Flinders Island Sustainability Plan:

Renewable Energy Plan

Prepared for:	Flinders Council
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transport infrastructure | community infrastructure | industrial infrastructure | climate change




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Disclaimers

pitt&sherry wishes it to be noted that this Report does not amount to a due diligence with respect to any particular project or investment. Also, **pitt&sherry** provides no warranty of any sort to any party that chooses or claims to rely upon this Report as if it were investment advice.

Hydro Tasmania wishes it to be noted that while it has provided information to this Report, it does not necessarily endorse the Report or its findings. As noted in the Report, Hydro Tasmania is a key stakeholder in the Flinders Island power system, as asset owner, as a renewable energy developer and as the organisation that carries an 'obligation to supply' the Island with electricity on terms agreed with the Tasmanian Government under a 'Community Service Obligation'.

Executive Summary

Renewable Energy Plan for Flinders Island aims to provide the Council and the community with an overview of key issues and opportunities surrounding the provision of electricity on the Island and, in particular, a move from a diesel based to a renewable energy based power system.

Power demand on Flinders Island is currently modest, dominated by residential and light commercial loads. Demand has grown only slowly over time, at around 2% per year. The current supply solution is largely diesel fired and performs reasonably well, albeit with some seven (or more) blackouts per year. However, this is a high cost solution which is only made affordable for the Island by a very large Community Service Obligation (CSO) payment from the Tasmanian Government, which we estimate at around $3,500 per resident per year, along with Federal fuel tax credits. This solution also creates around 3,000 tonnes of greenhouse gas emissions per year at present, a figure that will grow through time.

The community's reliance on diesel – where costs are expected to continue to rise strongly in future – and on the CSO to offset these costs, represent significant risks for Flinders Island. Even under 'business as usual', demand growth over time would mean that additional costs will be incurred to operate, maintain and expand the existing power system. At the same time, significant costs would be incurred in moving to a greater share of renewable energy, including for 'system assets' that do not directly earn revenue. If the Island is successful in winning a substantial capital injection towards the up-front capital costs of a renewable energy system, it will then enjoy the benefits of lower operating costs over time.

Under its *Ministerial Charter* with the Tasmanian Government, Hydro Tasmania is obliged to supply electricity on Flinders Island. While other parties can and do generate electricity on the Island, Hydro Tasmania has a central role to play in any scenario, and the nature of the constraints and opportunities facing that business should be borne in mind when considering future options.

In Chapter 3 we project electricity demand out to 2030 under a range of plausible scenarios. Under a business-as-usual scenario, with little growth in the population, demand in 2030 is expected to be some 45% greater than in 2011. If there were no (significant) investments in renewable energy in this scenario, diesel fuel consumption for power generation would rise to some 1.6 million litres (Ml) a year by 2030, costing some $2.2 million/year at today's diesel prices (or around $2,500/head for fuel alone). This scenario would also generate annual greenhouse gas emissions of some 4,140 tonnes by 2030.

We then examine two 'stepped up growth' scenarios that show the impact for electricity supply and demand to 2030 of:

- A significant expansion in agricultural production (for example leading to significant areas under irrigation)
- An additional 10 houses per year being built (in addition to 5 – 10 per year under business as usual) ('Scenario A'), or an additional 20 houses per year ('Scenario B')
- The flow-on consequences of the higher population for commercial sector power demand

In Scenario A by 2030, the total population is expected to reach 1060 residents and the housing stock to reach some 624 houses, compared with 905 residents and 532 houses under business-as-usual. Annual electricity consumption would more than double from its current level to around 9,700 MWh per year, with diesel consumption rising to some 2.5 Ml. At today's prices (that risk to rise sharply) this would cost some $3.6 million for fuel alone. Greenhouse gas emissions associated with this power generation would rise from around 4,150 t CO_2-e in 2030 under BAU to around 6,670 t CO_2-e in this scenario, some 61% higher.

In Scenario B, the total housing stock is projected to reach 804 houses in 2030, while the resident population would be around 1,366 persons. Annual electricity consumption in 2030 in this scenario would approach 11,000 MWh, some 73% higher than under business as usual and

13% higher than Scenario A. As a result, and without investment in renewable energy, diesel consumption for power generation in 2030 would exceed 3 Ml, associated with over 8,000 t CO_2-e of greenhouse gas emissions, at a cost in today's prices for fuel alone of some $4.3 million, or $3,148 per person.

In both Scenarios A and B, significant investment in the existing diesel-fired power system would be required to meet expected demand. This would drive up Hydro Tasmania's costs and increase the risk of higher electricity tariffs on the Island.

In Chapter 4 we review the renewable energy resources available to Flinders Island. We review a range of relevant renewable energy technologies and their indicative costs. We also discuss some essential system design considerations including the critical role of enabling and energy storage technologies in facilitating a transition to 100% renewable energy on Flinders Island. These 'system assets' may comprise a significant share of future costs, yet they do not directly produce any revenue, raising important questions as to how these costs are met. Finally in Chapter 4 we set out a number of relevant case studies from as near as King Island to as far away as Antarctica and the Canary Islands.

Flinders Island possesses world-class wind and tidal flow resources. Of these two, the technologies for the capture of wind energy are quite mature, while tidal flow technologies are developing rapidly but are not yet fully mature. We note that significant funding is likely to be directed into tidal (and other ocean energy resources, such as wave energy) systems in coming years, including through the $10 billion *Clean Energy Finance Corporation*, and Flinders Island is well-placed to capture a share of this investment. Flinders Island also possesses useful solar and biomass resources, including waste-to-energy opportunities that, in addition to producing energy, could reduce the Island's carbon footprint (see the companion *GHG Minimisation Plan*).

In Chapter 5 we draw out of the preceding analysis three primary options for a 100% renewable energy system design for Flinders Island, noting that there are many other possible solutions and variations that could be considered. In short, these three are:

1. A wind-biodiesel solution, with battery and other enabling technologies
2. A wind-mini-hydro solution, with pumped sea-water storage
3. A wind-cable solution, connecting Flinders Island to the Tasmanian mainland

At the end of Chapter 5 we provide a brief financial analysis of the two highest priority options. Option 1 is the lowest cost, 100% renewable energy solution, followed by Option 2. Lower system costs may be able to be achieved at less than 100% renewable energy, but we have not examined such solutions. The optimal mix of contributions from different technologies depends on final costs for each and the pricing and other terms offered to different generators. Cost estimates have been firmed up following the community consultation phase.

Following publication of the initial Consultation Paper, there were opportunities for written and face-to-face consultations, that took place in late February / March 2012. This phase allowed the Council and community to identify a preferred renewable energy solution which in this case is Option 2, the wind / mini hydro scheme preferred on the basis of completeness of GHG aims and its functional reliability. Following this **pitt&sherry** completed a more detailed design and costing for that solution and prepared a funding submission from the Council to the Federal Government, with the aim of winning substantial funding support to enable the Island's Renewable Energy Plan to be implemented.

Some key issues still remain for the Council and Flinders Island community to continue to explore regarding the energy future of the Island. These issues will require further introspection as funding arrangements proceed and are complex issues around:

- Who will own and manage the system through time?
- Who will pay for (all aspects of) the investment, and on what terms?

- What risks is Flinders Island exposed to from issues such as the CSO, fuel prices, peak oil, climate change and carbon pricing – and how should it respond?
- What outcomes are required in terms of energy security, power quality and reliability, in order to meet the aspirations of the whole community?
- What opportunities and benefits are there for the Island from moving to 100% renewable energy, greater energy efficiency and even towards a zero carbon economy?
- Overarching all of this, what is the role of renewable energy in contributing the community's vision of its own future to 2030?

For readers with limited time, we note that Chapter 5 outlines the key options for Flinders Island, while Chapter 6 set out some key issues that should be considered.

1. Background and Context for the Project

1.1 Background

Flinders Council has contracted **pitt&sherry** to assist in developing a comprehensive Sustainability Plan for the municipality. The Sustainability Plan has two key components:

1. A Renewable Energy Plan, including a community supported vision to enable Flinders Island to reduce its reliance on diesel generated energy and see a substantial shift to the use of renewable energy
2. A Greenhouse Gas Minimisation Plan, including opportunities to reduce or offset greenhouse gas emissions by improving carbon sequestration opportunities, biodiversity enhancements and waste management practices.

The Sustainability Plan will be supported by a submission to the Federal Government for whole or partial funding of the required infrastructure.

This document focuses on the Flinders Island Renewable Energy Plan. A separate paper will be prepared on the broader sustainability and greenhouse gas minimization aspects.

The development of an integrated Renewable Energy Plan was identified as the first amongst the *Flinders Council Priority Projects 2010*. The Council's aim is that the Renewable Energy Plan will embody a clear vision for the Island's energy future, and offer evidence-based pathways for reducing the Island's reliance on diesel for electricity generation. The Council expects that renewable energy solutions will deliver energy security and reliability for the Island, along with realistic costs. Solutions must be practical and implementable, and we have been asked to investigate a range of ownership models, including partnerships where appropriate. Finally, the Plan is intended to enable Flinders Island to embrace renewable energy opportunities and position the Community and Council to take advantage of any opportunities that present through the carbon price, associated support programs and other potential funding sources.

The full Project Brief is reproduced in Appendix 1. Note that this Report focuses primarily on Flinders Island, although the energy needs and systems on Cape Barren and Clarke Islands are also discussed briefly. Also note that the non-electricity needs of the Island (including transport fuels) are discussed in more detail in the separate *GHG Minimisation Plan*, while this paper focuses on electricity.

1.2 Purpose

This document is designed to set out the key energy issues and renewable energy options for Flinders Island. It is intended to:

- Provide a resource for consultations with the community and Council
- Help the community develop its own unique vision of a sustainable energy future for the Island
- Identify key issues and practical considerations to be borne in mind

Specifically, this report comprises three key sections:

1. A summary and analysis of the existing Flinders Island energy system, including the nature of the current energy task, existing infrastructure and key performance issues
2. Projections for the future requirements of the energy system, including future energy demand scenarios
3. An overview of key renewable energy options, including indicative costs and feasibility considerations

In conclusion this document sets out two preferred options and informs the bid for funding.

2. Existing Electrical System and Demand

2.1 Overview

Flinders Island is the largest of 52 islands in the Furneaux Group, located in Bass Strait between the North Eastern tip of Tasmania and Wilson's Promontory in Victoria. The 40th parallel passes through the North of Flinders Island, which has an area of 1,333 square kilometres. Flinders Island is blessed with a mild, maritime climate, which also includes world-class renewable energy resources such as wind, solar and tidal energy. The breathtaking scenery, including massive granite outcroppings from the Darling Ranges that run North-South, the Strezlecki National Park, and some 30 white-sand beaches, attract over 4,000 tourists each year, swelling the permanent population of around 800 persons, primarily during the Summer months.

Flinders Island is also home to important rural industries including agriculture (beef, sheep and wool, wallaby, horticulture, wine), fishing (including crayfish and abalone) and tourism ventures that, together with the services sector, generate important income and employment for the community.

Note that while renewable energy developments on Cape Barren and Clarke Islands are mentioned in passing, the focus of this study is on Flinders Island.

2.2 Existing Electrical System

2.2.1 Whitemark Power Station

At present Flinders Island generates almost all of its electricity needs from diesel. The Whitemark Power Station - which is owned by Hydro Tasmania and operated by Aurora Energy under a contractual arrangement - utilises four diesel generator sets (gensets) ranging in capacity from 300 kW to 1250 kW. The power station has a total installed capacity of 2.8 MW and firm capacity (that is, not counting the largest unit) of 1.5 MW. The No.1 unit (550 kW) is scheduled for replacement (with a larger, 720 kW unit) in 2012, taking firm capacity up to 1.7 MW. The other units have relatively low operating hours (except for the smallest, 300 kW unit), and the station is good condition and well maintained. Diesel storage is 100,000 litres. This means that from full, the tanks provide around six weeks of electricity generation under average operating conditions.

The power station output is managed automatically via a control system that responds to changes in power quality, typically changes in frequency and/or voltage. When these parameters deviate from their set points, eg due to changes in the electrical load in the network, the control system responds in the first instance by increasing or decreasing the output of the operating genset(s) or, in the second instance, by changing the number/size of the gensets operating, until optimal conditions are restored. In principle these system changes happen automatically and are not apparent to electricity users.

Figure 2.1: Whitemark Power Station, Flinders Island

Source: Hydro Tasmania website

Manual scheduling of generating units also occurs in some circumstances. For example, the largest unit is generally connected prior to an electrical storm given its greater capacity for fault 'ride-through' (that is, to keep on generating even when the network is struck by lightning, for example). The power station has an internal switchyard including transformers which step-up the voltage from 440 V at the gensets to 11 kV to supply the distribution network. The system is managed by two permanent staff members (of Aurora Energy) with support from the Tasmanian mainland as necessary.

2.2.2 Performance

By way of background, the reliability of conventional power generation (as distinct from the poles and wires) is largely a function of having sufficient spare generating capacity available to cover the load at all times. The minimum 'firm' capacity targeted is to be able to meet expected peak load without the largest unit in operation (for example, it may be out for scheduled or unscheduled maintenance). At present, firm capacity is almost double peak demand[1], providing a good degree of reserve margin. Other factors that affect reliability include inertia, or the ability of the system to resist change, for example because of 'spinning reserve' or thermal inertia in boilers (in thermal power systems); and fault ride-through capability, which refers to the ability of the power station to continue to operate despite a (temporary) short circuit somewhere in the network, for example due to a lightning discharge.

The Whitemark Power Station performs well for a station of this type, with the main issue being that under low load conditions – for example at night, or at other times when only one, small generating unit may be operating - the generating unit is vulnerable to 'tripping' (disconnecting from the network) when a 'fault' occurs somewhere on the network, such as a lighting strike or a temporary short-circuit. Note that tripping is a planned safety or protection mechanism both for electricity users and for the power station, to limit risks associated with electrical faults. However, such an event causes a black out on the Island. There were seven such events in 2009-10, although only one of these was attributed to the power station (the others were attributed to events in the distribution network, as discussed below).

[1] In this Report, 'peak demand' refers to the statistical concept of a '95% probability of non-exceedance' (95% POE); that is, there is a 95% probability that the peak will not exceed the named value during the relevant time period. The historical peak load on Flinders Island has been reported at around 1.1 MW.

Recovery from a black out requires the manual intervention of the station operator and normally takes around 30 minutes to accomplish, provided there are no serious or ongoing fault conditions, in which case these must be corrected before the power station can be reconnected. There is a 15 minute delay period after a black-out for safety reasons, which allows police on the Island to verify that no industrial or vehicle accidents have been reported that may have been the source of the electrical fault.

As noted, the risk of unnecessary 'tripping' is managed by connecting the largest generating unit when an electrical storm is expected, as it has the greatest 'ride through' capacity. Also, the smallest and oldest genset is scheduled for replacement with a larger machine in 2012. This should improve fault ride-through performance. We note that the Tasmanian Economic Regulator has reported that the number of outages attributable to generation faults fell from 19 in 2008-09 to just 2 in 2009-10. This is attributed to improve control systems and replacement of the No. 2 (550 kW) generator. The Regulator reports that the contribution of the power station to 'system average interruption duration index' (or SAIDI – see Glossary of Key Terms) was just 13 minutes during 2009-10, the lowest since 2004, while its contribution to 'system average interruption frequency index' (or SAIFI – see Glossary of Key Terms) was also low at 1.06 interruptions in that year.

Note that it would be possible to change the dispatch arrangements to further improve fault ride-through performance, for example by scheduling at least two generating units to be operating at all times. However, such an operating strategy would lead to increased diesel consumption, greenhouse gas emissions and operating and maintenance costs. It would also not prevent all outages, for example those caused by damage to the power lines.

We note that it would also be possible in principle for perhaps one of the four gensets within the power station to be upgraded, for example at asset renewal time, to a 'low load' type, albeit at some incremental cost to Hydro Tasmania. A low load diesel unit would help facilitate a higher penetration of renewable energy on the Island, as these units can respond more quickly than standard units to variations in both load and renewable energy supply, whilst maintaining power quality and system stability.

While the operating costs of the Whitemark Power Station are confidential, we estimate (based on other remote power stations of a similar type) that they would be at least $400/MWh, or $0.40c/kWh, for the power station alone (that is, before the costs of operating the distribution network are taken into account). These costs have been rising strongly in recent years due primarily to higher diesel costs, and they are likely to continue to rise in future.

2.2.3 Existing Wind Turbines

Two small wind turbine generators (WTGs) have been operating on Flinders Island for several decades. The wind turbines are privately owned and situated on land leased from the Flinders Island Aboriginal Association. They are operated under connection and power purchase agreements with Hydro Tasmania. The turbines are 25 and 55 kW units that represent less than 3% of the installed capacity on the Island.

2.2.4 Performance

The larger, 55 kW unit (shown below, installed in 1988) is currently operating while the smaller, 25 kW unit (not shown, installed in 1996) appears not to be in operation as at late 2011. We estimate that the 55 kW unit would produce around 190 MWh per year, or around 4.5% of annual electricity consumption. Natural fluctuations in the output of this unit (as a result of changing wind conditions) are likely to place little stress on the Whitemark Power Station control strategy, given its modest size.

The site upon which these turbines are located is excellent – as discussed in Chapter 3, one of the best wind sites in the world. Therefore, despite the small size of these units by modern standards, it is likely that they have repaid their investment cost many times over. The fact that the larger unit in particular is still operating reliably after 24 years provides a good indication of the potential for wind power as a solution for the Flinders Island community.

While details of the Power Purchase Agreement for these wind turbines are confidential, the operating costs are likely to be no more than half of those for the Whitemark Power Station. As a result, every unit of output from these wind turbines has helped to reduce the costs of delivered electricity on the Island.

Figure 2.2: Privately owned, 55kW wind turbine near Whitemark

Source: http://ramblingsdc.net/Australia/WindTas.html#Flinders_Island_Wind_Farm:

2.2.5 Wind Turbines under Construction

The private company Flinders Island Renewable Energy (FIRE) has, during this analysis, been progressing through development applications and now construction has started for a single 300kW Enercon turbine near the same site as the other wind turbines. Their project is progressing rapidly and expected to be producing power by mid-year. For this purpose we have now added the output from this turbine to the analysis scenarios. FIRE have generously, but confidentially, provided feedback on our projections of expected production to ensure that the assumptions used are close to those in their business model.

2.2.6 Solar Photovoltaic (PV) Installations

The number of photovoltaic (PV) installations on Flinders Island is growing due to a range of factors:

- Falling market prices for PV modules
- Small-scale Technology Certificates that are available as part of the Federal Government's Small-scale Renewable Energy Scheme
- Various grant funding programs including from the Federal and State Governments

- A State Government policy that requires 'one for one' feed-in tariff be offered for small scale systems[2]

Several Council facilities feature PV systems on their roofs, including Council chambers and the airport, as do the Whitemark bakery (owned and operated by the Flinders Island Aboriginal Association Incorporated) and many houses. In addition, five new PV projects are currently being implemented with the support of the State Government Renewable Energy Fund. These projects will add some 71.5 kW to Hydro Tasmania's estimate of 105 kW of installed PV capacity in Flinders Island in late 2011. As discussed further in Chapter 3 and Section 4.2, we expect continued investment in solar installations on Flinders Island in future, as we calculate that solar systems are already (marginally) cost effective on Flinders Island - even without capital subsidies - and this cost-effectiveness is expected to increase through time due to rising electricity prices and falling PV system costs.

2.2.7 Performance

PV panels have the benefits of being very reliable, with a working life of 25 years or more, as well as simplicity and low-maintenance characteristics. They also add diversity to the power system. For example, their power output is greatest on sunny days in Summer when lower wind conditions are possible and when their output will offset air conditioning load in houses and businesses. However, as discussed further below, peak electricity demand on Flinders Island occurs on Winter mornings and evenings when PV output will be low.

Grid-connected PV systems utilise (in effect) the whole electricity system as a 'storage' device, by exporting surplus power to the grid when PV output is high and consumption low (eg, during the middle of summer days) and import power from the grid at night or whenever output falls below consumption. When few such systems are connected to a grid, this does not create problems for system management. However, as the share of PV (or other unscheduled renewable energy technology) capacity rises, additional investment may be required within the power system to manage the variability of output, and the costs associated with this investment must be recovered – normally through higher tariffs. These issues are discussed further in Section 4.2.

2.2.8 Distribution Network

The distribution network comprises three overhead feeders of 11kV. The main feeders run for approximately 330km giving good but not complete access to three-phase power for all consumers on the Island. There is no high voltage transmission network on the Island. As demand on the Island increases, and/or if additional generation is added into the network, it is likely that some upgrading of parts of the network will be required to manage the larger (and potentially more complex) power flows.

2.2.9 Performance

The reliability of the Palana feeder is lower than the other two feeders due to its longer length and exposure as an overhead feeder. Also it has only one mid-point recloser along its length, which can lead to greater numbers of customers being shed in response to a network event. In 2008-09, and on average across the network, 1486 minutes were lost as a result of network outages, although this fell dramatically to just 318 minutes in 2009-10. This compares favourably with an average over the last 8 years of around 400 minutes. This indicator is known as SAIDI, or system average interruption duration index (see Figure 2.3 below). A second complementary indicator is the 'system average interruption frequency index (SAIFI), which was around 9 in 2009-10, close to the 8-year average performance (see Figure 2.4 below).

[2] Tasmanian Government policy requires Aurora Energy (and Hydro Tasmania on Flinders Island) to pay customers an equivalent tariff for net exports from small scale renewable energy systems (up to 10 kW) to that which is paid by customers.

