Introduction to solar energy

Energy Centre summer school in Energy Economics
22-26 February 2016

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Outline

The resource

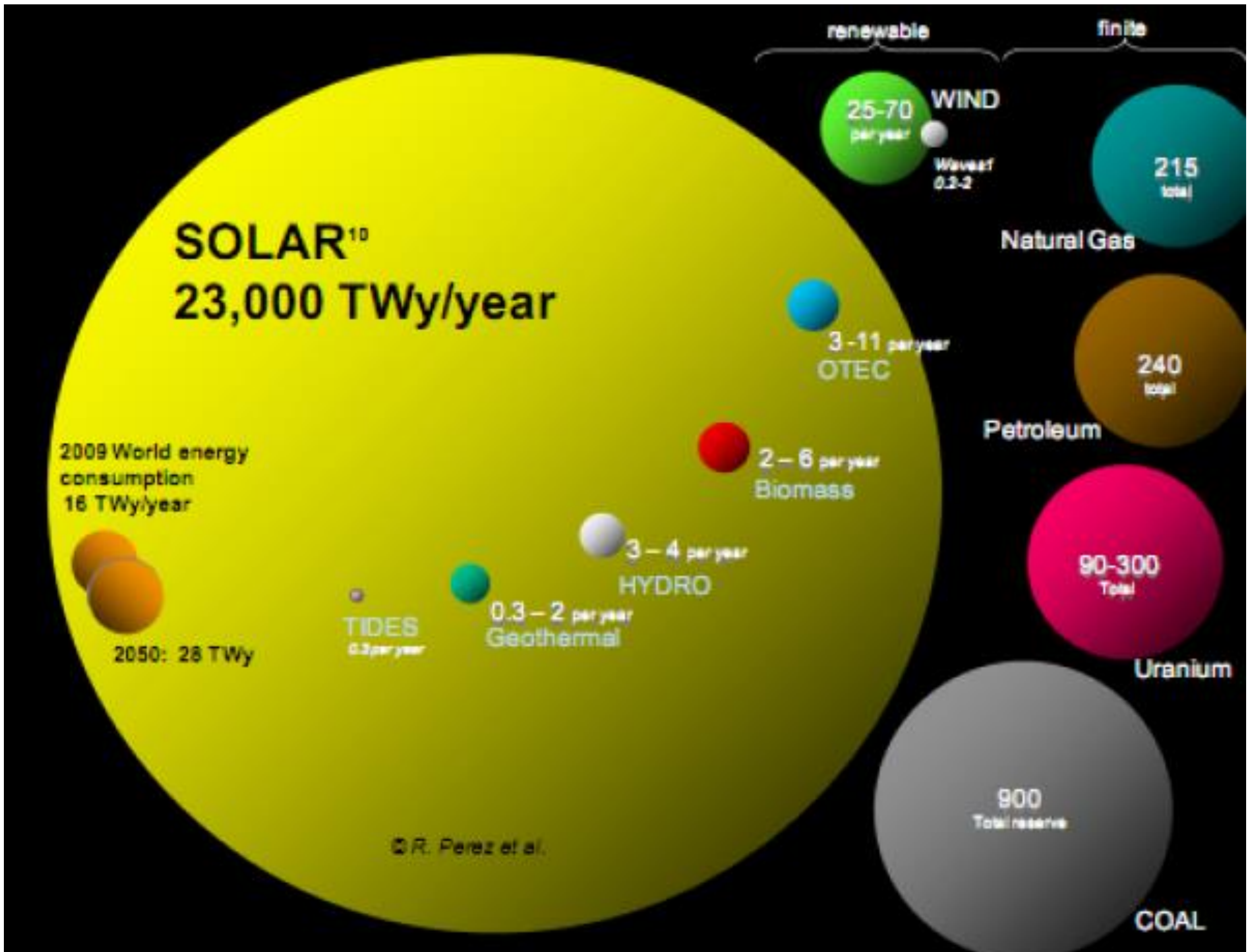
The technologies

Solar energy in the world

Solar energy in New Zealand

Research at the Energy Centre

The resource



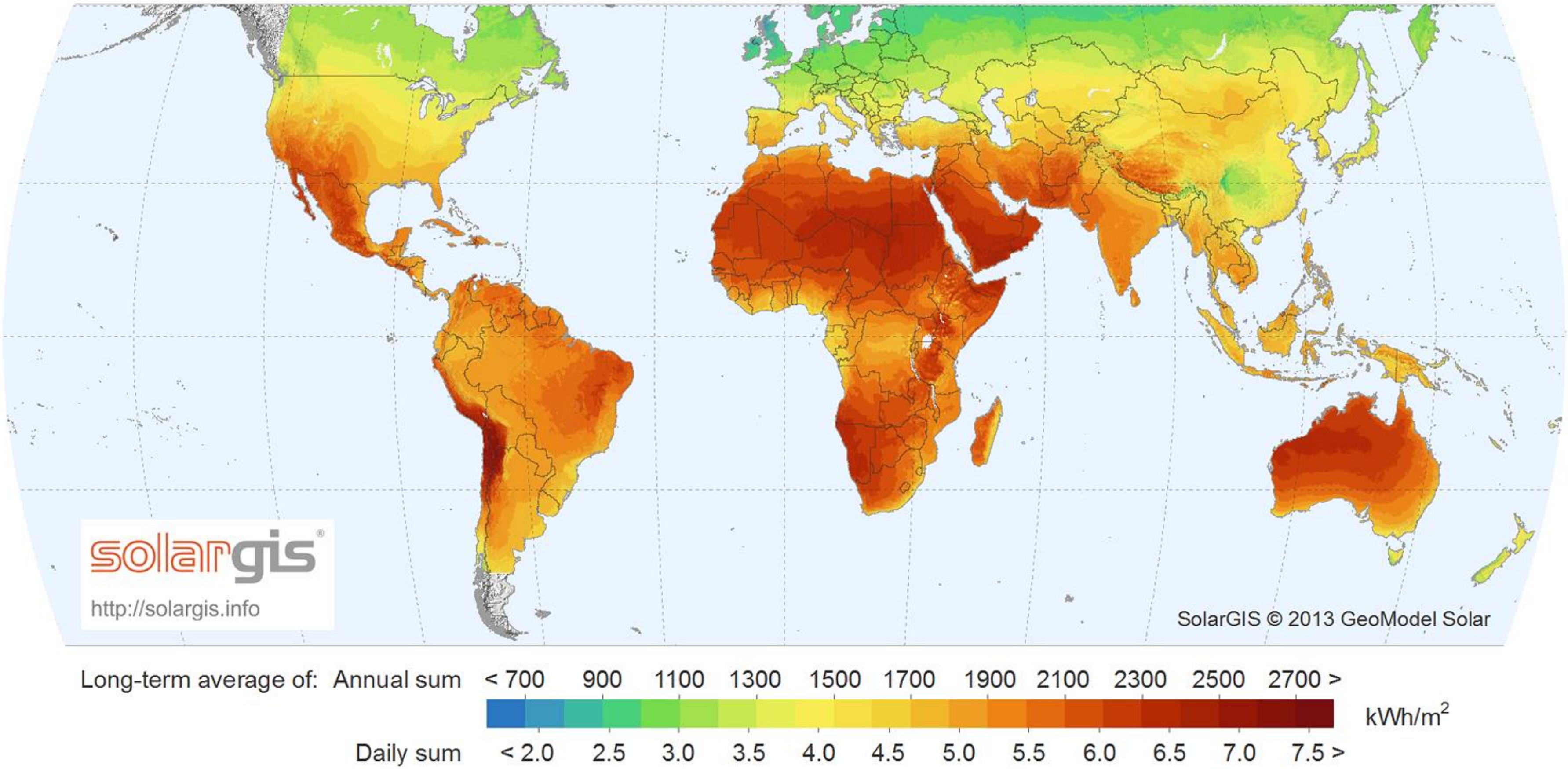
The figure compares the 2009 and expected 2050 annual energy consumption of the world to

(1) the known reserves of the finite fossil and nuclear resources and

(2) the yearly potential of the renewable alternatives.

The volume of each sphere represents the total amount of energy recoverable from the finite reserves and the energy recoverable per year from renewable sources.

The resource



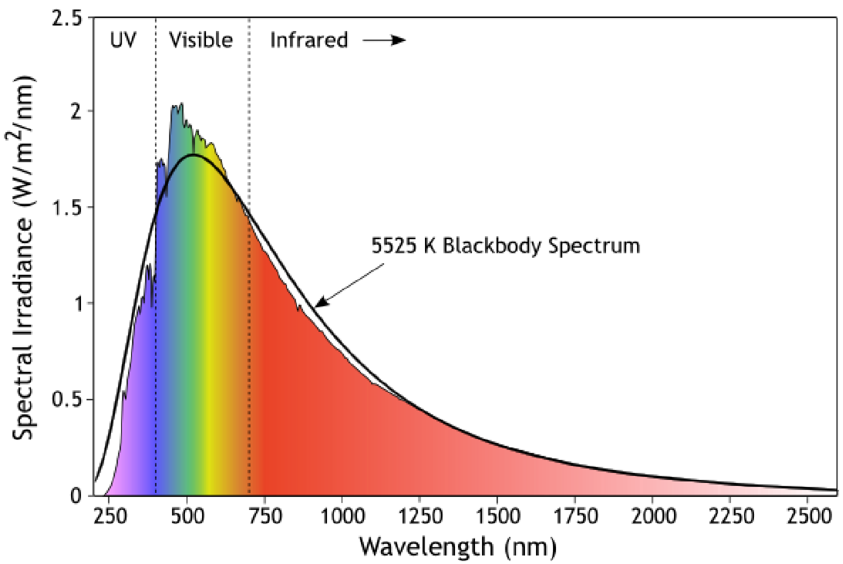
The resource

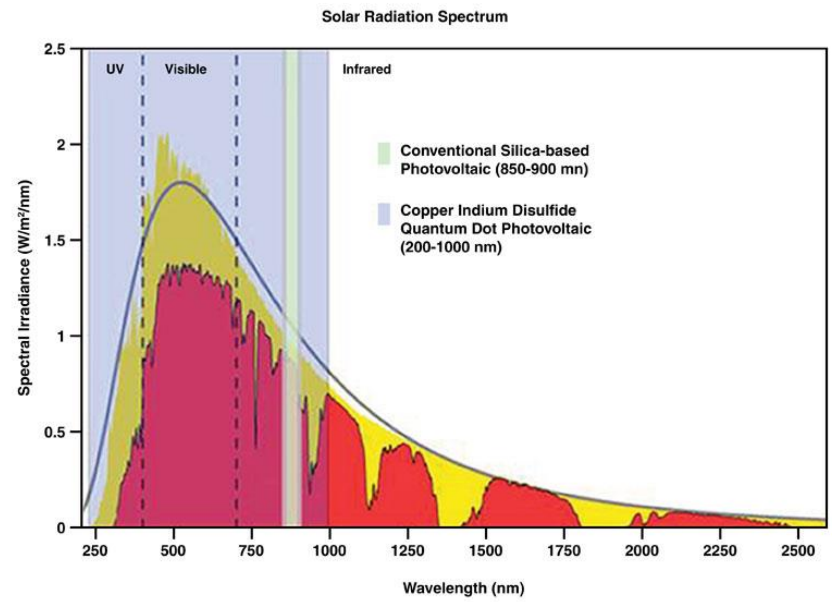
The solar spectrum is similar to that of a black body with temperature about 5778K.

