

Cost of kWh produced and Payback Time of a PV-Solar-Thermal-Combined Rooftop Collector at Different Locations in New Zealand

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Abstract

The cost of the produced energy from an electric/thermal rooftop solar generator and the payback time is calculated for different geographic locations in New Zealand. The system consists of separate units of photovoltaic and thermal solar collectors suitable for a single household use. The operational data of an evacuated tube solar thermal collector and an average polycrystalline solar photovoltaic solar generator are taken as a basis for the calculation. The annual amount of energy produced and the resulting savings over the system lifetime are presented. The potential advantages provided by this comprehensive use of solar radiation are emphasised.

1. INTRODUCTION

It is most common in New Zealand for water and space to be heated directly by electricity. This situation is due to the fact that NZ has traditionally had an abundance of natural hydroelectricity produced, transmitted and distributed efficiently with minimal polluting effect. The energy consumption in water and space heating for domestic and industrial use is considered to account for 40 - 60 % of the total electricity energy consumption.

The recently released National Energy Efficiency and Conservation Strategy, **ref. [1]** announces a target to increase renewable energy supply to provide a further 25-55PJ/year (6,944–15,278 GWh/year) of consumer energy by 2012. The target represents a 19-42 percent increase over the current renewable energy supply. The renewable energy target is intended to give effect to the required progressive transition to renewable energy. This is in stark contrast to the recent history where over the last decade the market share of total consumer energy provided by renewables has declined to 29 percent (132 PJ = 36,667 GWh) in 2001.

As grid-connected photovoltaics (GC-PV) are highly recommended for urban use representing typical distributed generation to provide support to the national grid, it is yet possible that photovoltaic electricity may in turn be utilised for heating purposes. This work is an attempt to introduce the economics of a GC-PV combined with a suitable domestic solar water heater in order to encourage the use of both types of solar energy where applicable. The use of a separate solar heater adds, as expected, advantages to the economics of the whole system. The operational data of an evacuated tube solar thermal collector (ETC) and an average polycrystalline solar grid-connected photovoltaic solar generator are taken as a basis for the calculations. The annual amount of energy produced, the resulting savings over the system

lifetime and the payback time are presented.

2. THE MODEL

Operational data resulting from field measurements of an evacuated tube solar collector heater having a collector area of 1.37m² tested at Christchurch as described in **ref. [2]** and the interpreted operation data of a 1 kWp-GC-PV system at different locations in NZ is applied to economic models in order to help assess the economic performance of the combined system. **Figure 1** shows the average energy yield of the combined system and the average availability of solar radiation at Christchurch.