Figure 2.3: System Average Interruption Duration Index (SAIDI) for each feeder on Flinders Island

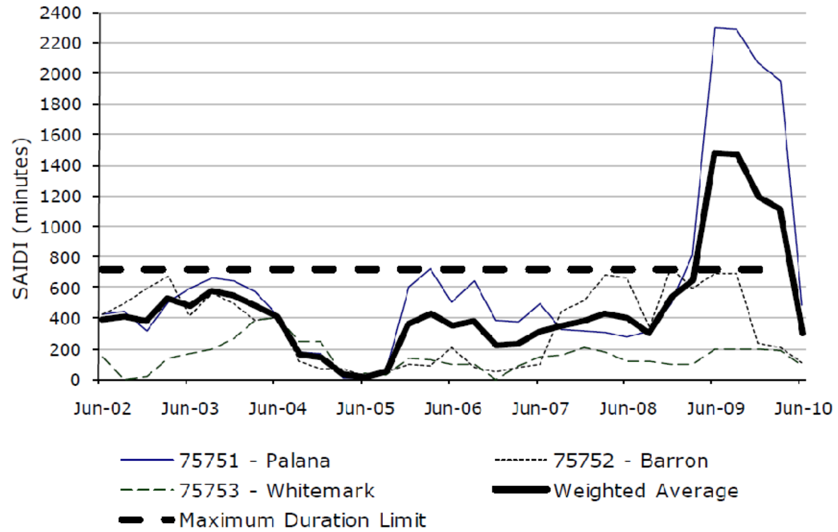
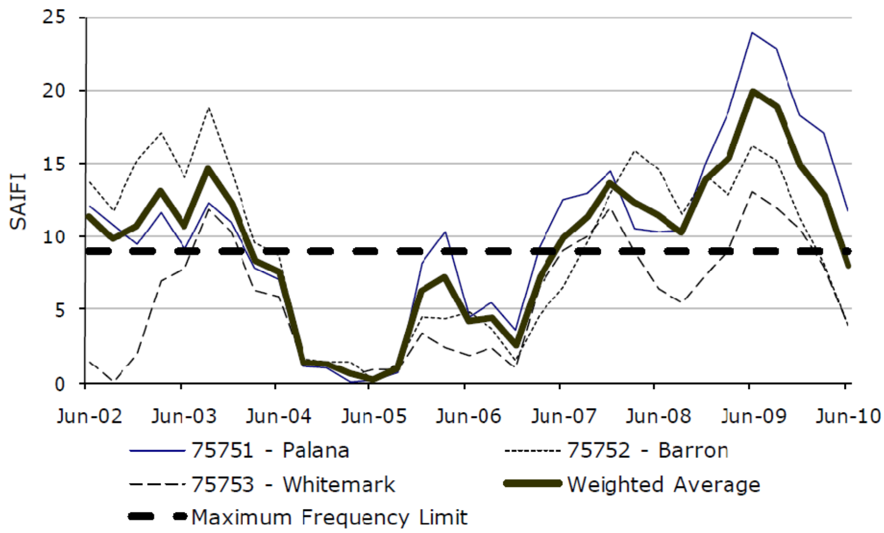


Figure 2.4: System Average Interruption Frequency Index (SAIFI) for each feeder on Flinders Island



Source (both Figures): Tasmanian Energy Supply Industry Performance Report 2009-10, Office of the Tasmanian Economic Regulator

2.2.10 System Ownership, Management and Pricing

The majority of electricity generation and distribution assets on Flinders Island are owned by Hydro Tasmania and managed under contract by Aurora Energy. Exceptions to the rule include the two existing wind turbines and the rooftop PV installations which are owned either privately or by the Flinders Council. The long-standing arrangement between Hydro Tasmania and Aurora Energy reflects the pragmatic judgment that the majority of system maintenance tasks on Flinders relate to the poles and wires rather than to the power station, and this is the province of Aurora Energy. We note that private company ownership now will include FIRE Pty Ltd (Flinders Island Renewable Energy), for their 300kW wind turbine installation near Whitemark.

From a legal and policy perspective, Flinders Island falls outside the National Energy Market which stretches from Tasmania to South Australia and North Queensland.

This is essentially because Flinders and King Islands are not electrically connected to either the Tasmanian or Victorian grids. As a result, operational arrangements for electricity generation, distribution and retailing on the Bass Strait Islands are unlike those in the majority of Australia, and are much more akin to the 'vertically integrated' model that applied in Tasmania until 1998, for example.

Because of these legislative arrangements, Hydro Tasmania has – under its *Ministerial Charter* with the State Government - an obligation to supply Flinders (and King) Island:

> *"The Minister expects that Hydro Tasmania will continue to provide an electricity generation, distribution and retail service on King and Flinders Islands. The Government will ensure that arrangements are established to compensate for the additional costs incurred in delivering these services. The Minister expects that Hydro Tasmania will meet its Community Service Obligations (CSOs) as efficiently and cost effectively as possible. It will advise the Minister of any implications for the cost of delivery of its CSOs."* [3]

As noted, linked to Hydro Tasmania's obligation to supply is a 'Community Service Obligation' (CSO) Agreement between the State Government and Hydro Tasmania, which essentially requires that:

a) Hydro Tasmania must provide subsidised electricity (and pensioner concessions) to the Islands on the terms specified in the Agreement

b) the Treasurer must reimburse Hydro Tasmania for the costs (including administration costs) incurred. Hydro Tasmania is obliged to deliver the CSO in an efficient and cost effective manner, but is also entitled to earn a normal rate of return on the capital it invests.

The CSO amount is based on the 'net avoidable cost' that Hydro Tasmania incurs, taking into the revenue it receives from electricity sales, customer contributions, diesel fuel excise rebates and other sources, on the one hand, and the costs it incurs, including diesel fuel costs, operating and maintenance costs (including labour and administration), depreciation and an allowance for return on capital invested, on the other hand.

The details of these calculations, which must be presented to the Treasurer on a quarterly basis, are commercial-in-confidence. However, we note that the State Budget currently allows some $7 million per year for the CSO for the Bass Strait Islands and that the actual cost to government of the CSO in 2009-10 was approximately $6.6 million[4]. If we assume that CSO costs per customer are similar on King and Flinders Island[5], then some $2.3 million of this amount would be attributable to Flinders Island, or around some $3,550 per customer on average in that year.

The pricing of electricity on Flinders Island is determined from time to time by the Treasurer in accordance with the requirements of the CSO and *Electricity Supply Industry (Tariff Customers) Regulations 2008*. Tariff 51 applies to all customers on King and Flinders Islands and currently sets an energy charge of 24.23 c/kWh, along with fixed daily charges (for the network and metering) of 77.76 c/day. Pensioners are eligible for an energy rebate of 100.66c/day. There is no off-peak tariff available on Flinders Island, and it is likely that this reflects the fact that there is no significant advantage in shifting load on the Island to off-peak times[6].

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[3] Extract from *Ministerial Charter* provided by Hydro Tasmania.

[4] Office of the Tasmanian Economic Regulator, *ESI Performance Report 2009-10*, p. 141.

[5] Arguably CSO costs per customer on Flinders Island may be higher than on King Island due to the greater length of network per customer (0.5 km/customer on Flinders; 0.33 km/customer on King), and also due to the current limited penetration of renewable energy on Flinders Island.

[6] Fuel consumption is minimised by ensuring that gensets are able to run efficiently loaded, ie, at greater than 50% or preferably 75% capacity factor, for most hours during a year.

Note that the tariff paid on the Bass Strait Islands is actually lower than Tariff 31, the standard residential light and power tariff paid on mainland Tasmania, which currently stands at 25.132c/kWh, while fixed charges amount to 89.145 c/day. However many customers on the Tasmanian mainland access a lower 'Hydroheat' tariff (Tariff 42) for electric hot water and space heating, which currently stands at 15.157 c/kWh for energy and 17.266 c/day for fixed charges. As a result, electricity bills may be somewhat higher on Flinders Island than for a comparable customer on the Tasmanian mainland, despite the substantial CSO. The higher price environment improves the financial attractiveness of cost-effective renewable energy or energy efficiency investments on the Island, while at the same time reducing the CSO cost to the Tasmanian Government. As discussed further below, this is one important driver for a move to renewable energy on Flinders Island.

2.2.11 Cape Barren and Clarke Islands

While the focus on this study is on Flinders Island, we note that Cape Barren Island received a major electricity upgrade in 2009 with a three-stage project that involved:

a) Upgrading of diesel generation

b) Upgrading control systems and the network

c) Installation of two 20 kW wind turbines

d) Installation of 3 kW of solar panels

e) Installation of a large battery bank

The total cost of this project, which was implemented by Hydro Tasmania's Entura Division and IT Power (Australia)[7], was $1.3 million.

Clarke Island also has a small hybrid diesel/wind/solar power installation including 2.4 kW of solar panels and a 1kW wind generator, with a 7kW inverter and firming from a 1050 Ah battery bank and a small diesel generator. This system was designed by Apollo Energy in 2009 to eliminate diesel fuel use under normal operating conditions[8].

Note that the CSO arrangement between Hydro Tasmania and the Tasmanian Government covers Flinders and King Islands but neither Cape Barren nor Clarke Islands.

2.3 Electricity Demand

2.3.1 Overview

Flinders Island has no major industrial or large commercial loads at present. The major electricity consumers include the supermarket, tavern/hotel, abattoir, hospital, other commercial enterprises, farm businesses and houses.[9]

The average demand for electricity was 490 kW in 2010, with a peak demand (95% POE) of just over 920 kW, while annual energy consumption in 2010 was around 4,300 MWh. The peak demand in 2010 occurred on the evening of 30 June; that is, in mid-winter.

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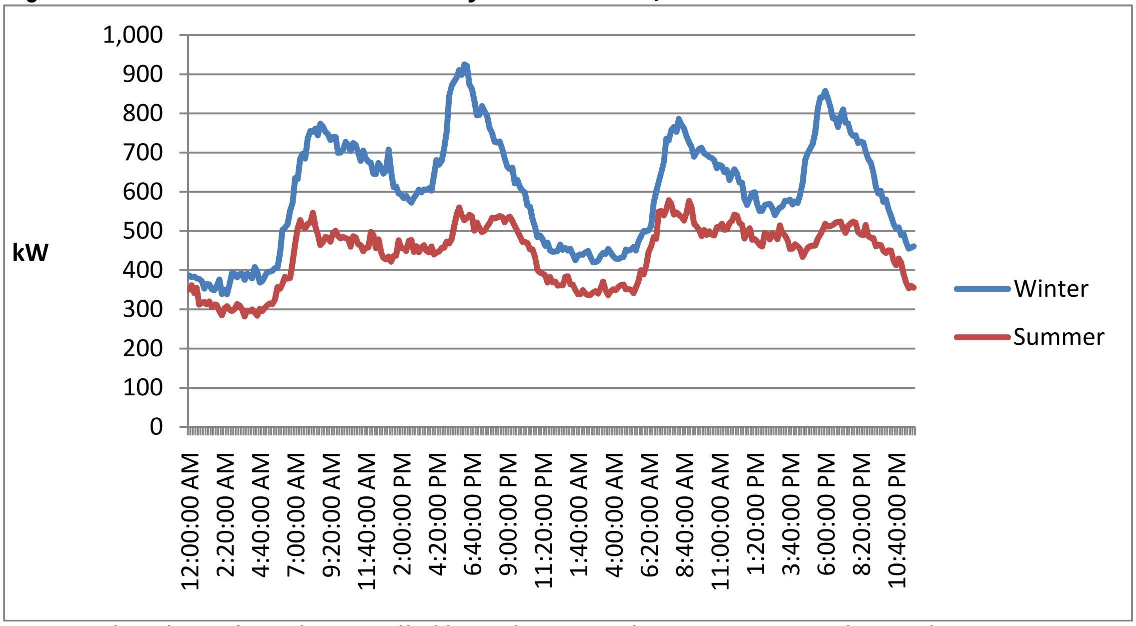
[7] From http://www.jennymacklin.fahcsia.gov.au/mediareleases/2008/Pages/1.2mill_renew_energy_06nov08.aspx

[8] R. Wells and D. Porter (Apollo Energy), *Clarke Island Case Study – Hybrid SPS Installation*, Regional Electrical Engineering Forum 2009 – IDC Technologies, available at http://idc-online.com/pdf/Papers/WELLS.pdf.

[9] Note that this study has not included any energy auditing or direct data collection on electricity end use, and we acknowledge the support and co-operation of Hydro Tasmania in providing **pitt&sherry** with confidentialised demand data *inter alia*.

Consistent with the largely residential/commercial load, Figure 2.5 below shows that the daily load profiles show a 'double peak' pattern – that is, morning and evening peaks. These peaks are of a similar magnitude in summer (less than 600 kW each), but in winter, peaks are both significantly higher than in summer (between 800 kW and 900 kW) and also more pronounced in the evenings, consistent with residential space heating, cooking, lighting and hot water loads. Overnight demand drops off considerably to a low point at around 2am of some 300 kW in summer and 350 kW in winter.

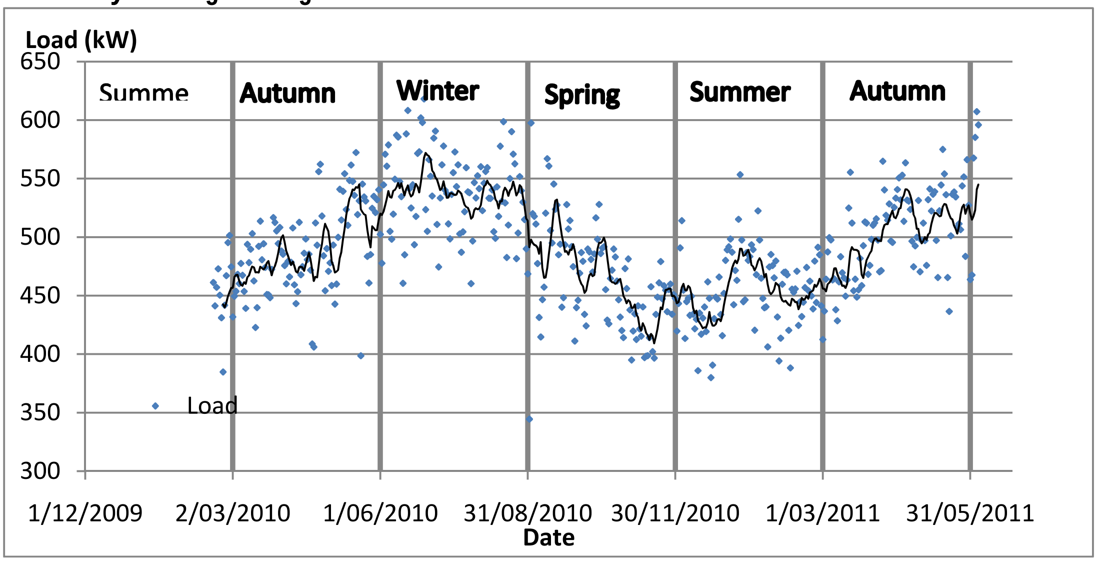
Figure 2.5: Summer and Winter 2-day Load Profiles, Flinders Island



Source: pitt&sherry from data supplied by Hydro Tasmania. Data corresponds to 18/2-19 February and 30/6 – 1/7/2010.

The seasonal profile of demand is evident in Figure 2.6 below, which shows average demand for electricity rising though Autumn, peaking in Winter and falling to a low point in late Spring/early Summer. While this data only covers an 18 month period, it is likely that this pattern is broadly representative of seasonal trends.

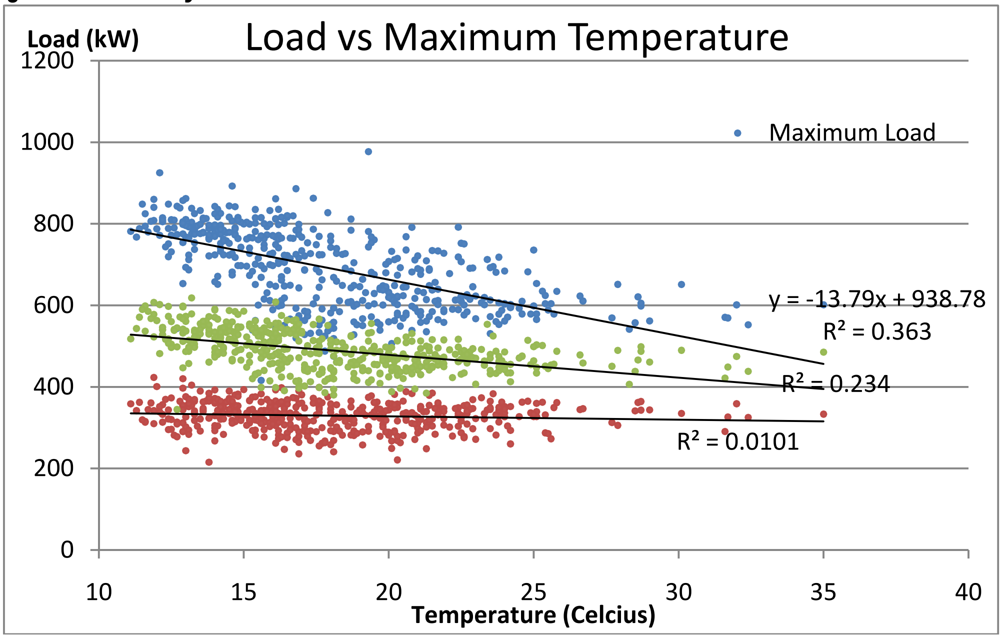
Figure 2.6: Average Daily Load by Season, Flinders Island, 16 months to June 2011, and 7-day Moving Average



Source: pitt&sherry from data supplied by Hydro Tasmania

Figure 2.7 below confirms that the maximum demand for power correlates reasonably well with the inverse of temperature; that is, more power is demanded on colder days. By contrast, the minimum load (which occurs overnight) is quite constant all year around, and is likely to consist largely of the major cool rooms and refrigeration tasks on the island, as well as key residential loads such as hot water and space heating.

Figure 2.7: Daily Load Distribution for Flinders Island in 2010



Source: pitt&sherry from data supplied by Hydro Tasmania

3. Projections to 2030

The previous sections have outlined the nature and performance of the current electricity system on Flinders Island, along with the current demand for electricity. In planning for the future energy needs of the Island, however, it is important to anticipate all reasonable contingencies. Given uncertainties, a scenario planning approach is taken. The purpose of these scenarios is not to be prescriptive or to make forecasts, but rather to illustrate the consequences of different plausible futures for Flinders Island.

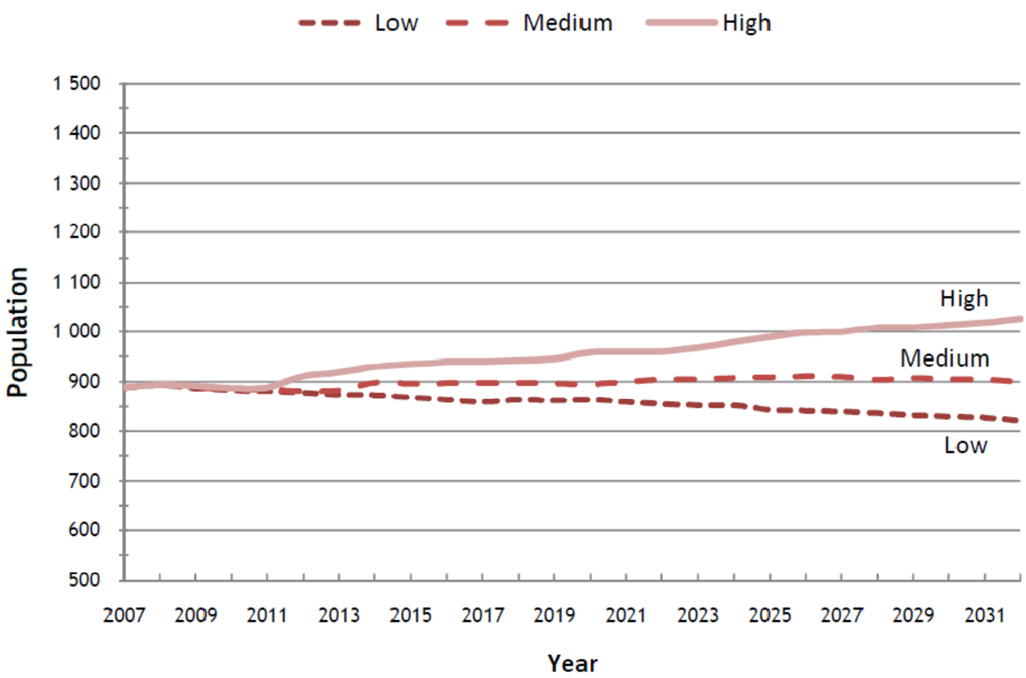
3.1 Economic and Population Growth

Growth in economic activity on the Island, and growth in the permanent population and tourist numbers, will tend to increase the demand for electricity, other things being equal. Three growth scenarios are discussed further in Section 3.2 below. Beyond absolute population numbers, general trends such as an ageing population, smaller household sizes (fewer people per house) and increasing intensity of energy use (more energy per person, due to increased demands for air conditioning, computing equipment, entertainment devices and standby power consumption) – are all tending to push up energy demand.

Population Growth
In 2008, the Estimated Resident Population of the Flinders Municipality was 905 people. Flinders Municipality has a relatively stable population; the residential population growing by just 20 people from 2004 to 2008, which is approximately 0.5% per annum over this period.

In December 2008, the Tasmanian Demographic Change Advisory Council (DCAC) produced a series of population projections for each Tasmanian municipal area out to 2032.

Figure 3.1: Flinders Municipality Population Projections to 2032



Source: ABS (2010)

In the subsequent projection, the 'medium' population scenario is used for the 'business as usual' case, but faster rates of population growth are embodied in the two 'stepped up growth' scenarios, as detailed below.

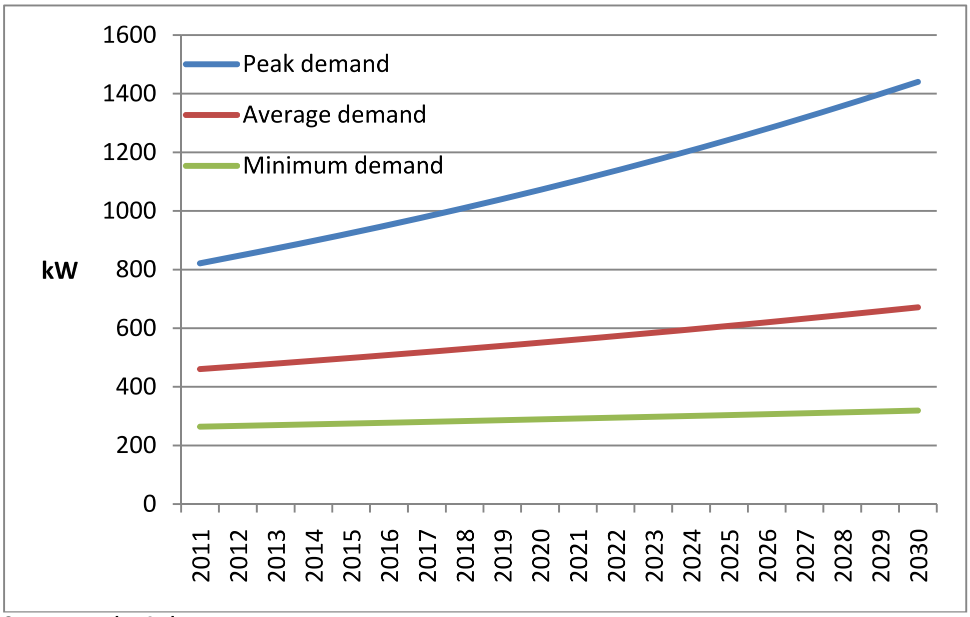
3.2 Demand and Supply Projections

3.2.1 'Business as Usual' Scenario

As noted above, electricity demand on Flinders Island has grown on average at around 2% per year over a long period of time, while 'medium' population growth projections are largely flat. This report therefore adopts this 2% figure as an assumed rate of growth in *average* demand in the business as usual, or BAU, scenario to 2030. However, consistent with past trends, we assume a faster rate of growth in peak demand of 3% per year and a slower rate of growth in minimum demand of 1% per year.

