



BUSINESS SCHOOL
ENERGY CENTRE

Energy Centre's Auckland solar power online tool documentation

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Background

Solar power has been rapidly growing in New Zealand with the total installed capacity increasing five-fold over the last three years (2014 - 2017). Most of the growth has taken place in the residential sector. Auckland Council has a goal of 970 MW installed capacity of solar photovoltaics by 2040. To assess this in number and size of solar installations we need to assess the solar energy potential on Auckland rooftops. In this study we have used LiDAR data to develop a digital surface model of the city, including topography, buildings and trees. With this model the ArcGIS solar radiation tool has been used to calculate the annual solar radiation on each square meter of roof area, taking into account latitude, time of year, time of day, average climatic conditions, surface orientation and slope, and shading from nearby buildings and trees. The results show a roughly 5% underestimation in comparison with NIWA's SolarView tool for north-facing unshaded surfaces and a roughly 10% underestimation for east- or west facing surfaces, which should be taken into account when planning a solar PV investment. This webtool can be used as an educational tool for a first approximation of solar potential on a rooftop, but the results should be considered case by case, as more complex rooftops may not be accurately represented at a one square meter resolution.

System options

The ArcGIS solar radiation calculations give the total annual solar radiation per square meter. To estimate an annual electricity output, we need to make assumptions on

- 1) The size of the PV system installed
- 2) Efficiency of the panels and system losses

In the **first dropdown menu**, the user has the option to choose between four system sizes:

- 1) 14 m², corresponding to a standard PV system of roughly 2 kW
- 2) 20 m², corresponding to a standard PV system of roughly 3 kW
- 3) 28 m², corresponding to a standard PV system of roughly 4 kW
- 4) 36 m², corresponding to a standard PV system of roughly 5 kW

The options for PV technologies and their specifications are derived from the National Renewable Energy Laboratory's (NREL) user manual for their PVWatts calculator [1]. A standard PV system refers to a poly- or mono-crystalline PV technology with a 14-17% panel efficiency. The solar radiation values given for different areas in the information panel for a selected roof give the average solar radiation of the square metres with the highest solar radiation on that rooftop. These square metres could all be in close proximity to each other on the roof, which is often the case on large simple-structured rooftops, or distributed on different sections of the roof, as can happen with roofs with complex structures including several sub-sections with different orientation. It is up to the user to visually inspect whether the PV system size they are assessing would indeed fit as one installation on one section of the roof, or if the panels would need to be installed in smaller groups in various sections of the roof.

In the **second dropdown menu**, the user has the option to choose a PV technology, with a given panel efficiency.

- 1) Standard PV (poly- or mono-crystalline PV technology), with an average efficiency: 15%,
- 2) Premium PV (high-efficiency mono-crystalline PV with anti-reflective coating), average efficiency: 19%,
- 3) Thin film PV, average efficiency: 10%

To each technology system losses of 12% are added, following the system losses specified in [1], with the elimination of losses from shading, which are accounted for in the solar radiation calculation. These losses include soiling, mismatch, wiring, connections, light-induced degradation, nameplate rating, availability and the inverter. Assuming 12% system losses is a general approximation, and the exact figure for a specific system will need to be adjusted according to individual system specifications and conditions.

The efficiency assumptions are summarized in table 1.

Table 1: PV technology options and corresponding efficiency assumptions.

Technology	Panel efficiency	System losses	Overall system efficiency
Standard PV	15% (14-17%)	12%	13.2%
Premium PV	19% (18-20%)	12%	16.7%
Thin films	10%	12%	8.8%

Additional losses not accounted for here include temperature related losses. Reference [1] quantifies these losses as 0.47% per °C above 25°C for standard PV, 0.35% / °C for premium PV and 0.20% / °C for thin films. Also, annual degradation of the panel will cause efficiency losses of roughly 1% per year. We have accounted for this in the calculation of annual output over the system lifetime in the economic assessment in the following section.