- 52-55% infrared
- 42-43% visible
- 3-5% UV

- 1361 W/m2 at the top of the atmosphere, direct radiation

- Absorption bands mainly from ozone, oxygen, water vapour, carbon dioxide



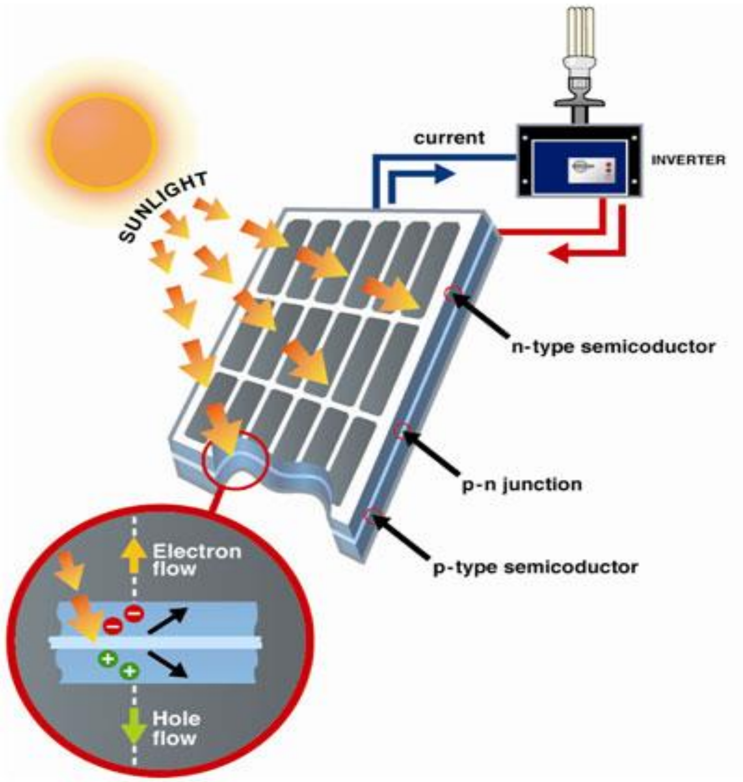


Two basic ways to capture solar energy

- Heat – through absorption by gaseous, liquid or solid materials
  - sanitary water heating,
  - evaporating water and drying things (notably crops and food),
  - space heating (a major driver of energy consumption),
  - mechanical work or electricity, (**solar thermal electricity – STE**).

- Photoreaction
  - Photosynthesis
  - Conduction of electrons in semiconductors – conversion of sunlight into electricity (**PV**)

Solar PV (photovoltaic)

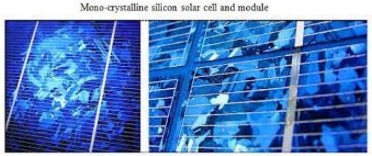


Source www.geoliving.co.uk

When the sunlight or any other light is incident upon a material surface, the electrons present in the valence band absorb energy and, being excited, jump to the conduction band and become free.

PV technologies


Mono-crystalline silicon solar cell and module


Polycrystalline silicon solar cell and module

Crystalline Silicon PV (c-Si)

Most widely used and developed in the world:

92% of global production in 2015

Efficiency: 12-18%.

Thin films (a-Si, CdTe, CIS)

8% of global production in 2015

Costs less in energy and material than c-Si (above)

Efficiency: 5-11%

Concentrating solar PV / advanced thin films

Still under development!

Aim: high efficiency using materials that are non-toxic and abundant

Efficiency: 20-60%

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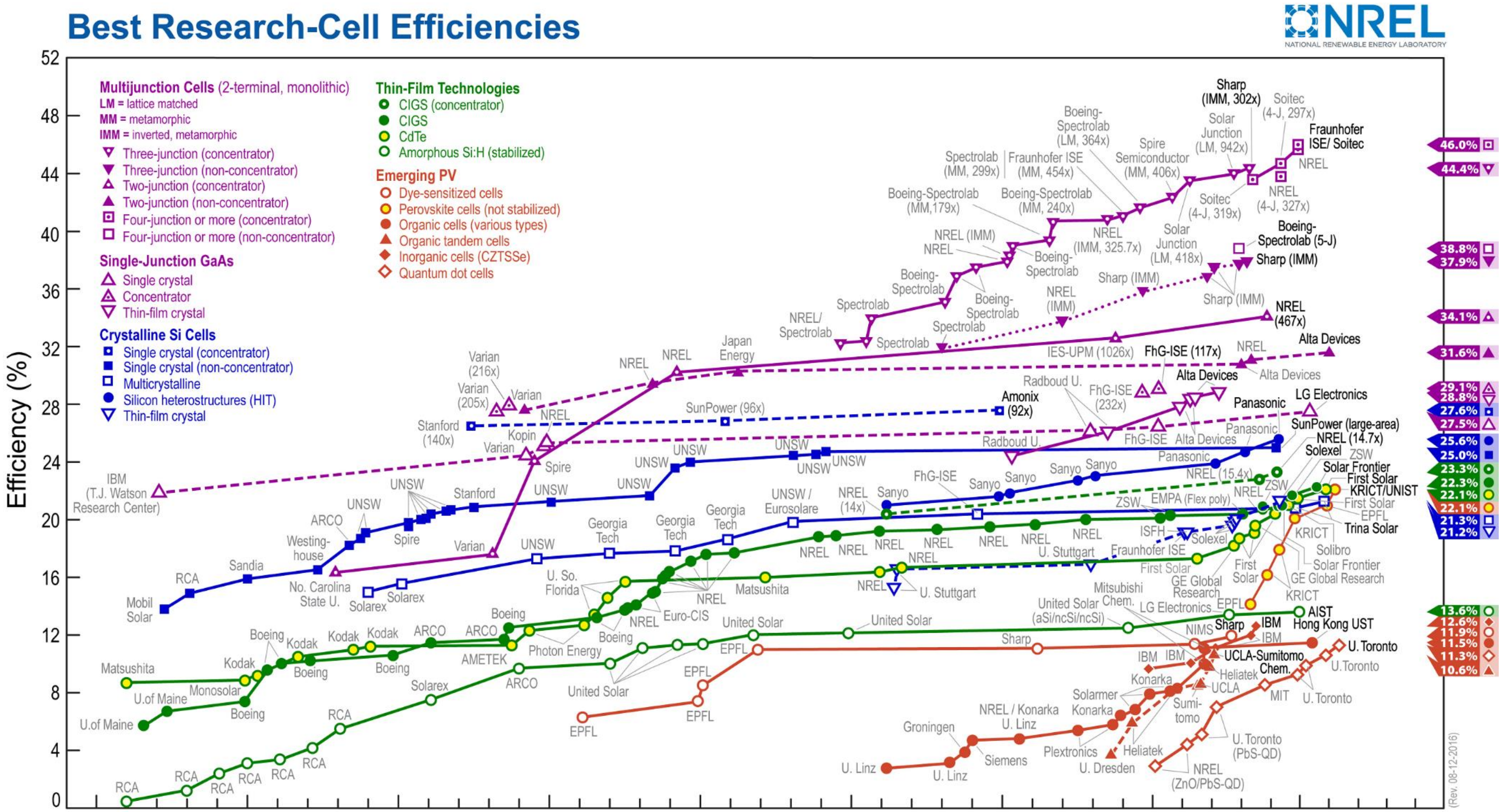
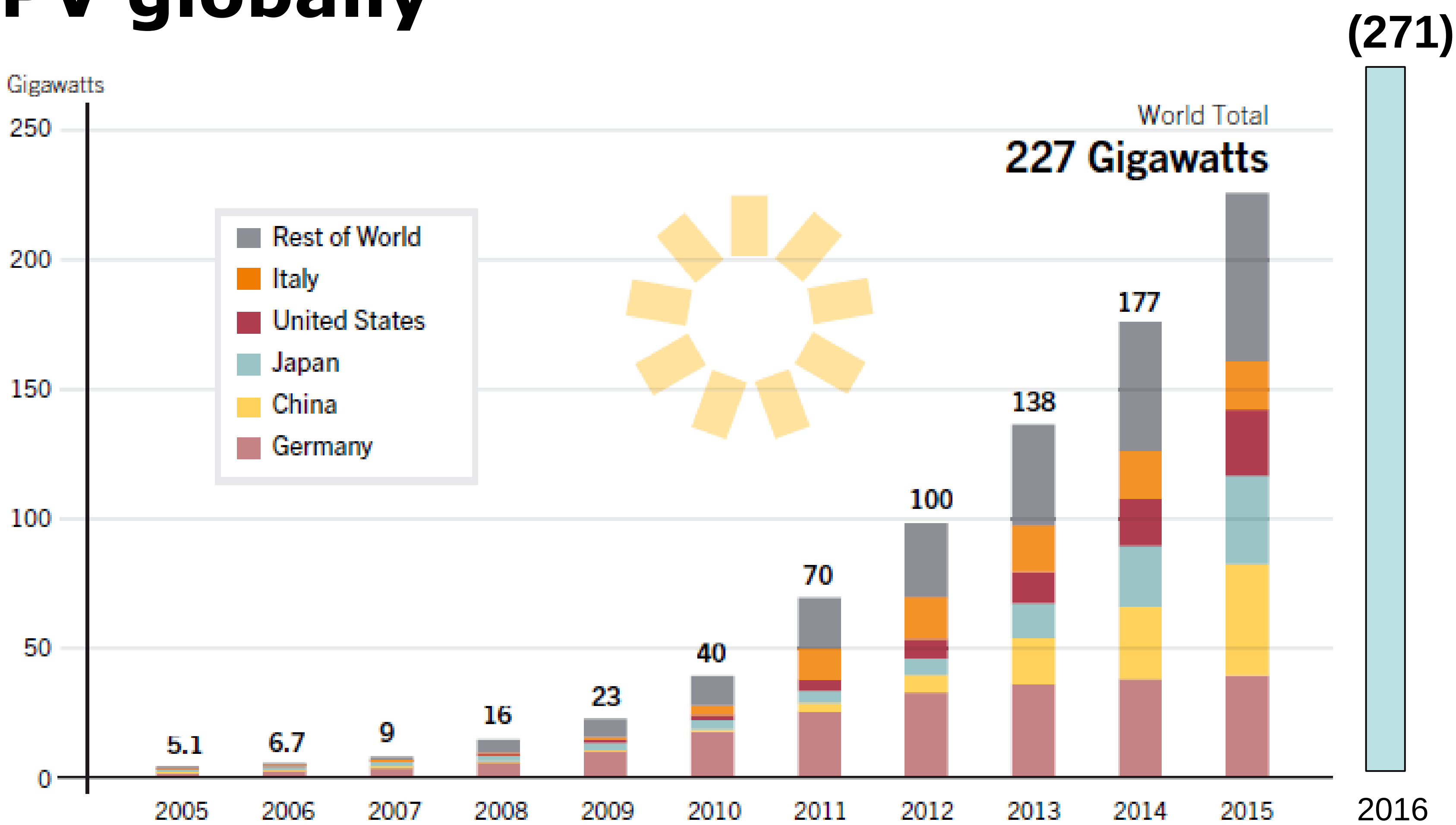
Best Research-Cell Efficiencies

