	156,003	163,363	171,070	179,139	187,588	196,434	205,697	215,396	
Cumulative Savings and Cashflow (£)	-683,509	-611,178	-536,621	-458,539	-376,767	-291,131	-201,448	-107,529	-9,172	93,830	201,697	314,657	432,951	422,657	552,383	688,233	830,494	979,468	1,135,471	1,298,835	1,469,905	1,649,044	1,836,632	2,033,066	2,238,764	2,454,159	
Discounted Cashflow (£)	-683,509	67,916	65,734	64,640	63,563	62,504	61,463	60,438	59,430	58,439	57,463	56,504	55,561	-4,540	53,720	52,822	51,939	51,070	50,216	49,376	48,549	47,736	46,937	46,151	45,377	44,617	**634,115**
Cumulative Discounted Cashflow (£)	-683,509	-615,592	-549,858	-485,219	-421,655	-359,151	-297,689	-237,251	-177,821	-119,382	-61,919	-5,414	50,146	45,606	99,326	152,148	204,087	255,157	305,373	354,748	403,298	451,034	497,971	544,121	589,498	634,115	

14.3 Appendix C - Environmental Scoping

14.3.1 Offshore Wind

Receptor	Recommended Surveys and Studies
Geology	- Geotechnical surveys - Geophysical surveys - Bathymetric surveys - Side scan surveys
Hydrodynamics	- Hydrographical surveys - Bathymetric surveys - Wave data studies
Ornithology	- Aerial and boat based ornithological surveys - Studies into migratory routes - Studies into breeding and feeding grounds
Flora and Fauna	- Population studies - Phase 1 habitat surveys - Noise and vibration studies - Pelagic surveys
Visual Impact	- Photomontages - Seascape character assessment
Heritage and Culture	- Desktop surveys - Site specific surveys
Socio-economics and Recreation	- Desktop surveys - Employment sector studies - Population surveys
Navigation and Shipping	- Hydrographical surveys - Nautical surveys - Radar surveys
Aviation and Telecommunication	- Desk surveys

14.3.2 Tidal

Receptor	Recommended Surveys and Studies
Geology	- Geotechnical surveys - Geophysical surveys - Bathymetric surveys - Side scan surveys
Hydrodynamics	- Hydrographical surveys - Bathymetric surveys - Wave data studies
Ornithology	- Aerial and boat based ornithological surveys - Studies into migratory routes - Studies into breeding and feeding grounds
Flora and Fauna	- Population studies - Phase 1 habitat surveys - Noise and vibration studies - Pelagic surveys
Visual Impact	- Photomontages - Seascape character assessment
Heritage and Culture	- Desktop surveys - Site specific surveys
Socio-economics and Recreation	- Desktop surveys - Employment sector studies - Population surveys
Navigation and Shipping	- Hydrographical surveys - Nautical surveys - Radar surveys
Aviation and Telecommunication	- Desk surveys

14.3.3 Onshore Wind

Receptor	Recommended Surveys and Studies
Geology	- Geotechnical surveys - Geophysical surveys
Hydrology	- Hydrology surveys - Surface and ground water surveys - Soil assessment
Air Quality	- Air quality monitoring
Ornithology	- Aerial and boat based ornithological surveys - Studies into migratory routes - Studies into breeding and feeding grounds
Flora and Fauna	- Population studies - Phase 1 habitat surveys - Noise and vibration studies
Visual Impact	- Photomontages - Visual impact assessment - Landscape character assessment
Heritage and Culture	- Desktop surveys - Site specific surveys
Socio-economics and Recreation	- Desktop surveys - Employment sector studies - Population surveys
Traffic and Access	- Traffic surveys - Swept path analysis
Aviation and Telecommunication	- Desk surveys