Economic assessment

Annual revenue

The total annual revenue (R_a) of the PV system is modelled as a sum of savings from not having to buy electricity from the retailer and revenue from exporting excess solar power to the grid. Default values of 27c/kWh and 8c/kWh are given for electricity rates when buying electricity from the grid and selling to the grid, respectively. The user can change these values to reflect the scenario they want to simulate. The rate of self-consumption, v_{sc} , gives the share of annual PV output that is directly consumed by the household. This is an important parameter and needs to be estimated by the user: compare your annual electricity consumption to the estimated generation of your selected PV system, and consider much of the PV output might you be able to consume directly. This percentage can be increased by installing e.g. a battery storage system – but then you will need to adjust the initial investment costs to reflect that, and potentially consider a replacement of battery after perhaps 10-15 years. Assuming that panel degradation over time causes an annual 1% drop in system efficiency gives the annual revenue:

$$R_a(n) = v_{sc} * E_{PV} * 0.99^n * p_r + (1 - v_{sc}) * E_{PV} * 0.99^n * p_{pb}$$

where

v_{sc} = share of self-consumption, specified as a percentage of PV system annual output that is consumed by the household (**USER INPUT** – no default),

E_{PV} = PV system annual output (in year n),

p_r = retailer's electricity price (what you are saving) (**USER INPUT** – default 27c/kWh), and

p_{pb} = retailer's pay-back rate (what you earn exporting) (**USER INPUT** – default 8c/kWh).

The Annual revenue in the webtool gives the annual revenue in the first year ($n=0$), after which the value will decrease due to panel degradation, as given by the equation above.

Net present value

Calculating a net present value (NPV) gives the total economic value of the PV system over its lifetime. The NPV is the sum of all annual revenues and all annual costs (assuming total investment costs in year 0 and a replacement of inverter in year 15) over an assumed lifetime of the project. Cost estimates are taken from recent research on the economics of solar power in New Zealand [2]. The equation is given as:

$$NPV = \sum_{n=1}^L \frac{R_a(n)}{(1+r)^n} - \left(I_{n=0} + \frac{I_{n=15}}{(1+r)^{15}} + \sum_{n=1}^L \frac{C_{o\&m}}{(1+r)^n} \right)$$

where

$I_{n=0}$ = Investment costs in year 0 (**USER INPUT** – default \$3000/kW),
 $I_{n=15}$ = Investment costs in year 15, replacement of inverter (**USER INPUT** – default \$400/kW),
 $C_{o\&m}$ = Annual operation and maintenance cost (**USER INPUT** - default assumption \$20/kW)
 r = discount rate / interest rate (**USER INPUT** – default 5%), and
 L = PV system life time in years (**USER INPUT** – default 25 years).

Note: The investment cost is assumed to be taken “from savings”. No financial cost for this is included here. Hence, when comparing this value to other investment options, the NPV should be compared to the NPV of investing the same amount elsewhere. If a loan is taken, the NPV of the total cost of the loan should be used as initial investment cost.

Things you should know

This model has been built mainly with open source software and resources received at no cost from external partners. There are a few caveats that come with this that you might want to know, to better understand where some of the flaws are coming from:

- 1) The software used for searching by address is an open source resource and unfortunately not always the most accurate one. An address search will generally take you to a point on the street in the proximity of the address, and you will then need to click on the building you are interested in to get the solar potential values in the information panel. Do check that the address at the top of the information panel – which appears once you have clicked on the building – is the address that you are looking for.
- 2) The building outlines are in some cases outdated, in which case the layer with the solar radiation data will show a different shape building than the underlying satellite imagery basemap. If you spot solar radiation results that clearly do not match the shape of the roof underneath, please use the “report issue” field to let us know. You do not need to give the address as it will be automatically recorded if you have clicked on that area. However, sometimes you will see that the outlines seem correct, but there seems to be a shift in the solar potential circles. This can be due to a mapping error between the file for building outlines and the basemap, but this effect is also common especially with tall buildings, where the aerial photograph is often not captured directly above the building, shifting the roof in relation to the ground level.

Where to next?

Other solar calculators include

- SEANZ Optimiser: www.solaroptimiser.nz
- EECA’s Solar Calculator: www.energywise.govt.nz/tools/solar-calculator/
- NIWA’s SolarView: <https://solarview.niwa.co.nz/>
- NREL’s PVWatts Calculator: <http://pvwatts.nrel.gov/>

If you are interested in going further in your investigation of solar PV feasibility on your roof, the next step could be contacting a knowledgeable designer installer through SEANZ (Sustainable Electricity Association New Zealand):

<http://www.seanz.org.nz/Resources/How-to>

References

- [1] Dobos, A.P., *PVWatts Version 5 Manual*, National Renewable Energy Laboratory (NREL), Technical Report, NREL/TP-6A20-62641, September 2014.
- [2] Miller, A., Hwang, M., Lemon, S., Read, E. G., Wood, Alan, *Economics of Photovoltaic Solar Power and Uptake in New Zealand*, EEA Conference & Exhibition 2015, 24-26 June, Wellington.