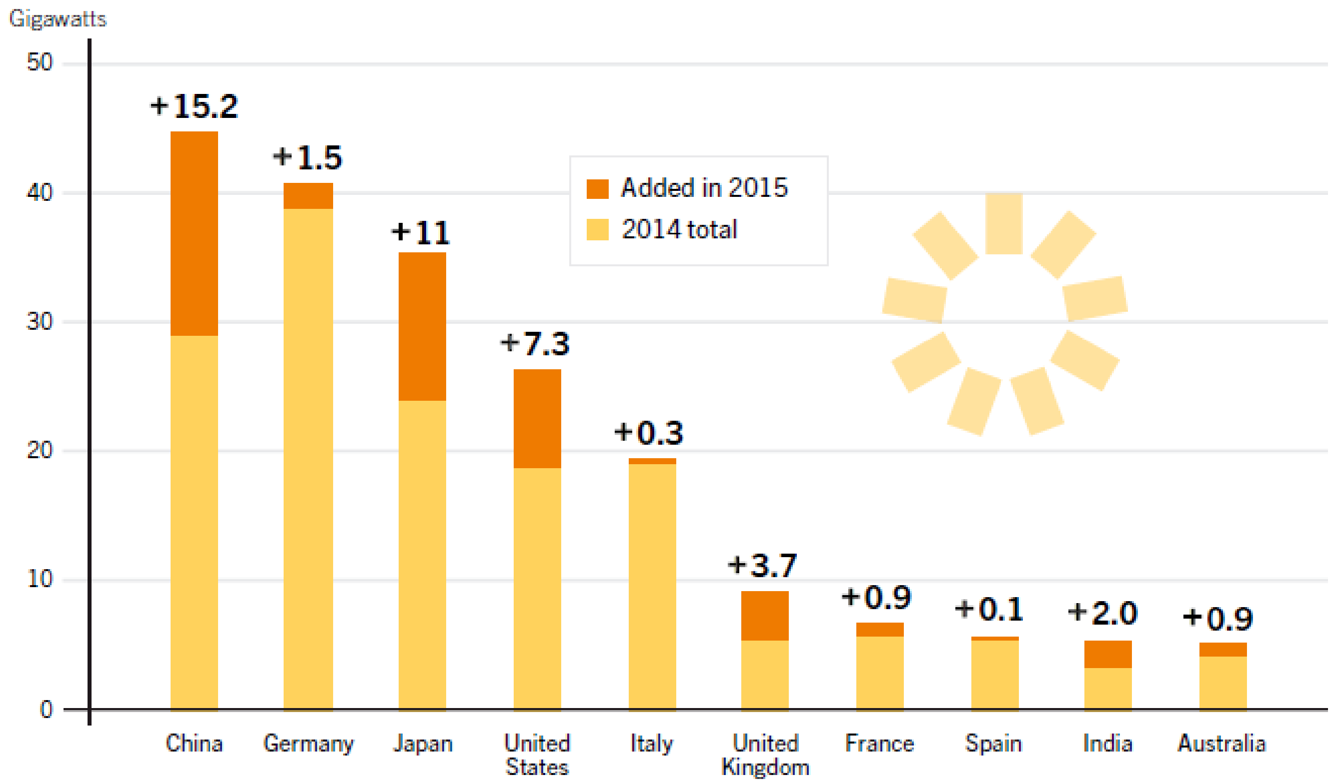


PV globally



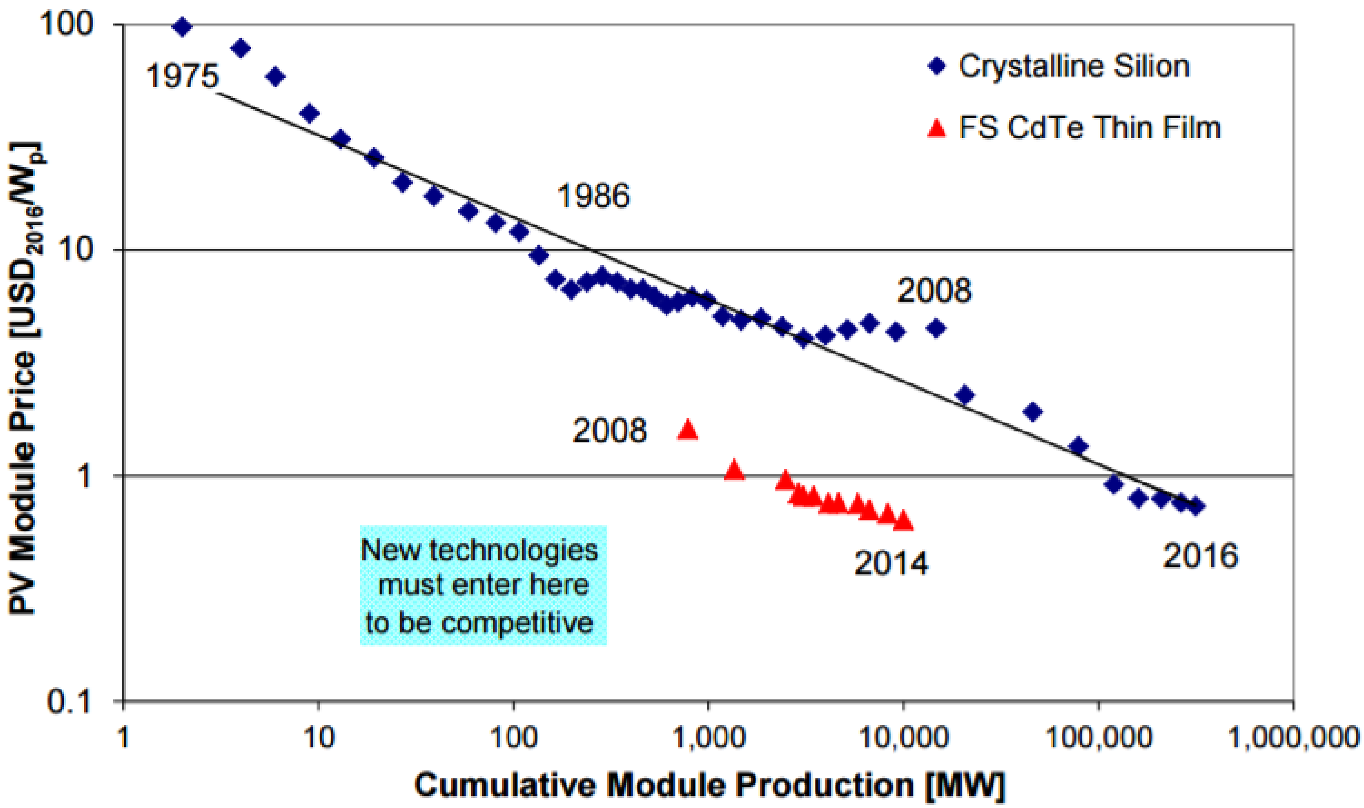
Source: REN21, 2016. *Renewables 2016 Global status report*

PV by country



Source: REN21, 2016. *Renewables 2016 Global status report*

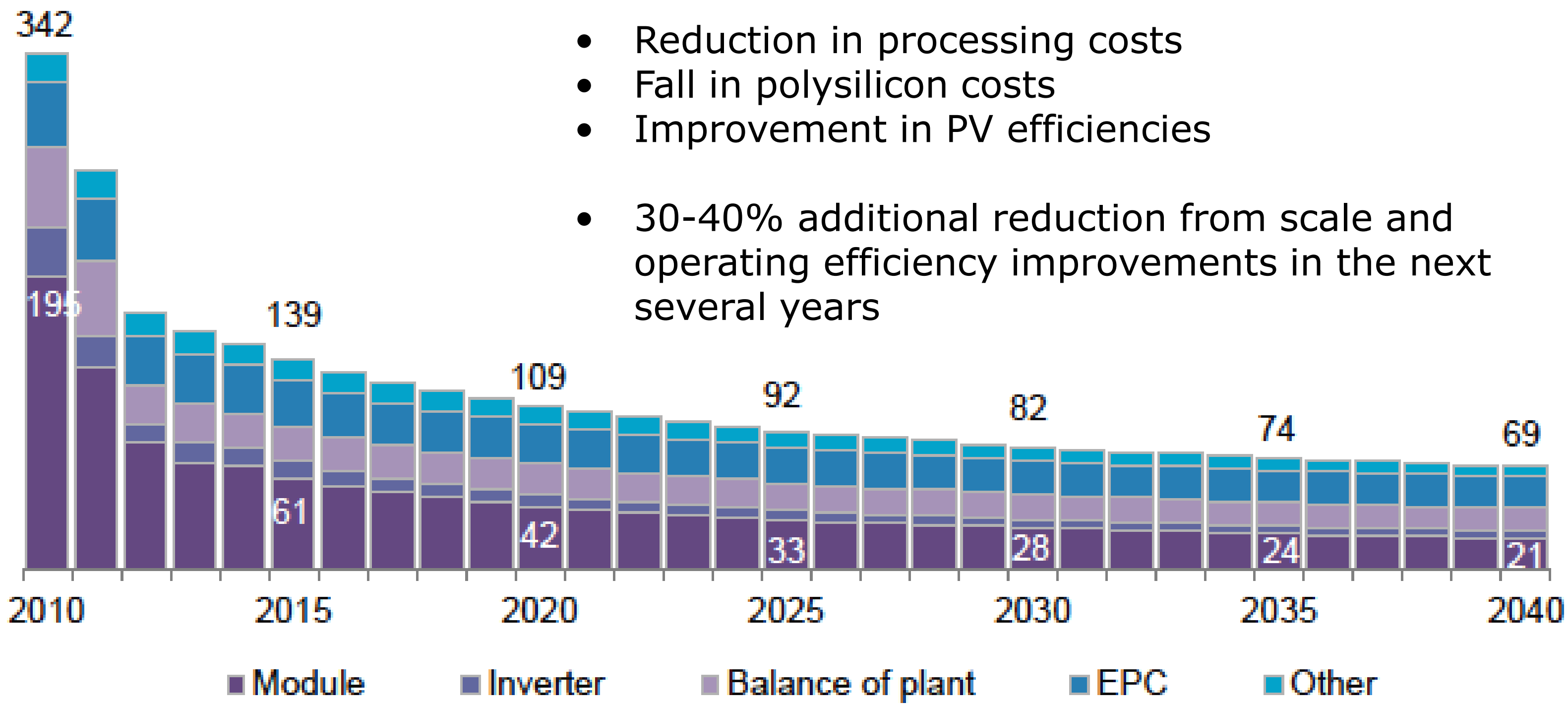
PV price-experience curve



Source: JRC, 2016. *PV status report*

Costs - PV

Figure 4: Forecast fixed-axis utility PV capex, 2010-40 (2014 US cents/W, central scenario)



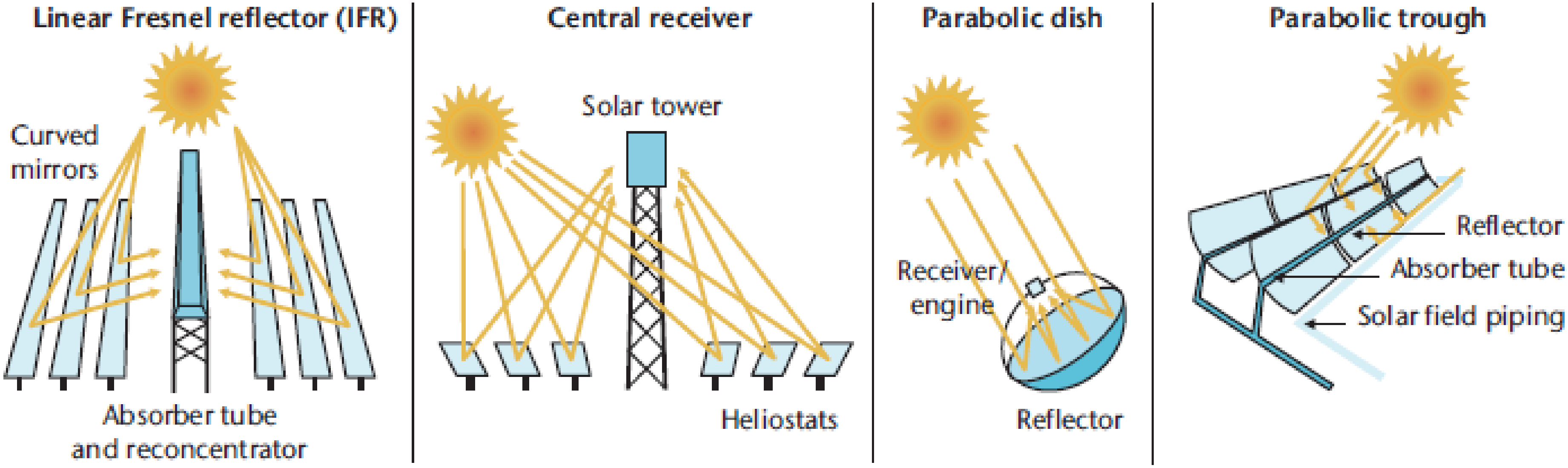
- Reduction in processing costs
- Fall in polysilicon costs
- Improvement in PV efficiencies