The BAU scenario sees average (final) demand rising from around 460kW in FY2011 to some 670kW in 2030 (see Figure 3.2 below). Peak final demand rises from around 820kW in 2011 to some 1440kW in 2030. These figures exclude network losses. Total electricity consumption, including network losses, rises from around 4,300 MWh in 2011 to around 6,250 MWh in 2030 (as shown in Figure 3.3 below).

Figure 3.2: Flinders Island Projected Electricity Demand to 2030: Business-as-usual



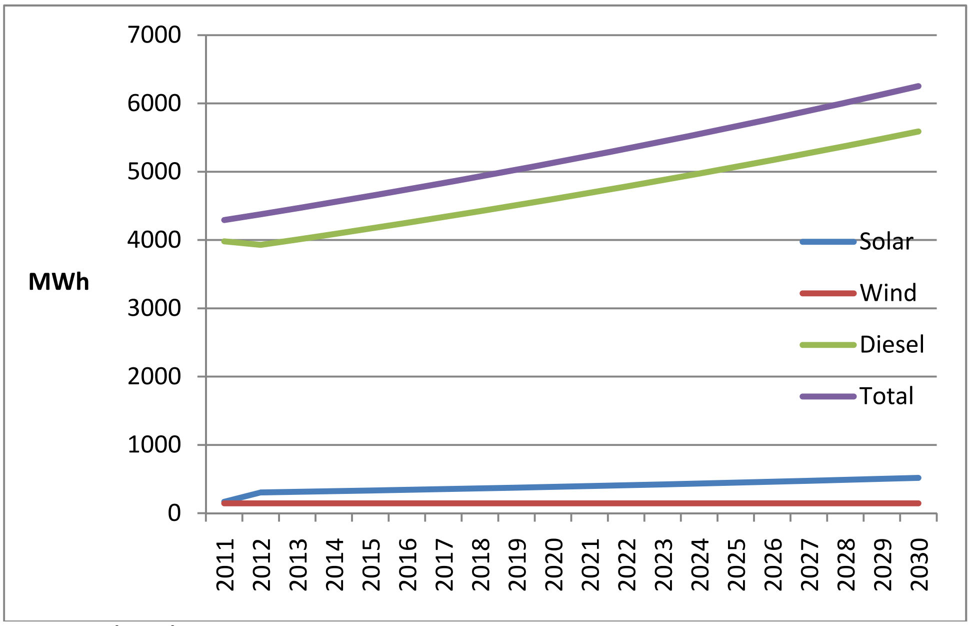
Source: pitt&sherry

On the supply side, we assume in the BAU scenario that solar capacity continues to grow sharply in the short term, rising from around 105 kW of peak power (kWp) installed in 2011 to around 190 kWp installed in 2012 (due to the outcomes of the Renewable Energy Fund Round 1 noted above). Growth in capacity is then assumed to grow at a steady 3% per year, reaching some 325 kWp in 2030. Assuming a capacity factor of 18.2%, the output from solar systems rises from around 170 MWh in 2011 to some 520 MWh in 2030, equivalent to more than 8% of electricity consumption on the Island in that year.

We note that this amount of solar penetration may well require some investment in system assets to accommodate the increased variability of output. At the same time, the assumed 3% annual growth in PV capacity may be considered conservative, due to rising private cost effectiveness of PV systems, as discussed in Section 4.2, and also noting that past trends that show a much faster growth rate.

In the BAU scenario, we assume that the existing 55kW wind turbine continues to operate, (although it may well be expected to be decommissioned well before 2030). We estimate the output of this wind turbine to be around 190 MWh per year, or some 4.5% of total annual consumption. Note that the following projections do not yet take into account the recently-approved FIRE wind development: this project will be modelled and included within the final Renewable Energy Plan for Flinders Island.

Figure 3.3: Flinders Island: Projected Electricity Supply: Business-as-usual to 2030



Source: pitt&sherry

The majority of supply in this scenario is met from diesel fired generation at the Whitemark Power Station, with its output modelled to grow from just under 4,000 MWh in 2011 to some 5,600 MWh in 2030. Note that, assuming the planned 2012 replacement of the No. 1 generating unit proceeds and even without further expansion, the average capacity factor for the power station as a whole would be around 22% in 2030. Firm capacity would exceed expected maximum demand in 2030 by some 250 kW, assuming the 2012 capacity of the Whitemark power station is maintained through time.

Under business as usual, fuel consumption in 2030 would be approaching 1.6 million litres (Ml) per year, generating over 4,100 t CO_2-e per year of greenhouse gas emissions. At today's prices, the fuel alone would cost some $2.2 million per year, or close to $2,500 per resident.

3.2.2 'Stepped up Growth' – Scenario A

We have prepared two scenarios to illustrate the impact of faster growth in power demand. The key assumptions underpinning Scenario A include, first, a significant expansion in agricultural activity on the Island. We assume that from FY2013, 1000 acres (404 ha) are irrigated, for example to enable an expansion of beef and lamb production for export. We then assume that the area under irrigation increases 5% every year to 2030. By 2030, this adds some 870 kW to peak demand on the Island, although the impact on average demand is smaller, as irrigation is assumed to occur only during 4 months of the year (Summer). Irrigation adds some 1350 MWh to annual electricity consumption by 2030.

We also assume for Scenario A that an additional 10 new houses are built annually, over and above those that are expected to be built under BAU. By 2030, this scenario implies that there would be some 625 houses[10] and 1,050 residents on the Island, compared with some 530 houses and just over 900 residents under BAU. The new houses are assumed to be 5 star as required under current Tasmanian law, each consuming around 6,700 kWh per year. An allowance of 6kVA is made per dwelling, although the average demand increment per house is typically around 7.5% of this theoretical peak. By 2030, this adds more than 1,000 kW to peak demand, although only some 80 kW to average demand, and leads to additional electricity consumption in the order of 1,200 MWh, equivalent to over one quarter of the current total consumption.

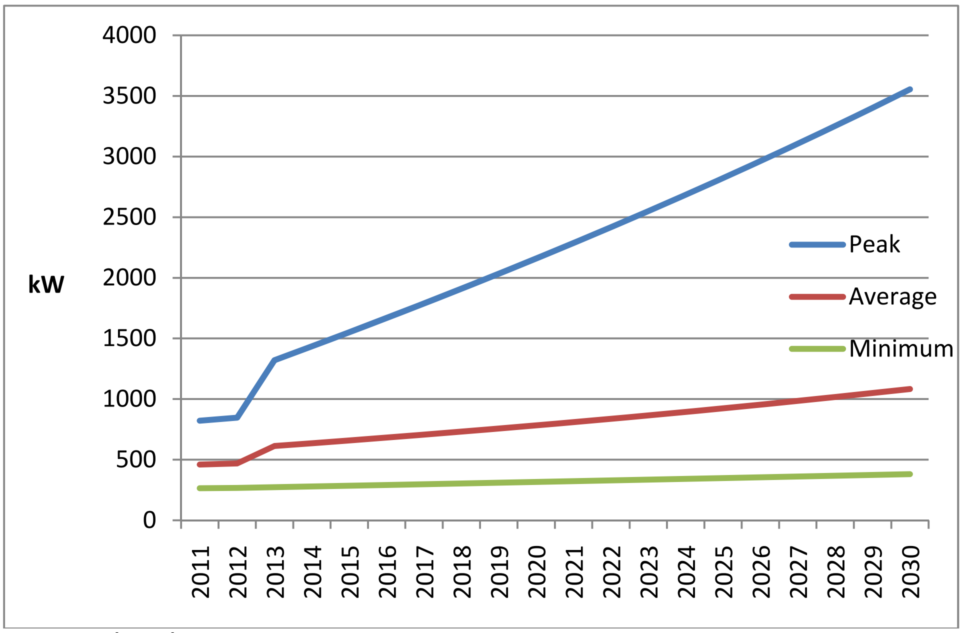
We acknowledge that this projected increase, particularly in peak demand, but in energy consumption as well, consequent upon a modest number of additional houses every year, may appear out of scale with existing peak loads on the Island. The current modest demand peak reflects the nature of the existing housing and appliance stock on Flinders Island, but this provides very little guide to the future.

New houses in Australia are, on average, the largest in the world at around 250 sqm, while air conditioning (for heating and cooling) and very substantial 'entertainment equipment' loads (TVs, DVDs, computers, games consoles, home theatres, etc) are becoming ubiquitous. We also note that Tasmania has elected not to phase out electric storage hot waters systems in new housing, and this will add significantly to peak loads in new housing when compared to more efficient hot water technologies. While it is possible that the new housing stock on Flinders Island might differ from this average – and indeed, the Flinders Council could potentially influence this through planning provisions – we have no reason to assume this. Further, electricity systems are designed using conservative assumptions in order to minimise the risk of outages caused by inadequate capacity or unanticipated peak demand.

Finally for Scenario A, we assume that the increase in population in this scenario pulls through additional demand for electricity in the commercial sector (supermarket, hospital, retail, etc), in the same ratio as current consumption, that is, around 50% of the residential demand. By 2030, this adds another 160 kW to peak demand, 40 kW to average demand (a smaller differential given the flatter nature of the commercial load) and around 600 MWh to annual consumption.

[10] We assume 1% per year of the existing housing stock is 'retired' (demolished or substantially upgraded).

Figure 3.4: Flinders Island Projected Electricity Demand to 2030: Stepped Up Demand Scenario A



Source: pitt&sherry

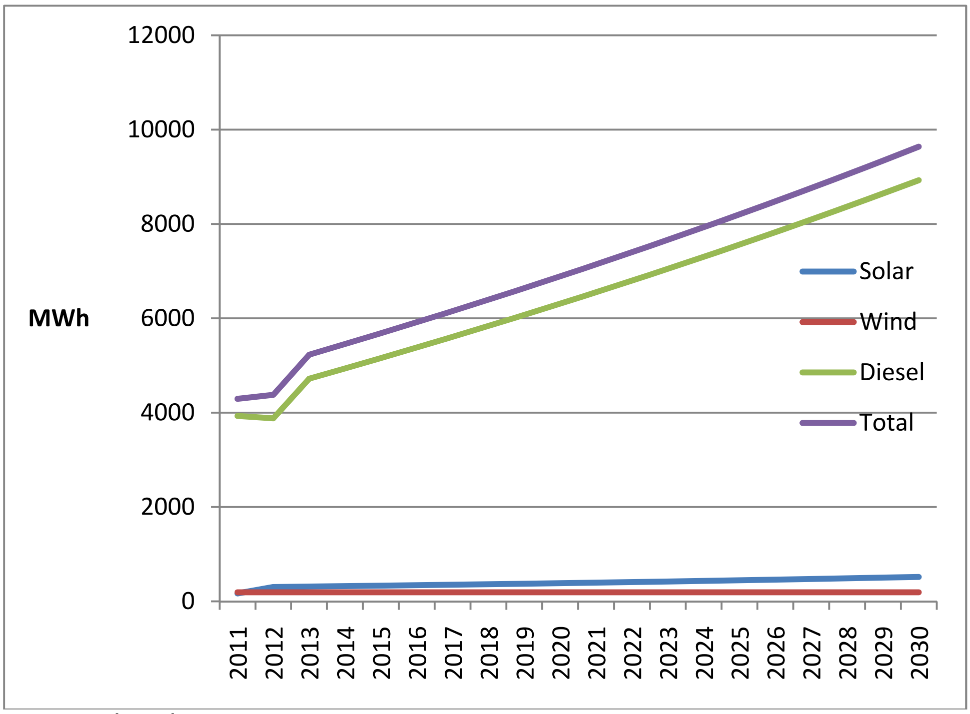
In aggregate Scenario A would see peak demand lifted by around 2.1 MW by 2030, when compared to BAU, to some 3.6 MW, and total electricity consumption more than doubled to around 9,700 MWh per year, as shown in Figure 3.4 above. Average demand, however, increases more modestly to over 1 MW in 2030 – still more than double the 2011 figure.

On the supply side we assume that, following the current significant investment in solar energy on the Island, capacity expands somewhat faster than under BAU at 5% per year from 2013 on, while the existing 55kW wind turbine continues to operate. Diesel is then assumed to make up the balance of electricity requirements, as shown in Figure 3.5 below.

This scenario would lead to a substantial increase in diesel consumption for power generation and associated greenhouse gas emissions, again assuming no significant investments in renewable energy. Diesel consumption would rise to some 2.5 Ml in 2030, up from around 1.55 Ml under BAU in the same year.

At today's prices, this would cost an additional $1.35 million over and above the BAU cost of around $2.2 million – that is, a total fuel bill in 2030 of around $3.6 million - making no allowance for carbon pricing or the other factors noted in Section 3.1 above. Greenhouse gas emissions associated with this power generation in 2030 would rise from around 4,150 t CO_2-e under BAU to around 6,700 t CO_2-e, an increase of 61%.

Figure 3.5: Flinders Island: Projected Electricity Supply to 2030: Stepped Up Demand Scenario A



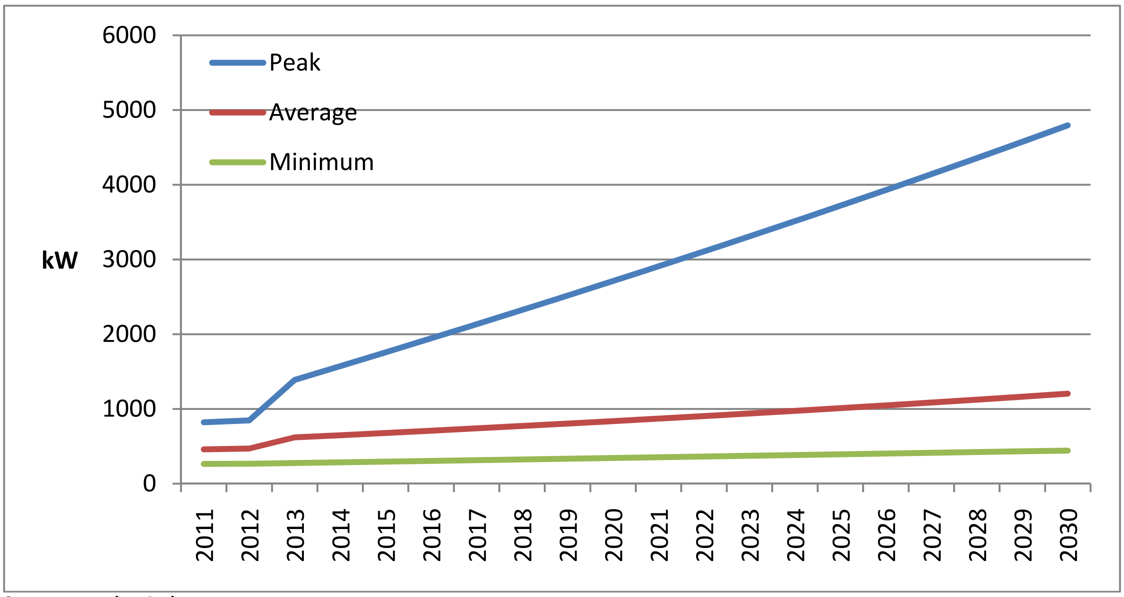
Source: pitt&sherry

It should be noted that a peak demand 3.6 MW in 2030 – as implied in this scenario - would require significant investment by Hydro Tasmania in diesel generation capacity, at least in the absence of significant investment in renewable energy. Peak demand would exceed current firm capacity by around 2017 in this scenario. By 2030, the current level of firm capacity would fall short of peak demand by some 1.9 MW. Recovering the costs associated with this investment should be expected to drive up the cost of the CSO and thus pressure to increase electricity tariffs on the Island.

3.2.3 'Stepped up Growth' – Scenario B

Scenario B makes the same assumptions as Scenario A with respect to stepped up agricultural production, but tests the impact of adding 20 houses per year, above those expected under BAU, along with the additional commercial sector demand this would pull through. In Scenario B, the total housing stock would reach 804 houses in 2030, while the resident population would be around 1,350 persons. Peak electricity demand would be some 3.4 MW higher than BAU in 2030, reaching around 4.8 MW in that year (see Figure 3.6 below). As with Scenario A, however, average demand grows much more slowly than peak demand, reaching around 1.2 MW in 2030, still a substantial 260% increase over 2011.

Figure 3.6: Flinders Island Projected Electricity Demand to 2030: Stepped Up Demand Scenario B



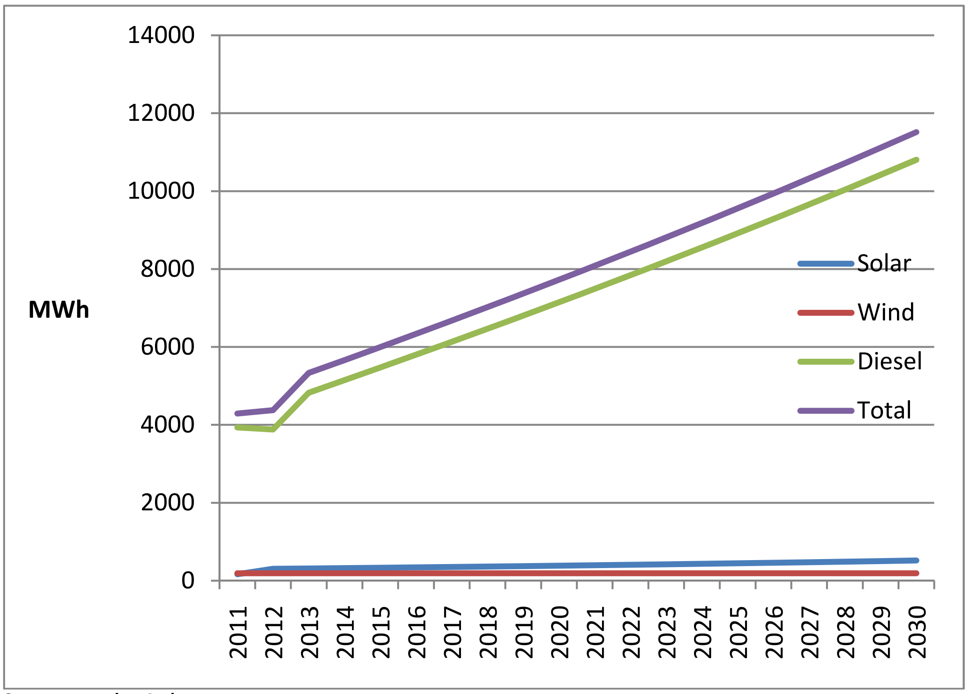
Source: pitt&sherry

In this scenario, total annual electricity consumption in 2030 would be around 73% higher than BAU, reaching over 11,500 MWh per year (see Figure 3.7 below). Without significant investment in renewable energy, diesel consumption in 2030 would exceed 3 Ml, associated with over 8,000 t CO_2-e of greenhouse gas emissions, at a total cost at today's prices of some $4.3 million, or $3,150 per person (for fuel alone).

In Scenario B, to an even greater extent than in Scenario A, the existing firm capacity of the Whitemark power station would need to be significantly expanded to cover expected peak demand. Peak demand would exceed 2012 firm capacity by no later than 2015 in this scenario, and exceed it by a substantial 3.1 MW in the absence of new investment. As noted in Section 3.2.2 above, this scenario would therefore require significant investment on the part of Hydro Tasmania, driving up CSO costs and hence pressures to lift the electricity tariff on Flinders Island.

It is important to note that the scenarios above are not forecasts. Rather, our intention is to illustrate the consequences for the Flinders Island energy system of different plausible futures. Many of these consequences will arise regardless of the specific evolution of energy supply and demand on the Island. The scenarios provide baselines or benchmarks against which to consider the merits of different renewable energy options for the Island.

Figure 3.7: Flinders Island: Projected Electricity Supply to 2030: Stepped Up Demand Scenario B



Source: pitt&sherry

4. Renewable Energy Opportunities Assessment

Flinders Island possesses world-class wind and tidal resources and also has excellent solar resources, along with biomass and waste streams that could also be used for energy production. There is the potential for Flinders Island to meet 100% of its electricity needs from renewable, zero carbon sources. Indeed, the potential also exists, over time, to replace other fuel consumption (such as transport fuels) with renewable energy, or even to consider exporting renewable energy to Tasmania and/or the mainland.

Renewable energy sources generally share the property that the 'fuel' (wind, sunshine, rain) comes for free – unlike conventional fossil fuel powered generation - but the penalty is that the capital cost of renewable energy installations is typically higher than for conventional power stations. This extra upfront investment replaces the ongoing risk and liability associated with fuel costs and – critically – reduces or eliminates greenhouses gas emissions. Note that biomass systems often have fuel costs associated with the collection, processing and transportation of biomass resources to a power generator. On the other hand, some biomass fuels can be stored and therefore contribute to the security of the overall power system.

Each renewable energy resource has unique properties that need to be understood and planned for to ensure that the overall electricity system is stable and secure. They vary in energy density, intermittency/reliability, predictability, storage capacity, unit cost and indirect or system costs. The following section therefore briefly reviews the renewable energy resources available on Flinders Island along with the main technologies used to capture these resources. Note that this project has not allowed for original resource mapping or measurement and therefore the information below should be treated as estimates only. Also, it is possible that other resources are available on the Island that have not yet come to our attention.

4.1 Wind Energy

Flinders Island, situated in mid-Bass Strait and exposed to the Roaring 40s, has one of best wind regimes in the world for power generation purposes.