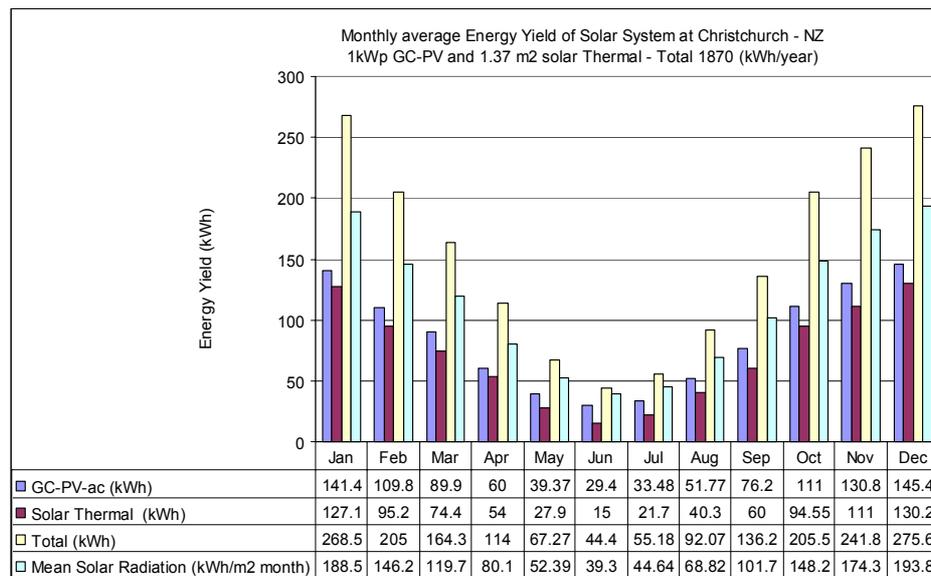


Figure 1. Average Energy yield/year of the proposed combined solar system and average availability of solar radiation at Christchurch

The total model system cost interpreted according to present New Zealand market data is shown in **Table 1**.

Table 1: System Cost

| Item | No. Units | Total cost range NZ \$ |
|---|-----------|------------------------|
| PV module | 1 | 8,000 |
| Modules installation, Wiring & Cabling | | 1,500 |
| Inverter (PCU) 700 W-ac | 1 | 2,500 |
| Evacuated tube solar thermal 1.37 m ² unit | 1 | 2,500 |
| Total Initial Capital Investment | | 14,500 |

The electric energy demand of a typical average household has been implemented in the calculation in order to demonstrate the impact of the installed combined solar system on the energy consumption. The assumption made in this analysis is that the kWh produced by the solar water heater during any one year is sufficient to completely replace the electrical kWh that would have otherwise been used. The contribution made by the GC-PV system added to

that of the solar thermal system results in the total reduction in the energy demand from the utility grid. **Figure 2** shows the resulting electric energy savings for one-family household implementing the proposed combined solar system at Christchurch.

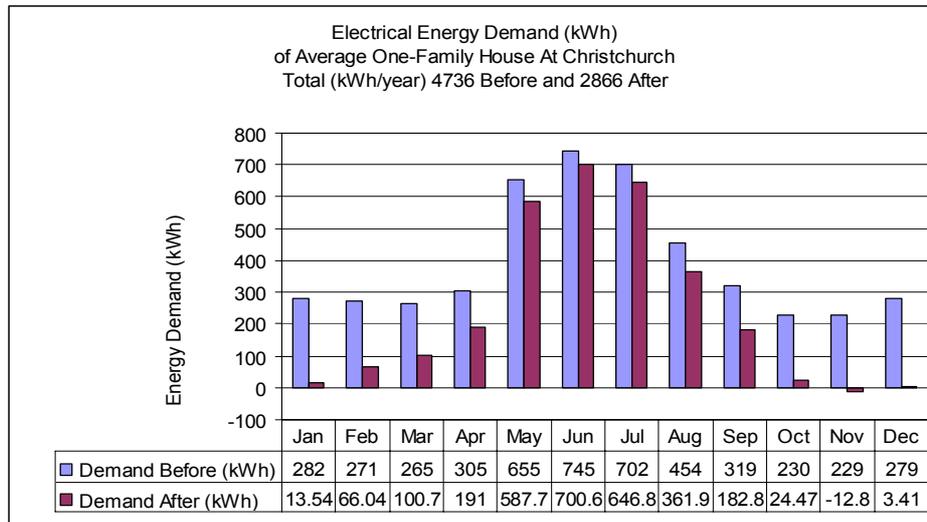


Figure 2. Realisable electric energy savings from the proposed solar system.

At other locations in New Zealand the energy yield of an identical system will vary according to the availability of solar radiation. It is expected that in northern parts of the country a considerable increase in energy yield could be achieved.