- 30-40% additional reduction from scale and operating efficiency improvements in the next several years

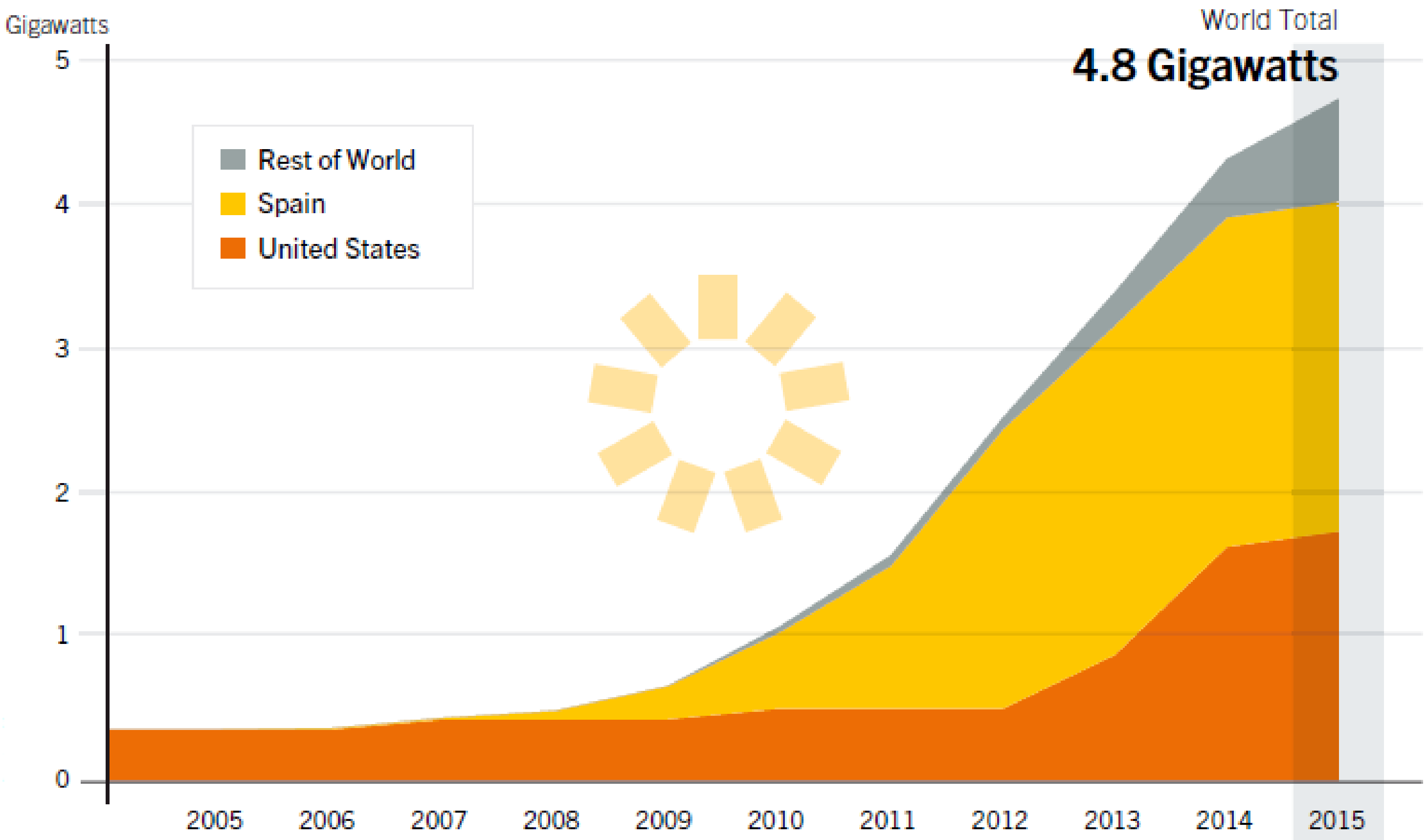
Source: Bloomberg New Energy Finance

Concentrating solar power (or solar thermal electricity)

- Generating solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area.
- Electricity is generated when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator.



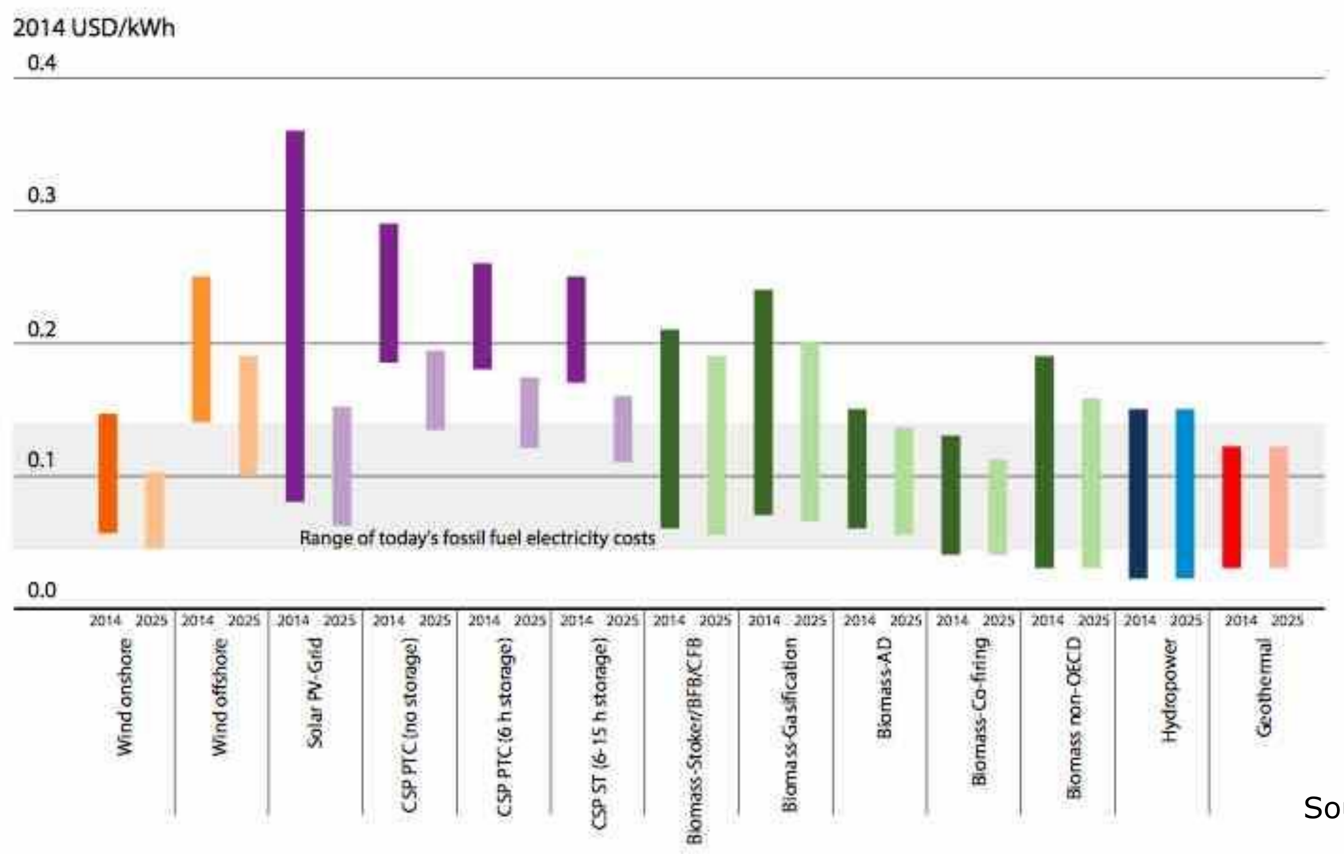
Solar thermal electricity globally



Source: REN21, 2016. *Renewables 2016 Global status report*

Energy cost projections for renewables

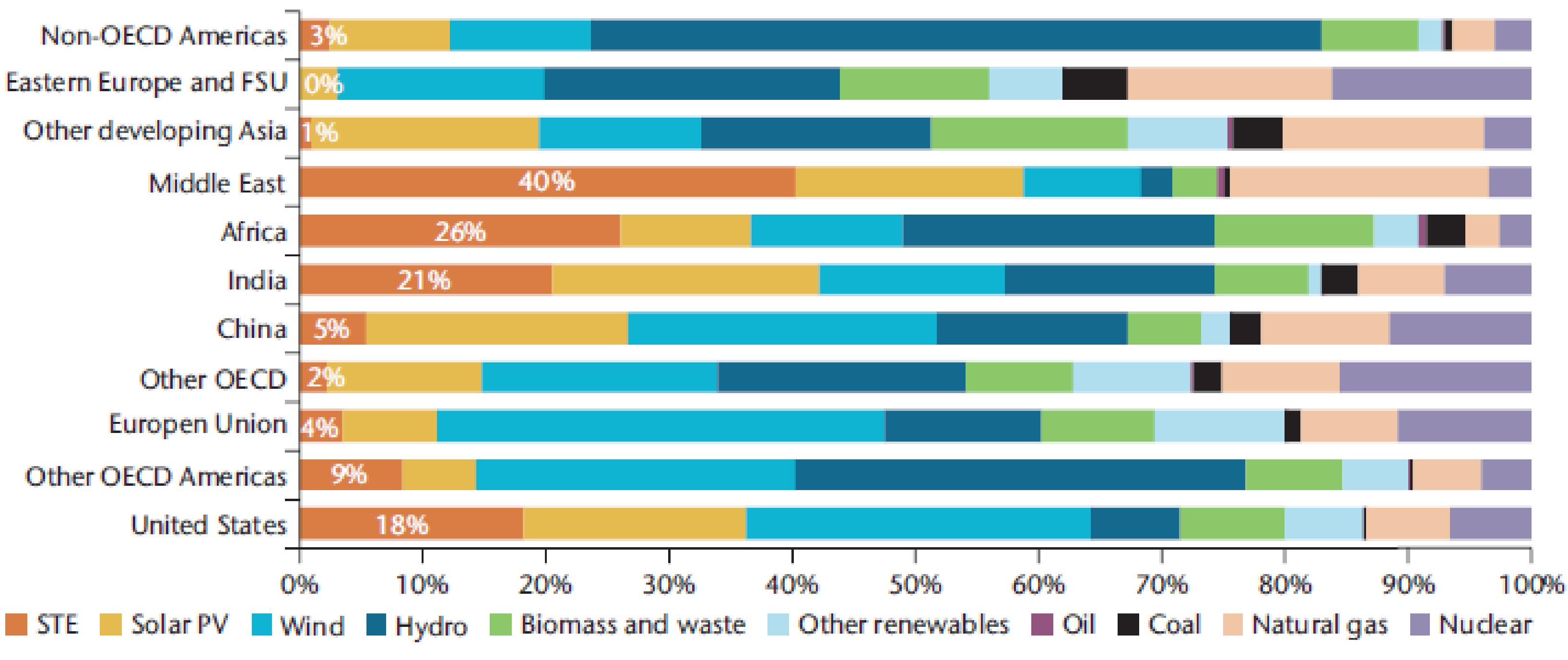
FIGURE 10.1: LCOE RANGES BY RENEWABLE POWER GENERATION TECHNOLOGY, 2014 AND 2025



Source: IRENA 2014

PV and STE in the future (high renewables scenario)

Figure 11: Generation mix by 2050 in the hi-Ren Scenario, by region



KEY POINT: In the hi-Ren Scenario, STE is the largest source of electricity in Africa and the Middle East by 2050.

