EECA

Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Off-shore and off the grid: generating renewable energy on the Department of Conservation's off-shore islands

Inspiring energy efficiency · advancing renewable energy

Contents

Photo credits:

Introduction

The Energy Efficiency and Conservation Authority (EECA) is a New Zealand Government organisation set up to “encourage, support, and promote energy efficiency, energy conservation, and the use of renewable sources of energy”.

To help demonstrate the potential roles, benefits, and costs of off-grid generation which uses renewable energy technologies such as photovoltaics (solar), micro wind turbines, and micro hydro turbines, EECA has undertaken a review of a number of significant off-grid generation systems recently installed by the Department of Conservation (DOC).

DOC manages natural and historic heritage assets by conserving, advocating, and promoting natural and historic heritage. The Department manages a number of off-shore islands around New Zealand which have unique flora and fauna. These islands serve as important sanctuaries for threatened mainland species.

The purpose of this study is to provide a comparative analysis of five major renewable energy upgrade projects that have been installed on islands maintained by DOC so that the economics can be better understood and that the lessons learnt can be used by other potential users of stand alone power systems (SAPS).

Executive summary

This report reviews five renewable energy systems which are already installed on islands maintained by DOC. The renewable energy systems, primarily comprising photovoltaics (solar electric panels), battery banks, and inverters, contribute to meeting electricity demand on the island and help reduce diesel consumption. The islands covered in this report are Little Barrier Island, Tiritiri Matangi, and Motuihe in the Hauraki Gulf, Mana Island near Wellington, and Maud Island in the Marlborough Sounds.

Fuel switching from diesel to renewable energy options is shown to be an economically attractive option in many situations. Although the upfront expenditure is often relatively high, the life-cycle system costs of using renewable energy technologies are often cheaper than continued reliance on diesel generation. This is primarily because the ongoing costs of delivering fuel, especially to remote locations, and of operating and maintaining diesel generators and other equipment, can result in very high costs of electricity generation. After installing renewable energy technologies, the cost of generation has, in some cases, reduced by over $2/kWh, significantly reducing the day-to-day cost of running the island infrastructure.

Using renewables also has important environmental benefits. Every year these five projects are saving nearly $90,000 in operating budgets (funding that can now be put into core conservation activities), 60 tonnes of CO_2, and 22,000 litres of diesel. The risk of transporting diesel fuel in sensitive environments is reduced, staff time previously required for generator maintenance is freed up, the islands are increasingly sheltered from future oil price increases, and air quality on the islands has improved.

The energy system upgrades

Prior to the upgrades, like many off-grid electricity generation systems in remote and rural parts of New Zealand, the systems in this report relied almost entirely on diesel generators to generate electricity. In some cases, such as on Little Barrier Island, the diesel generator charged battery banks that stored electricity until needed, whereas at other sites, such as on Mana Island, the diesel generators supplied load directly. Diesel generators typically have lower upfront capital costs but higher ongoing fuel and maintenance costs, compared to renewable energy technologies which typically have higher upfront costs but minimal ongoing costs. In addition, diesel generators typically have much lower efficiency when being used at part load, such as when they are being used to meet variable demand load directly, compared to when they are used at full load. Therefore if a battery bank is installed and used to 'smooth out' electricity supply, the diesel generator can be used much more efficiently in short bursts at full load to charge the batteries when required. This alone will result in savings in diesel consumption.

All five systems studied in this report utilised photovoltaic (PV) modules as part of the renewable energy upgrade. PV directly converts energy in sunlight into electricity and is considered amongst the most reliable renewable generation technologies, and with no moving parts they have the lowest maintenance overhead and a life expectancy typically over 20 years. Small wind turbines are often cheaper than PV on a dollar per watt ($/W) basis, however they tend to have greater maintenance requirements and in remote locations this can be a deterrent. Small-scale hydro can be a good option, and is often the cheapest in terms of total capital cost and the cost of generation (c/kWh), however it is site-specific and not a possibility at many locations.

Overview of stand alone power systems (SAPS)

SAPS, which have no connection to the electricity distribution network, usually have the following elements:

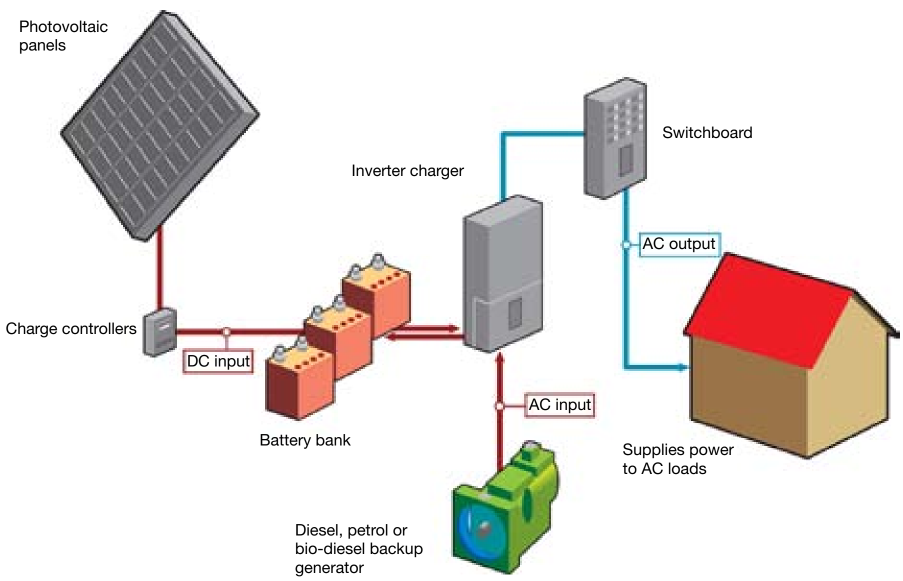
- renewable electricity generation components: the most common are photovoltaics, micro and small wind turbines, and micro or small hydro turbines. It is quite common to have more than one renewable energy generation source within a system
- electricity storage, usually in the form of deep cycle batteries
- devices to manage the system, including charge controllers to manage the batteries, inverters to change the DC output of the renewable energy generation technologies to AC for use in appliances, and 'dump' or 'diversion' loads for when the battery bank is fully charged
- fossil fuel-based back up generation to provide security of supply, in case the renewable energy technologies are not able to charge the batteries sufficiently for the times when there is insufficient sun, wind, or water in the streams to meet demand.

Figure 1. A battery bank installed on a concrete base, with the enclosure removed

Energy efficiency and conservation is also very important in SAPS, because the less electricity required the smaller and cheaper the generation system. It is always less expensive and easier to reduce energy use or use it more efficiently than it is to generate electricity. Solar water heating is often used alongside SAPS, and good insulation and efficient lighting and appliances are very important. It is common to use alternative fuels where possible, such as LPG for cooking, and wood burners to provide heating.

Figure 2 below shows the components of a typical SAPS.

Figure 2. Indicative component diagram of a typical SAPS



Motivations for installing renewable energy

For the systems analysed in this report, the motivation for upgrading the systems to incorporate renewable sources of energy can be summarised as:

Failure of the existing systems

In four out of the five installations considered, the primary driver for upgrading the system was failure (or high risk of failure) of the existing system and concern that the island would be without electricity supply. Most often the battery bank was the component of the existing system that was at risk.

A need to reduce high operating costs

The cost of delivered diesel to remote sites can be considerable. At the time of writing, in many situations diesel costs more than $1.80 per litre delivered, compared to on the mainland where it is closer to $1.00. This results in very high operating costs for diesel-based systems. Prior to the renewable energy upgrade the annual operating cost for the diesel-based system on Tiritiri Matangi was in excess of $40,000. This included fuel costs, regular transport of diesel to the remote site, and maintenance and servicing of the generator.

Providing insulation against fluctuating and increasing diesel costs

Decreasing reliance on diesel to generate electricity increases resilience against disruptions in oil supply and price ‘spikes’, and insulates against longer-term concerns about price uncertainty and global oil supplies.

Reduction in risk of contamination of marine reserves through transporting diesel

Given the nature of the conservation work conducted by DOC, ongoing high use of diesel in fragile environments posed a significant risk. By upgrading to renewable sources of energy, the risk of contamination in delicate ecosystems was greatly reduced.