3. ECONOMIC ANALYSIS

The life-cycle analysis is used in order to evaluate the economic performance of the proposed solar system. The life-cycle cost of a solar system is its initial cost plus the lifetime cost of maintenance and operation discounted to the present time. The life-cycle benefit of the solar system is the total value of all the energy produced over the system lifetime similarly discounted to the present time. The methodology used in this report is comprehensively reported in **ref. [3]** and **[4]**. Costs and benefits for each operational year are projected and then discounted back to the year of installation to obtain the "present value". The present value of the benefits is then compared to the present value of the costs. In order to carry out the economic calculation the following assumptions are made:

- r interest rate 7% p.a.
- N lifetime of the system in year
- t marginal tax bracket 0 % (no governmental subsidies)
- g savings escalator 0.10, i.e. 10% p.a.
- CI Initial capital of investment in NZ\$ are 12000 for GC-PV and 2500 for the thermal ETC
- OM+TI Operation, Maintenance + Insurance first year 0.2% of invested capital
Maintenance & Insurance increase at 5%/year

The total energy savings per year for the operation of the subject system in kWh/year and the average solar energy availability for different locations, as provided by NIWA, are summarised in **Table 2**.

Table 2: Average solar energy availability and forecasted energy production of a 1-kWp GC-PV and a 1.37m² ETC solar heater at different locations in New Zealand

| | Auckland | Wellington | Christchurch | Dunedin |
|---|----------|------------|--------------|---------|
| Total average solar radiation (kWh/m ² year) | 1575.33 | 1422.28 | 1357.56 | 1252.78 |
| Total energy Yield (kWh/year) | | | | |
| GC-PV | 1181.5 | 1066.7 | 1018.7 | 939.58 |
| ETC | 999 | 878 | 851.3 | 759.13 |
| Combined system GC-PV + ETC | 2180.5 | 1944.7 | 1870 | 1698.7 |

The economic viability of the system will be determined by the comparison of costs to benefits. In the following the Net Present Value of Lifetime System Cost PV_C and the Net Present Value of Lifetime System Benefit PV_B will be calculated and compared.

3.1. Net Present Value of Lifetime System Cost

System cost includes the initial investment capital (CI) needed to acquire and install the system plus Insurance (TI) and Operation & Maintenance (OM+TI) Cost. The present value of lifetime system cost, PV_C is given by:

$$PV_C = CI + \frac{(OM+TI) \times CI}{CRF}$$

CRF = Capital Recovery Factor

The Capital Recovery Factor (CRF) is used to discount future payments to the present and is expressed as:

$$CRF = \frac{r(1+r)^N}{(1+r)^N - 1}$$

3.2. Net Present Value of Lifetime System Benefit

By using a constant rate to represent long-term escalation, it is possible to obtain the present value of the lifetime benefits (PV_B) by multiplying the First Year Benefit X_0 by a single calculated parameter M_B , the benefits present value multiplier, which can be accounted using the following expression:

$$PV_B = M_B X_0, \quad M_B = \begin{cases} \frac{1+g}{r-g} \left[1 - \left(\frac{1+g}{1+r} \right)^N \right]; & r \neq g \\ N; & r = g \end{cases}$$

3.3. Payback time

Usually the payback time is computed as the time at which first cost and annual expenses with compounded interest equal the total savings of energy cost with compounded interest, **ref. [5]**. **Figure 3** shows the present value of the cost and benefit of the subject combined system at Christchurch showing the point of intersection where the costs equal the benefits for different system lifetime of 5 – 30 years. The relation describing the payback time of the proposed combined system for different energy prices at different locations in New Zealand is presented in **Figure 4**. The same relationship for the grid connected photovoltaic system without combination with the solar thermal unit is presented in **Figure 5** while **Figure 6** shows the relationship regarding the solar thermal unit without the GC-PV.