14.3.4 Commercial PV

Receptor	Recommended Surveys and Studies
Geology	- Geotechnical surveys - Geophysical surveys - Side scan surveys
Hydrology	- Hydrology surveys - Surface and ground water surveys - Soil assessment
Air Quality	- Air quality monitoring
Ornithology	- Aerial ornithological surveys - Studies into migratory routes - Studies into breeding and feeding grounds
Flora and Fauna	- Population studies - Phase 1 habitat surveys - Noise and vibration studies
Visual Impact	- Photomontages - Visual impact assessment - Landscape character assessment - Solar reflection studies
Heritage and Culture	- Desktop surveys - Site specific surveys
Socio-economics and Recreation	- Desktop surveys - Employment sector studies - Population surveys
Traffic and Access	- Traffic surveys - Swept path analysis

14.3.5 Pumped Hydro

Receptor	Recommended Surveys and Studies
Geology	- Geotechnical surveys - Geophysical surveys - Bathymetric surveys - Side scan surveys
Hydrodynamics	- Hydrographical surveys - Bathymetric surveys
Hydrology	- Hydrological surveys - Surface and ground water surveys - Soil assessment
Air Quality	- Air quality monitoring
Ornithology	- Aerial and boat based ornithological surveys - Studies into migratory routes - Studies into breeding and feeding grounds
Flora and Fauna	- Population studies - Phase 1 habitat surveys - Noise and vibration studies
Visual Impact	- Photomontages - Visual impact assessment - Landscape character assessment
Heritage and Culture	- Desktop surveys - Site specific surveys
Socio-economics and Recreation	- Desktop surveys - Employment sector studies - Population surveys
Traffic and Access	- Traffic surveys - Swept path analysis
Aviation and Telecommunication	- Desk surveys

14.4 Appendix D - Economic Modelling

14.4.1 Impact of changing debt share on electricity price required for project viability

DEBT SHARE 65%	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV	£ 113,749,304.13	£ 111,165,650.06	£ 107,879,105.89	£ 398,122,564.44	£ 389,099,473.61	£ 377,576,870.62
IRR	12.68%	12.72%	12.67%	12.68%	12.72%	12.67%
Payback (years)	7.2	7.3	7.59	7.16	7.29	7.59
LCOE	£ 0.11	£ 0.09	£ 0.08	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.15	£ 0.10	£ 0.05	£ 0.15	£ 0.10	£ 0.05
Total price of electricity from offshore wind (£/kWh)	£ 0.25	£ 0.20	£ 0.14	£ 0.25	£ 0.20	£ 0.14

IRR goal seek to 12%

DEBT SHARE 65%	30MW		
Case	Worst	Mid	Best
NPV	£ 107,058,364.85	£ 104,192,593.21	£ 101,448,889.64
IRR	12.00%	12.00%	12.00%
Payback (years)	7.3	7.5	7.76
LCOE	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.15	£ 0.10	£ 0.04
Total price of electricity from offshore wind (£/kWh)	£ 0.24	£ 0.19	£ 0.14

Please Note: To use goal seek to establish what subsidy would be required for an IRR, NPV or other variable of interest that would be necassary to make the project viable for developers, this will need to be done on each individual sheet.

DEBT SHARE 75%	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV	£ 107,730,155.28	£ 105,669,905.45	£ 103,168,467.66	£ 377,055,543.46	£ 369,864,367.50	£ 361,089,636.81
IRR	11.91%	11.99%	12.00%	11.91%	11.99%	12.00%
Payback (years)	7.4	7.5	7.80	7.35	7.49	7.80
LCOE	£ 0.11	£ 0.09	£ 0.08	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.15	£ 0.10	£ 0.05	£ 0.15	£ 0.10	£ 0.05
Total price of electricity from offshore wind (£/kWh)	£ 0.25	£ 0.20	£ 0.14	£ 0.25	£ 0.20	£ 0.14

IRR goal seek to 12%

DEBT SHARE 75%	30MW		
Case	Worst	Mid	Best
NPV	£ 108,561,080.54	£ 105,771,323.94	£ 103,189,772.65
IRR	12.00%	12.00%	12.00%
Payback (years)	7.3	7.5	7.80
LCOE	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.15	£ 0.10	£ 0.05
Total price of electricity from offshore wind (£/kWh)	£ 0.25	£ 0.20	£ 0.14