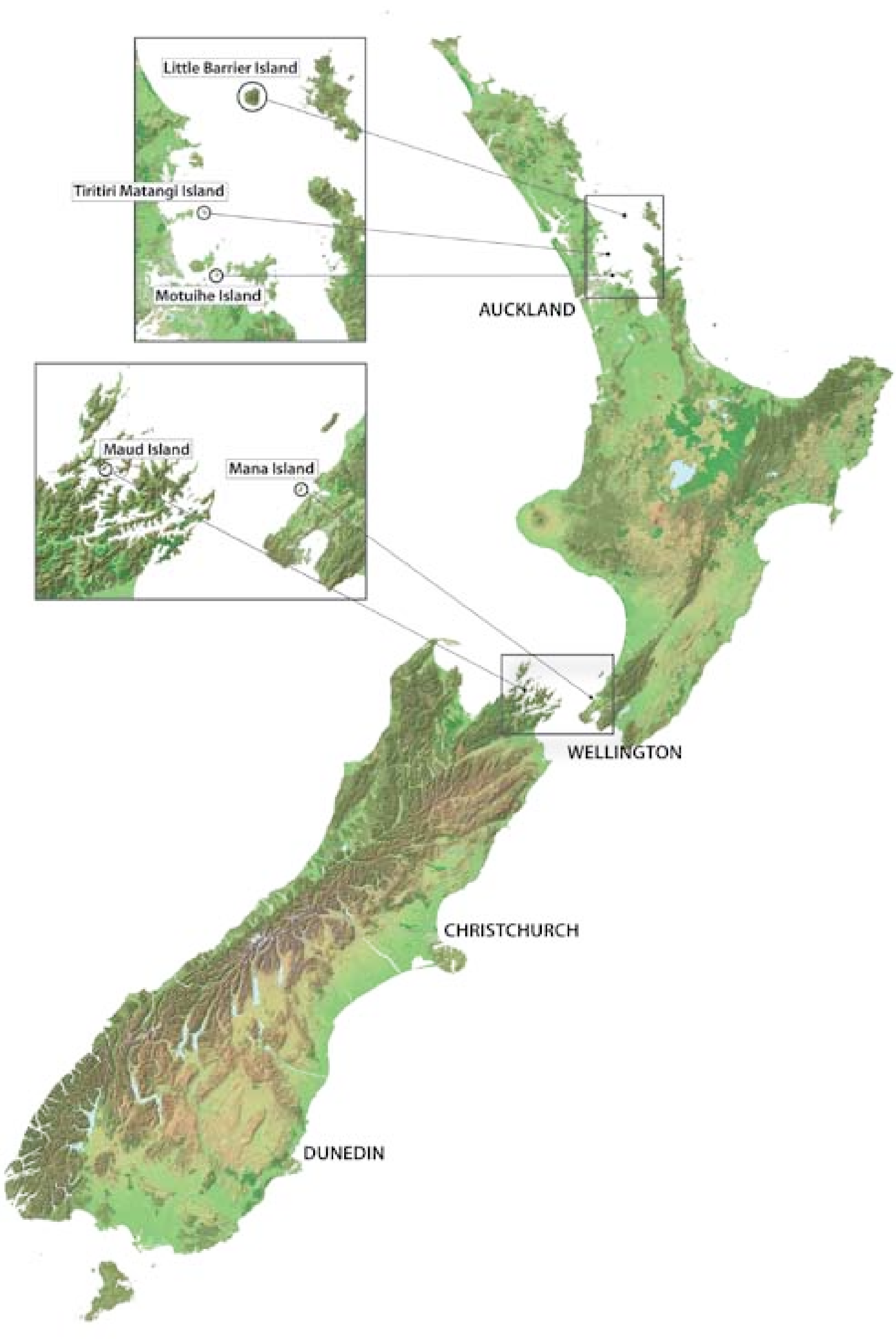
Support for DOC’s message of conservation by reducing reliance on fossil fuels

The Department has a target to reduce its diesel consumption on off-shore islands by 50% by 2012. The projects outlined in this report all contribute to achieving this target.

Overview of the systems studied

The five SAPS considered in this report were on Little Barrier, Tiritiri Matangi, and Motuihe in the Hauraki Gulf, Mana Island near Wellington, and Maud Island in the Marlborough Sounds. The locations of these projects are shown in Figure 3.

Figure 3. Location of the islands



Financial analysis

SAPS based on renewable energy technologies are very site-specific, and are designed and built according to the energy resources available at the site, energy demand profiles and patterns, and other unique requirements and specifications. This can make it difficult to compare systems and benefits, savings, and costs incurred across different systems.

This report uses the 'levelised energy cost' (LEC or $/kWh) to compare the 'before' and 'after' energy systems and show the impact that the upgrade had on the cost of generation. This approach discounts the stream of costs over the life of the project and divides it by the discounted stream of benefits (i.e. electricity generated) that the system provides over the same period. The stream of costs takes into account costs over the project's lifetime including capital expenditure (capex), operation and maintenance (O&M), and fuel costs, and the stream of benefits includes the energy output of the system. The LEC ($/kWh) is equivalent to the average price a consumer would have to pay per kilowatt-hour (kWh) of electricity to repay the developer to cover the capital and ongoing operation and maintenance costs, and all fuel expenses, with a rate of return exactly the same as the discount rate used.

The calculation for LEC is mathematically represented as:

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where 'LEC' is the average cost of electricity generation over the life of the project, '*I*' is the capex investment, '*M*' is the operation and maintenance costs, '*F*' is the cost of fuel, '*E*' is the amount of electricity generated, '*r*' is the discount rate chosen, and '*n*' is the life of the system.

In addition to the LEC, the 'savings' in discounted cashflow over the life of the systems are presented, and effectively show the difference in the cost of operating the original system over a 20-year period, compared to the cost of operating the new renewable energy-based system over the same time period. Sensitivity analysis is also undertaken on several parameters to indicate how the savings could change in certain scenarios.

Other measures include the annual reduction in system operating costs, which serve to 'free up' operational budgets for other priorities, and the 'simple payback' which is an undiscounted measure of how long it would take to pay off the investment with the annual savings.

Capital costs

The analysis undertaken in this report compares old generation plant (typically diesel-based generation systems sometimes many years old) with new systems which have been installed recently. The financial analysis relies on an estimation of capital cost, and while the old systems typically had sunk capital costs, in many cases imminent failure prompted the system upgrade. Where the old system was close to failure, approximate component replacement costs are assumed in the analysis in future years, depending on how much life remained in the equipment. The future replacement costs represent the capital costs that would have been incurred if the old system had simply been upgraded and maintained, or replaced with a similar diesel-based system. For the new systems the capital cost is simply a cost incurred in year one, although the battery bank is assumed to require replacement after 10 years, and this cost is also built into the model.

Figure 4. An inverter installed on the PV system on Little Barrier Island

Incomplete data

Conducting the financial analysis was made difficult due to the relatively limited amount of data and information available on the costs and performance of the systems. Incomplete data, and limited planning, scoping, or feasibility work for some of the energy system upgrades have rendered it difficult to confidently assess the performance of the systems. Data gaps have resulted in a range of assumptions, with varying degrees of confidence, being present in the analysis. The analysis may be considered indicative only and the limitations caused by the data gaps should be acknowledged.

Assumptions used

The analysis uses a set of generic assumptions and inputs, unless specific data are available. These assumptions are described below.

Lifespan of system: 20 years

The components of the system have different lifespans. PV modules are usually warranted for between 20 to 25 years, although may continue to generate electricity for longer than this. Batteries and other components, on the other hand, will usually need to be replaced more frequently. A replacement cost for the batteries is built into the model in year 10.

Discount rate: 6% (real, pre-tax)

The LEC calculation discounts the time series of expenditure and benefits to their present values by applying a discount rate. The discount rate considered appropriate may vary from situation to situation, and may depend on factors such as the cost of securing capital or may be related to the rates of return required from typical investments. In this analysis, the base-case discount rate is 6% (real, pre-tax) and the sensitivity analysis shows the results at a 10% discount rate.

Annual increase in diesel cost: 3.15% (real increase)

The base-case modelling uses an annual increase in diesel cost of 3.15% per year. This is based on the International Energy Agency's World Energy Outlook 2009, which forecasts oil prices out to 2020 and 2030. Calculating the average annual compounding/cumulative percentage increase indicates an annual increase of 4.75% to 2020 and 3.15% to 2030.

Estimated PV capacity factor: 12% to 15%

The capacity factor of a generation plant, such as PV, is the ratio of the actual output of the plant over a period of time and the output of the plant if it had been generating at its full rated output, for the same period of time. For example, if a 1kW PV array could generate at that rate continuously for one year, the output would be 8,760kWh as there are 8,760 hours in the year. However, obviously PV cannot produce electricity at night, and less when it is cloudy or during winter, so the array will typically only generate between 1,051kWh (12% capacity factor, more common in southern regions of New Zealand) and 1,314kWh (15% capacity factor, more common in northern regions) per year. Capacity factor should not be confused with a measure of the efficiency of the PV cells of wind turbine.