Solar power
Keep it in the ground

Morocco to switch on first phase of world's largest solar plant

Desert complex will provide electricity for more than 1 million people when complete, helping African country to supply most of its energy from renewables by 2030

Arthur Neslen

Thursday 4 February 2016 11.47 GMT

Phase one of Morocco's vast $9bn Ouarzazate solar power plant provides 160MW of its ultimate 580MW capacity. Photograph: Graeme Robertson for the Guardian

WEATHER | NEWS 30 NOVEMBER 2016

India unveils the world's largest solar power plant

The country is on schedule to be the world's third biggest solar market next year.

Images have been released showing the sheer size of a new solar power plant in southern India.

The facility in Kamuthi, Tamil Nadu, has a capacity of 648 MW and covers an area of 10 sq km.

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Duarzazate solar power plant provides 160MW of its ultimate 580MW
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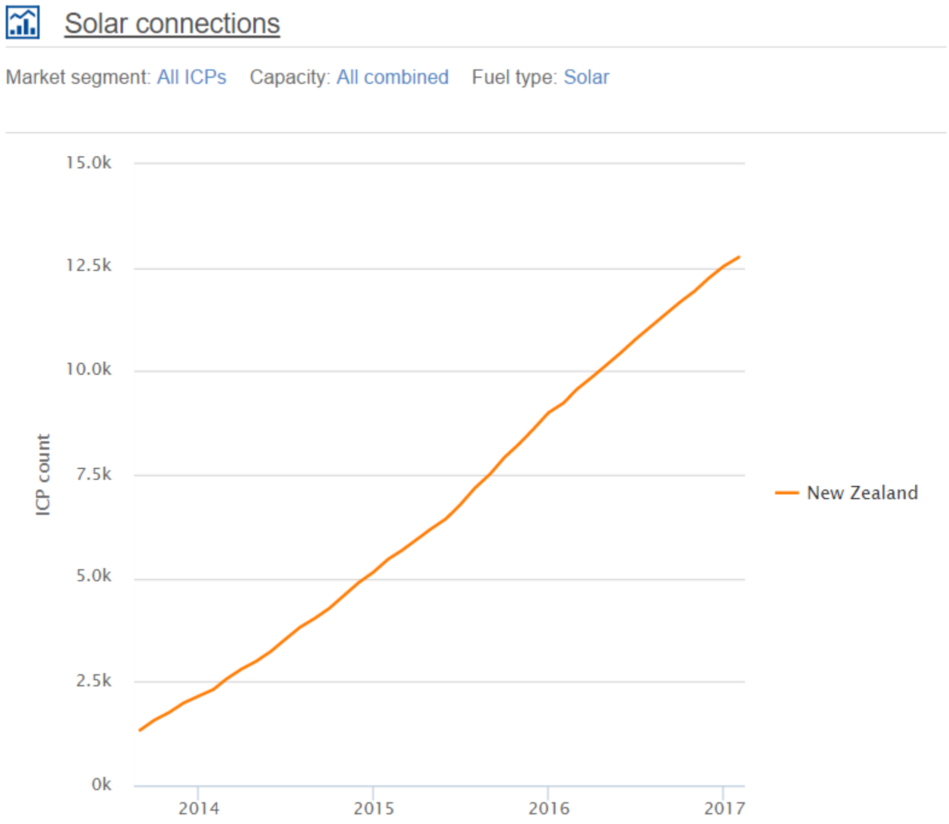
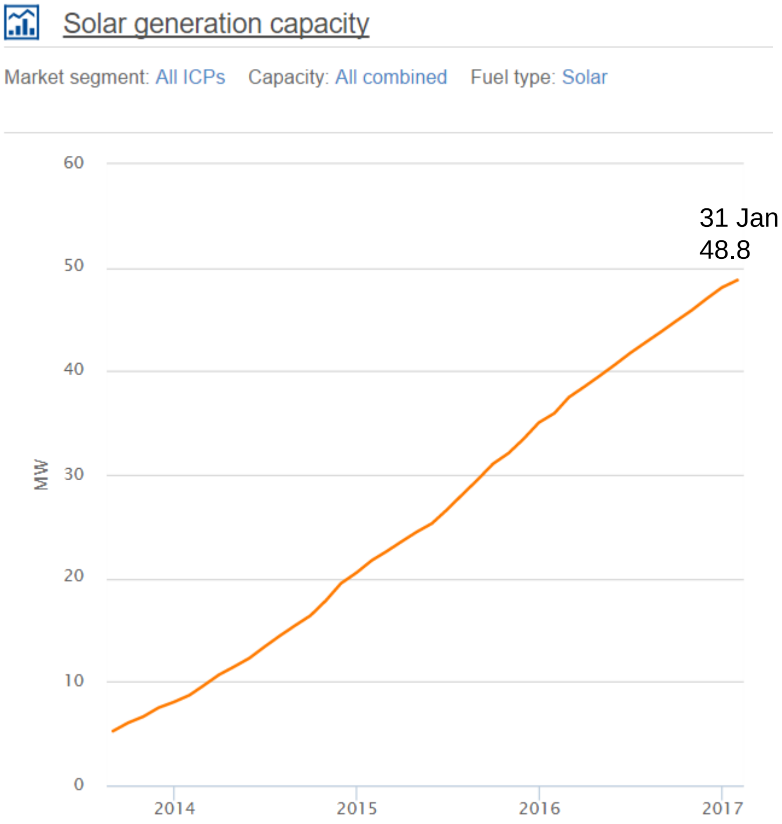
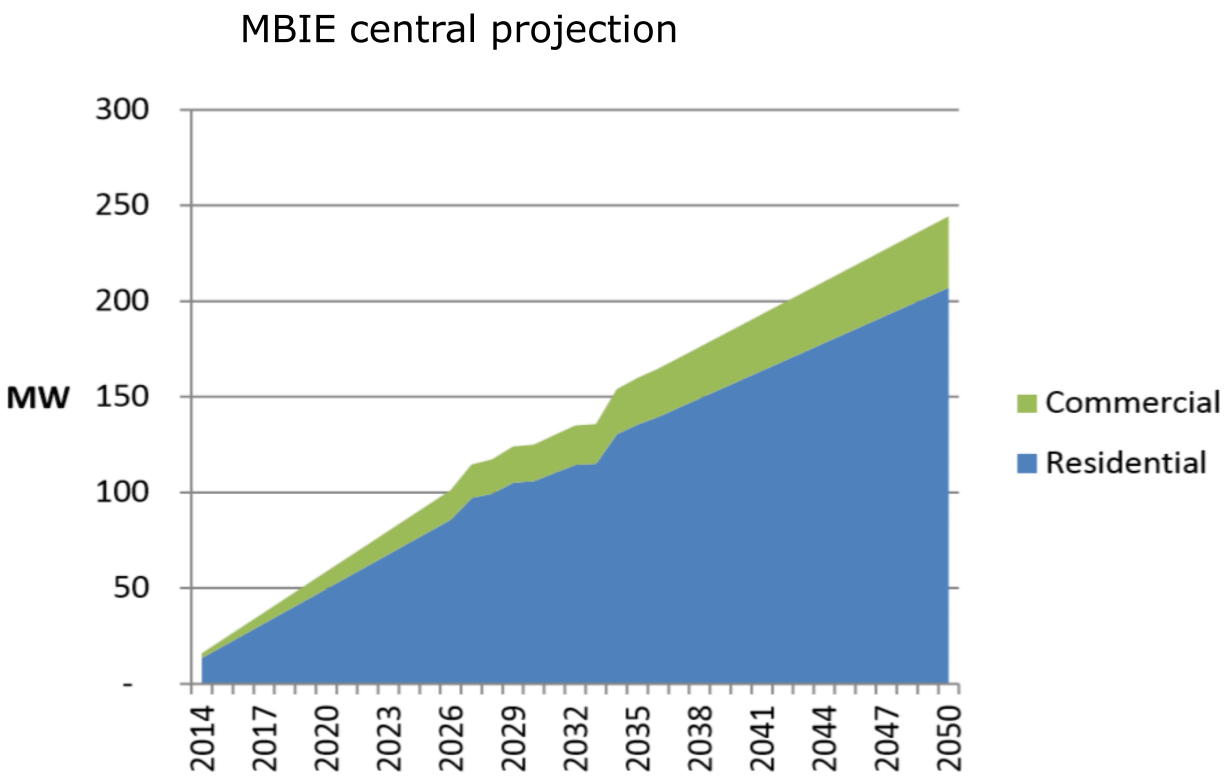
Solar power in New Zealand





MBIE projection for solar power



Solar research at the Energy Centre

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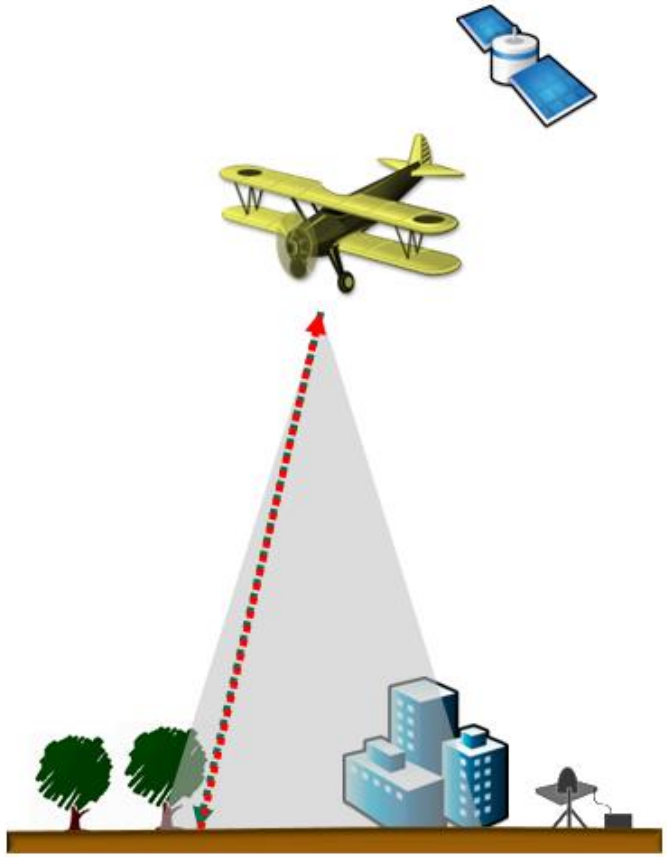
Solar potential in Auckland rooftops using LiDAR data



Lidar (light detection and ranging) is an optical **remote-sensing technique that uses laser light to densely sample the surface of the earth**, producing highly accurate x,y,z measurements.

Laser pulses emitted from a lidar system reflect from objects both on and above the ground surface: vegetation, buildings, bridges, and so on.

One emitted laser pulse can return to the lidar sensor as one or many returns (reflect from multiple surfaces).

The first returned laser pulse is the most significant return and will be associated with the highest feature in the landscape like a treetop or the top of a building. The first return can also represent the ground, in which case only one return will be detected by the lidar system.

