Energy Centre's Solar Power Web-based Map- 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 three 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) 35 m2, corresponding to a standard PV system of roughly 5 kW
5) 50 m2, corresponding to a standard PV system of roughly 7 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

The total annual revenue (I_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. Assuming panel degradation over time causes an annual 1% drop in system efficiency gives the annual revenue:

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

where
v_{sc} = share of self-consumption (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 27), and
p_{pb} = retailer's pay-back rate (what you earn exporting) (USER INPUT – default 8c).

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 amortization) over an assumed lifetime of the project. The equation is given as (or is it?? Equation to be checked!):

$$NPV = \sum_{n=1}^{L} \frac{I_a(n)}{(1+r)^n} - P * \frac{r\,(1+r)^n}{(1+r)^n - 1}$$

where
P = Total investment costs (USER INPUT – default $3000/kW),
r = discount rate / interest rate (USER INPUT – default 4%, 6%?), and
L = PV system life time (USER INPUT – default 20 years).

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 errors 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 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 no 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 of that area.

Where to next?

Other solar calculators include

- SEANZ Optimiser: www.solaroptimiser.nz
- EECA’s Solar Calculator: www.energywise.govt.nz/tools/solar-calculator/
- 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 SEANZ (Sustainable Electricity Association New Zealand) designer installer:

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.