Figure 5. PV array framing being installed on a roof on Mana Island

Electricity demand / generation

In many cases electricity demand loads and generation output are not monitored or measured on off-grid systems. In some cases energy audits have been conducted as part of the project plan, however in other situations the energy demand loads and generation output can be calculated by knowing annual diesel consumption in litres, and an assumed generator efficiency.

Diesel generator efficiency

Specific fuel efficiency of diesel generators can vary, however most modern diesel generators have an efficiency of between 0.2 and 0.5 litres of diesel per kWh generated. Generator efficiency is usually higher if it is being run at or close to its rated power output. For example, a generator with a rated output of 20kW will be most efficient if the instant demand load is as close to 20kW as possible (for example, 0.36L/kWh). If demand drops by 50% the generator does not have to 'work hard' and more diesel is required per kWh of output than is otherwise the case (for example, 0.41L/kWh), and if the load drops by 75% it becomes even less efficient (for example, 0.55L/kWh).[1] In some cases, under reduced load excess fuel may be left in the cylinders of the generator and this can shorten the life of the generator.

For systems without batteries, where the generator is supplying load directly, it is quite common for demand load to fluctuate, and accordingly the efficiency of the generator may be much less than if the generator was used in short bursts to charge batteries directly under optimum load.

In the analysis the efficiency of the generator under the old systems, where no batteries were present, is often assumed to be less than the efficiency of the generator under the new system, where it is being used periodically under optimum load to charge the batteries at times when the PV array and/or wind turbine are unable to provide enough charge.

Operation and maintenance costs (O&M)

O&M costs vary depending on the age, complexity, quality, and other characteristics of the system and its components. In many cases specific O&M costs are unknown for the islands reviewed, however for Little Barrier Island detailed records of all costs have been kept and these are used to calculate indicative O&M costs on the other islands where no specific data are available.

O&M costs relating to the diesel-based systems are based on a 'per litre of diesel used', rather than an 'hours of operation' basis, as the diesel consumption (unlike number of hours of operation) is known for all islands. Individual cost components taken into account are: labour (cost to DOC is $85/hour); oil for the generator ($8 per litre); oil filters ($20 each); and mechanics ($1,680 per year, includes an overhaul every five years).

[1] For some examples, see http://www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx and http://www.cumminspower.com/www/common/templatehtml/technicaldocument/SpecSheets/Diesel/na/d-3425.pdf

For the PV-based systems, the O&M costs for the diesel generator above are reduced, but not eliminated, and the additional costs of a specialised technician for the renewable energy system are included (approximately $500 per year).

Non-financial benefits

The financial analysis of the systems takes into account some benefits of the systems, but not all. Other benefits, some less tangible, and others difficult to monetise, are excluded from the cost benefit analysis. It is important to note that the value of these benefits can be significant and should be included in overall assessment of the viability of the energy system upgrade.

Risk of diesel price increase

Continued heavy reliance on diesel for electricity generation exposes owners and operators of such systems to the risk that diesel costs may increase significantly, both temporarily and longer-term, which can greatly increase ongoing operating expenses. This, in turn, reduces available funding for core activities and departmental priorities. Reducing this risk by investing in renewable energy technologies, with low operating costs, provides greater certainty of future out-goings.

Opportunity cost

Diesel-based systems require substantial ongoing O&M work, including changing generator oil, replacing filters, and other mechanical repairs. In the remote off-shore islands described in this report, the maintenance requirements often meant that the island's staff had to spend considerable periods of their time, including their free time, repairing and maintaining the generator system to ensure that electricity supply was not unnecessarily interrupted. This situation is compounded by the fact that in many situations trained mechanics were unavailable, leading to staff who specialise in the conservation of indigenous flora and fauna having to 'learn' a new trade to maintain the systems. Continued maintenance of diesel plant can result in lost opportunity to work on other tasks. Switching to a system with lower operating and maintenance costs can free up staff to completely focus on their core areas of expertise and responsibility.

Visitors' perceptions

Many of the islands covered in this report receive high levels of visitors and tourists throughout the year. DOC's stated aims are to conserve, promote, and advocate for the protection of natural and historic heritage so that these values can be passed on undiminished to future generations. Renewable sources of energy, such as solar and wind energy, emit few or no greenhouse gas and other emissions, and more clearly align with DOC's values than continued reliance on fossil fuels, and present a more congruous image for visitors to areas of natural and environmental significance.

Environmental impact

Combusting diesel fuel results in release of nitrogen oxides (NOx) and sulphur oxide (SOx) as well as particulate matter into the local environment. The environmental benefits of reducing these emissions and pollutants can be considerable, especially in sensitive environments.

In addition, by reducing the use of diesel the risk of spillage and contamination of natural and ecologically significant areas is reduced.

Figure 6. PV array installed on Mana Island

Overview of the systems

The table below provides a summary of the five SAPS reviewed. Further detail is included in the sections below:

	Little Barrier Island	Tiritiri Matangi	Motuihe Island	Mana Island	Maud Island
Electricity demand (kWh p.a.)	7,154	10,461	5,628	9,000	3,300
Previous system	10kVA diesel generator with battery bank and inverter	2 x 10kVA diesel generators, battery bank and inverter	10kVA diesel generator, battery bank and inverter, 1.4kWp PV array	3 x 10kVA diesel generators	Diesel generator with battery bank, and micro-hydro unit.
New system	3.5kW PV array, 48V battery bank, Sunny Island AC Grid	7kW PV array, 48V Absolyte battery bank, Sunny Island AC Grid	1.9kW PV array, 2 x 24V battery banks, Outback inverters, new Kubota generator	2.9kW PV array, 1 x 48V battery bank, SMA inverters	2.592 kW PV roof mounted array
Approximate system upgrade cost	$125,000	$250,000	$78,721	$91,978	$79,300
Renewable energy system capacity	3.5kW	7kW	1.9kW	2.9kW	2.6kW
Operational cost savings per annum	$18,747	$41,221	$1,999	$23,538	$3,598
Simple payback on investment	6.7 years	6 years	39 years	4 years	22 years
Change in cost of generation	-$1.66/kWh	-$2.30/kWh	+$0.87/kWh	-$1.15/kWh	-$0.22/kWh
Change in diesel consumption	-5,289 litres	-7,990 litres	-549 litres	-6,550 litres	-1,417 litres

Summary of issues and findings

Analysis of the five off-grid energy supply systems reviewed in this report illustrates that in many situations fuel switching from diesel-based generation to renewables can be a cost-effective step to take. The main findings of this work are broadly discussed below.

The importance of good data

In order to accurately specify, size, and install any energy supply system, it is vital to have good data and information on current and future energy requirements, the characteristics of the current electricity supply, and a good understanding of what you want the upgrade to achieve. Insufficient quality data were available for the completion of this analysis, and numerous assumptions had to be used.

The table below illustrates the data that can be useful to help scope the project where planning to replace diesel. Not all of this information is required in every case, however the more information available the fewer assumptions are required.

Information required	Possible source of data
Diesel consumption	Diesel generator log books; data logging; monthly or annual fuel bills
Electricity demand loads	'Bottom-up' energy audits of all sites and appliances connected to the supply system
Generator output	Logging or monitoring of the generator; metering at demand centres (although distribution losses may need to be taken into account)
Generator efficiency	Can be calculated if diesel consumption and generator output are both known (litres p.a. divided by generator output – kWh p.a.)
Cost of diesel (delivered) per litre	Suppliers' invoices
O&M costs	Suppliers' invoices. Should take into account labour, freight, items such as oil, filters, and other parts, regular maintenance or overhauls, specialist technicians, etc., as appropriate

Correctly sized systems

In the absence of good data on the existing energy supply system, there is a risk that the proposed system will be either under- or over-sized. Under-sized systems may make an insubstantial reduction in diesel consumption. This can be seen in the system installed on Motuihe, where a 1.9kW PV array is only able to provide approximately one-third of the electricity demand on the island. In this situation the system fundamentally remains a diesel-based system with PV back up, rather than the other way round, however once the project is completed this will be rectified.

System design and specification

It is important to ensure that the system proposed is suitably designed and specified, and that the consumer and supplier both know and agree what the system will achieve. All parties involved in the installation of the system should have a clear understanding of any assumptions that are being used, what equipment is going to be installed in the system, and all relevant other terms and conditions.

The Sustainable Electricity Association of New Zealand (www.seanz.org.nz) has prepared a model contract that can be used to govern the installation of SAPS.