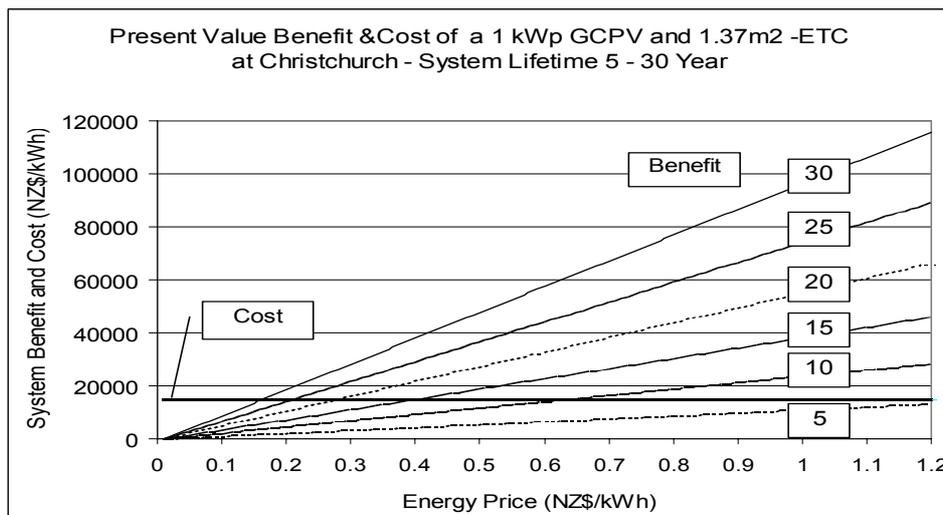


Figure 3. Present value of system benefit and cost vs. present energy price at Christchurch – System Lifetime 5-30 Year.

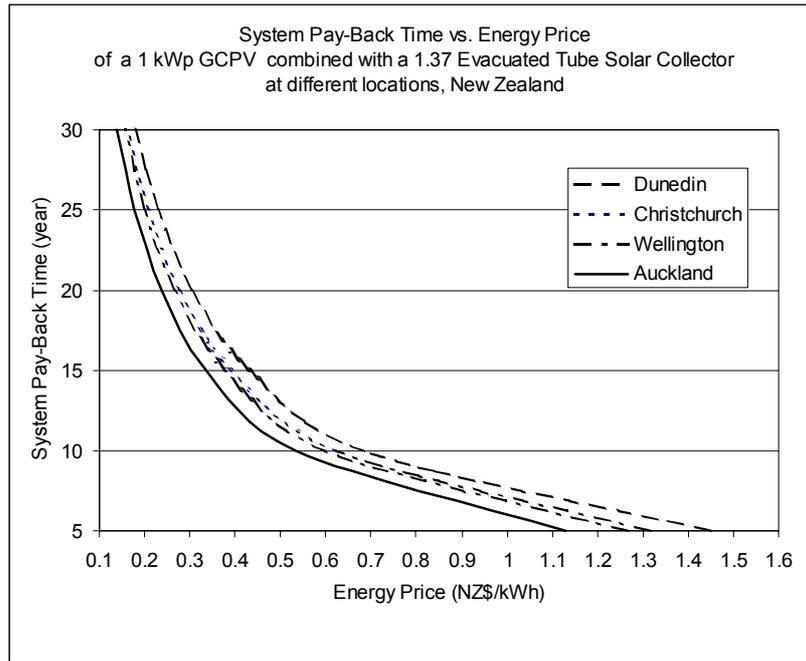


Fig. 4 Payback time of the combined system vs. present energy price.