The quality of wind resources for power generation is determined by:

- The average wind speed (generally summarised in an annual average figure – the average of all hours over a typical year, measured or imputed at a certain height above ground level), where 6 metres/second is considered a minimum benchmark for commercial wind generation
- The consistency (or conversely, variability) of the wind (which is measured by a large number of indicators such annual, monthly, daily or hourly minimum and maximum average wind speeds; the frequency and duration of extreme events – both high and low wind conditions; the consistency of wind direction (wind rose), etc)
- Other quality factors such as wind shear (differences in wind speed at different altitudes above ground level), wind turbulence and other characteristics

There are various observations of wind quality on Flinders Island. One observation of the quality of the wind resource on Flinders Island is offered by 3Tier's *FirstLook* software interface which ranks Flinders Island at 98% in a global wind ranking; that is, it possesses better wind resources than 98% of the world's surface.

The Bureau of Meteorology measures wind speed at 10 metres above ground level at the Whitemark airport, and indicates that the mean wind speed at that location varies between a minimum monthly average of around 5.3m/s in June to a maximum of around 7.2m/s in December.

However, wind speeds are greatly influenced by proximity to the ground, and for commercial wind generation purposes, are generally monitored at 30 metres above the ground or more to minimise the effects of ground based turbulence. Wind turbines may be positioned at 40 to 90 metres above the ground, depending upon their size, precisely to benefit from the stronger and more consistent wind conditions typically found at such elevations.

More importantly for power generation purposes, Hydro Tasmania has monitored actual wind conditions at Hays Hill near Whitemark for an extended period beginning in 1991, using masts at a number of heights including one at 30 metres about ground level (placing it some 160 metres about sea level). While the detail of the resulting data is confidential, it confirms that this is a world-class wind site, with a very consistent W-SW wind rose, average wind speeds in excess of 9 metres/second and low variability on an annual, seasonal and daily basis. For example, only for some 5% of all hours during an average year would there be insufficient wind for any generation. This is important, because in a renewable energy system where wind is the primary source of energy generation, these 'wind lull' times (their frequency and duration) determine the amount of energy that must be stored and/or the operational strategies for managing other generators on the network.

The monitoring has also confirmed that the incidence of very strong winds – strong enough to cause the wind turbine to shut down for safety reasons – is only around 0.1% of annual hours (with a maximum recorded wind gust of around 36 m/s or 130 kph). In an average year, wind turbine generators (WTGs) would be producing at least some electricity at that site for around 95% of the time.

Overall, it is clear that Flinders Island possesses an exceptional wind resource. Also – and while this is not recommended – we note that in theory the electricity needs of the Island could be met by a *single* WTG of modest size (with significant storage and other system assets). In practice, several smaller WTGs would provide superior security of supply, but the community need not be concerned about a proliferation of wind turbines being installed on the Island to cover its electricity needs.

4.1.1 Wind Turbine Generators (WTGs)

Wind turbine generators (WTGs) were first commercialised at a large scale in the early 1970s and are now a mainstream electricity generation technology right around the world. At the end of 2010, world wind installed capacity amounted to some 197 GW – equivalent to around four times the total electricity generation capacity from all sources in Australia. It is noteworthy that world wind capacity in 2010 grew a substantial 24% over the 2009 level despite the global financial crisis[11].

The energy in the wind is proportional to the cube of the wind speed, which means that a doubling in wind speed increases the potential energy output of a wind turbine eight fold. On standard diesel mini-grids, output from wind generators is typically restricted to around a third of the load to ensure power quality control (the optimal contribution depends on diesel genset sizes and load patterns). Increasing the wind contribution beyond this threshold requires significant expenditure on storage, other system assets, advanced monitoring and controls, and other scheduled generation units. These issues are discussed further in Section 4.6 below.

With world class wind resources and high diesel operating costs, Flinders Island is an ideal location for the installation of WTGs. Indicative costs for larger, grid-connection wind turbine installations are around AUD2.5 million per MW, although costs will be higher (per MW) for smaller scale installations, multiple machines and remote locations.

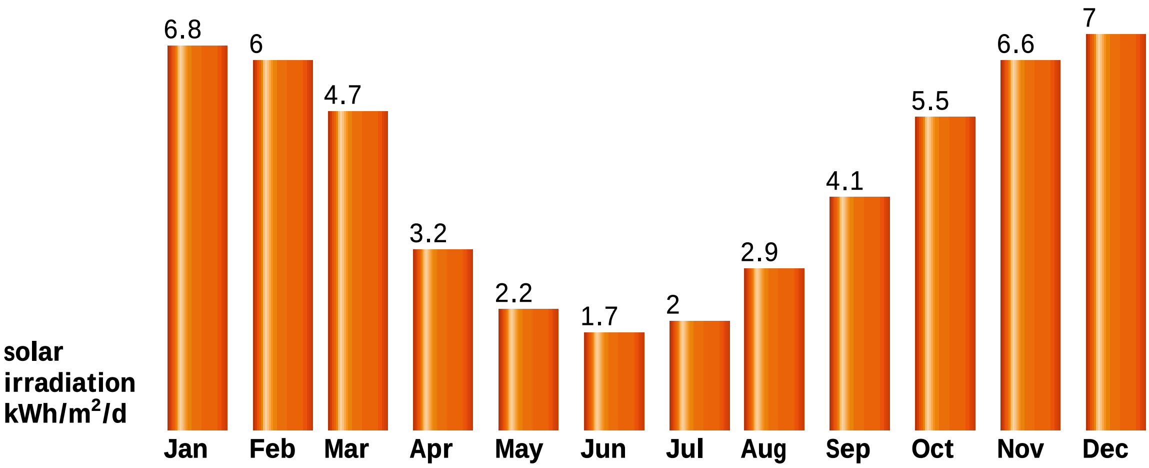
[11] *Global Wind Report – Annual Market Update 2010*, Global Wind Energy Council, April 2011, p. 11.

Hydro Tasmania has examined the potential for WTGs, and related system designs and grid-integration issues, in some detail. Wind based systems have consistently been found to be the least-cost generation approach. A 2006 study, for example, examined the scope to install two 660kW WTGs, together with enabling equipment including transformers and control system upgrades. All up this project was costed at around $5.5 million (around $6.4 million in today's dollars, or $4.8m/MW) and was expected to save around 60% of the diesel used for power generation.

4.2 Solar Energy

Solar resources are widely distributed and reasonably consistent from place to place provided that local effects like low level cloud or fog are infrequent. However, solar irradiation (sunlight striking the ground) varies from no output up to full output on a daily cycle and also varies markedly on a monthly basis, as shown in Figure 4.1 below.

Figure 4.1: Solar irradiation in Flinders Island



- *Average solar irradiation: 4.37 kWh/m^2/day*
- *Minimum (monthly avg) solar irradiation: 1.72 kWh/m^2/day*
- *Maximum (monthly avg) solar irradiation: 6.98 kWh/m^2/day*

Source: www.energymatter.com

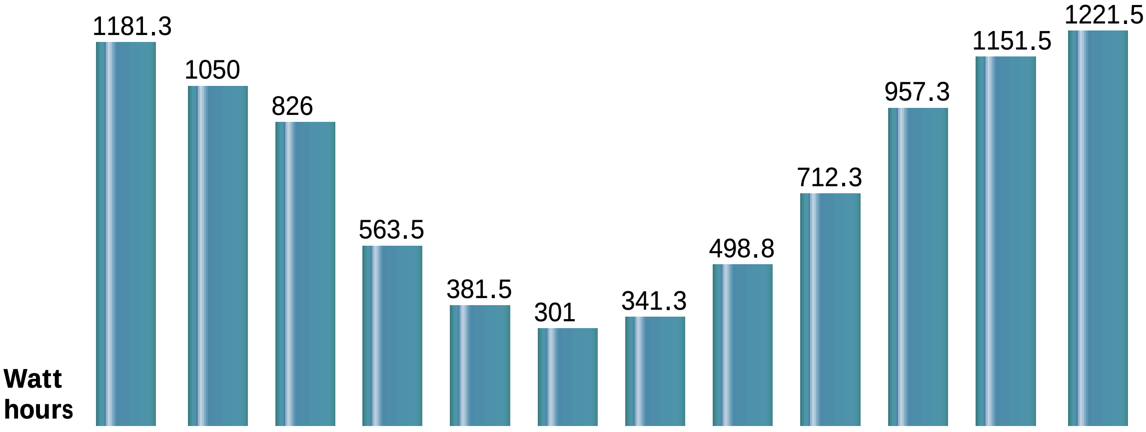
As with wind turbines, micro-siting of solar panels is very important, in particular ensuring that they are not shaded and that they are appropriately orientated towards North, with fixed systems tilted at around the latitude of the site (so, around 40 degrees from the horizontal on Flinders Island), or else utilising solar tracking devices to aid efficiency.

Broadly speaking, solar output falls slowly with increasing latitude. We estimate annual output of PV panels in Melbourne at 1,427 kWh/kWp installed (16.3% capacity factor), while for Hobart, we assume a value of around 1,400 kWh/kW (16% capacity factor) [12]. A further observation is available from the web-based publication, energymatters[13], which relates directly to Flinders Island (see Figure 4.2 below).

We note that this data is broadly consistent with our own estimates but implies a slightly higher yield at some 1,590 kWh/kWp (18.2% capacity factor), which may relate to optimal tilt. We use this value in our modelling.

[12] Note these estimates are based (for consistency) on panels with a 22.5 degree tilt; thus somewhat better results are likely with optimal tilt.
[13] www.energymatters.com

Figure 4.2: Conergy Solar Panel 175Watt 24Volt output in Flinders Island for 24V battery charging solar systems



- *Average daily solar module output: 764 Wh***
- *Minimum daily (monthly avg) output: 301 Wh***
- *Maximum (monthly avg) solar output: 1221 Wh***
- *Average annual output of this solar panel: 279 kWh***

*** There may be additional losses in MPPT / inverters (if any).*

Source: www.energymatters.com

While there are good solar resources on Flinders Island, the relatively low capacity factor when compared to wind or other generation options, together with the dip in output during the Winter months shown in Figure 4.2, are inherent characteristics of solar panels. Their benefits include excellent reliability and longevity, low maintenance, zero emissions or fuel use, and a good correlation with Summer load like air conditioning. At the same time, they provide no energy storage or system inertia, no output at night and lower output at peak demand times on Flinders Island, which as noted earlier are Winter mornings and evenings.

4.2.1 Solar Energy Technologies

There is a wide range of solar energy technologies. Concentrating solar troughs, dishes or towers use mirrors to concentrate sunlight onto receivers that typically heat a working fluid, which is then used in steam or other generators to create electricity. These systems generally track the sun. Compared with other solar systems, concentrating solar systems are generally larger scale and can deliver significant amounts of power. Some systems utilize molten salts or other systems for energy storage and are capable of delivering near continuous power output. However, such systems are at a relatively early stage of development and are not likely to be least cost for Flinders Island.

Flat plate PV cells or panels, or PV films, convert sunlight directly into electrical energy using semiconductor materials such as monocrystalline or polycrystalline silicon. This technology was originally developed by NASA for use in satellites. PV panels have no moving parts, contributing to their high reliability and lifetimes (exceeding 25 years) and virtually nil maintenance requirements. The technology is modular, meaning that systems can be designed that are suitable for very small scale applications (eg, off-road vehicles and campers) through to megawatt scale arrays. Solar panels can be fixed or mounted on tracking systems. The latter increase efficiency but also cost and complexity, requiring a careful consideration of incremental benefits. Generally, as PV panel costs fall (see below) the additional costs of tracking systems are harder to justify. Note that all solar systems require appropriate installations, including optimization of location and tilt to maximize output.

Until recently, cost was the primary barrier to the uptake of solar PV. However, PV panels have dropped dramatically in price in recent years notably due to production with high scale economies and low costs in China. PV module prices have declined along a well established learning curve, which has seen cost reductions of 22% for each doubling of cumulative capacity, over the last few decades. The global installed capacity of PV systems increased to 10 Gigawatt-peak (GWp) in 2010.

The International Energy Agency (IEA) and the EPIA expect further cost reduction with increased production capacities, improved supply chains and economies of scale. China has experienced a 20-fold increase in production capacity in four years, increased expansion of global production capacities for key components (including modules and inverters) and is continuing to exert downwards pressure on prices. A surge in silicon production capacity (a key commodity) has both alleviated supply constraints, and continued to increase. Further technological cost reduction opportunities are in train. Based on these drivers, the IEA and EPIA have made cost projections using learning rates of 18%, slightly lower than the historical average of 22% (see Figure 4.3 below).[14]

Figure 4.3: Expected PV Cost Reductions

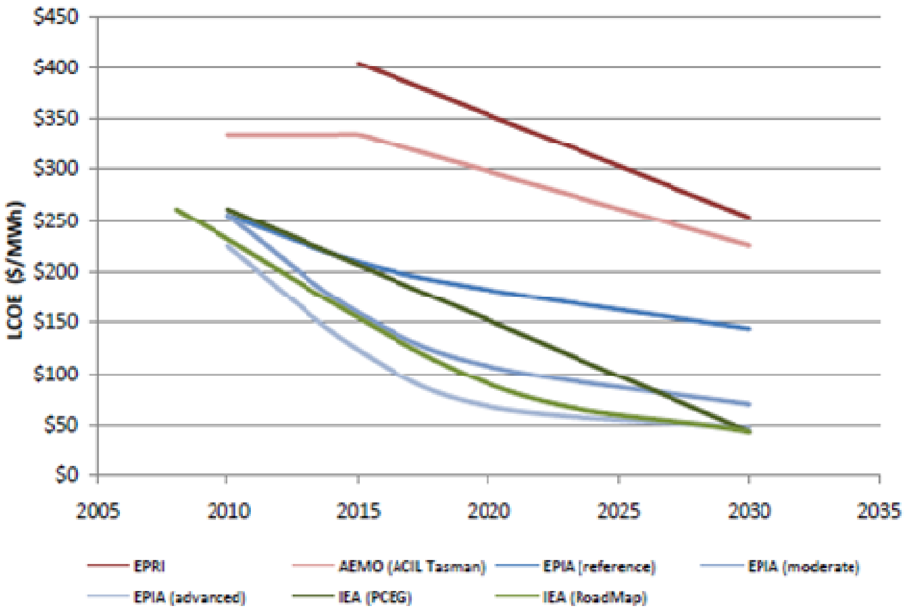


Figure 1: Solar photovoltaic cost projections (Direct Normal Irradiation = 2445 kWh/m2/yr)

Source: Renewable Energy Technology Cost Review – Melbourne Energy Institute, March 2011

We estimate that, assuming a feed-in tariff equivalent to the current electricity tariff on Flinders Island, PV systems are already just cost-effective at an (unsubsidised) capital cost installed of $4,400/kWp: that is they offer a benefit cost ratio of 1 over 20 years at a 7% discount rate. With rising electricity prices and falling PV costs through time (we assume $2,900/kWp by 2020), PV will be increasingly cost effective on Flinders Island, even without capital subsidies. On this basis we expect PV capacity on the Island will continue to grow over time.

The primary disadvantage of PV panels is their relatively low capacity factor, or energy output per unit installed capacity, primarily driven by their need to be exposed to sunlight to generate electricity. As discussed earlier, the output of PV panels varies both on a 24 hour and also a seasonal cycle.

[14] *Renewable Energy Technology Cost Review* – Melbourne Energy Institute, March 2011.

As with WTGs, PV systems are typically unscheduled and do not contribute inertia or ancillary services to a network, and they do not store energy (although there are some more elaborate and higher cost solar technologies that do involve short term energy storage). The primary utility of PVs in a power system, therefore, is to inject energy to offset loads, particularly loads that are correlated with their output such as air conditioning. They can also increase diversity in supply, for example contributing energy on still summer days when WTG output may be low or nil.

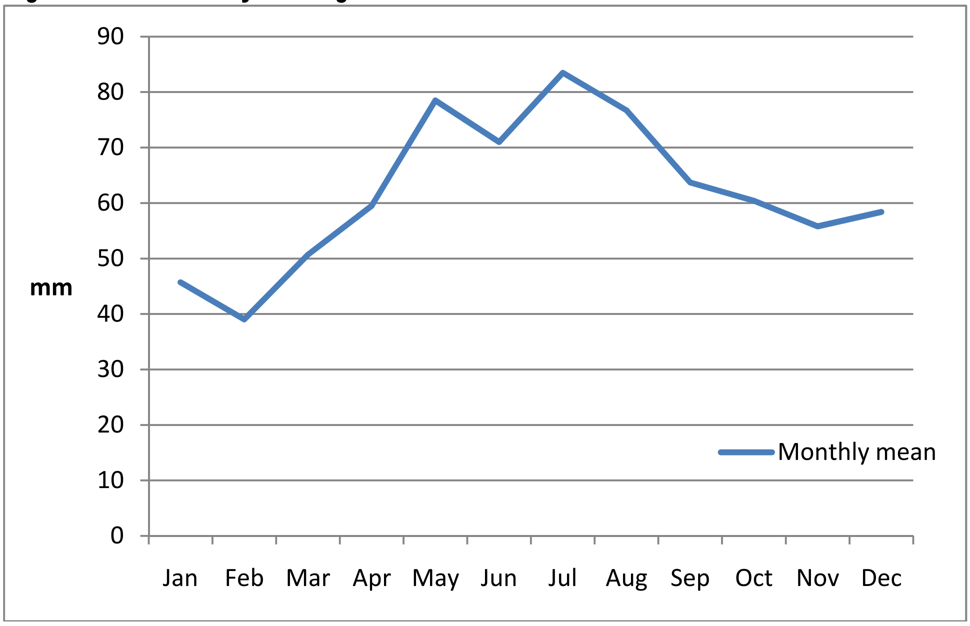
Solar hot water systems are solar thermal systems that capture and store solar energy as heat, rather than converting it to electricity. Flinders Island already has a very high share of solar hot water systems, although the majority of these are older, flat plate systems with relatively low efficiency. These systems are electrically boosted and so if efficiency is low, or the collectors are not functioning correctly, these systems may act like conventional electric storage hot water systems. New evacuated tube solar collectors are more efficient and also are able to operate at lower light levels and angles, extending their solar capture abilities on a daily and seasonal cycle. Unfortunately, the Federal Government's Small scale Technology Certificate (STC) scheme does not apply to the replacement of existing solar hot water systems, effectively discouraging the uptake of new solar hot water systems on Flinders Island.

Finally, there are hybrid concentrating/PV systems which combine mirror with PV cells to increase the efficiency of the PV cell and reduce costs (since mirrors are cheaper than PV cells). Such systems are more akin to pure concentrating solar arrays in that they must track the sun for efficiency, increasing installation and maintenance costs.

4.3 Hydrological Energy

Mean rainfall over Flinders Island is well above the national average at 744mm per year, and consistent with values for Northern Tasmania and Southern Victoria. Monthly average rainfall data is shown in Figure 4.4 below, with a typical Winter peak.

Figure 4.4: Monthly Average Rainfall Data: Flinders Island



Source: Bureau of Meteorology – Climate Statistics for Australian Locations

However the terrain on Flinders Island is such as there is only limited natural storage of fresh water, and mainly at low elevations on the East of the Island. There are no natural storages at elevation.

Groundwater resources for South Eastern Flinders Island (approximately South of Memana Road) have been monitored and modelled recently by Hocking et al Pty Ltd[15]. This study finds *inter alia* that "…the Tertiary basalt aquifer (in specific locations) has sufficient water resources for be further developed sustainably beyond stock and domestic water supplies to small scale irrigation demands (e.g. around 20 Ml/year)'.

This resource could in principle be sufficient to be used as a 'working fluid' in a closed loop mini-hydro system with pumped storage, as discussed in Section 4.8.2. However in practice there are always losses from such systems, for example evaporation from dam storage. Such losses could be minimised through installing a 'skin' on dam storage, but at a cost. There would also be costs associated with the extraction and transportation of this groundwater to a mini-hydro site. Finally there would be 'opportunity costs' from this use of the water resource: that is, water used for power generation would no longer be available for irrigation or other uses, and these may conceivably be higher value applications. Further examination of this resource may require field studies, and we again note that this study was restricted in its geographic scope to South Eastern Flinders Island. Resource availability may differ elsewhere on the Island.

4.3.1 (Mini) Hydro Technologies

Please refer to Section 4.8.2 below.

4.4 Tidal and Wave Energy

Both tides and ocean waves contain very large amounts of energy. This energy may be considered renewable as it is driven by gravitational forces (tides) and wind primarily (waves), resources which are not depleted (other than at a very local scale) by their use for energy generation purposes. Tidal and, to a lesser extent, wave energy flows may be predicted with some precision for long periods of time, which is an important commercial consideration.

The common challenge with both tidal and wave resources is primarily an engineering one – how to design and construct devices which are sufficient robust to withstand the large energy flows that they will be subjected to and the harsh (salt water) operating environment, while yielding useful amounts of electricity at an affordable cost. This challenge is a significant focus for research and development activity around the world, including in Australia where at least $5 billion of additional renewable energy technology commercialisation funding is expected to be invested by the newly-established Clean Energy Finance Corporation in coming years. It is therefore reasonable to expect that tidal and wave energy technologies will advance rapidly over the next decade and may well become a fully commercial prospect within that timeframe.

Tidal energy may be divided into two different categories: tidal streams and tidal heights. The maximum tidal range on Flinders Island appears to be around 2.8 metres[16]. This modest value (compared with other sites where tidal ranges exceed 10 metres, for example around the Kimberley coast of WA) may be suitable for small scale systems, for example utilising a tidal barrage and turbines optimised for very low head applications.

Tidal stream energy (the energy contained in tidal flows), on the other hand, appears to be a very significant resource around Flinders Island – possibly one of the best in the world[17].