Competitive tendering

Projects that are competitively tendered for often result in better outcomes than where a single supplier has been selected to complete the work. As well as potential cost savings, competitive tendering allows for a variety of system designs, equipment, brands, and technologies to be appraised prior to contract negotiation. Suppliers and installers will often be able to provide good advice and suggestions about how to improve the quality of the proposed system.

Little Barrier Island

Little Barrier Island (Hauturu) is one of New Zealand's most valuable nature reserves. Its Maori name means 'resting place of the winds'.

Figure 7. Ground-mounted BP Solar PV array on Little Barrier Island

The island is a specially protected nature reserve, where human impacts are kept to a minimum and extreme care is taken to keep the island free of introduced animals and plants. The island is located 80km off the coast of Auckland.

The programme to upgrade Little Barrier's SAPS began in the 2005/6 financial year when a renewable energy consultant was commissioned to run a selection process for a preferred supplier. The primary motivation for the upgrade was the pending failure of the existing diesel generator, inverter, and battery bank system. Had this failed, the island would have had no option but to run the generators 24 hours a day to provide power.

The original system on Little Barrier Island consisted of one 10kVA diesel generator (make unknown), and a battery bank of unknown size with DC/AC inverters for conversion. A significant proportion of the electricity produced was being lost due to the failing battery bank which reportedly would not hold a charge for longer than two hours.

Following completion of the selection process, Reid Technology Ltd of Auckland was selected to supply a new system comprising:

- 1 x 3.5kW of ground-mounted PV consisting of 20 x BP Solar 175W panels
- an Absolyte 48v battery bank with Sunny Island inverters creating an AC network
- the existing diesel generator, incorporated into the new system.

Importantly, a significant amount of energy efficiency work has also been undertaken on the island. This included the replacement of the old gas hot water system with a solar water heating system that uses gas backup.

System at a glance

	Original system	New system	Change
Approximate capital costs	Assumed replacement costs: $20,000 for batteries year 1; $15,000 for generator year 15; $8,000 for inverter in year 8	$125,000; assumed battery replacement cost in year 10	
Demand (kWh p.a.)	7,154	7,154	
Operating costs p.a.	$20,828	$2,081	-$18,747
Cost of energy	$3.68/kWh	$2.02/kWh	-$1.66/kWh
Diesel consumption	5,723 litres	434 litres	-5,289 litres
$/Wp installed		$36	
NPV of cashflow over lifetime of project	$301,600	$165,385	$136,215 savings

The installation of the renewable energy system had an immediate effect on the operating costs of the system, resulting in a saving of over $18,000 per year and a reduction in diesel consumption from approximately 5,700 litres per year to just over 400 litres per year. In addition, the levelised cost of energy reduced by -$1.66/kWh to approximately $2.02/kWh.

Over the lifetime of the system, the present value of the cashflow reduced from over $300,000 to $165,000, realising a savings of over $136,000 over the 20-year period. The positive economics of this project are primarily driven by the high levels of diesel savings, and this means that the simple payback of the system is as little as 6.7 years.

Figure 8 below shows the makeup of fuel sources for the Little Barrier Island project before and after the upgrade and shows the impact that the new renewable energy system has had on Little Barrier's overall electricity supply. Currently the photovoltaic array provides approximately two-thirds of the island's electricity demand.

Figure 8. Little Barrier Island – Renewable energy fraction

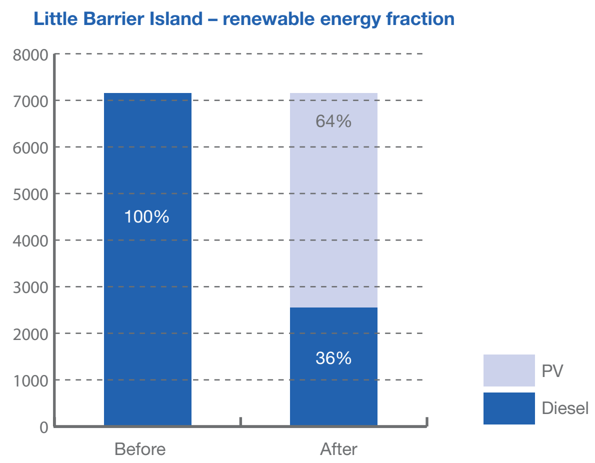


Figure 9. The 48v battery bank

Figure 10. The Sunny Island inverter

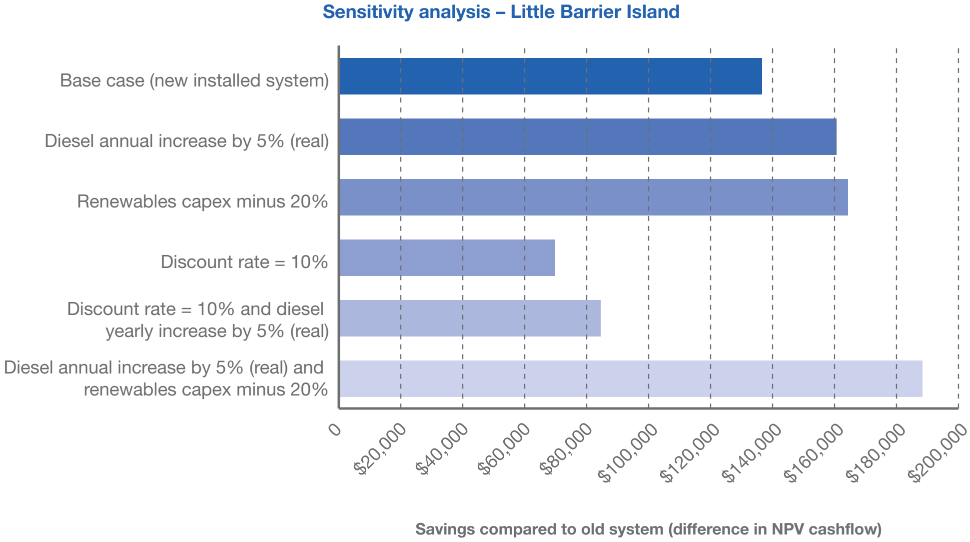
The success of the Little Barrier system has been the catalyst for other DOC sites to consider upgrading diesel-based systems. While component prices have decreased since 2005, making this project look expensive in comparison to other more recent projects, the chosen technology is still the latest available and feedback from staff on the island has been overwhelmingly positive. The process undertaken by the Little Barrier staff now serves as a template for other renewable energy SAPS installations.

Sensitivity analysis

Sensitivity analysis was conducted to assess how various factors would affect the economics of the project. The analysis below shows the potential savings that could be realised in each scenario considered, by comparing the difference between the net present value (NPV) of the cashflow for the new system and the NPV of cashflow for the original system, under the same scenario. A higher figure indicates that the new system would accrue greater benefits, compared to the original system, under the scenario considered.

The analysis shows that positive economic returns are realised under all the scenarios considered. Unsurprisingly, given that the project has been able to save considerable quantities of diesel each year, if the real annual increase in the cost of diesel is 5%, instead of 3.15% as considered in the base case, the savings over the lifetime of the project are even greater. Further, it should be noted that this installation was completed in 2005, and since then the costs associated with PV modules have decreased, which suggests greater returns could be achieved today. This is reflected in the scenario 'renewables capex minus 20%', which similarly results in greater savings.

Figure 11. Sensitivity analysis – Little Barrier Island



Tiritiri Matangi

Tiritiri Matangi ('looking to the wind' or 'wind tossing about') is one of the most successful conservation projects in the world. Unwanted predators have been eradicated, and the once-pastoral island has been replanted with native trees. The sanctuary is open to the public and is only 4km off the coast of the Whangaparaoa Peninsula.

Figure 12. Ground-mounted BP Solar PV array on Tiritiri Matangi

Commencement of the Tiritiri Matangi SAPS upgrade happened in parallel with the Little Barrier Island project (2005/6 financial year).

As with Little Barrier Island, the primary motivation for the installation was the imminent failure of the existing system which comprised two Lister 10kVA diesel generators, a battery bank of unknown make and size, and an inverter system. Unfortunately, the total electricity output of the old system is unknown due to the failure of the battery banks to hold charge, which resulted in the need to produce significantly more electricity than should have been required. However, once the battery bank was replaced the new system produced a total of 10,461kWh in the 2007/8 year.

Reid Technology Ltd of Auckland was selected as the main contractor for this upgrade. The new system comprises:

- a relatively large 7kW of ground-mounted PV consisting of 40 x BP Solar 175W panels
- 2 x Absolyte 48v battery banks with Sunny Island inverters creating an AC network
- existing 2 x 10kVA diesel generators, incorporated into the new system.