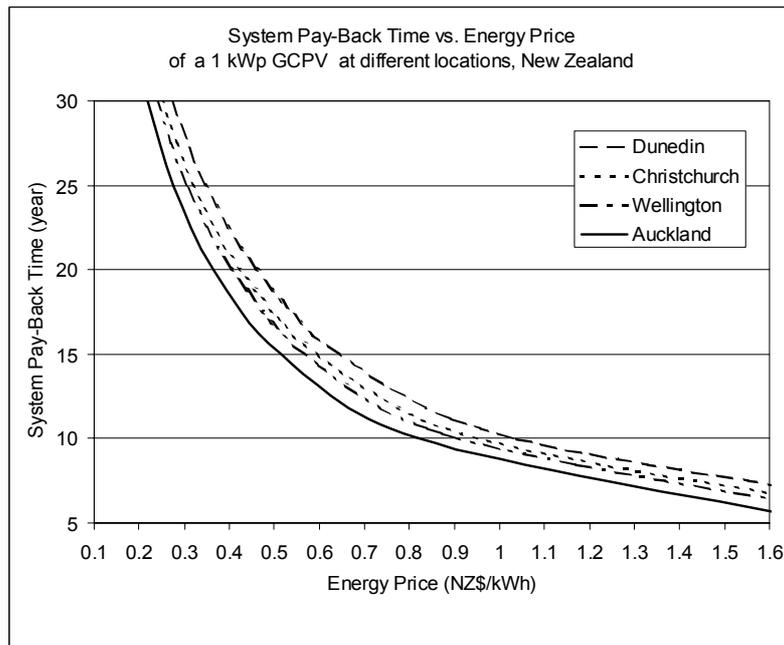


Fig. 5 Payback time of the 1 kWp GC-PV system vs. present energy price.

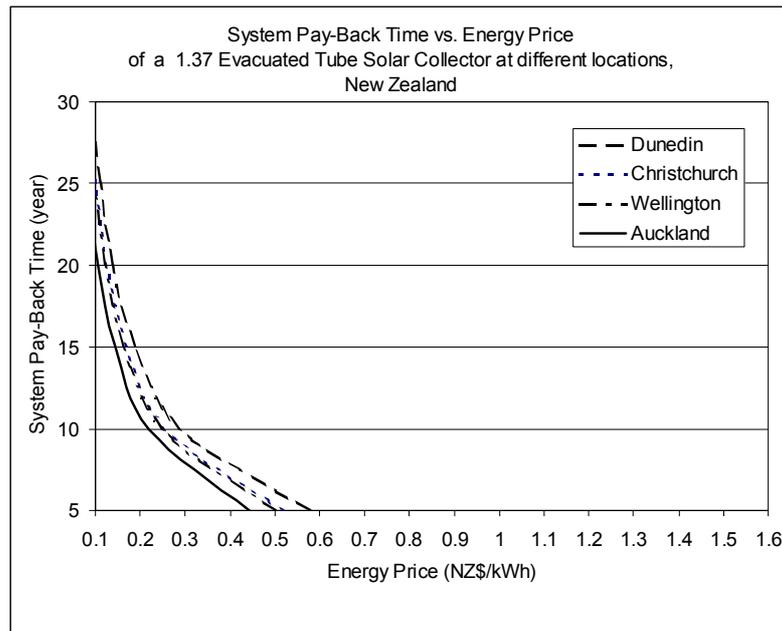


Fig. 6 Payback time of the Evacuated Tube Solar Collector vs. present energy price.

The calculations show that as expected the combination of the GC-PV system with a solar thermal unit improves the economics of the whole system and reduces the payback time. Solar favourable locations such as Auckland demonstrate shorter payback time and hence better economics for the technology.

Based on a current averaged price of 18c per kWh, the payback time for a combined system is approximately 25 years. If the price should rise beyond this, and there is no reason to suspect it will not do so, the payback time is a little as ten years (in Auckland) at an electricity price of 50c per kWh. If purely economic rationale is used there is little economic benefit, based on current costs, in this form of renewable energy supply. If a wider picture is taken and some of the intangible benefits, not discussed in this paper, are also considered, then in terms of social and environmental payback these systems may prove to be more attractive.

4. CONCLUSIONS

The analysis presented in this paper for a combined solar installation including GC-PV and solar thermal units at a typical domestic house has shown that such a system will present realisable benefits in each of the four main population centres in New Zealand compared to simple GC-PV systems operated separately.

With the current uncertainties surrounding future electricity pricing and the requirements for a move to an increased use of renewable energies, the time has never been more opportune for an increased uptake of such systems in New Zealand.

5. REFERENCES

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