DEBT SHARE 85%	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV	£ 101,711,006.42	£ 100,174,160.85	£ 98,457,829.43	£ 355,988,522.48	£ 350,629,261.38	£ 344,602,403.00
IRR	11.16%	11.26%	11.33%	11.16%	11.26%	11.33%
Payback (years)	7.6	7.7	8.10	7.56	7.70	8.10
LCOE	£ 0.11	£ 0.09	£ 0.08	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.15	£ 0.10	£ 0.05	£ 0.15	£ 0.10	£ 0.05
Total price of electricity from offshore wind (£/kWh)	£ 0.25	£ 0.20	£ 0.14	£ 0.25	£ 0.20	£ 0.14

IRR goal seek to 12%

DEBT SHARE 85%	30MW		
Case	Worst	Mid	Best
NPV	£ 110,055,526.44	£ 107,347,390.74	£ 104,928,548.60
IRR	12.00%	12.00%	12.00%
Payback (years)	7.4	7.5	7.84
LCOE	£ 0.11	£ 0.09	£ 0.08
GEL buying Price (£/kWh)	£ 0.095	£ 0.095	£ 0.095
Additional Subsidy Required (£/kWh)	£ 0.16	£ 0.11	£ 0.05
Total price of electricity from offshore wind (£/kWh)	£ 0.26	£ 0.20	£ 0.15

14.4.2 Viability of GEL as investor including consideration of different fuel displacement

Results of modelling where price of imported electricity rises by inflation only

Ratio represents displacement of: imported electricity: local diesel generation

20:80	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	£ 19.99	£ 157.43	£ 300.04	£ 69.95	£ 554.90	£ 1,050.14
IRR	2.43%	15.16%	27.64%	2.43%	15.25%	27.64%
Payback (years)	11.3	7.1	5.52	11.29	7.10	5.52
LCOE	0.111	0.095	0.077	0.111	0.094	0.077

50:50	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	-£ 10.77	£ 101.51	£ 214.72	-£ 37.69	£ 358.41	£ 751.51
IRR	-1.39%	10.31%	20.96%	-1.39%	10.39%	20.96%
Payback (years)	14.7	8.4	6.28	14.67	8.34	6.28
LCOE	0.111	0.095	0.077	0.111	0.094	0.077

80:20	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	-£ 41.52	£ 45.58	£ 129.40	-£ 145.33	£ 161.93	£ 452.89
IRR	-5.90%	5.00%	13.72%	-5.90%	5.07%	13.72%
Payback (years)	19.7	10.6	7.59	19.70	10.61	7.59
LCOE	0.111	0.095	0.077	0.111	0.094	0.077

Results of modelling where price of imported electricity jumps by 3p/kWh in 202

20:80	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	£ 20.82	£ 159.17	£ 309.55	£ 72.86	£ 560.98	£ 1,083.44
IRR	2.52%	15.28%	28.16%	2.52%	15.37%	28.16%
Payback (years)	11.2	7.1	5.51	11.23	7.09	5.51
LCOE	0.111	0.095	0.077	0.111	0.094	0.077

50:50	30MW	0	0	100MW	0	0
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	-£ 8.69	£ 105.84	£ 238.50	-£ 30.41	£ 373.63	£ 834.77
IRR	-1.12%	10.65%	22.44%	-1.12%	10.73%	22.44%
Payback (years)	14.4	8.3	6.17	14.37	8.25	6.17
LCOE	0.111	0.095	0.077	0.111	0.094	0.077

80:20	30MW			100MW		
Case	Worst	Mid	Best	Worst	Mid	Best
NPV (£million)	-£ 38.19	£ 52.51	£ 167.46	-£ 133.68	£ 186.28	£ 586.09
IRR	-5.32%	5.65%	16.51%	-5.32%	5.72%	16.51%
Payback (years)	19.1	10.3	7.13	19.06	10.29	7.13
LCOE	0.111	0.095	0.077	0.111	0.094	0.077