System at a glance

	Original system	New system	Change
Approximate capital costs	Assumed replacement costs: $20,000 for batteries year 1; $30,000 for generators year 15; $8,000 for inverter year 8	$250,000; assumed battery replacement cost in year 10	
Demand (kWh p.a.)	10,461	10,461	
Operating costs p.a.	$43,100	$1,879	-$41,221
Cost of energy	$4.82/kWh	$2.51/kWh	-$2.30/kWh
Diesel consumption	8,369 litres	379 litres	-7,990 litres
$/Wp installed		$36	
NPV of cashflow over lifetime of project	$577,746	$301,703	$276,043 savings

Figure 13. The 7kW PV array

The Tiritiri Matangi installation is the largest off-grid system owned by DOC and is one of the largest in New Zealand. To date the system has performed well and has provided real ongoing savings for the island staff.

Despite the relatively high capital cost, the system is shown to have very positive benefits, and this is primarily due to the fact that the large 7kW PV array can generate enough electricity to reduce diesel consumption by almost 8,000 litres per year. The reduction in the cost of generation, from over $4.80 to approximately $2.50, is the most significant of all the systems analysed.

Figure 14 highlights the impact that the new renewable energy system has had on Tiritiri Matangi's overall electricity supply makeup. A combination of high electricity demand loads and a failing battery bank meant that the previous operational running costs per year were in excess of $40,000. The new system has reduced this to under $2,000 and diesel now only contributes 12% of the power needed, topping up the battery charge if the PV array has not produced enough during the day.

Figure 14. Tiritiri Matangi – Renewable energy fraction

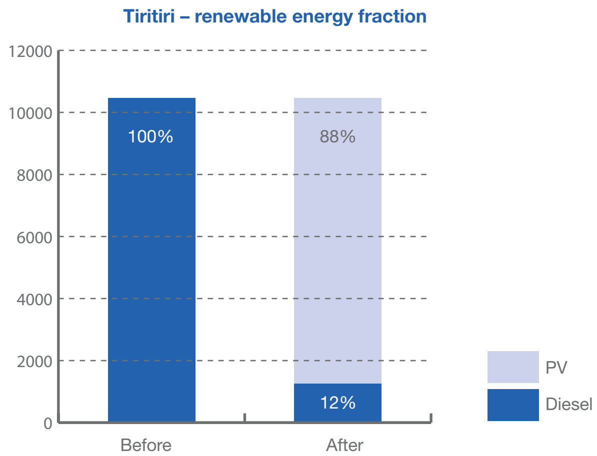


Figure 15. The two Sunny Island inverters

Figure 16. The two 48V battery banks

Sensitivity analysis

Sensitivity analysis was conducted to assess how various factors would affect the economics of the Tiritiri Matangi project. The analysis below shows the potential savings that could be realised in each scenario considered, by comparing the difference between the NPV of the cashflow for the new system and the NPV of cashflow for the original system, under the same scenario. A higher figure indicates that the new system would accrue greater savings, compared to the original system, under the scenario considered.

Due to high levels of diesel being displaced, sensitivity analysis for the Tiritiri Matangi system shows, as it does for Little Barrier Island, positive returns under all the scenarios considered.

Figure 17. Sensitivity analysis – Tiritiri Matangi

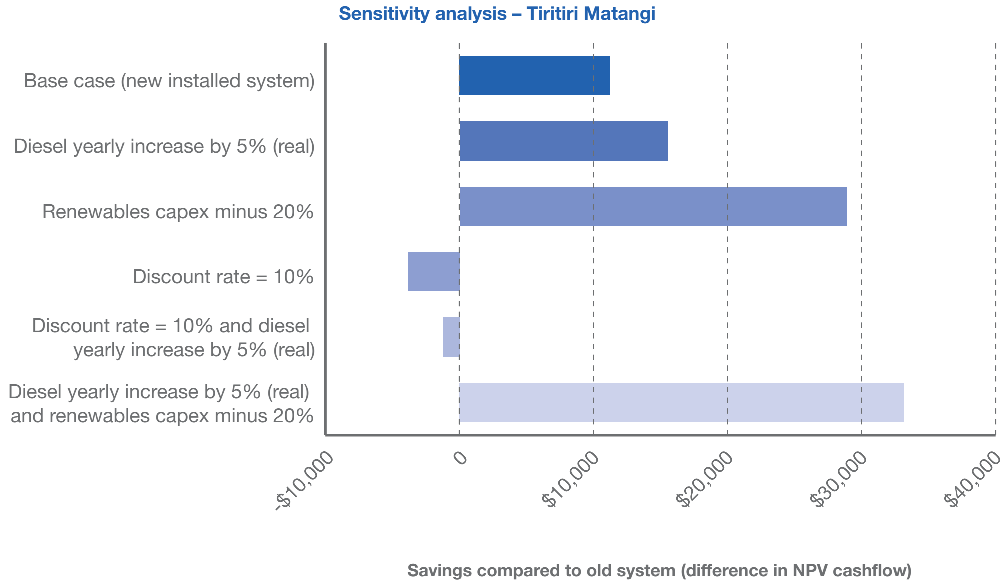


Figure 18. The PV array on Tiritiri Matangi

Motuihe Island

Figure 19. The two types of PV modules installed on Motuihe

Motuihe Island has played a significant role in Auckland's development. Two pa were constructed on the island's headlands, with one – Mangoparerua – noted as an important battle site. In 1872 a ship brought smallpox into Auckland harbour and Motuihe was selected by Auckland's Board of Health as the site for a human quarantine station. It was used for this purpose again in 1918 when an influenza epidemic swept the country. Most of the markers on the island's small cemetery relate to the illness at that time. At the outbreak of World War 2 the quarantine station was converted and enlarged to become HMNZS Tamaki, a naval training base and part of the coastal defence network. It continued in peacetime to be used for basic training in seamanship, fitness, and discipline before moving to the North Shore in 1963. DOC inherited the infrastructure left by the Navy.

Security of electricity supply was the primary driver for the installation of a renewable energy-based SAPS on Motuihe Island. The island used to be connected to the electricity network on the mainland, however the undersea cable had been dragged up numerous times by passing vessels and eventually it became too costly for the local network company (Vector Ltd) to reinstall and maintain it. Once the decision was made not to repair the cable, electricity on the island was provided by a 10kVA Lister diesel generator and distributed around the island through the existing underground cabling.

In 2005, due to increased demand for electricity on the island, DOC engaged Earth Energy Systems Ltd to design, supply, and install a larger renewable energy system to offset rising diesel costs and provide better security of supply. This was Stage 1 of the energy system upgrade.

The following components in Stage 1 were installed:

- 2 x 27kWh battery banks with 3kW Outback inverters
- 480Wp of PV in two roof-mounted arrays, to complement the 1.4kWp array from an earlier installation
- 1 x 13kVA Kubota diesel generator.

Figure 20. The new Kubota generator on Motuihe

The relatively small 1.9kW PV array is still only able to contribute around one-third of the island's electricity demand, and as a result diesel reliance remains relatively high. At present the system cannot simultaneously meet all the peak demand of the island and the system is controlled by the DOC Ranger via a switching system. The next step in this project is the planned Stage 2 upgrade, which involves increasing the size of the PV arrays in 2010/11 at an additional cost of approximately $33,000. There is also a future planned upgrade of the island's internal distribution network and improvement to the water pumping efficiency, which will reduce electricity demand further.

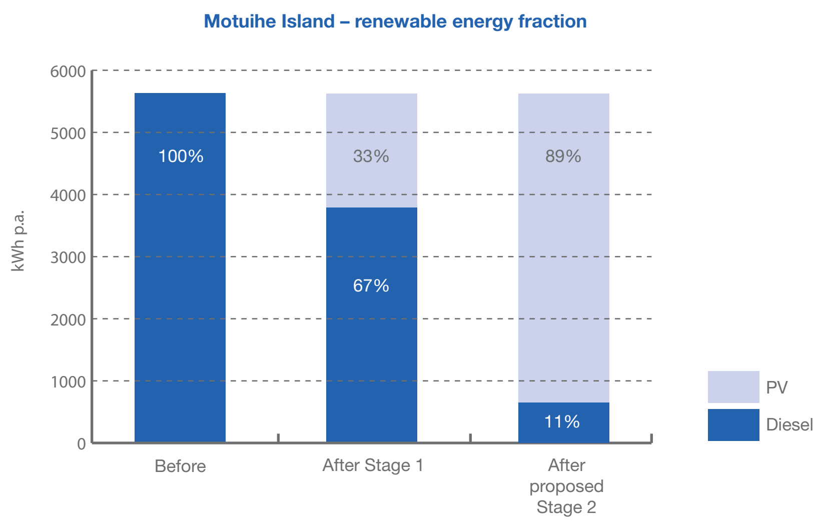
System at a glance

	Original system	New system	Change
Approximate capital costs	Assumed replacement costs: $15,000 for generator year 15	$78,721; assumed battery replacement cost in year 10	
Demand (kWh p.a.)	5,628	5,628	
Operating costs p.a.	$6,144	$4,145	-$1,999
Cost of energy	$1.32/kWh	$2.20/kWh	+$0.87/kWh
Diesel consumption	1,688 litres	1,139 litres	-549 litres
$/Wp installed		$41	
NPV of cashflow over lifetime of project	$85,516	$141,775	-$56,259 savings

Although the Motuihe upgrade project commenced at a similar time to Little Barrier and Tiritiri Matangi, the nature and extent of energy use on the island compared to the other installs meant that the system design and implementation is markedly different. The majority of the costs of Motuihe were related to infrastructure, such as new distribution cabling and transformers, as opposed to renewable electricity supply itself, and as a result Motuihe should not be seen as a completed project. A number of water storage and pumping issues have required addressing before the final system components can be installed, and current electricity demand on the island is considerably greater than was anticipated in 2005. Nevertheless, even in its current form the installed system is making an impact on diesel consumption on the island.