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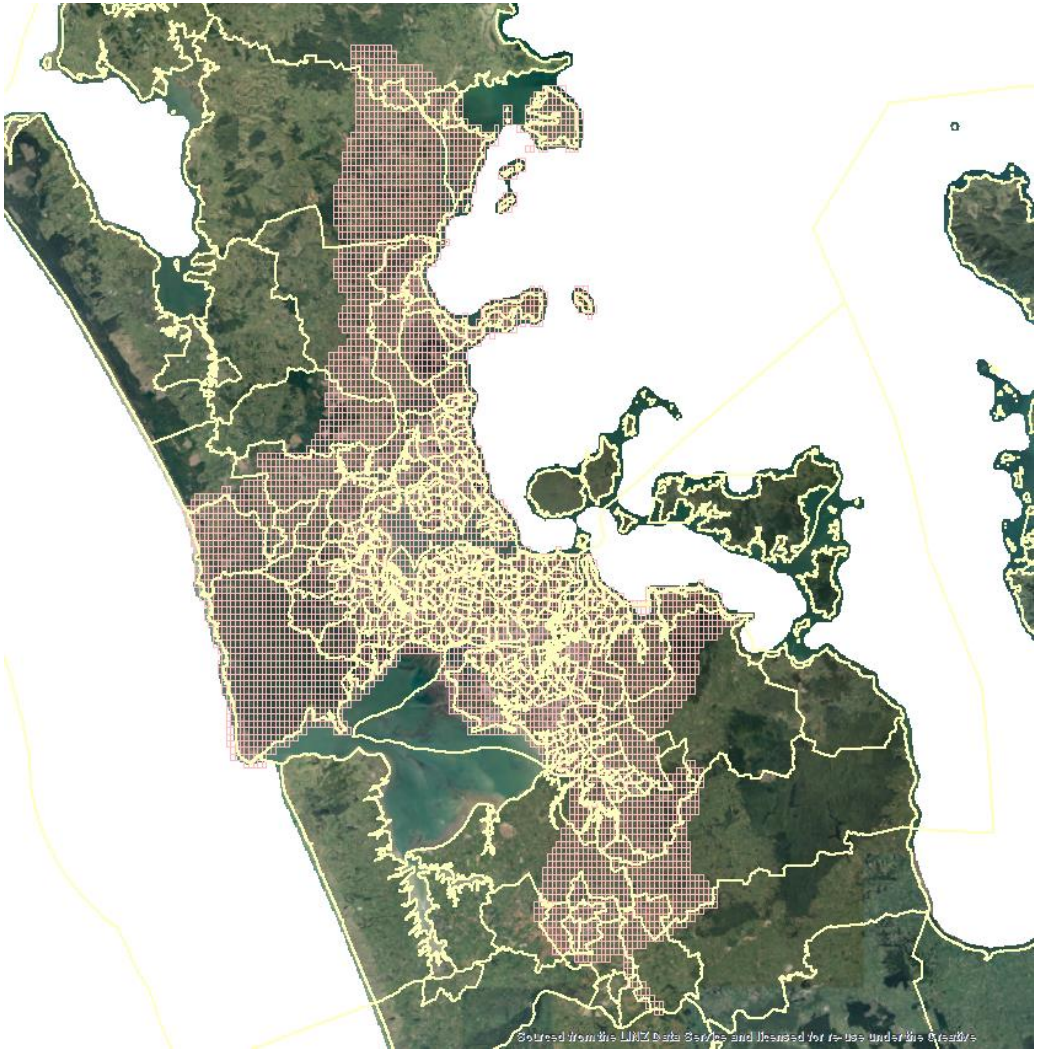
Data

Collected by NZ Aerial Mapping and Aerial Surveys Limited for Auckland Council in 2013/2014.

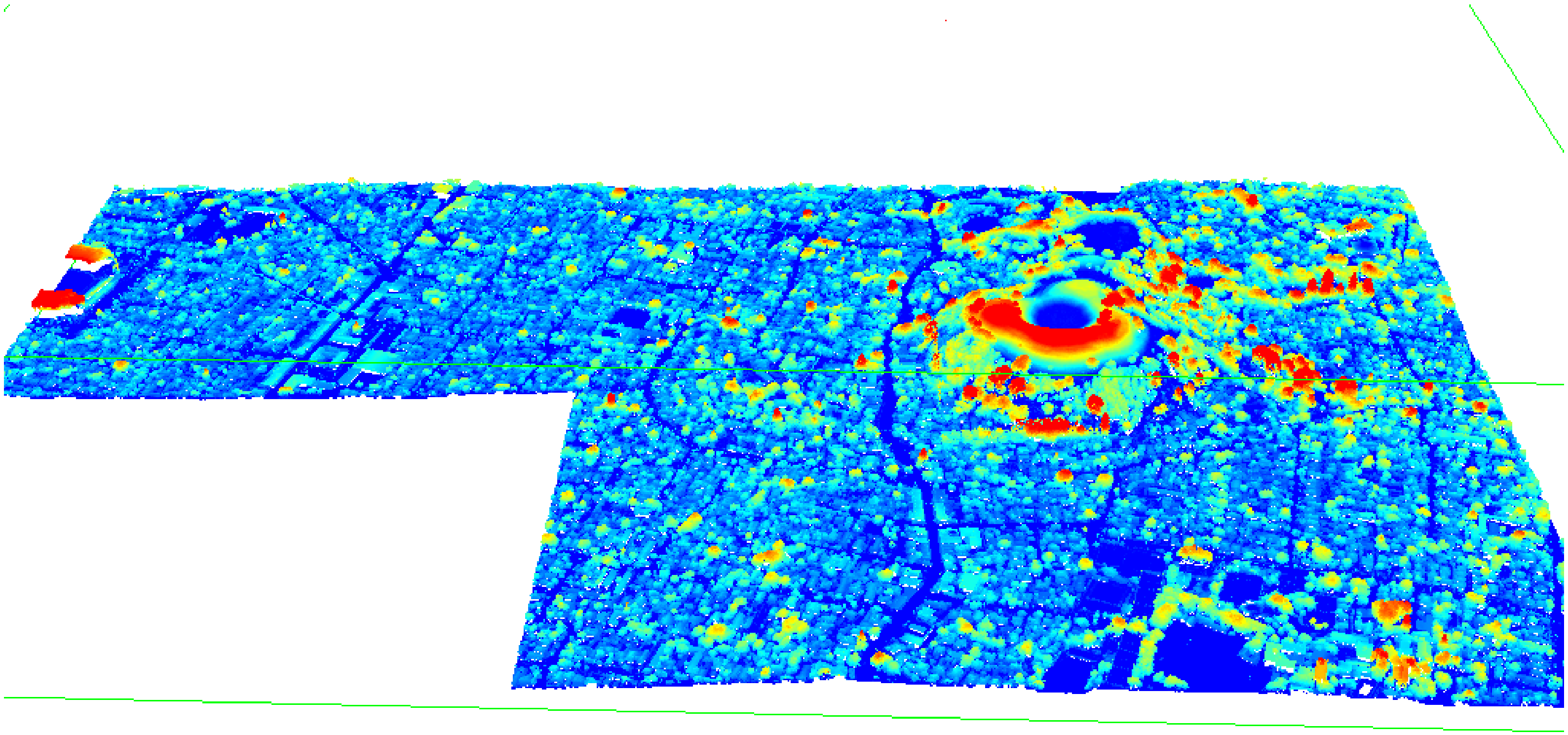
Flight info:
Altitude 900m, 1600m, 1000m
Scan frequency 36Hz, 45Hz, 42.9Hz