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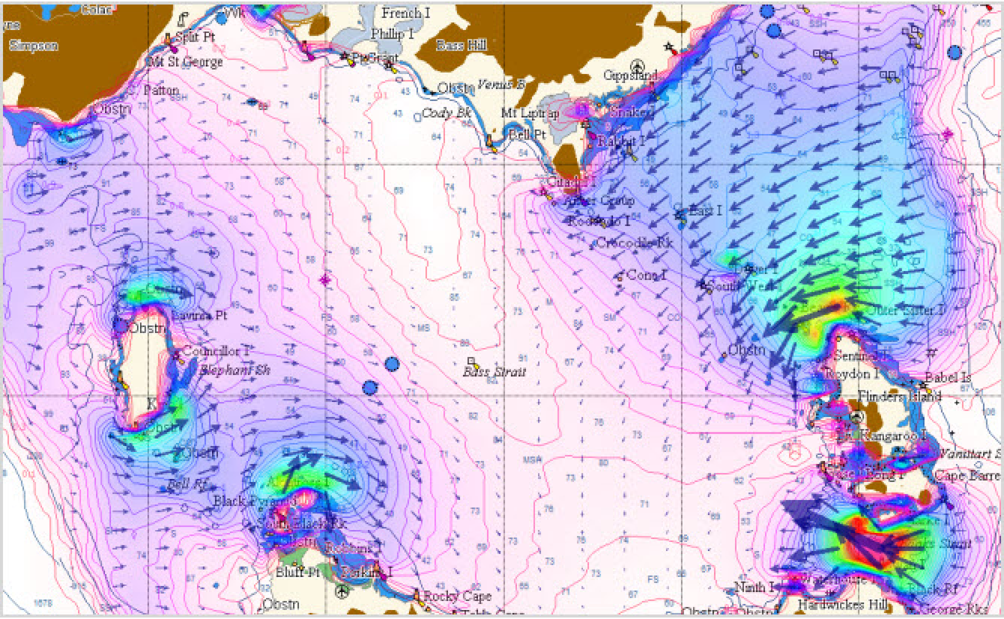
[15] Hocking et al (2010).
[16] http://www.tide-forecast.com/locations/FlindersIsland-Australia/tides/latest
[17] Tidal flows are less well mapped around the world than many other renewable energy resources, so there is greater uncertainty about this. However, it has been claimed that Banks Strait represents one of the top three potential tidal flow resources in the world.

While tidal flow speeds are significantly lower than average wind speeds, the greater density of water when compared to air means that, in principle, much more energy can be captured for a given 'swept area' of an tidal turbine than for a wind turbine. Tidal flows have the advantage of being highly predictable (for decades in advance), but the disadvantage that flow rates fall to zero at the turn of each tide. For an islanded power system, this means either than another form of 'back-up' generation, or an energy storage system, would be required to provide continuous, baseload power.

According to the Clean Energy Council (CEC)[18], the Banks Strait between NE Tasmania and Clarke Island offers tidal flow speeds of up to 2.6 m/sec. The following figures from Tidetech, also indicate a significant tidal flow in Banks Strait and possibly also off the Northern tip of Flinders Island.

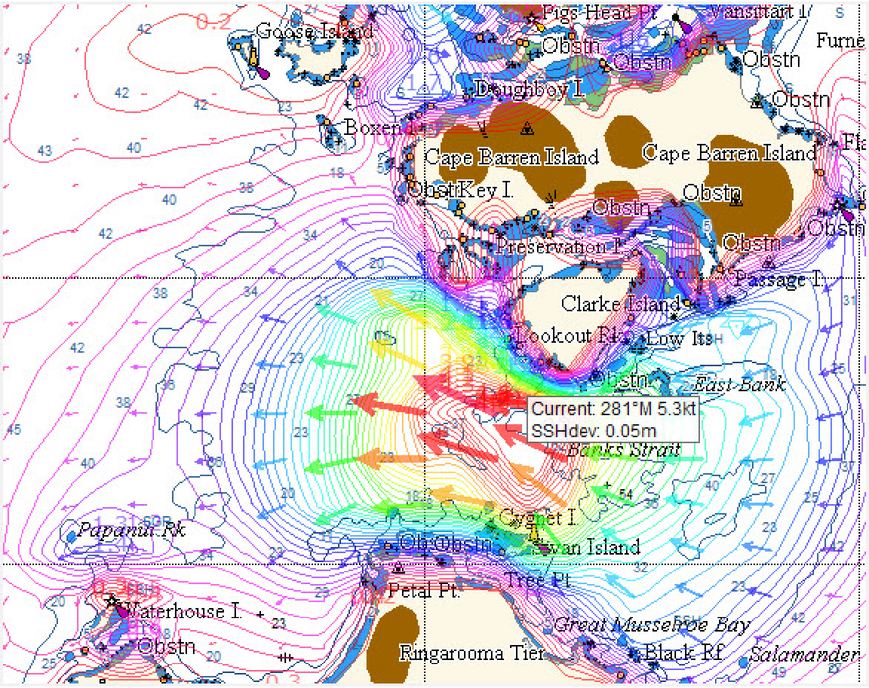
Figure 4.5: Tidal Flows, Bass Strait and Flinders Island



Source: http://www.tidetech.org/bass-strait-tidal-streams

[18]http://ecogeneration.com.au/news/australian_ocean_power_waves_tides_and_other_ocean_currents/061601/

Figure 4.6: Tidal Flows, Banks Strait



Source: http://www.tidetech.org/bass-strait-tidal-streams

The CEC reports that a company, BioPower Systems, has conducted preliminary investigations, site analysis and site design for a potential pilot tidal stream installation at Flinders Island, noting that speeds above 2.5 m/sec can be commercially viable for this technology. The bioSTREAM™ employs an oscillating hydrofoil system to extract energy from moving water, and the CEC notes that the system would include a power conversion module developed in collaboration with Bosch Rexroth, CNC Design and Siemens to deliver the appropriate power quality. **pitt&sherry** understands from BioPower Systems that it has permits in place that would enable this project to proceed, but that the company is currently focusing on a wave energy project at Port Fairy, VIC. The Flinders Island tidal stream project remains a prospect for development at some point in the future.

Tenax Energy is another company which, according to their website, is seeking government approval to explore the Banks Strait project further. Tenax Energy is an Australian company that has identified Banks Strait as one of three Australian locations with the necessary combination of tidal flow speed, deep water to drive tidal energy turbines and proximity to electricity grids. The turbines they propose to use are described as conceptually similar to wind turbines, but are turned by tidal flows.

Regarding wave energy, **pitt&sherry** has not be able to source specific data in the vicinity of Flinders Island. Generally, wave energy is primarily a square function of wave height or amplitude, while it is also related to wave speed. This means that wave height or amplitude is the key determinant of wave energy, rather than wave speed. The energy contain in waves, which is ultimately generated by changes in air pressure over the oceans and also by wind, can be very great indeed. As with tidal stream energy, extracting that energy represents a major engineering challenge; one which is being tackled with very many innovative technologies and systems around the world.

Our professional judgement is that tidal flow and wave energy systems are unlikely to be able to provide a reliable, baseload power solution for Flinders Island at this time. However, the existence of a world-class tidal flow resource in at least Banks Strait means that there may well be an opportunity to promote Flinders Island to the national and indeed global renewable energy development and investment community as an ideal location to locate pilot and commercialisation-scale installations. This would create significant interest, as well as direct investment, in the Island – with potential for spillover benefits for economy – while such installation would also contribute useful amounts of renewable energy to the Flinders Island grid. As with many other renewable energy resources and systems reviewed in this paper, tidal and wave energy systems would require significant investment in storage and other system assets in order to achieve a high penetration of renewable energy on Flinders Island.

4.5 Biomass Energy (including Waste to Energy)

Biomass energy can be produced from plants, wood, residues (for example sawdust and sugar cane residue, after crushing) and animal wastes. It can be used directly (for example, burning wood for heating and cooking) or indirectly, by converting it to a liquid or gas fuel (for example, producing ethanol from sugar crops or producing methane, or natural gas, from animal manures).

There are many biomass energy and waste-to-energy streams that can be commercially harvested. These include:

- Sewage gas that captures the methane emitted from the solid organic components of sewage
- Landfill gas that captures the methane emitted from landfills
- Agricultural-related wastes such as livestock wastes. When animal manure is mixed with water and put in an airtight container called a digester, methane gas (or biogas) is produced by bacteria. The biogas can be burned directly for cooking or heating, or used as fuel in electricity generators. The effluent (unused wastes) from the digester must be taken away and used or disposed of safely because it may contain harmful substances and bacteria.
- Food industry wastes and abattoir wastes can also be used to produce biogas in digesters or, as discussed below, biofuels
- Agricultural crops, such as sugar beet for ethanol or canola for biodiesel
- Urban biomass such as food-related wastes, garden organics, paper and cardboard material, and timber from construction and demolition sites
- Wood-related wastes such as wastes produced in the harvesting and processing of wood such as sawmill and pulp-mill residues

Generally, woody biomass and solid municipal wastes have the advantage that they can be stored and converted into electricity as required. By contrast, green wastes and waste streams from agriculture and agricultural product processing are generally not feasible to store and must be processed into energy (or fuels) as produced. A dedicated landfill site, which is sealed and allows anaerobic production of methane, represents something of a hybrid, as methane output of such systems can be stored and regulated to a degree. A majority of waste water processing sites and larger landfill sites in Australia feature some form of methane capture and recovery, whether for flaring or beneficial use, including for electricity generation. In Queensland, for example, the Luggage Point Treatment Works produces methane gas from sewage. The gas is burned in the power station to produce 3,200kW of electrical power. A cogeneration system uses the biomass to produce both heat and electricity when both are needed.

Energy production from biomass is an effective use of waste products and it also reduces the significant problem of waste disposal. However, biomass has relatively low energy density, so transport and handling costs may make it uneconomical in Australia unless the energy conversion process is close to a concentrated source of biomass, such as a sawmill, sugar mill or pulp mill. There can be other problems (eg odour) when digesters are used.

Flinders Island's modest physical size means that transportation costs may be able to be minimized, particularly with good planning and co-operative development, for example leading to co-location of facilities that have synergistic properties.

From a greenhouse perspective, conversion of methane to carbon dioxide by combustion represents a major benefit, as methane is about 23 times more powerful as a greenhouse gas than CO2, while CO2 generated ultimately from biological processes is 'zero rated' in emissions accounting[19].

Critical to the viability of these resources for power generation is the volume and reliability of the feedstock. These issues are being examined in the separate *Flinders Island Greenhouse Gas Minimisation Plan*.

A particular biomass opportunity of relevance to Flinders Island is that the abattoir (owned and operated by Flinders Island Meat) has the potential to produce tallow from its waste products, which could be directly fired as a fuel or else could be processed to make biodiesel. Indeed, Flinders Island Meat has a well developed rendering plant project proposal, at this point for the production of tallow and meat meal. The potential of such a plant is that it could a) reduce greenhouse gas emissions from the existing waste stream; b) produce tallow or biodiesel as an energy source (tallow could be used on site, but biodiesel may be able to be used for power generation and/or transport on the Island); and c) produce a meat-meal by-product that could, for example, be processed into valuable products like dog food.

It is important to note that biodiesel can begin to freeze or gel as the temperature drops, meaning that fuel tanks and lines may need to be heated. Biodiesel must be stored separately from mineral diesel, meaning that additional storage tanks would need to be installed if the fuel were to be used at the Whitemark Power Station. Note that the King Island case study below is expected to include the use of biodiesel at the Currie Power Station, and lessons from this experience may be able to be transferred to Flinders Island.

4.6 System Design Considerations

Electricity is an unusual commodity. Most traded products, even perishable foodstuffs, can be chilled or frozen and kept in good condition until they reach market days, weeks or months after production. Electricity, on the other hand, is very difficult to store in significant quantities. At the same time, the demand for electricity rises and falls by the minute (or indeed by the milli-second), in a largely unpredictable fashion[20], as individual appliances or pieces of equipment are switched on and off. Yet we all expect that, whenever we switch on a device, sufficient power of the right quality will be available to power that device.

This demanding and constantly changing operating environment requires a set of control and management strategies that aim to ensure that the load is met and that power quality is maintained at all times. These control strategies are most usefully considered in terms of a timeline that varies from milliseconds to seconds (for responding to changes in frequency); seconds to minutes (for ramping up or down generation in response to (or anticipation of) load changes, or responding to ongoing frequency or voltage issues); hours and days (noting, as per Chapter 2 above, the distinct pattern of load changes over a typical day on Flinders Island); seasons; and even years (certain energy storage systems, such as dams, may contain years worth of energy).

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[19] On the grounds that the carbon embodied in those processes was originally extracted from, and would naturally be returned to, the environment.

[20] Demand is forecast using statistical methods, generally with a reasonable degree of accuracy. However the exact level of demand from minute to minute is not knowable with precision and can only be estimated.

Considering short term management, in conventional power systems, fossil fuel based or hydro generators use stored energy (fuel, or water in the case of hydro generators) to ramp up and down as necessary to match the load (load-following), with a margin of 'spinning reserve' to cover short term variability. These generators are considered to provide (at least) two distinct services: energy, on the one hand, and 'ancillary services', on the other hand, which include frequency raising and lowering in different timeframes and voltage control, *inter alia*. For larger and longer term changes in load, individual generation units are added or removed as required. The control logic can potentially run the other way as well: if there is insufficient generation capacity (or stored energy) to meet the instantaneous load, control systems may be able to 'shed' load in real time (cut off certain customers or loads within customers' sites) in order to restore system balance. When the underlying problem with capacity or energy is addressed, then the customer or load can be restored.

When unscheduled[21] renewable energy generation is connected to a grid, however, further variability is introduced, as the output of these systems fluctuates up and down in response to resource flows, and not (necessarily) in response to changes in load. Networks that have high *inertia*, due to spinning generators or (in thermal systems) a thermal boiler, have the ability to resist changes in network conditions (frequency, voltage) by responding quickly and 'energetically' to such changes, thereby restoring equilibrium. Wind turbine generators and solar PV installations do not generally contribute inertia to a network, and this demands that other 'enabling' devices are connected to the network to provide these requirements. It follows that as the share of unscheduled renewable energy on a network rises, so the requirement for (and cost of) enabling devices also rises.

Before reviewing such devices, we consider the longer term management strategies. As discussed in Section 3.1, the *security* of a power system – its ability to continue to meet demand at all times – is a function of having sufficient energy in storage, readily available for conversion into electricity[22]. For coal fired power systems, the stored energy is the amount of coal in the coal-yard; for gas fired power systems, it is the volume of gas in the pipeline at sufficient pressure (the "line-pack"); for hydro based systems like the Tasmanian mainland, it is the volume of water stored in dams. However wind power and most solar systems do not store energy at all – rather they convert a 'flow' of renewable resources directly into electricity in proportion to the wind strength or solar irradiation at the time. Thus, for these systems to deliver security, they must be supplemented by some external form of energy storage. The options for such storage are also examined below.

Note that the line between enabling technologies and storage technologies is blurred: batteries, for example, can be considered as both. As noted above, the key distinction relates to the time period over which they are intended to operate – some enabling technologies are designed to respond in milliseconds (but may only be able to do so for seconds or minutes), while some energy storage systems (such as deep water storages) may be designed to provide energy security over multiple year timeframes.

[21] That is, devices where the output is not controlled but rather responds to changing resource flows, such as wind turbine generators and solar panels. Unscheduled generators are generally not load-following (but may be able to be made to respond in some way to changing load conditions).

[22] This follows directly from the first law of thermodynamics, which states that energy can neither be created nor destroyed, but merely converted from one form to another. Thus, what we commonly refer to as "power generation" does not generate energy at all – rather it is a process that converts one form of energy (stored fuel, or else renewable energies like wind and solar) into another form of energy – electricity.

4.7 Enabling Technologies

Enabling technologies are so named because they enable a higher percentage of renewable energy (particularly, unscheduled renewable energy) to be utilised while maintaining appropriate power quality and system stability. There are very many devices (and control strategies, software, prediction tools, etc) which may claim to enabling technologies: here we review only the major classes.

4.7.1 Resistor Banks

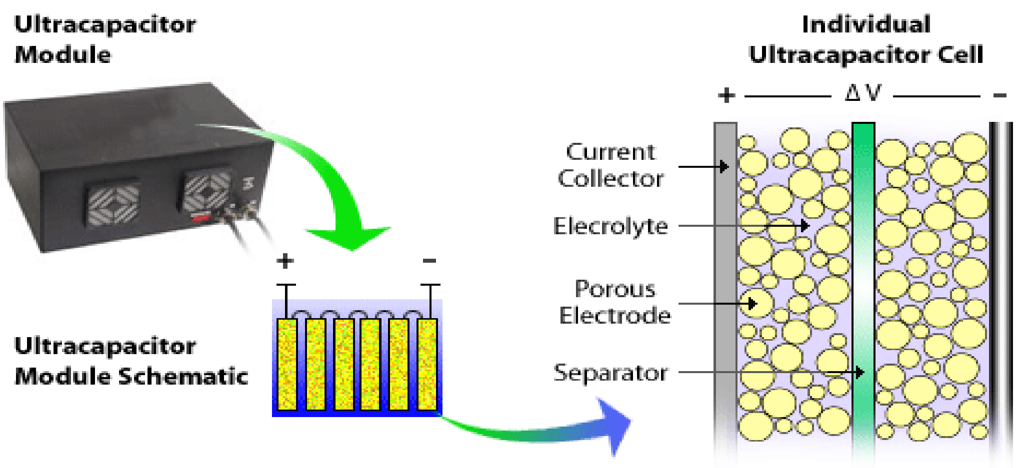
Resistors are conceptually simple devices (analogous to an electric bar radiator or electric hot water storage system) which enable surplus electricity to be removed quickly from the system in order to manage 'over-speed' conditions (eg, in a wind-powered system, where the wind suddenly picks up or demand suddenly falls, leading to rising frequency). They do this by converting the surplus electricity into heat, which is then either dissipated to the earth or atmosphere, or in some cases may be stored as hot water which can then be used to supply energy services (see for example the Mawson Case Study below). Generally however, resistors do not enable stored energy to be recovered, and therefore the overall use of energy is less efficient. However, they are typically significantly cheaper than systems that do enable recovery (such as capacitors and batteries or other storage devices, discussed below) and are effective in managing temporary over-frequency conditions (by increasing the load). Where the resistor bank is loaded, reducing that load can also provide some frequency raise reserve, assuming that there is spare generation available.

4.7.2 Capacitors/Ultra Capacitors

Capacitors or ultra-capacitors (see Figure 4.7 below) are energy storage devices that differ from batteries in that energy is stored electro-statically rather than electro-chemically. Practically, they offer greater potential for rapid charging and discharging at higher power levels, but store much less energy than equivalent sized batteries. Ultra capacitors also offer much longer charge/discharge cycle lives than batteries. Give their technical characteristics, they are highly suitable for frequency and voltage regulation applications.

Capacitors underpin a number of 'power electronics devices' such as static synchronous compensators (statcoms) and static VAR compensators (SVCs). These power electronics devices are particularly useful for rapid response voltage regulation and management of power factor, although unlike synchronous condensers (below) they do not provide inertia or fault contribution.

Figure 4.7: Ultra Capacitor Schematic



Source: http://www.nrel.gov/vehiclesandfuels/energystorage/ultracapacitors.html

4.7.3 Synchronous Condensers

Synchronous condensers are devices, analogous to large unloaded electric motors, that are typically used to correct poor power factor in a network. This in turn reduces the amount of 'real power' that needs to be supplied to meet loads. Synchronous condensers are able to absorb or supply reactive power, thus contributing to voltage regulation, and also supply inertia and fault contribution to assist with network stability.

It should be noted that some wind turbine generators have poor fault ride-through characteristics, while more modern designs typically have better performance in this area and may provide 'synthetic inertia'. Thus the choice of turbines may well have implications the costs incurred in the wider power system, including for devices that can compensate for any shortcomings in generator performance.

4.7.4 Flywheels, Diesel Uninterruptible Power Supplies (D-UPS)

Flywheels are short-term energy storage devices that work by converting surplus electrical energy into rotational energy, by spinning a high speed flywheel that is typically manufactured from high-strength composite material and suspended on magnetic or hybrid, low-friction bearings in near vacuum conditions. Their advantages over other devices include high energy efficiency, high power output and very long cycle lives (much greater than other storage devices) and higher energy densities than batteries. Their disadvantages include relatively limited energy storage capacity and high cost. Primarily they are suitable for frequency and voltage regulation and are often partnered with wind turbines (for example by Western Power in WA) given their capacity to compensate for fluctuations in the output of WTGs, smoothing their power output.

A diesel uninterruptible power supply (D-UPS) combines a flywheel storage device with low-load diesel generator. Surplus electricity can be stored in the flywheel of a D-UPS and drawn down as necessary, as described above, but in addition, when stored energy in the flywheel is insufficient, the diesel generator is switched on within a few seconds and supplies additional energy to assist in meeting load and power quality requirements. For Flinders Island, there may be the opportunity to use one or more D-UPS in place of existing diesel gensets in the Whitemark Power Station. This would help to enable a high unscheduled renewable energy share and potentially enable the conventional diesel generators to be shut off and retained in an emergency back-up role (see Chapter 5). The potential to operate D-UPS on biodiesel would need to be confirmed. We note that Hydro Tasmania's King Island Renewable Energy Integration Project (see Section 4.9.4 below) is likely to collect data in this area that would be relevant for Flinders Island.

4.8 Energy Storage Technologies

There is a wide range of longer term energy storage technologies with widely differing characteristics, including many different battery technologies, pumped storage systems, thermal storage systems, compressed air storage systems and others. Generally they can be characterised by their power (in kW or MW), capacity (in kWh or MWh) and duration (in hours or other time units)[23]. In some cases energy *density* is also relevant, or the amount of energy stored per unit weight or volume.

Storage systems can be thought of as comprising three sub-systems: charging, storage and discharging. For example in a pumped storage hydro solution, electric (or other) water pumps and associated infrastructure provide the 'charging' system; a dam or other water storage reservoir provides the 'storage' system; while a hydro generator and associated infrastructure (penstock, etc) provide the 'discharging' system. All

[23] A 1 MW battery rated for 250 MWh, for example, could support a 1 MW load for 250 hours, or a 0.5 MW load for 500 hours.

storage systems involve some losses of useful energy and can be characterised by their overall or system efficiency (energy out as a percentage of energy in).

The text below reviews battery and pumped storage solutions. Thermal storage (in which electricity is converted into heat, the heat is stored (for example in a carbon block), and then the heat later extracted and reconverted to electricity via a steam turbine, is not considered a viable candidate for Flinders Island due to a relative lack of technical maturity and uncertain costs. Compressed air systems are suitable for small scale applications only.

4.8.1 Batteries

Batteries are devices which store electricity chemically. Many different materials (liquids, gels, solids) have electrochemical properties, and this is a very active area of technology development, with new and improved technologies and specifications available on virtually a weekly basis.

Traditional lead-acid battery systems have been used to store electricity generated by wind and solar PV systems. They are relatively cheap, reasonably reliable, widely available and modular. However they also have performance limitations including relatively short life cycles (measured in charge/discharge cycles), and high maintenance demands. A range of 'advanced' lead-acid batteries are becoming available with higher efficiencies and total cycles than traditional lead-acid batteries (see Figure 4.8 below).