Figure 21 highlights the impact that the new renewable energy system has had on Motuihe's overall electricity supply makeup, and the potential impact once Stage 2 is completed.

Figure 21. Motuihe Stage 1 and proposed Stage 2 – renewable energy fraction

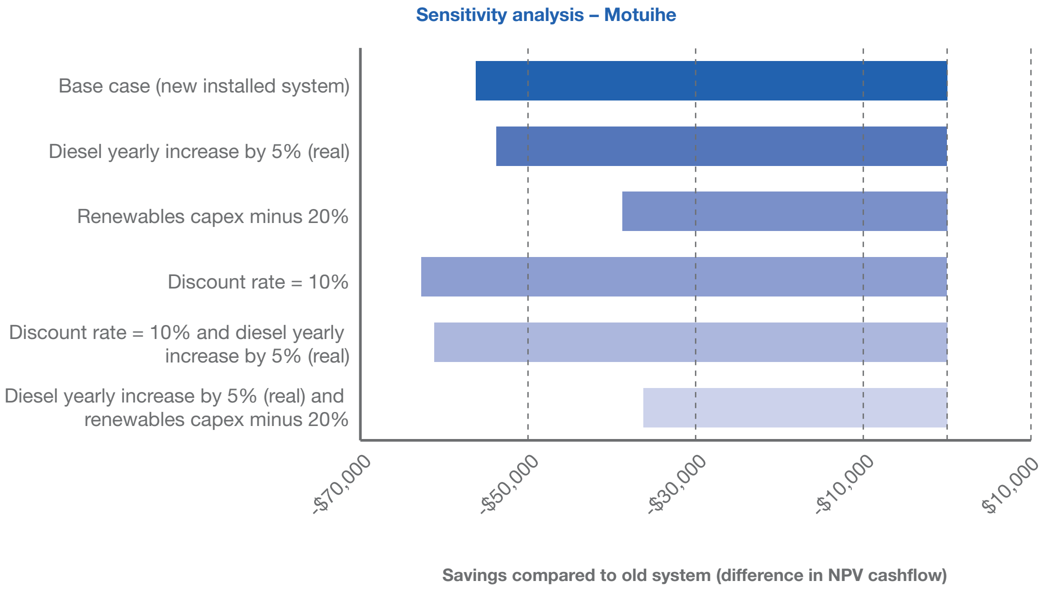


Sensitivity analysis

Due to the fact that the energy system upgrade on Motuihe is still incomplete, the financial viability of the work can not yet be fully ascertained. Future planned work to increase the size of the PV array will increase the renewable fraction and result in increased diesel reduction.

A significant percentage of the total Stage 1 costs on Motuihe were related to infrastructure improvements and installing a new diesel generator. These measures, though important, have naturally not delivered the same significant energy benefits which have been seen on some of the other islands and for this reason sensitivity analysis shows negative results. It is important to remember also that the project remains incomplete, and the 1.9kW PV array is unable to provide a substantial renewable energy fraction, as can be seen by comparing the 33% fraction on Motuihe with 64% and 88% on Little Barrier and Tiritiri respectively. Stage 2 of this project will see a much greater renewable energy fraction, and a correspondingly high reduction in ongoing diesel costs.

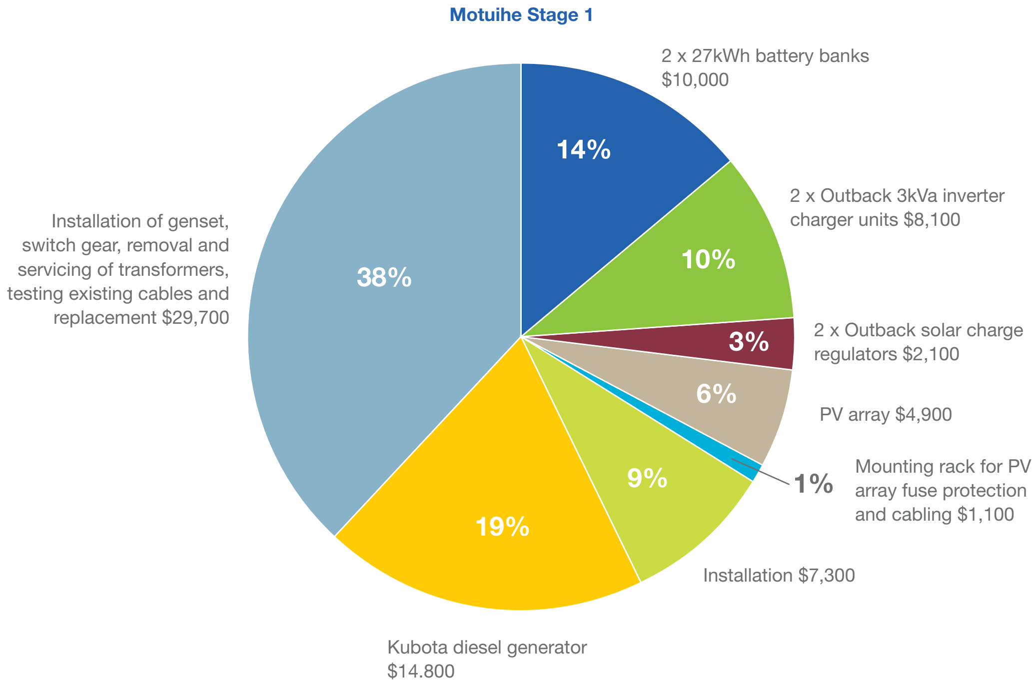
Figure 22. Sensitivity analysis – Motuihe Stage 1



System costs

The overall cost of the Stage 1 installation on Motuihe was $78,700. The majority of this cost was for the new generator, and repairs to the island's infrastructure including servicing and repairing the transformers, rather than the renewable energy system.

Figure 23. Cost breakdown of Motuihe Stage 1



Mana Island

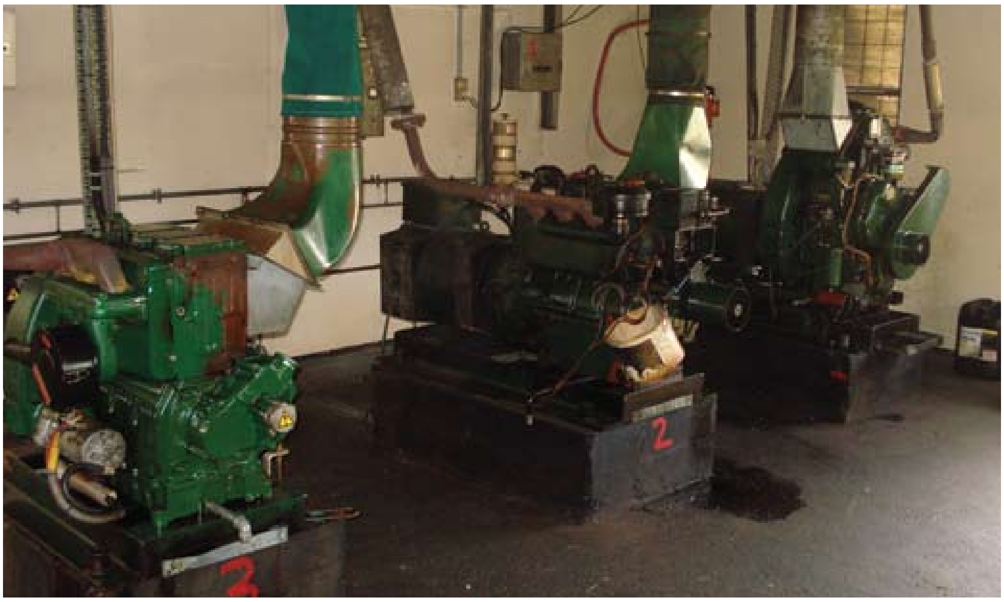
Mana Island passed into Crown ownership in 1865 and grazing continued until 1986 when the last cattle were removed. Sheep had been removed earlier after an outbreak of disease.