Average point spacing: minimum 1.5 points per m2

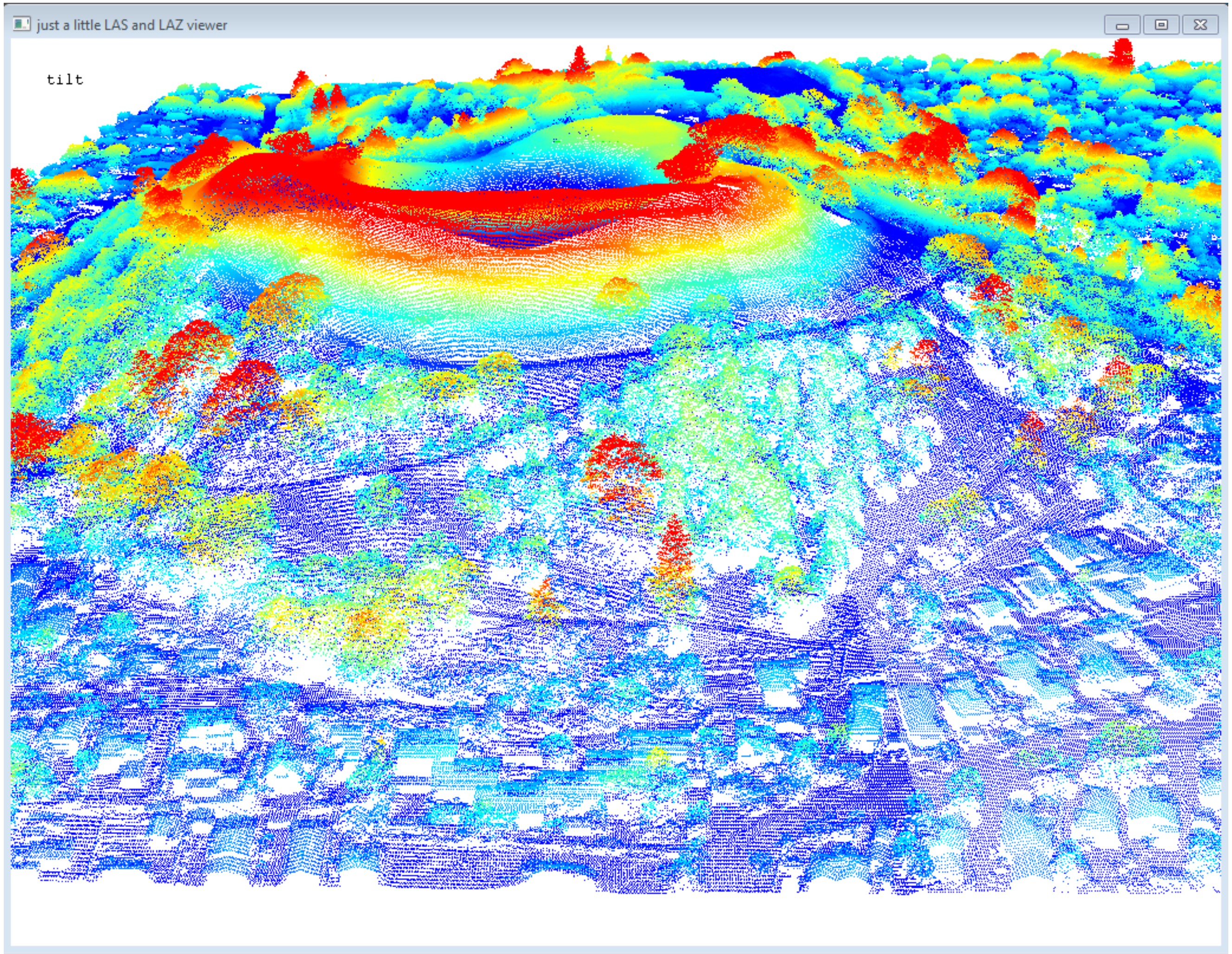
Vertical accuracy: +/-0.1m



LiDAR data example



LiDAR data example: Mt Eden



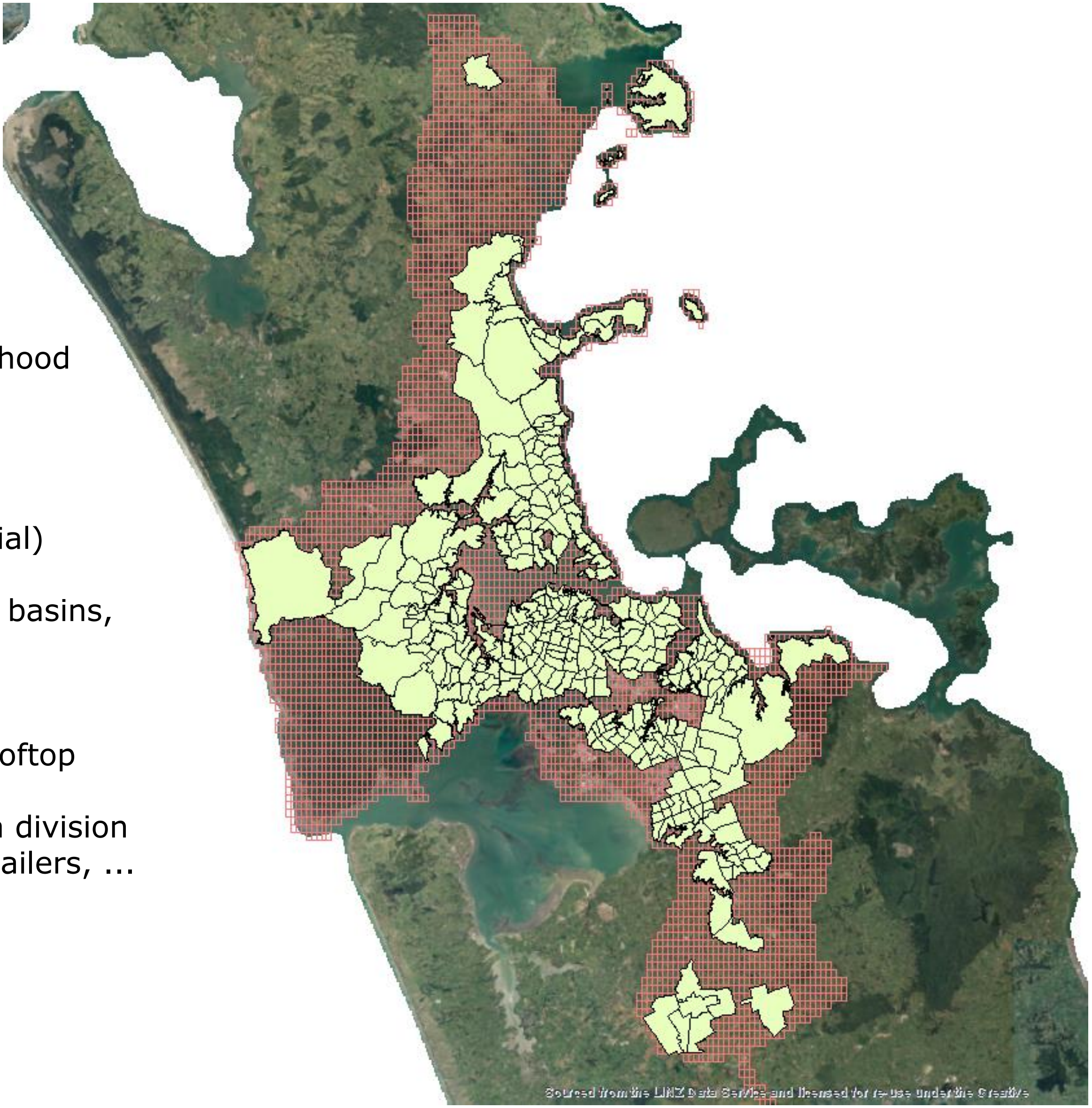
Approach

Divide data into subsets for
- Data management
- Comparison of results per neighbourhood

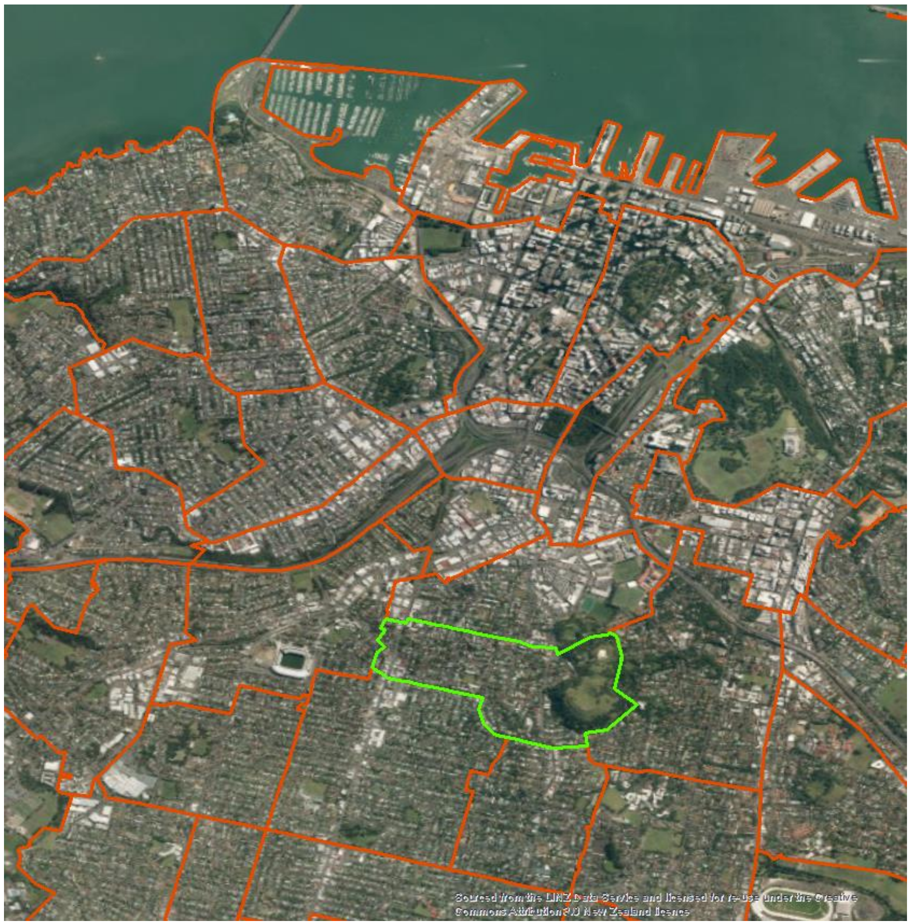
Use census 2006 area divisions
- Eliminated
  - Only partial lidar coverage
  - Large areas with few (residential) houses
  - Areas with no buildings (water basins, marinas etc)
- 334 area divisions

Calculate solar potential metrics per rooftop

Calculate comparative metrics per area division
  - Relevant for policy makers, retailers, ...



Results: Sherbourne neighbourhood



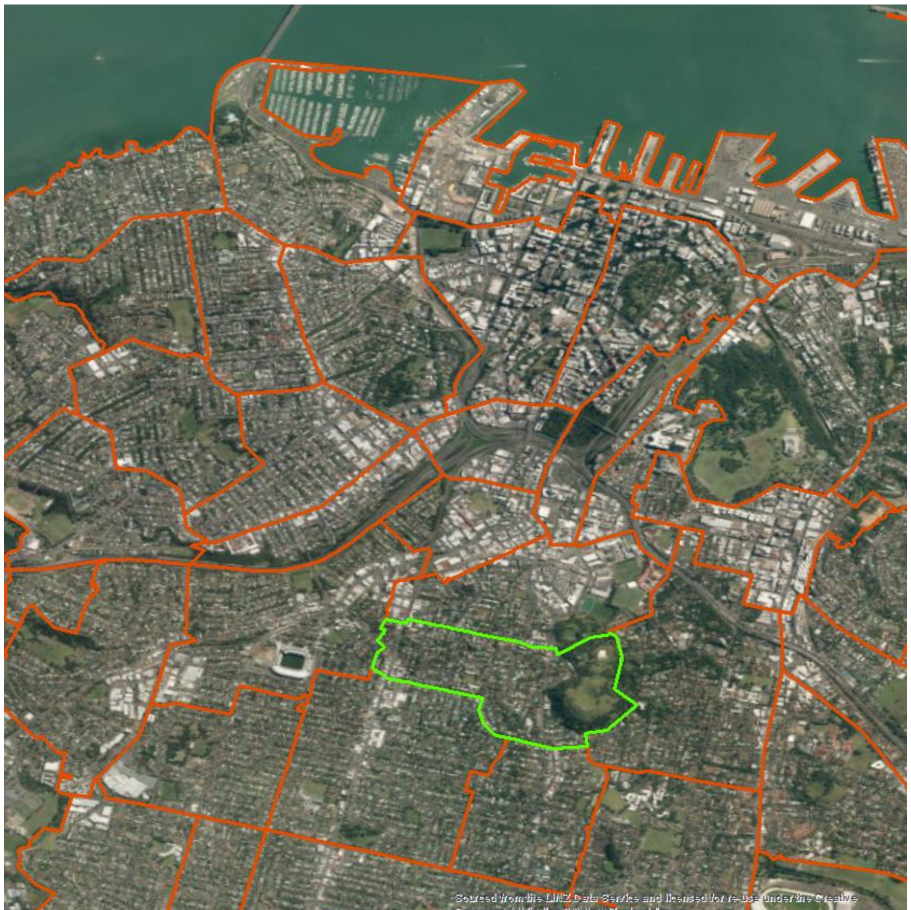
Approach

- Digital terrain model
- Digital surface model (objects only)
  - ➢ Final digital surface model
- Building outlines

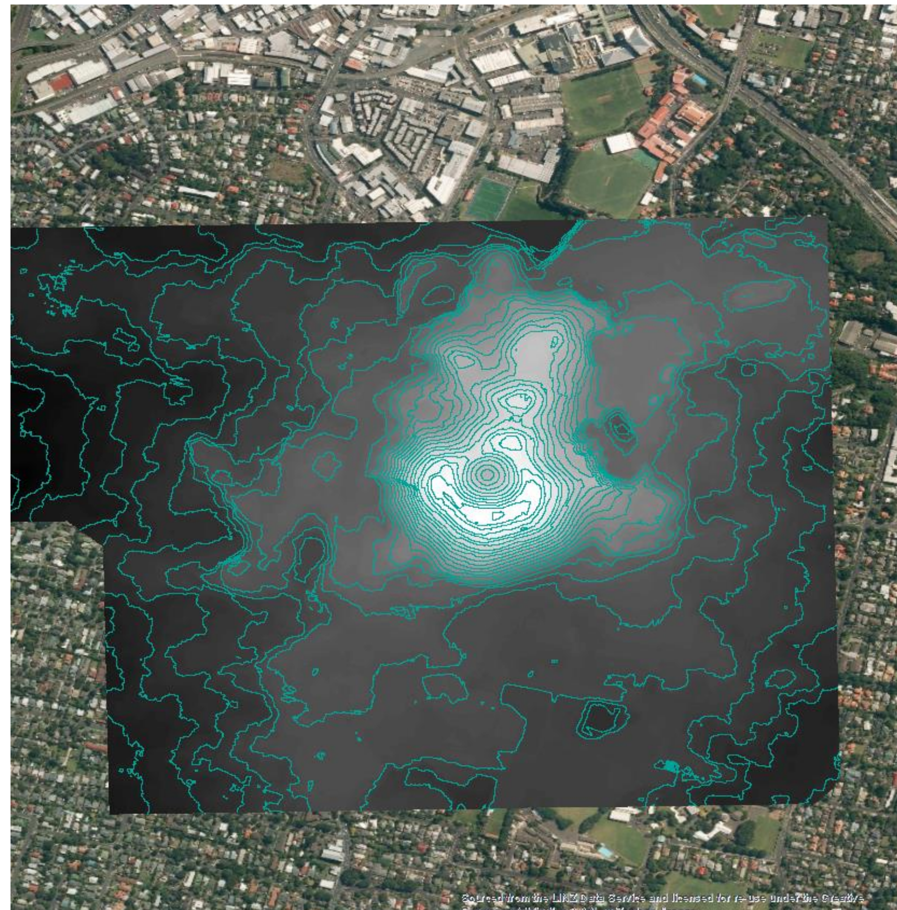
- Outputs rasters:
  - Elevation
  - Slope
  - Aspect

- Solar radiation tool:
  - Annual solar radiation raster

Auckland area units, Sherbourne marked



Digital terrain model (DTM)