Lithium-based (Li-ion) batteries are rapidly developing as both large and smaller scale energy storage devices. Traditional graphite materials used in conventional lithium-ion batteries are being replaced with a proprietary, nano-structured lithium titanate. Compared to lead-acid-batteries lithium-ion are more compact; with greater energy density; lower capacity loss and impedance growth; longer life (greater than 10,000 full charge-discharge cycles); and overall efficiencies of 87% - 92%. Li-ion developer Altair Nanotechnologies is reported as having 1 MW/250 kWh trailer-mounted Li-ion battery systems in service, capable of providing fast frequency response for up to 15 minutes, while A123 Systems has a 2 MW unit serving the California ISO and another 12 MW installed at a substation in Chile[24].

Figure 4.8: Cost comparison of energy storage options for frequency regulation and renewable integration

Energy Storage Options for Frequency Regulation and Renewable Integration

Applications:

- Utility Frequency Regulation
- Power Quality
- Defer Capital Cost Deferral

Technology Option	Maturity	Capacity (MWh)	Power (MW)	Duration (hrs)	% Efficiency (total cycles)	Total Cost ($/kW)	Cost ($/kW-h)
Flywheel	Demo	5	20	0.25	85-87 (>100,000)	1950-2200	7800-8800
Li-ion	Demo	0.25-25	1-100	0.25-1	87-92 (>100,000)	1085-1550	4340-6200
Advanced Lead-Acid	Demo	0.25-50	1-100	0.25-1	75-90 (>100,000)	950-1590	2770-3800

Source: EPRI (2010)

[24] Electric Power Research Institute (2010) *Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits*.

Notes and Assumptions:
1. These systems may also be applicable for smoothing intermittency of wind and photovoltaic power generation as well as C&I power quality applications. All systems are modular and can be configured in both smaller and larger sizes not represented. Figures are estimated ranges for the total capital installed cost of "current" systems based on 2010 inputs from vendors and system integrators. Included are the costs of power electronics if applicable, and all costs for installation, step-up transformer, and grid interconnection to utility standards. Smart-grid communication and controls are also assumed to be included.
2. For all options, process and project contingency costs are included depending on technical maturity of the system.
3. Li-ion battery systems are finding initial use in this application. There are several different types of Li-ion chemistries, each with their own cost and performance characteristics. Data shown is the average of currently available systems. Each chemistry will have its own cost structure, so actual selected system costs may vary. Durability and life-cycle cost data is unavailable at this time. Battery replacements over the book life must be considered in a lifecycle analysis.
4. Flywheel systems are finding initial use in this application. Durability and life-cycle cost data is unavailable at this time. Flywheel replacements over the book life must be considered in a life-cycle analysis.
5. For all systems, future system costs may be lower than shown after early demonstrations are proven and validated, products become more standardized, and initial engineering costs have been removed.

Figure 4.9: Bulk Electricity Storage Options

Bulk Energy Storage Options to Support System and Large Renewable Integration

Applications:
- **Wholesale Markets**
- **Wind Integration**
- **Ancillary Services**

Technology Option	Maturity	Capacity (MWh)	Power (MW)	Duration (hrs)	% Efficiency (total cycles)	Total Cost ($/kW)	Cost ($/kW-h)
Pumped Hydro	Mature	1680-5300	280-530	6-10	80-82 (>13,000)	2500-4300	420-430
		5400-14,000	900-1400	6-10		1500-2700	250-270
CT-CAES (underground)	Demo	1440-3600	180	8	See note 1 (>13,000)	960	120
				20		1150	60
CAES (underground)	Commercial	1080	135	8	See note 1 (>13000)	1000	125
		2700		20		1250	60
Sodium-Sulfur	Commercial	300	50	6	75 (4500)	3100-3300	520-550
Advanced Lead-Acid	Commercial	200	50	4	85-90 (2200)	1700-1900	425-475
	Commercial	250	20-50	5	85-90 (4500)	4600-4900	920-980
	Demo	400	100	4	85-90 (4500)	2700	675
Vanadium Redox	Demo	250	50	5	65-75 (>10000)	3100-3700	620-740
Zn/Br Redox	Demo	250	50	5	60 (>10000)	1450-1750	290-350
Fe/Cr Redox	R&D	250	50	5	75 (>10000)	1800-1900	360-380
Zn/air Redox	R&D	250	50	5	75 (>10000)	1440-1700	290-340

Source: EPRI (2010)

Notes and Assumptions:
1. All systems are modular and can be configured in both smaller and larger sizes not represented. Figures are estimated ranges for the total capital installed cost of "current" systems based on 2010 inputs from vendors and system integrators. Included are the costs of power electronics if applicable, and all costs for installation, step-up transformer, and grid interconnection to utility standards. Smart-grid communication and controls are also assumed to be included.

2. For all options, process and project contingency costs are included depending on technical maturity of the system.
3. Pumped hydro: Storage durations can exceed 10 hours. There is very limited new cost data on pumped hydro facilities. Costs vary significantly by site but values presented include project contingencies and substation and interconnection costs.
4. Advanced lead-acid batteries: Cost estimates are based on use of advanced industrial-grade batteries from a number of suppliers. Battery life-cycle costs can vary considerably by supplier depending on the design basis duty cycle and design life. Battery replacement costs, while not shown, need to be considered as a variable O&M expense in any life-cycle analysis. Capital costs are reported on a "rated" MWh delivered per cycle basis. Costs for 50-MW systems are based on development of conceptual designs.
5. Flow batteries: Redox battery systems can be sized for a wide range of power and duration of energy storage. Technology options for large vanadium, Zn/Br, Fe/Cr and Zn/air redox have not yet been built for large grid-scale (+10 MW) applications. Estimates are based on conceptual engineering designs, vendor quotes, site layout and grid interconnection estimates performed by EPRI. Vanadium systems are technically more mature, while Fe/Cr and Zn/air options still in the lab and early R&D stage of development.
6. For all systems, future system costs may be lower that shown after early demonstrations are proven and validated, products become more standardized, and initial engineering costs have been removed.

Lithium based batteries are being applied at scales relevant to Flinders Island. Lithium-ion batteries are being deployed, for example, in Kotzebue, a remote Alaskan town of 3,000 residents, to store electricity generated by wind turbines and reduce the town's reliance on diesel. Also, it is reported that the company Hawaii Natural Energy is proposing to use lithium-ion batteries to deliver a 1 MW energy storage system to test solar energy integration. The primary focus of the project is to demonstrate battery storage's ability to increase integration of solar photovoltaic (PV) into Hawaii's energy system. Hawaii is targeting 40% of generation from renewable sources by 2025, meaning adequate storage will be imperative.[25]

Other battery technologies include flow batteries, such as the Vanadium Redox battery described in the King Island case study, and others noted in Figure 4.9 above. This figure, from the respected Electric Power Research Institute (EPRI) in the United States, also offers a cost comparison of bulk storage options (in USD) and capacity, power and duration data for each.

The EPRI Figures above provide indicative cost estimates in US dollars. For another observation, GreenTechMedia indicates that the cost of Li-ion ranges from USD400 per kilowatt-hour to USD1,200 per kilowatt-hour installed[26], although the EPRI estimate above is significantly higher. GreenTechMedia also reports that China's BYD is building utility-scale battery based grid storage from their LiFe (lithium-ferrous) batteries for ancillary services and energy arbitrage. The 4 MW batteries are believed to cost around USD500/kWh. As the pace of battery development and commercialisation is very rapid, actual prices delivered to Flinders Island would need to be discovered by tender.

4.8.2 Pumped Storage Mini Hydro

Mini-hydro power is a proven, reliable and potentially cost effective technology for the production of renewable electricity. Its advantages include:

- High efficiency (70 - 90%)
- High capacity factor (typically >70% compared with 10%-20% for solar and 20% - 40% for wind)
- Predictability and consistency of output, varying with annual rainfall pattern and with output often correlated with demand, i.e. output is maximum in Winter

[25] http://www.a123systems.com/
[26] http://www.greentechmedia.com/

- The potential for significant energy storage and scalable energy output – subject to site-specific factors
- Reliability and durability - systems can be engineered to last for 50 years or more

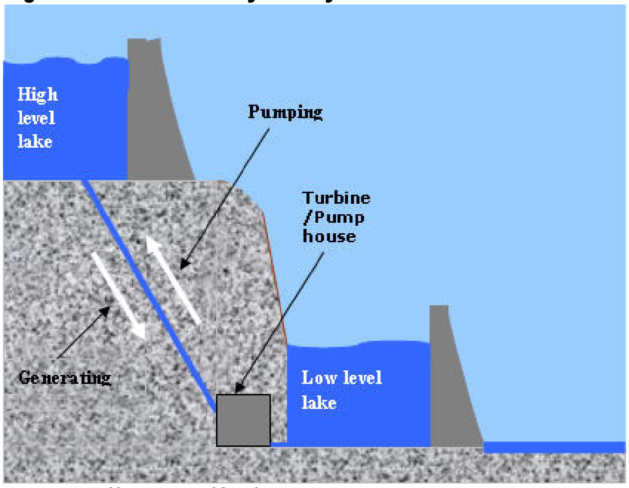
In general, success factors for a mini hydro system include:

- The existence of a suitable waterfall or weir and a turbine site (ie, suitable head on site)
- A consistent flow of water (at a usable head or height)
- The acceptability of diverting water to a turbine
- The potential site access for construction equipment
- The demand for electricity and the prospect of a grid connection at reasonable cost
- The social and environmental impact on the local area
- Land ownership and/or the prospect of securing or leasing land for the scheme at a reasonable cost
- An appropriate matching of power system needs with design power and annual energy output

Where it is not feasible to construct a dam for storage of natural water flows, it may be possible to utilise a *pumped storage* solution, as illustrated in Figure 4.10 below. Here, water may be run from top storage to the bottom via turbines, as per a conventional hydro solution. In addition, however, when there is surplus energy available from other sources (eg, wind turbines), water may be pumped from the bottom storage to the top storage for later use, eg, during wind lull periods.

The main advantage of pumped storage systems is that they can provide very large energy storage capacity compared to other storage solutions, limited only by the size of the water reservoirs. For example, rather than 'spilling' spare energy (by feathering wind turbines, for example) - meaning that zero percent of that energy is stored for future use – a mini-hydro with pumped storage system will enable a significant share that energy to be recovered and used when needed in future. Second, they offer the potential to 'smooth' the production of renewable energy from sources like wind and PV, turning them from intermittent sources into a fully controllable and dispatchable source, capable of providing ancillary as well as energy services. Pumped storage hydro systems are technically proven and relatively low risk, and overall they provide an 'elegant' solution for storing and making effective use of spare, intermittent renewable energy.

Figure 4.10: Mini Hydro System Schematic



Source: climateandfuel.com

The primary disadvantage of mini-hydro with pumped storage is cost. First, when compared to a conventional hydro solution, pumped storage systems require additional expenditure for pumps, pipeline infrastructure and other civil works. In some cases, it is possible to use the same pipeline for charging (the rising main) and discharging (the penstock) the upper storage, thereby avoiding some additional cost. However, this may limit operational flexibility, as the plant must operate in one of two distinct modes. Second, pumping water is an energy-intensive activity and requires that significant 'spare' energy is available for this purpose. This means that, in total, more renewable energy capacity has to be installed – first, to provide the spare energy for the 'charging system' – for example for wind turbines - and second to provide the 'discharging system' (the mini-hydro generator). This increases total system cost. Finally, overall system efficiency can be relatively low: there are losses (of up to 30%) on charging, and further losses on discharging, with overall efficiencies falling as low as 50% (although the EPRI reports cited in Section 4.8 above indicates efficiencies of up to 82%).

The El Hierro case study below features a pumped storage system, and the applicability of this option on Flinders Island is discussed further in Chapter 5, Option 2.

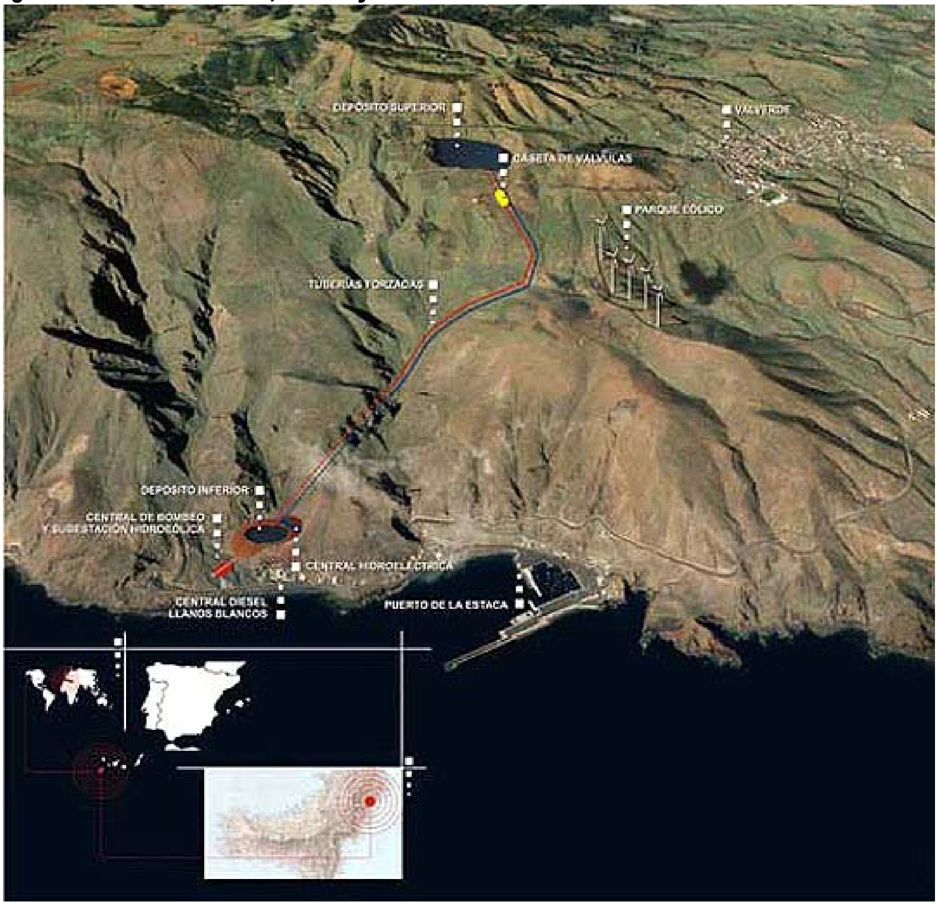
4.9 Renewable Energy System Case Studies

4.9.1 El Hierro – Wind and Pumped Storage Hydro

The Spanish island, El Hierro, is part of the Canary Islands and has a population of about 11,000. Like Flinders Island, it has relied on diesel generators for its electricity supply. To eliminate the reliance on diesel, a near complete combined wind and hydro renewable energy project will supply the island with about 80% of its energy needs. El Hierro also has excellent irradiation conditions and the remaining 20% of energy needs will be generated by solar thermal collectors and grid-connected photovoltaic systems.

The project consists of an 11.5 megawatt (MW) wind farm and an 11.3 MW hydroelectric pumped storage plant. By communicating with the wind farm, a control solution will automatically start releasing water from an upper reservoir to generate power at the hydroelectric plant whenever the wind power generated is insufficient to meet demand. Conversely, excess wind power will be used to pump water to the upper reservoir, for use when wind power is low.

Figure 4.11: El Hierro, Canary Islands



Source: ABB

The scheme is intended to generate three times the island's basic energy demands – for permanent residents, farming co-operatives, fruit and fish canneries – leaving some leeway to cater for the 60,000 tourists who visit El Hierro every year. Surplus output will power three desalination plants, delivering 11,000 cubic metres of fresh water a day, enough to cover part of the irrigation needs[27].

4.9.2 Mawson Station, Antarctica – Wind Diesel Hybrid

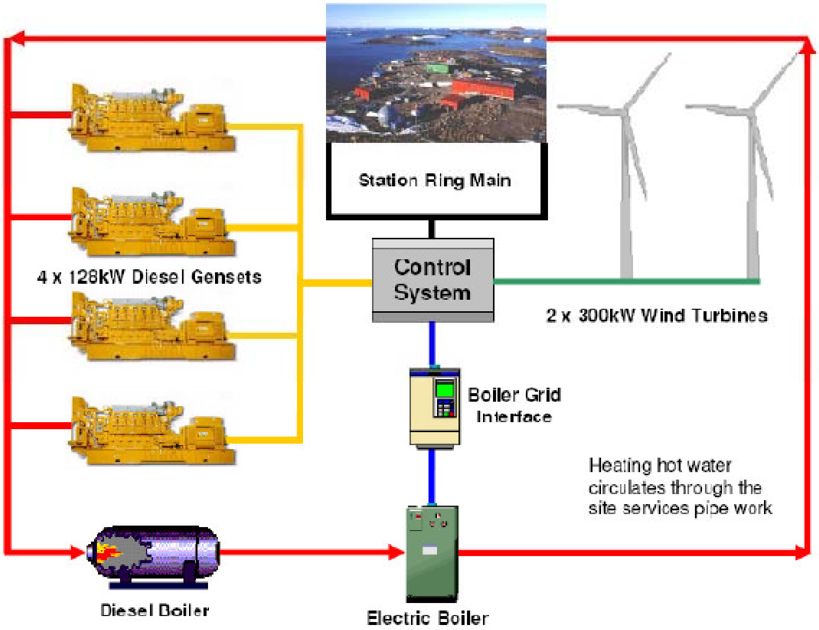
Winds on Flinders Island are a gentle breeze compared to those at Mawson Station in Antarctica. The station is situated where katabatic winds (cold dense air formed over the ice cap is pushed downhill helped by gravity) peak. Monthly average wind speed varies from 9.6 metres per second to 20 metres per second.

Two 300kW wind turbines were installed at Mawson Station in 2003. Diesel capacity is 480kW. While the wind speeds are very high, there is also considerable variability. One diesel genset is therefore run constantly at low power to provide spinning reserve. An electric boiler is also an essential element of the Mawson system. A 'Boiler Grid Interface' heats water for the station's hot water when excess wind power is available. The electrical load of the boiler can also be quickly reduced when wind suddenly drops, allowing the reduced wind power and single genset to continue to meet the station's base load. This provides an example of the use of a resistive load (discussed at Section 4.7.1) to assist with power regulation, but in this case the heat energy is able to be stored to provide useful energy services.

[27] http://www.expo21xx.com/automation77/news/20165_abb_energy_island/news_default.htm

Annual wind penetration of the station's electrical and heating loads has varied between 33 and 39 percent. The best penetration over a month has been 60%. Diesel savings are around 160,000 litres a year. Figure 4.12 below illustrates the Mawson Station system. [28]

Figure 4.12: Mawson Station Power Supply Schematic



Source: D. Waterhouse (2009)

4.9.3 Samso (Denmark) – Wind, Cable System

Samso is a Danish Island of around 4000 inhabitants. The main industries are agriculture and tourism. Twenty-one onshore and offshore wind turbines allow Samso to make the claim of being 100% renewable. The turbines supply all of Samso's electricity needs and offset the non renewable energy still used on the island – mainly petroleum products that power the island's transport and agricultural equipment fleet.

Unlike Flinders Island, however, Samso is connected to the mainland grid via an undersea electrical cable. This serves two very important purposes. It allows the island to export their excess wind generated electricity – which generates income for the islanders who have shares in the turbines. It also means that the necessary system reliability and balance are provided by largely coal fired power stations on the Danish mainland.

Despite the fact that Samso is connected to the mainland, there are potentially useful lessons for Flinders Island. For example, Samso has undertaken energy efficiency and fuel switching programs to ensure that they don't consume excessive electricity, with the aim of maximising exports that can be sold to the mainland. Space heating is the largest energy use in Samso homes. Samso has chosen to develop small district heating models in most of the 21 villages on the island, fired mainly by wheat or rye straw.

[28] Source: Waterhouse, David, *Remote Power Supply Case Study: Wind Turbines at Australia's Mawson Station, Antarctica,* Session 8 of Regional Electrical Engineering Forum 2009 – IDC Technologies.

These systems were chosen to replace the oil burning furnaces - and mean that more electricity is left over for sale to the mainland.[29]

4.9.4 King Island Renewable Energy Integration Project

King Island is well known to the Flinders Island community, and the renewable energy project currently under way there provides a useful case study. King Island's main electricity generation assets at present are:

- Three 1600 kW and one 1200 kW diesel generating sets
- Three 275kW directly coupled fixed pitch Nordex wind turbines
- Two 850kW pitch controlled Vestas V52 wind turbines
- 100kW solar array consisting of six panel arrays (privately owned)

Hydro Tasmania has recently developed the King Island Renewable Energy Integration Project (KIREIP) which aims to increase the percentage of electricity provided by the wind and solar assets – reducing the fuel costs and carbon emissions associated with the diesel generating sets.

The renewable energy penetration at present is around 41.5% (updates are available at the web reference below). KIREIP aims to supply over 65% of annual electricity demand with renewable – and up to 100% at times. The main elements of the project are as follows.

Wind farm expansion

Development approvals for two wind turbines at Huxley Hill are in place. The increased wind capacity will mean more time when the system is at, or near 100 per cent renewable.

Biodiesel trial

The biodiesel trial will determine whether to fully integrate biodiesel into the power station. The trial results will be relevant to Whitemark Power Station.

Diesel UPS

The installation of a diesel-uninterruptible power supply (D-UPS) will allow the four diesel units to remain offline during periods where wind and solar energy generation exceeds the customer demand.

Vanadium redox battery (VRB) repair

Hydro installed this experimental storage solution some time ago – but it has not been operational recently. The VRB will be repaired and updated if feasible – or it will be replaced with an alternative storage option such as Lithium Ion batteries.

Carbon block

The proposed Carbon Block Energy Storage System is an alternative storage system to batteries or stored hydro. Thermal energy / heat is stored then later converted into kinetic energy to generate electricity. The process involves heating graphite, and extracting the heat through imbedded heat exchangers. An Organic Rankin Cycle (ORC) generator uses the heat to generate electricity. The ORC runs at lower temperatures than steam turbines, similar to a steam turbine but able to run at lower temperatures, and these systems are already used in the geothermal industry.

[29] Source: Biello, David, '100 Percent renewable? One Danish Island Experiments with Clean Power' Scientific American, January 2010, internet accessed.

Smart grid/Demand management

This is the demand management aspect of the project and involves working with relatively large energy consumers on load management. Participating sites will have smart meters installed to allow for sophisticated load and system management. In the short term this will reduce diesel use & allow for better system control over the long term.[30]

4.9.5 Parachilna, SA – Diesel, Solar and Batteries

Parachilna is a small community in outback South Australia which, like many isolated towns in Australia, has no grid connection. These communities can be thought of as 'electrical islands' as their electrical systems are stand-alone. In Parachilna, three diesel gensets of between 52kW and 96kW service the great majority of the average daily load of 631 kWh.