DOC took over management of the island in 1987 and began to restore Mana to its natural state.

In 2008 Right House Wellington visited Mana Island and recommended the installation of a renewable energy system to reduce diesel consumption. Elemental Energy and Right House were appointed to install the new system which was completed in October 2009.

Reducing high ongoing costs was the primary driver for installing a SAPS on Mana Island. Until the new system was installed, power for operations was provided by three 10kVA single phase Lister diesel generators directly powering load (i.e. with no battery storage) when required. Using diesel generators like this is a particularly inefficient way to provide electricity to a site, as the type of diesel generator used was not capable of variable speed load provision.

Figure 24. The three Lister diesel generators



Prior to the upgrade the annual electricity demand on the island was around 9,000kWh, which equated to an annual running cost in excess of $12,000 per year. A comprehensive energy efficiency programme has helped to reduce the energy costs on the island.

Figure 25. The PV array being installed on a framing system

The following components were installed in the system upgrade:

- 2.9kW PV array consisting of 18 x Sharp 162W modules
- 48v Absolyte battery bank with Sunny Island inverters.

The existing diesel generators were retained. However, by using them to charge the battery bank rather than provide direct power to load, their efficiency has been dramatically improved.

System at a glance

	Original system	New system	Change
Approximate capital costs	Assumed replacement costs: $45,000 for generator year 15	$91,978; assumed battery replacement cost in year 10	
Demand (kWh p.a.)	9,000	5,000	
Operating costs p.a.	$25,547	$2,009	-$23,538
Cost of energy	$3.39/kWh	$2.23/kWh	-$1.15/kWh
Diesel consumption	7,020 litres	470 litres	-6,550 litres
$/Wp installed		$32	
NPV of cashflow over lifetime of project	$349,665	$128,061	$221,604 savings

Figure 26. The solar water heating system being installed. Photo credit: Right House

Mana Island provides a good example of the difference that energy efficiency measures can make to a renewable generation project. Total demand on the island was reduced from 9,000kWh p.a. to 5,000kWh p.a., through the installation of energy efficient light bulbs, draught proofing, solar hot water, and the replacement of an old refrigerator. This resulted in a significant reduction in the overall electricity consumption and in turn reduced the required capital expenditure for upgrading the electricity generation system, resulting in a more economic project.

Operating costs were reduced from approximately $25,000 per year to $2,000.

Figure 27. Mana Island – renewable energy fraction

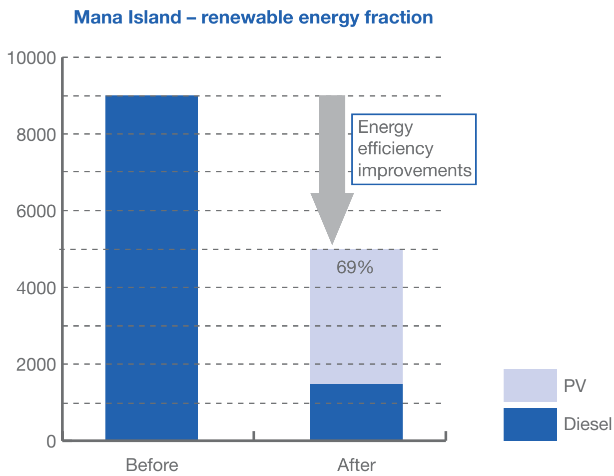


Figure 27 highlights the impact that the new renewable energy system has had on Mana Island's overall electricity supply makeup.

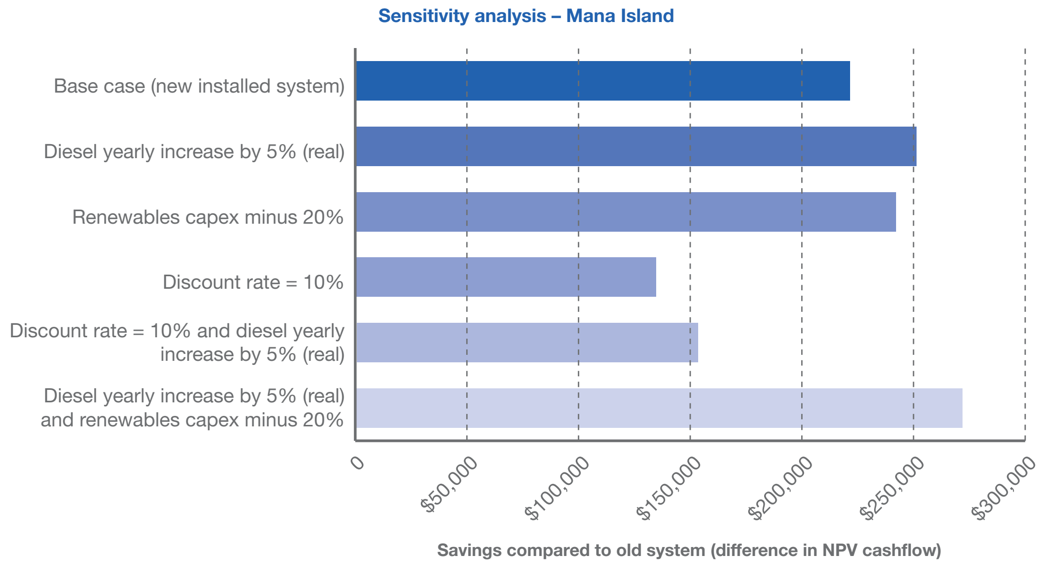
Figure 28. PV modules being unpacked on Mana Island

Figure 29. Batteries being transported to Mana Island

Sensitivity analysis

The energy system upgrade on Mana Island is another example of a good, economic project using renewable energy to reduce diesel consumption. The savings are most sensitive to increasing costs of diesel, and the discount rate assumed in the analysis.

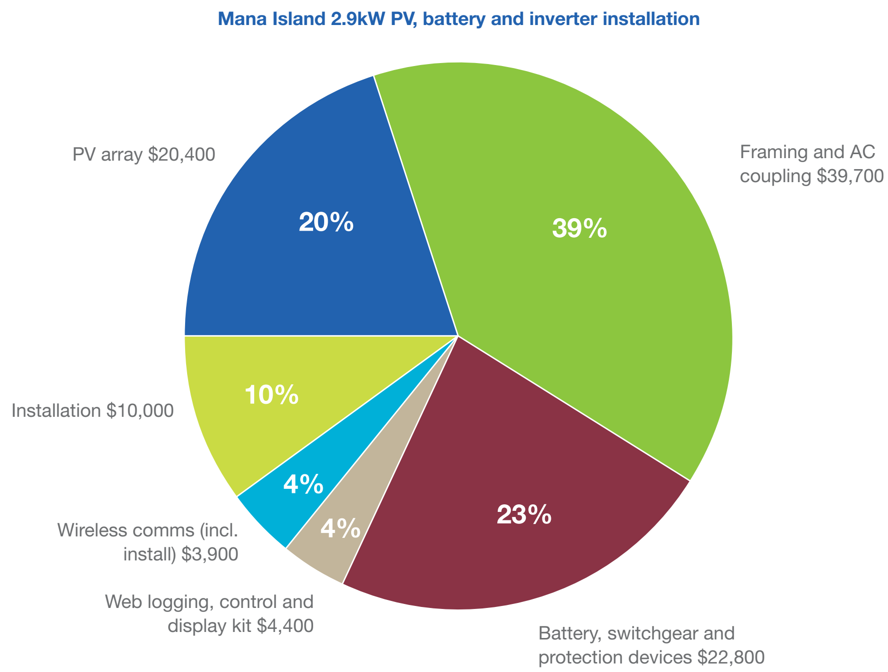
Figure 30. Sensitivity analysis – Mana Island



System costs

The overall cost of the installed system on Mana Island was just over $91,000, which at $32/Wp of installed renewable capacity is broadly representative of the best performing systems analysed. The breakdown of the costs is shown in Figure 31.

Figure 31. Cost breakdown of Mana Island system



Maud Island

Maud Island (Te Hoiere) first came into service as a wildlife refuge in 1974 when the then owner, Jack Shand, agreed to let the island be used as a home for what at the time was believed to be the last kakapo from Fiordland. Te Hoiere was purchased in 1976 to protect the endemic Maud Island frog and as a safe refuge for critically endangered species, such as kakapo and takahe.