With funding from the Renewable Remote Power Generation Program, a 21kW solar array and a 60 lead acid battery bank were installed in 2002 with the aim of reducing diesel consumption. Optimal integration took some time to achieve. Improvements to integration have recently occurred with the installation of remote control and monitoring in early 2011. This reduced operational costs and provides the ability to reduce solar power input when necessary to optimise the performance of the diesel gensets. The modest size of the PV array means that it only contributes around 12% of Parachilna's electricity needs[31].

4.9.6 Lady Elliot Island – Solar Diesel Hybrid

This resort island on the Barrier Reef caters for 150 visitors with 25 staff. In 2008, a hybrid solar diesel power station replaced the existing diesel gensets. The power system includes 20kW of solar panels, 48 deep cycle lead-acid batteries, an inverter system and a single diesel genset.

Following this project, fuel use has dropped from 550 litres to 160 litres a day. The genset is turned off at night, bringing the twin benefits of fuel savings and noise reduction - important on a resort island. The fuel reductions and diesel night time shutdown are made possible from the combination of:

- Solar panels with battery storage
- A move to gas for hot water and cooking
- Energy efficiency and energy conservation measures

The island's desalination plant is designed for high energy efficiency, and guests at the resort are encouraged to minimise power use during the evenings. The system allows for solar panels to be added in the future – the resort owners aim to increase the use of solar power retaining the diesel genset for backup only. The project attracted funding from the Commonwealth Government's Renewable Remote Power Generation Program (which has since closed).[32]

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[30] Source: Hydro Tasmania website: http://www.kingislandrenewableenergy.com.au/ accessed 21/12/2011.

[31] Source: KPMG, 2011, *Review of the Remote Areas Energy Supply Scheme*, for Department of Transport Energy & Infrastructure SA, pp. 133, 134.

[32] Source: EcoGeneration, Nov 2009, *Island equilibrium – Finding the perfect renewable balance on Lady Elliot Island,* accessed at http://ecogeneration.com.au/news/island_equilibrium/008719/

5. Renewable Energy System Options for Flinders Island

This Chapter identifies the system options, or combinations of technologies, that are most likely to be technically and economically feasible for Flinders Island, subject to appropriate due diligence. It should be noted that other options may be possible, and that there are many variants within each broad option. Each option aims to achieve 100% renewable energy generation but may or may not do so in all time periods.

Note that it is not intended to provide a highly detailed description of options at this point in time. The aim of this paper, and the subsequent consultations on the Island, is to assist the Flinders Council and community to consider the issues regarding its power supply and renewable energy opportunities, and to work towards a preferred approach. The preferred solution has more detailed analysis and costings in the funding submission to the Federal Government.

5.1 Option 1: Wind-Battery-Biodiesel

In this option the primary energy generation source would be wind energy. This may be the ideal renewable energy resource on Flinders Island, at least from a technical perspective, given the quality of the wind resource and proven and relatively low cost of wind turbine generator technology. As noted in Chapter 2, solar PV is likely to contribute to renewable energy generation on Flinders, but we do not assume *additional* PV as part of this solution.

To cover the expected future load (discussed in Chapter 3), a total of around 1.5 MW of wind turbine generator capacity would be installed in three or four turbines (for security, an '*n minus 2*' condition is preferred for an isolated grid, meaning that system security can be maintained with the two largest generation units disconnected). Note that this much wind capacity would very often generate more energy than is required to meet instantaneous demand, notably overnight when demand is low. While as discussed earlier it is possible to 'spill' or 'dump' surplus wind energy, this solution envisages storing as much of this energy as is economically feasible in batteries and other devices (see below) to provide short term load-following and ancillary services capability, with the aim of starting (bio) diesel gensets as infrequently as possible.

Solar photovoltaic (PV) installations are already present on the Island and are set to expand as noted earlier. Solar PV is expected to add modest amounts of energy but will provide diversity of generation sources and help offset summer loads in particular such as air conditioning. In this option we do not assume specific additional solar installations (beyond those discussed in Chapter 3), although this option could be considered.

When wind and solar energy are insufficient to meet current demand in this solution, large 0.5 to 1 MW scale batteries (for example, lithium ion batteries, as discussed in Chapter 4) would initially be drawn upon to support demand (for up to 2 hours, but more probably 30 minutes or less). Fast response frequency would be provided by resistor banks as discussed in the previous Chapter, along with the battery. For additional support, a diesel UPS – potentially fuelled by biodiesel produced entirely or in part on Flinders Island – would provide both short term load-following capability and ancillary services. The remaining or existing conventional diesel gensets – which may be converted to run on biodiesel, would provide firming and back-up capacity.

The overall advantages of this solution include:

- Effective utilisation of the Island's excellent wind resources
- Effective utilisation of existing system assets on the Island
- Relatively low technical and operating risks, including due to the use of multiple WTGs and relatively mature system assets

- The potential for 100% renewable energy (provided biodiesel is used) or high renewable energy penetration (around 75%) without biodiesel
- The potential for a least cost solution

The potential disadvantages of this solution include:

- System integration and control complexities at high renewable energy penetrations, requiring additional management personnel on Island
- A possible cost premium for biodiesel (which may be able to be offset by on-Island production, and which may also reduce through time due to market trends discussed in the next chapter)
- Low levels of energy storage, requiring ongoing reliance on liquid fuels for energy security, some or all of which may need to be transported to the Island

We note that Hydro Tasmania has completed a system design solution for Flinders Island that is very similar to above, albeit without the biodiesel option, and has in the past sought funding to proceed with such an investment. Hydro Tasmania would expect such a solution to deliver up to 80% renewable energy, and we note that biodiesel could potentially cover the balance. Hydro Tasmania has indicated an approximate cost for its particular solution of around $15 million if 75%+ renewable energy were targeted, while costs around $10 million were estimated if 45%+ renewable energy were targeted.

As also noted above, the 300 kW FIRE wind development will need to be factored into this and subsequent options. This proposed development will reduce the need for, and therefore costs associated with, additional wind turbines to meet a target of 100% renewable energy for the Island. In that sense it is fully complementary to the draft Renewable Energy Plan. As noted earlier, however, as the share of intermittent renewable energy on the Island rises, so does the need for investment in energy storage or other system control/power quality assets. This need is not strictly dependent upon which type of intermittent renewable energy is connected to the system – wind, wave, tidal or solar, for example – but rather is more strongly related to the *total share* of these intermittent systems within the overall power grid. This issue is discussed further in Section 6.2.1 below.

5.2 Option 2: Wind-Mini Hydro with Pumped Storage

In this option, wind energy would still provide the primary energy source for the Island. A similar capacity of around 1.5 MW (or slightly more) of WTG would, as above, create a significant surplus of energy on average. In this case, however, surplus wind energy would be utilised to pump water to an elevated storage, which would then be used to operate a mini-hydro generator.

There are two distinct sub-options, with quite different operating strategies. The first would involve a modestly-sized mini-hydro and fresh water storage, for example located near to the existing freshwater supply on Cannes Hill. Since freshwater on Flinders Island is scarce, this system is conceived of a ‘closed loop’ with minimal water losses, comprising upper and lower storages and a mini-hydro and pumping station at the lower storage site.

Hydro Tasmania has in the past investigated at a preliminary level a number of potential sites for such mini-hydro systems, including at South Pats River, Samphire Creek and Leventhorpe[33]. Samphire Creek was measured to offer the best stream flows, but all were judged insufficient for a run-of-river installation.

[33] Details of these studies were shared with pitt&sherry on a confidential basis, and Hydro Tasmania has approved the publication of the information that appears in this report.

At South Pats River, the potential to raise an existing dam wall by 4 – 5 metres was noted, which would create a modest 100,000m^3 to 150,000m^3 storage at low elevation. There are no large scale existing water storages at elevation on Flinders Island, and while the potential exists to create an additional storage of up to 200,000m^3 on Cannes Hill, Hydro Tasmania notes that the site is 'not ideal' and that extensive earthworks would be required.

Hydro Tasmania calculated that an optimum size for such an integrated mini-hydro system would be modest, with around 200kW mini-hydro generation capacity, around 300 kW pumping capacity and around 150,000m^3 of upper storage and 100,000m^3 of lower storage. There is only some 60 metres of head available at this location. A penstock or pipeline of some 850 metres in length and 75 cm in diameter would connect the two storages. Hydro Tasmania estimated that the overall efficiency of this system would be around 52%, with costs in the order of $2.2 million in 2006 (equivalent to around $2.6 million in today's dollars). It should be noted that there is no single optimal solution: the sizing of a mini-hydro with pumped storage system would depend upon other system parameters (demand and supply).

This option would have the advantage of storing, rather than spilling, significant amounts of wind energy, although total energy storage at Cannes Hill is limited by the terrain. When operating, the mini-hydro generator would be capable of load following and providing ancillary services, but there would be insufficient energy/water in storage to enable continuous operation. Annual output of the system was estimated at around 500 MWh/year, equivalent to less than 12% of current electricity consumption, or around 8% of expected 2030 consumption in the business as usual scenario. Therefore this sub-option would potentially require similar system or enabling technologies as described in Option 1, with the potential to downsize or dispense with a battery installation. Therefore, one way to compare the two options would be by comparing the relative costs and capacities of this mini-hydro solution with potential battery solutions, as per Option 1.

A second sub-option would involve the creation of a significantly larger pumped storage mini hydro system with greater storage, head and generation capacity, sufficient to meet the average demand of the Island for at least one month (we estimate that a 2.2 gigalitre water storage would effectively store 500 MWh of energy, equivalent to 6 weeks average electricity consumption in 2011). Mini hydro generation capacity would be in the order of 850kW (subject to more detailed modelling). Conceptually, this sub-option might be considered as a hydro-based solution with a wind energy charging system, or alternatively as a wind-based solution with extensive firming and storage from pumped storage hydro.

Given the lack of freshwater adjacent to elevated sites on Flinders Island, this solution would need to utilise sea water as the storage medium. The advantages of this solution include that there are many sites around Flinders Island where there are substantial elevations of 200 metres or more immediately adjacent to the coast, along significant areas of the North coast (for example in the North West or Killiecrankie area), minimising penstock length and associated costs and losses. We stress that significant geotechnical, environmental and heritage assessments would be required in the micro design and location of any mini hydro infrastructure. A further advantage of this solution is that the sea becomes in effect the lower storage in this system, potentially reducing civil engineering costs at sea level.

From the point of view of the electrical system, this sub-option provides the greatest energy security, including the greatest prospect of achieving 100% renewable electricity supply. This is because the larger pumping and storage capacity means that almost all surplus wind energy would be able to be stored and re-utilised, net of round-trip losses. Surplus wind energy at night, for example, would be expected to be stored given low overnight loads.

This solution would offer a number of control strategies, including varying pumping rates and/or mini hydro output in real time to provide load following and ancillary services. This offers the potential to reduce the need for enabling technologies such as resistors, ultracapacitors, batteries or diesel UPS systems, although more detailed modelling would be required to confirm the extent of this. It is likely in this solution that the existing diesel generators would rarely if even run, enabling them to be retained for back-up purposes in the event of failure of the mini hydro system.

The disadvantages of this solution would include the need to construct a large, lined upper reservoir (due to an expectation of sandy soils and the need to prevent contamination of ground water), and the costs associated with undertaking major civil works on the Island. Further engineering challenges would be posed by the use of salt water, including the need to control for electrolysis, weed and mollusc growth. However, we note that the extensive development of salt water desalination plants in Australia and around the world have generated innovative and proven strategies for managing these challenges. Finally, the additional of significant generation capacity on the North of the Island would require network reinforcement and – as with all options – significant evolution of system control strategies.

Costs are covered in more detail in Section 5.4.

We note that these costs relate only to the mini-hydro installation. In this option, the total installed generation capacity on the Island would be higher than for other solutions, as the mini-hydro system would be sized to be able to cover peak loads on the Island when required in addition to the wind capacity.

Note however that more detailed modelling may enable wind capacity to be down-sized in this option relative to Option 1.

5.3 Option 3: Wind-Solar-Cable

A third option could involve connecting the Island to the Tasmanian mainland via an undersea cable. While such an investment could eliminate the need for any on-Island renewable energy generation (and/or diesel use for power generation), this solution would not guarantee that 100% of electricity consumption on the Island would be from renewable energy sources. The Tasmanian system has averaged around 80% renewable energy in recent years. It would also mean that in the very unlikely event of a cable failure, the Whitemark Power Station would be required to meet the Island's load using – on a business as usual scenario – mineral diesel.

This option, therefore, could either be reduced to a cable-only solution (which would not generally deliver 100% renewable energy), or alternatively viewed as an opportunity to develop the Island's wind, and in future, tidal or other renewable energy resources, for export via the cable. In the latter case, the Island may well produce well more than 100% of its own requirements from renewable energy, with the balance exported (as per the Samso case study above).

In either case, the key benefit of an appropriately-sized cable is that it would eliminate the need for on-Island energy storage (other than fuel for back-up purposes), along with the majority of enabling technologies or other system assets, as the Island would be electrically interconnected with the Tasmanian mainland (and therefore the whole National Energy Market, subject to Basslink operating conditions). This would mean that at most times, power quality would be enhanced relative to business as usual, while energy security for the Island would be dramatically improved.

As noted, key disadvantages include the lack of the branding and environmental benefits associated with 100% on-Island renewable energy generation, residual technical risks associated with the cable (discussed below) and an expectation of relatively high capital costs plus exposure to the same carbon/electricity price risks as the rest of Tasmanian mainland[34].

With respect to costs, we note that Hydro Tasmania has also in the past conducted extensive and detailed analyses of different cable options for Flinders Island, most recently in 2006. Subject to more detailed analysis, a preferred cable route was identified of approximately 85 kms in length running from Musselroe Bay (on the assumption that the wind farm at that location proceeds, which now appears very likely) to Whitemark (or possibly Trousers Point), passing East of Badger Island. The cable would be buried in a trench on the sea floor and therefore well protected from damage (anchors, scallop dredges, etc), with an expected failure rate of 1 in 142 years. Total costs for this project were estimated at close to $22 million in 2006 (equivalent to some $26 million in today's dollars). However, it should be stressed numerous elements of the cost of such a project may have changed with no relationship to the CPI and would need to be re-estimated from the ground up if such an option were to be preferred. Recent descriptions of experience from cable laying projects would indicate that the final cost is likely to be in excess of the above $26m, but it is difficult to predict by how much. Additional capacity allowance for export of power from the island is likely to push this to the highest cost option on the basis of capital costs.

5.4 Detailed Costing of Options

The project brief calls for a more detailed analysis of two selected options following the public consultation phase. The following summarises the costing outcomes from each of the two preferred options.

5.4.1 Option 1: Wind-Battery-Biodiesel

The table below identifies the essential components following more detailed analysis. Pricing and sizing of units has been provided by project partners IT Power and others. Pricing necessarily includes differing capacities for the two differing battery types due to discharge rate limitations. Additional costs have been allowed for in Lithium Ion grid infeed management as systems of this size and type are somewhat rarer than the more conventional Lead Acid battery backup systems.

Item	Item Comments		
Preliminaries	Approvals, planning, engineering	$ 653,000	$ 653,000
Battery		Lead acid	Li-ion
lead acid	7.5MWh	$ 2,075,000	
Li Ion	4.5MWh		$ 1,950,000
Biodiesel			
on-island plant	estimate not including ancilliaries or ancilliary benefits	$ 5,000,000	$ 5,000,000
WIND			
Wind turbines	to achieve 1.8 MW installed capacity, includes installation, based on current generic market pricing (~1500/kW) moderated by Hepburn Wind completed pricing (~2500/kW). Includes power management infrastructure to grid but not grid infeed management	$ 5,000,000	$ 5,000,000
GRID ENABLEMENT			
Grid infeed management	required additions to existing feed management system	$ 300,000	$ 500,000
Enabling devices	Resistors and flywheel to smooth power supply from sudden drops / starts (0 to 2 seconds timeframe).	$ 1,600,000	$ 1,600,000
Enabling devices	Additional Turbine control systems to ensure 2 second reaction time	$ 400,000	$ 400,000
Total		$ 15,028,000	$ 15,103,000

[34] While outside the scope of this study, we expect Tasmanian wholesale electricity prices to rise in direct proportion to the carbon price.

The storage systems proposed would be limited by eventual growth in demand and require not only an expected battery replacement, but ultimately an increase in size as island usage increases.

The biodiesel plant proposed for the island with this system is difficult to price on a number of fronts – while there is adequate overall agricultural production through animal products on the island, there is a requirement for tallow diversion and possibly abattoir expansion to achieve this outcome on-island. The means by which this essentially separate business may be created and funded and the spinoff benefits that accrue to other island areas (such as facilitation of the island's greenhouse gas aims) have not been included in this crude estimate.

5.4.2 Option 2: Wind-Mini Hydro with Pumped Storage

As noted above there are several methods of dealing with this option. The following table details the component pricing for two "small" options and two "large" options. While the "small" options cost less they also provide for a much lower storage of energy (5 days at average usage). This means that under unfavourable conditions they are more likely to result in blackouts or the need for retention of the diesel generating system. This limitation is further complicated by the knowledge that power usage on the island is expected to increase, further limiting the usefulness of storage as time goes on. The small systems are therefore not preferred options in this report.

The degree of expected outages etc. can be determined from more detailed statistical studies of wind and solar patterns that is, however, outside the scope of this report. These studies could then be used to fully size the system components and determine any ancillary components needed to provide full power surety. The cost of these studies is included in the preliminary costs and may result eventually in a determination that the smaller systems, or something close to them will be adequate. This is an item of progress for the future as for now it is impossible to determine.

The large systems provide for a month of power provision at average use (and clearly less at peak usage). We consider this to be the safe option for current planning because it ensures that the system remains 100% renewable allowing for a long planning timeframe as usage increases.

Item	Item Comments				Cost
PUMPED SEAWATER HYDRO	Combined penstock/rising main				
		Fresh Water (Small)	Sea Water (Small)	Fresh Water (Large)	Sea Water (Large)
Preliminaries		$2,067,002.85	$1,631,909.10	$3,903,170.70	$2,690,000
Top Reservoir-Large	300mx400mx20m-(9.4m cut) – 20.5 days-12.25MWh (Seawater includes 2mm HDPE lining)			$10,952,450	$12,750,000
Penstock/Rising Main	Supply and Installation of 750mm (self cleaning 2.25m/s at 1.00 kL/s) $500/m	$550,000	$1,100,000	$550,000	$1,100,000
Includes Pigging Infrastructure	2.2km pipe				
Sea Water Intake-Rising Main Includes Pigging Infrastructure	Supply and Installation of 0.45km of 750mm (self cleaning 2.25m/s at 1.00 kL/s) $500/m		$225,000		$225,000
Mini Hydro (Duty)	Variable Flow (Extra Seawater Design 15%)	$1,300,000	$1,495,000	$1,300,000	$1,495,000
Mini Hydro (Standby)		$1,300,000	$1,495,000	$1,300,000	$1,495,000
Pump Station	Based on Meander Dam items and as per P Douglas; Includes Wet Well trash/fish rack and scour protection and standby backup pump..	$1,000,000	$1,000,000	$1,000,000	$1,000,000
Sub Total	all Hydro	$15,847,021.85	$12,511,303.10	$29,924,308.70	$20,755,000
WIND					
Wind turbines	to achieve 2.1 MW installed capacity, includes installation, based on current generic market pricing (~1500/kW) moderated by Hepburn Wind completed pricing (~2500/kW). Includes power management infrastructure to grid but not grid infeed management	$4,150,000.00	$4,150,000.00	$4,150,000.00	$5,800,000
GRID ENABLEMENT					
Grid infeed management	required additions to existing feed management system	$300,000.00	$300,000.00	$300,000.00	$300,000
Enabling devices	Resistors and flywheel to smooth power supply from sudden drops / starts (0 to 2 seconds timeframe).	$1,600,000.00	$1,600,000.00	$1,600,000.00	$1,600,000
Enabling devices	Additional Turbine control systems to ensure 2 second reaction time	$400,000.00	$400,000.00	$400,000.00	$400,000
TOTAL		$22,297,021.85	$18,961,303.10	$36,374,308.70	**$28,855,000.00**

It is worth noting for comparison purposes that the two larger systems provide for slightly less energy security than the current diesel storage (4 weeks vs. 6 weeks).

5.4.1 Option Comparison

Options compared on a purely financial basis appear relatively similar. Each option has differing performance characteristics and costs for maintenance and replacement. Battery systems require frequent replacement of batteries for instance while pumped storage requires more mechanical servicing and replacement of wearing parts.

Ultimately we have created an assessment of the nett present value (NPV) of option 1 and the large seawater variant of option 2.
These NPV calculations allow for replacement and maintenance, labour (but not for the biodiesel plant that is assumed to be run as a separate business) etc.

The calculated NPV assessed over a 20 year timeframe is detailed in Appendix 2. For the large seawater option the NPV is ~ $16m, of Option 1 is ~$21m.

NPV has been calculated as a "public purse" NPV and importantly this positive value in both cases means that there is a compelling economic argument as well as environmental and social argument for achieving the renewable energy plan outcomes.

6. Towards a Vision of a Renewable Energy Future for Flinders Island

6.1 Summary

This Paper has reviewed the nature and performance of the current electrical system on Flinders Island, including demand characteristics and existing system assets and control strategies. In short, power demand on Flinders Island is currently modest, dominated by residential and light commercial loads, and with a distinct daily 'double peak' and Winter system peak demand. Demand has grown only slowly over time, at around 2% per year. The supply solution is largely diesel fired and performs reasonably well, albeit with some 7 (or more) blackouts per year. However, this is a very high cost solution which is only made affordable for the Island by a very large Community Service Obligation (CSO) payment from the Tasmanian Government, which we estimate at around $3,500 per resident per year.

The reliance on both diesel – where costs are expected to continue to rise strongly in future – and on the CSO represent significant risks for the Flinders Island community and business sector. At the same time, rising solar capacity on the Island, and the prospect of additional wind capacity (noting the current development by FIRE Developments Pty Ltd, for example), mean that some system costs may be incurred to successfully integrate renewable energy in the near term, regardless of future trends.