The move gave Maud Island the distinction of being the first safe haven for kakapo. Kakapo remained a part of the island wildlife – with numbers reaching 18 at their peak in 2000 – until May 2003 when the last five were moved from Te Hoiere to islands more suitable as kakapo habitat. The original power system on the island comprised a small micro-hydro unit (producing approximately 400kWh per year) and two Lister 10kVA diesel generators (one 30 years old and the other six years old). These generation sources fed into a battery bank which was at the end of its useful life. As such, imminent system failure was the motivation for the Maud Island renewable energy project. At the time the total running cost was approximately $1,500 per year with a demand of around 3,300kWh.

Figure 32. The main house on Maud Island

In 2008 Right House visited the island and recommended the replacement of the existing system with a renewable energy SAPS. Elemental Energy and Right House were appointed to supply and install the system. This work was carried out in August 2009.

This system included:

- a 2.6kW PV array consisting of 16 x Sharp 162W modules
- a 48v battery bank with Sunny Island inverters
- the existing six-year-old 10kVA diesel generator was retained.

The system was designed to provide as close to 3,000kWh p.a. as possible, and the entire array was installed on the roof of the house because there were no other suitable locations. A ground-mounted array was considered, however this was deemed undesirable by DOC.

One of the challenges of the system was that the site loses the sun relatively early, and therefore to achieve the required yield with the array installed on the roof of the house, its size had to be relatively large. It is possible that the economics could have improved if a ground-mounted array had been used, however this was not suitable for other reasons.

A micro-hydro scheme was retained in the system, and this is now incorporated into the system.

System at a glance

The primary driver for the Maud Island system upgrade was, like others considered in this report, a failing battery bank. The opportunity was taken to substitute solar for diesel at the same time. The long-term viability of the micro-hydro system was unclear, so it was decided to install a PV array capable of producing as much of the site's electricity demand as possible. The complementary nature of different renewable generation systems, which are entirely dependent on intermittent fuels such as sunshine, wind, or rain, means that a degree of overlap can be extremely useful.

	Original system	New system	Change
Approximate capital cost	Assumed replacement costs: $45,600 quoted for battery replacement in year 1; $15,000 for diesel replacement in year 15	$79,300; assumed battery replacement cost in year 10	
Demand (kWh p.a.)	3,300	3,300	
Operating costs p.a.	$4,000	$402	-$3,598
Cost of energy	$2.67/kWh	$2.45/kWh	-$0.22/kWh
Diesel consumption	1,450 litres	33 litres	-1,417 litres
$/Wp installed		$24	
NPV of cashflow over lifetime of project	$101,140	$92,900	$8,239 savings

The potential savings available from this system, which only ever had to meet a demand load of 3,300kWh p.a., are always going to be limited, and this is reflected in the financial analysis for this project. However, the project achieved strong savings, and reduced the cost of electricity generation and operating costs.

Figure 33 highlights the impact that the new renewable energy system has had on Maud Island's overall electricity supply makeup. The new system is sufficient to provide all the electricity to the site. This has reduced the role of the micro-hydro to backup supply, particularly in the winter months when there is less sunshine for the solar panels and more water for the micro-hydro to run.

Figure 33. Maud Island – renewable energy fraction

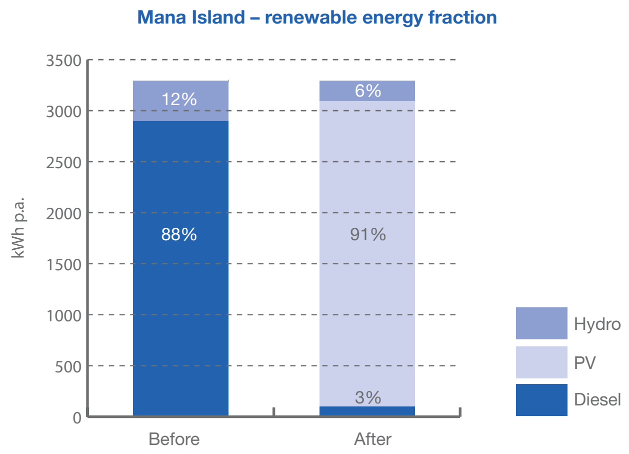
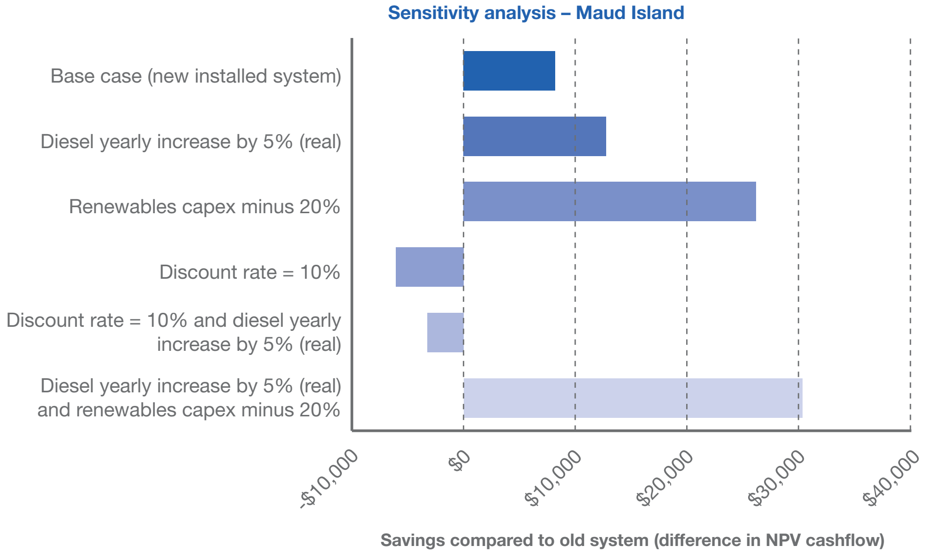


Figure 34. The new PV array and solar water heater installed on the bottom house

Sensitivity analysis

Ignoring the less tangible benefits of the system upgrade, the sensitivity analysis in Figure 35 shows that the renewable energy system has delivered strong benefits for the island under most scenarios.

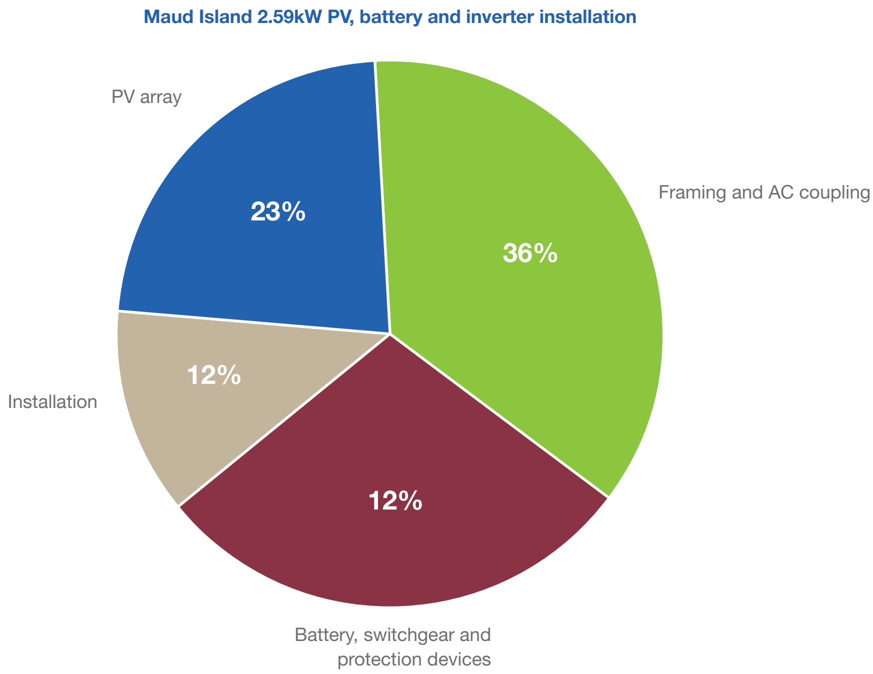
Figure 35. Sensitivity analysis – Maud Island



System costs

The breakdown of system costs for the Maud Island project is shown below.

Figure 36. Breakdown of system costs – Maud Island



EECA Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Level 8 · 44 The Terrace · PO Box 388 · Wellington · New Zealand
P: +64 4 470 2200 · **F:** +64 4 499 5330
www.eeca.govt.nz

New Zealand Government · EECA energywise · EECA BUSINESS · ENERGY STAR

JUNE 2010/EEC1510