We noted that Hydro Tasmania is obliged under its *Ministerial Charter* with the Tasmanian Government to supply electricity on Flinders Island. While other parties can and do generate electricity on the Island, Hydro Tasmania has a central role to play in any scenario, and the nature of the constraints and opportunities facing that business should be borne in mind when considering future options. This is discussed further in Section 6.2 below.

We projected demand under a range of plausible scenarios, and spelled out the consequences of these scenarios for the costs, risks and greenhouse gas emissions associated with meeting these demands from the current, largely diesel-based power system. Under a business-as-usual scenario, with little growth in the population, demand growth continues to be modest, nevertheless amounting to some 45% more electricity consumption in 2030 than in 2011. If there were no (significant) investment in renewable energy in this scenario, diesel fuel consumption for power generation would rise to some 1.6 million litres/year by 2030, costing some $2.2 million/year at today's diesel prices (or around $2,500/head for fuel alone) and creating some 4,140 tonnes of greenhouse gas emissions. As noted, the recent FIRE development has not yet been factored into these calculations, but will be included in the final Renewable Energy Plan.

We then examined two 'stepped up growth' scenarios that showed the impact for electricity supply and demand to 2030 of:

- A significant expansion in agricultural production (for example, requiring significant irrigation)
- An additional 10 (Scenario A) houses per year being built (in addition to 5 – 10 per year under business as usual), or an additional 20 houses per year (Scenario B)
- The flow-on consequences of the higher population for commercial sector power demand

In Scenario A by 2030, the total population was expected to reach 1060 residents and the housing stock to reach some 624 houses, compared with 905 residents and 532 houses under business-as-usual.

In this scenario, diesel consumption in 2030 would rise to some 2.5 Ml which, at today's prices, would cost some $3.6 million fuel alone - making no allowance for the impact of carbon pricing or the other factors on diesel prices. Greenhouse gas emissions associated with this power generation in 2030 would rise from around 4,150 t CO_2-e under BAU to 6,670 t CO2-e, an increase of 61% relative to BAU or 126% in absolute terms from current consumption levels.

In Scenario 2, the total housing stock was projected to reach 804 houses in 2030, while the population would be around 1,366 persons. Annual electricity consumption in 2030 in this scenario would approach 11,000 MWh, some 73% higher than under business as usual. As a result, and without investment in renewable energy, diesel consumption for power generation in 2030 would exceed 3 million litres, associated with over 8,000 t CO_2-e of greenhouse gas emissions, at a total cost at today's prices of some $4.3 million, or $3,148 per person (for fuel alone).

In Chapter 4 we reviewed the renewable energy resources available to Flinders Island, the state-of-play and indicative costs of the different renewable energy technologies, and discussed some essential system design considerations including the critical role of enabling and energy storage technologies in facilitating a transition to 100% renewable energy on Flinders Island. These 'system assets' may comprise a significant share of future costs, yet do not directly produce revenue, raising important questions as to how these costs are met. Finally Chapter 4 set out a number of relevant case studies from as near as King Island to as far away as Antarctica and the Canary Islands.

We noted that Flinders Island possesses world-class wind and tidal resources, along with useful solar and biomass resources, including significant waste-to-energy opportunities that, in addition to producing energy, could reduce the Island's carbon footprint.

In Chapter 5 we drew out of the preceding analysis three primary options for a renewable energy system design for Flinders Island, noting that there are many other possible solutions and variations that could be considered. In short, these three are:

1. A wind-dominated solution, with solar, battery and other enabling technologies, backed with biodiesels;
2. A mini-hydro solution with pumped storage and wind (and solar) energy as the 'charging system' for the storage; and
3. A cable solution connecting Flinders Island to the Tasmanian mainland.

We have now affixed indicative costs to these three options where the wind-biodiesel energy solution is the least cost, followed by mini-hydro, followed by the cable.

In the final section below, we draw out some of the key issues that the Council and Flinders Island community may wish to consider regarding the energy future of the Island. There are complex issues around:

- Who will own and manage the system through time?
- Who will pay for (all aspects of) the investment?
- On what terms?
- What risks is Flinders Island exposed to from issues such as the CSO, fuel prices, peak oil, climate change and carbon pricing – and how should it respond?
- What outcomes are required in terms of energy security, power quality and reliability, in order to meet the aspirations of the whole community?
- What opportunities and benefits are there for the Island from moving to 100% renewable energy, greater energy efficiency and even towards a zero carbon economy?

- Overarching all of this, what is the role of renewable energy in contributing the community's vision of its own future to 2030?

6.2 Consideration of Some Key Issues

6.2.1 System Ownership, Management and Maintenance

In considering its energy future, a fundamental question for the Flinders Island community is who will manage, fund and maintain through time the investments in renewable energy systems, and on what terms?

As noted in Chapter 2, the current power system on Flinders Island is essentially owned, funded and managed by Hydro Tasmania, albeit with private ownership of some wind and a growing amount of solar generation. In any renewable energy option that may be preferred for the Island, therefore, Hydro Tasmania should be considered as a key stakeholder and as a potential partner. As noted in Chapter 4, system control strategies and related assets are fundamental to the achievement of high renewable energy penetration rates. These assets have significant capital and in some cases operating costs, and they demand expertise for system design, installation and ongoing operation and maintenance. Also, it should be noted that an increase in renewable generation capacity on the Island may reduce the expected return on investment on existing generation and system assets, for example if the existing gensets run less frequently. At the same time, such assets will continue to incur maintenance costs. All of this may have financial implications for Hydro Tasmania.

We note that, in recent times, Hydro Tasmania's ability to invest has been constrained. The current investments taking place on King Island, for example, are one third funded ($15.3 million) by the Federal Government, and Hydro Tasmania also has a private equity partner for the project, CBD Energy Limited. As noted, however, Hydro Tasmania sought significant funding from the Federal Government for renewable energy investment of Flinders Island similar to Option 1 above, but this application was not successful. Practically speaking then, the Council's intention to apply for Federal funding is critical to unlocking the full renewable energy potential of the Island.

There would appear in principle to be two main models for proceeding. In the first model, the Council could work in partnership with Hydro Tasmania – as the current asset owner and manager - contracting them to undertake detailed design and potentially to project manage the procurement and installation of assets (although this may be considered a 'contestable' service), as a single (if possible staged) integrated project. In this model, the Council could retain ownership of all or part of the system assets it funds on behalf of the community and could potentially, by agreement with Hydro Tasmania, earn a commercial rate of return on its equity.

The renewable energy systems on the Island would lead to a reduction – a very large reduction if 100% renewable energy is achieved - in the ongoing costs of delivering power. It is important to note, however, that this in itself would not create any direct financial benefit for Hydro Tasmania, as CSO revenue would fall in direct proportion to its reduced operating costs. Indeed as noted, they may be exposed to additional costs associated with 'system assets'. However, the reduction in the CSO creates an unambiguous financial benefit for the Tasmanian Government. Noting that Hydro Tasmania is wholly owned by the Tasmanian Government, a connection may need to be made between the stream of CSO savings over time and the additional costs to Hydro Tasmania to ensure that the investment proceeds. Subject to final costings, we expect that a project to move to 100% renewable energy on Flinders Island would create significant net economic benefits as well as environmental and social benefits for Flinders Island valued at many millions of dollars in present value terms. We note that the option of funding some of Hydro Tasmania's costs from a Federal grant may also exist, reducing the 'ask' on Hydro Tasmania and/or its shareholders.

In the second model, Hydro Tasmania could continue to own and manage existing system assets, and the Council and potentially other third party, private investors would invest in, own and manage renewable energy generation (and possibly other system) assets. This model is successfully being demonstrated by FIRE Developments Pty Ltd (Flinders Island Renewable Energy) relating to the installation of a 300 kW wind turbine at Hayes Hill near Whitemark. In this model, the relationship between renewable energy generators (including the Council) and Hydro Tasmania would be 'arm's length' – that is, purely commercial. In practice, all or any owners of energy assets on the Island would need to apply to Hydro Tasmania for a connection agreement (setting out technical considerations and requirements) and a power purchase agreement (setting out the financial terms of the sale of electricity from the assets).

In this model – which could be considered a less 'planned' or 'integrated' approach than the first - the consequences of each proposed investment for both the integrity of the overall system and for the CSO would need to considered by Hydro Tasmania, as the system manager, and also by the Tasmanian Government, at least with respect to the CSO. This risks to lengthen decision-making times and may also affect the attractiveness of the commercial terms that Hydro Tasmania may be prepared to offer to third party investors.

Other options, and variations or combinations of options, could be contemplated.

Under either model, for example, third party investments at arm's length from Hydro Tasmania, such as that recently proposed by FIRE Developments Pty Ltd, could also proceed and complement the overall Renewable Energy Plan. Such developments are likely to reduce the residual requirement for investment in renewable energy *generation* assets, if Flinders Island is to reach its 100% renewable energy target. They may not, however, contribute to the investment in storage or other system assets which, as noted earlier in this paper, will be required to reach such high renewable energy penetration ratios. We do note, however, that the FIRE Developments project includes a significant investment in control system upgrades at the Whitemark power station to enable the effective integration of the FIRE project into its control strategies.

The increasing requirement for expenditure on storage and system assets as the share of renewable energy on the Island rises does have important commercial consequences. As noted in Chapter 5, these assets may not *directly* earn revenue, but they are essential to facilitating investments in renewable energy generation, regardless of who makes those investments. As an example, the costs and risks associated with these system assets are very likely to affect the terms that Hydro Tasmania would be willing to offer to developers of subsequent renewable energy projects. However, it is very difficult to analyse such issues in the abstract. In practice, these matters will be resolved through commercial negotiations between the relevant parties. Also in practice, we note that if the Council is able to win grant funding from the Federal Government, some of this funding may be able to contribute to the required investment in storage and other system assets. This would be likely to improve the commercial terms able to be negotiated for subsequent renewable energy developments. The eventual proper placement of these in the NPV model (rather than including them as public purse contributions) would increase the apparent value of the proposal.

Another possible model may be for Flinders Council to assume the ownership, control and management of the power system on Flinders Island. In principle, the benefits of this approach could include the opportunity for the Council to run the system as a cost or profit centre for the benefit of the community. However, it would also directly expose the Council to the financial and technical risks of managing a modern power system. This would require the Council to acquire and retain, or at least contract for, significant expertise in power system management. However, it is not clear whether Hydro Tasmania would agree to divest its assets on the Island, nor on what terms.

It would also require renegotiation of the CSO, which currently exists between Hydro Tasmania (not the Flinders Council) and the Tasmanian Government, and this renegotiation could expose the Council and community to some financial risks. It is suggested that such an option be treated with due caution and considered as a 'possible last resort', with appropriate due diligence to be undertaken if this model were to be further progressed.

In consultation the community has expressed acceptance of all these possible models.

6.2.2 Cost Effectiveness and Risk

While the CSO currently shelters Flinders Island from the full cost of delivering electricity on the Island, the community has an interest in ensuring that its power system is as cost effective as possible in order to:

- Minimise the extent of future tariff increases
- Reduce the risk that the CSO may prove unaffordable in future and thus be reduced or removed

The cost to the Tasmanian government of the Flinders Island CSO is incurred in two main areas – electricity generation costs and electricity network costs. The network costs (or cost of the 'poles and wires') are not strongly related to the generation type. The great opportunity to reduce the CSO therefore lies in making a sizeable upfront investment in renewable energy in order to realize a permanent reduction in fuel costs.

All energy systems involve risks. The current energy system on Flinders Island involves low technical risks but higher environmental and financial risks. In particular, it is highly exposed to the risk of higher diesel costs, both from market factors and from carbon pricing, and hence the risk of rising tariffs. The fossil fuel underpinnings of the current system are also contributing, albeit in a minor way, to rising global greenhouse gas emissions and climate risks.

In considering renewable energy alternatives to the current power system, the varying costs and risks associated with different renewable energy solutions should equally be borne in mind. Some systems - such as solar, wind and hydro, for example – have long pedigrees, low technical risk and costs that are readily understood. Other systems – such as wave, tidal and some but not all biomass systems – are less mature and may involve higher technical risks and costs in the short term. As discussed above, strategies to manage and mitigate risks – including via appropriate system design, integration and management – must also be considered regardless of technology choices.

In consultation the community has expressed interest in all these technologies, with no clear "leaders" but a consistent overarching aim of 100% renewable backed by clear support for a system that provides high reliability. Members of the community clearly understood that any cost effectiveness analysis of these options should be compared to current pricing that includes the CSO.

6.2.3 Peak Oil

As noted above, the risk of rising diesel costs is a key existing system risk for Flinders Island. In this context, there is a significant risk of rising market prices of diesel over time due to a phenomenon known as 'peak oil'. Peak oil refers to the fact that crude oil – from which the diesel fuel used in the Whitemark Power Station is manufactured – is becoming increasingly scarce due to declining success in exploration and strongly increasing demand associated with global economic growth, which is particularly concentrated in our Asia-Pacific region.

As crude oil reserves diminish through time, products derived from crude oil, including diesel, will become increasingly expensive. While Flinders Island is partially sheltered from the impact of higher diesel costs on electricity prices due to the CSO, rising diesel prices will significantly increase the cost to the Tasmanian Government of the CSO. This is likely to lead to at least ongoing increases in electricity tariffs on the Island, as the Government tries to recover some of this cost, but could ultimately lead to pressures to significantly reduce the CSO. If Flinders Island were exposed to the full cost of electricity generation from diesel (delivered cost around $0.60/kWh, or nearly three times the current tariff), the incentive to shift to more sustainable and more affordable renewable energy sources would be very strong indeed. The CSO currently masks this underlying reality.

At the same time as diesel prices rise, the cost-effectiveness of alternative fuels and technologies improves, in part because manufacturers of such alternatives have additional incentives to bring products to the market. Biodiesels is one examples of such an alternative, discussed in the next Chapter. In the transport fuels area, a large scale shift to electric vehicles now appears very likely – making it even more important that electricity is produced both securely and sustainably, including on Flinders Island. Alternatives outside the electricity generation field are discussed in the counterpart *Greenhouse Gas Minimisation Plan*.

In consultation the community clearly expressed that knowledge of these issues was part of their drive toward a renewable system.

6.2.4 Climate Change and Carbon Pricing

While peak oil and global economic growth are driving up *market* prices for fossil fuels, the introduction of carbon pricing in Australia from 1 July 2012 will further accelerate these trends. The Australian Government is placing a price on carbon emissions – including from fossil fuels used for power generation – for the express purpose of creating financial incentives to substitute fossil fuel use with alternatives, such as renewable energy, and also to create stronger financial incentives for energy efficiency and conservation.

The full carbon price (starting at $23/t $CO_{2\text{-}e}$) will be passed on, along with suppliers' margins, to diesel used for power generation on Flinders Island. We estimate the landed cost of diesel on Flinders at present to be around $1.80/litre, although a fuel tax credit of $0.38143/litre currently applies for off-road use including in power stations. From 1 July 2012, this credit will be reduced by $0.0621/litre, with further reductions annually thereafter, in line with average carbon prices. This mechanism is how the carbon price will be applied to off-road fuel use[35], lifting costs by a little over 4% in the first year and then rising over time.

6.2.5 Energy Security

Energy security is about having sufficient energy available, at all times, to meet expected demand. This differs from reliability, discussed below, which refers more to the technical performance of the power system. Energy security is bound up with how much energy is *stored* on the island, as the more energy that is stored, the longer it is certain that power needs will be able to be met. We noted that at present, Flinders Island has no more than 6 weeks of diesel fuel stored at the Whitemark Power Station (although this could be readily expanded). This means that energy security over longer periods than this is fundamentally dependent upon regular and dependable supplies of fuel arriving by ship. In practice, this arrangement has proved very dependable. However, as the consumption of electricity grows over time, greater energy storage capacity is required to maintain the same amount of energy security.

[35] Note that numerous conditions and exemptions apply in different sectors – see http://www.cleanenergyfuture.gov.au/transport-fuels/ for further information.

Energy security is a 'peace of mind' factor that matters not only for the quality of life of Flinders Island's inhabitants, but also to ensure that investment and business continuity is underpinned by a dependable, secure power system. This view was reflected in community consultation and feedback.

6.2.6 Power Reliability and Quality

The reliability of the existing power system was described in Chapter 2. Reliability refers to the number of times, and length of time, that power is cut-off. Power quality can refer to a number of factors, but generally to the incidence of power 'spikes or surges' (generally associated with above-normal frequency or voltage conditions) or 'brown outs' (low voltage or frequency conditions).

With businesses and households increasingly reliant upon information technology, electronic control and management systems – which rely on continuous and high quality power supply - continuous supply of high quality power is becoming more and more important. High power reliability and quality is expected by most tourists and businesses, and will help to make Flinders Island a desirable place to live and operate. This view was reflected in community consultation and feedback.

6.2.7 Renewable Energy 'Branding' Opportunities

With rising global and national awareness of the damage caused by emissions of greenhouse gases, and with initiatives like 'carbon footprinting' and 'carbon offsets' being adopted by more and more businesses, consumers are becoming increasingly sensitive to the carbon consequences of their decisions. Purchases of products and services, decisions about where (and for whom) to work, decisions about where and how to live, choices of holiday destinations and travel modes, are all increasingly being influenced by carbon emission considerations. Carbon pricing will only serve to reinforce these trends, by differentially imposing costs on activities (products and services) depending upon how carbon intensive they are.

As an island economy, these trends create both risks and opportunities for Flinders Island. The risks include rising transportation and energy costs, discussed above, which could discourage tourists and residents. At the same time, switching to renewable energy, and taking other initiatives to reduce energy consumption and non-energy greenhouse emissions, offers the prospect not only of offsetting these rising energy costs, but also of creating '100% renewable energy' or 'zero carbon' or 'low carbon' branding opportunities. While such branding must be able to be substantiated to the satisfaction of the Australian Competition and Consumer Commission (ACCC), the potential for attracting residents and tourists, new business and for adding-value to products and services exported from Flinders Island, is very significant. This view was reflected in community consultation and feedback.

6.2.8 Energy Efficiency

Energy efficiency is about obtaining the useful services that we need – like hot water, lighting, comfort, mobility, etc – while consuming the least amount of energy possible. This can make a great deal of sense financially, since saving energy is often cheaper than purchasing energy, but it also means that less electricity must be generated and distributed, leading to lower greenhouse gas emissions. Further, since it is relatively expensive to generate electricity on the Island, saving energy is even more cost effective from a societal perspective on Flinders than it is elsewhere[36]. One question for the Island to consider, therefore, is how much to focus on improving the efficiency of energy use, and how much to focus on the sustainability of energy supply (eg, by using renewable energy)?

[36] Note that the CSO means that some part of the total benefit from energy efficiency investments on the Island accrues to the Tasmanian Government (the cost of the CSO falls), but there is also a direct benefit to Islanders in the form of reduced energy bills.

Some options (like solar hot water) capture renewable energy and reduce the demand for electricity at the same time. The potential for energy efficiency improvement is considered in the separate *Greenhouse Gas Minimisation Plan*.

6.3 Next Steps

The key step is for the Council and community to submit a bid for funding that has been prepared as part of this project brief – this is the next step along the path to developing the Island's own vision for a renewable energy future.

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8. Appendix 2 - NPV Details (Example)

Cost and benefits were analysed for the purpose of calculating the Net Present Value of the project. The outcome was calculated on the public purse basis, knowing however that separate items (the CSO, the original grant and the income) may all be associated with different components (Federal, State and local governments) of the public purse.

Demand projections were allowed to follow scenario A (moderate growth) detailed in the body of the report but here also incorporate the new FIRE development's anticipated electricity production.

The costs include a one off grant for establishment of each option. Ongoing costs are labour (additional to that required under the existing system) and maintenance. In 2018, it is calculated that growth in energy demand will require additional capacity. The system will accept additional power from a range of sources – additional wind turbines, a solar PV installation, a tidal installation or biodiesel fuelled gen-sets are all reasonable possibilities. For the sake of both simplicity and conservatism, the additional power is costed at the litres of biodiesel required to meet projected power needs. The 'income' is a combination of the retail value of the generated electricity plus the elimination of the current subsidy in the form of the Community Service Obligation. The CSO sees the Tasmanian Government effectively pay for the bulk of the costs of the current system (mainly fuel). The CSO is calculated to grow in real terms at the same rate as the retail value of the electricity consumed. A discount rate of 7% was applied.

Both electricity and diesel are projected to rise in cost according to national expectations from different sources – for electricity a rapid rise of around 30% over the next two years followed by a yearly real price increase of 2%. Diesel is expected to rise in real terms at 1% per year.

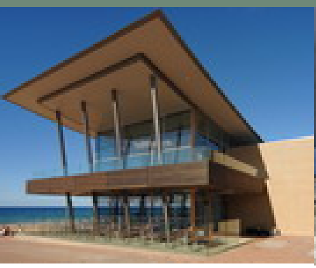
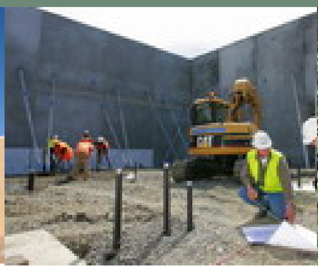
A snapshot of the Excel workings is provided below. Note the break from 2019 to 2041 – this gap enables the 30 year analysis to fit onto a page.

Annual maintenance is high (18% of installed capital) allowing for battery replacements while for option 2 it is set at 5%.

Public Purse Net Present Value

summary financials ('000s)		2012	2013	2014	2015	2016	2017	2018	2019	2041
Income / offsets										
annual supply value (retail)		1,029	1,246	1,326	1,411	1,498	1,590	1,686	1,786	3,226
annual CSO avoided		2,300	2,785	2,965	3,153	3,349	3,554	3,768	3,992	7,211
subtotal		3,329	4,031	4,292	4,564	4,848	5,144	5,454	5,778	10,436
Costs										
capital cost	grant	29,000	-	-	-	-	-	-	-	-
labour		170	170	170	170	170	170	170	170	170
additional capacity - biodiesel, wind, solar, tidal (costed at biodiesel)		-	-	-	-	-	-	78	193	2,439
maintenance	5%	1,435	1,435	1,435	1,435	1,435	1,435	1,435	1,435	1,435
subtotal		30,605	1,605	1,605	1,605	1,605	1,605	1,683	1,798	4,044
nett benefit		- 27,276	2,426	2,687	2,959	3,243	3,539	3,771	3,980	6,392
NPV (20 years)	7.0%	$15,217								
NPV (30 years)	7.0%	$27,234								

transport infrastructure | community infrastructure | industrial infrastructure | climate change

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