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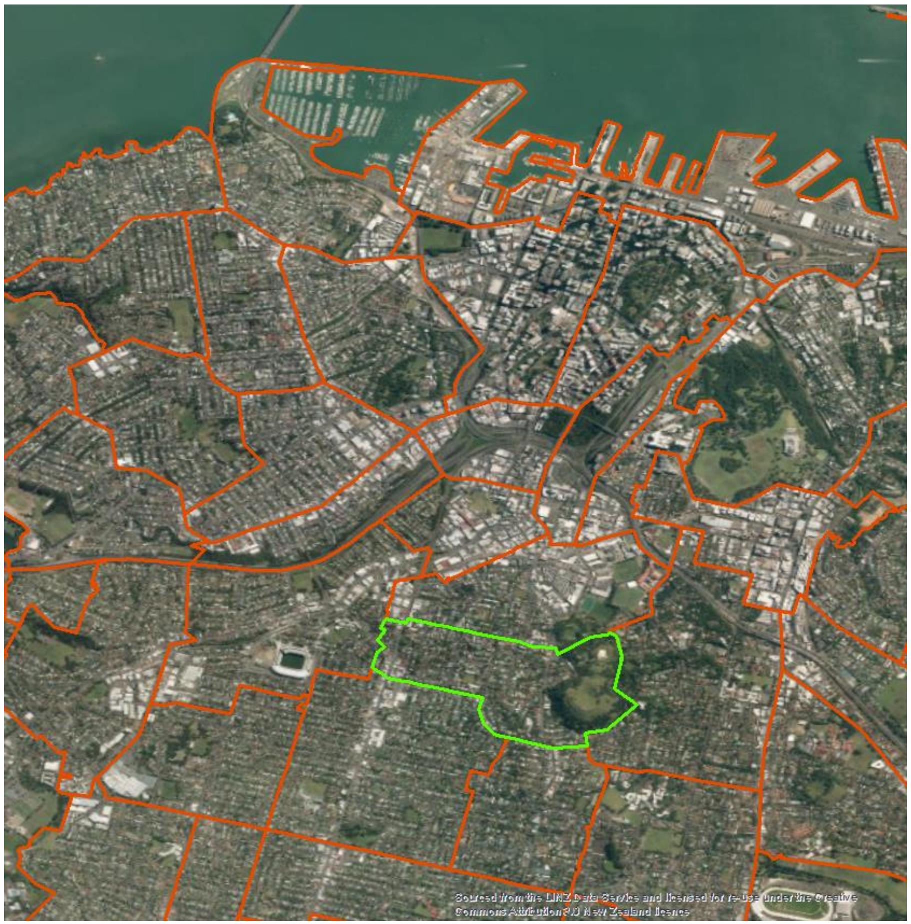
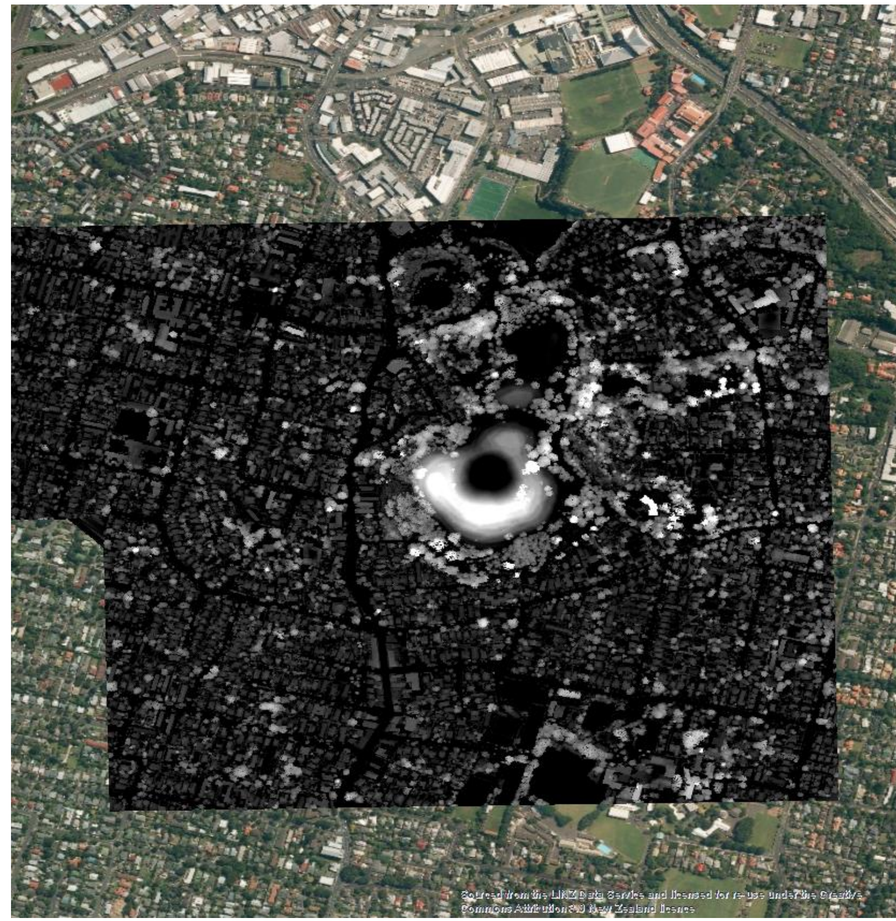
Auckland area units, Sherbourne marked

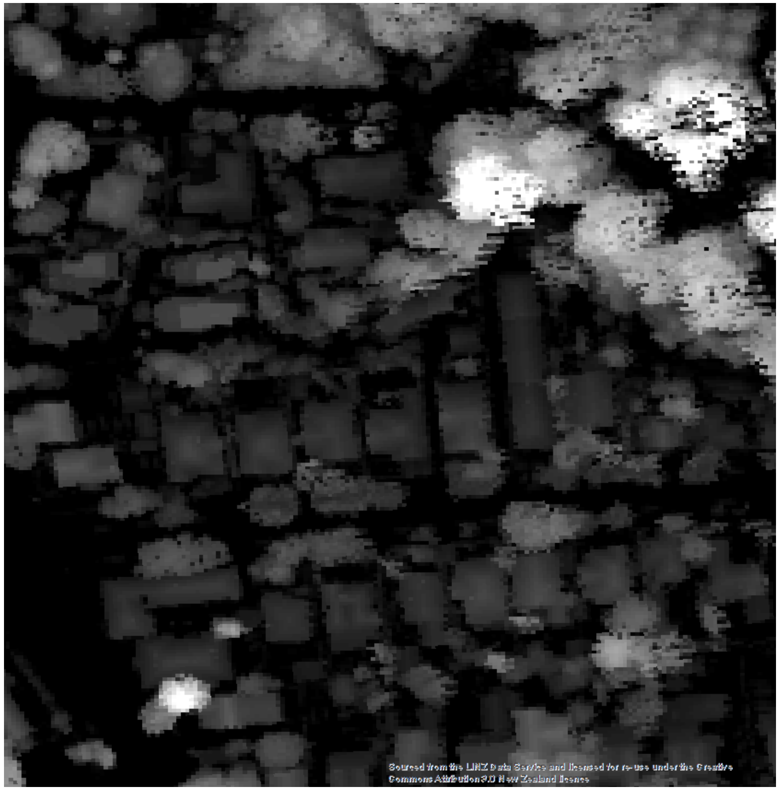


Digital surface model

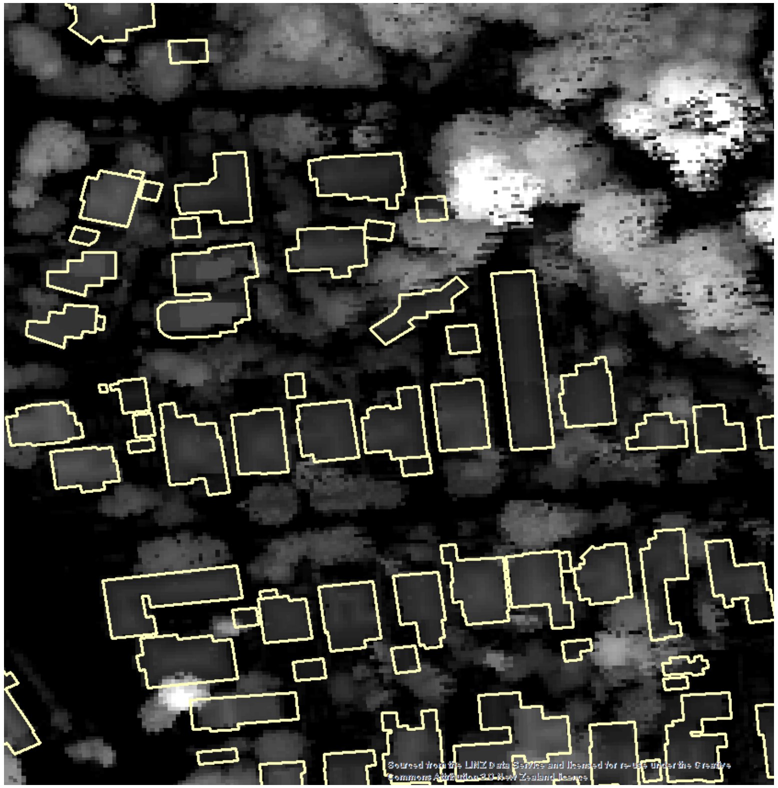


Building footprints

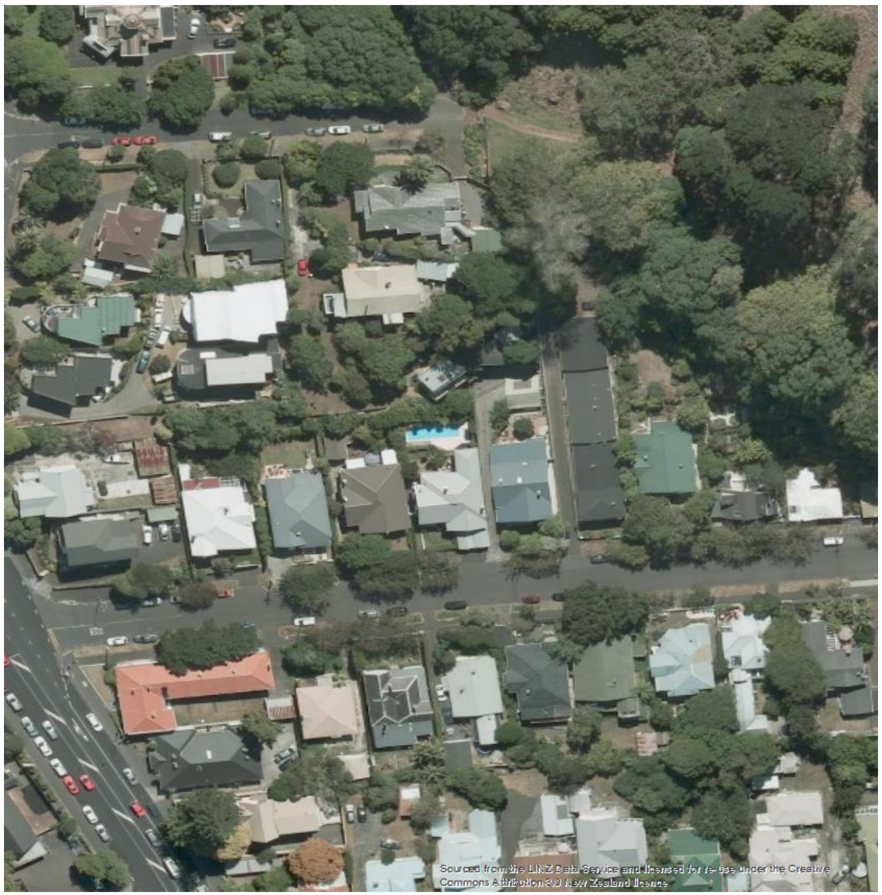
DSM zoomed in



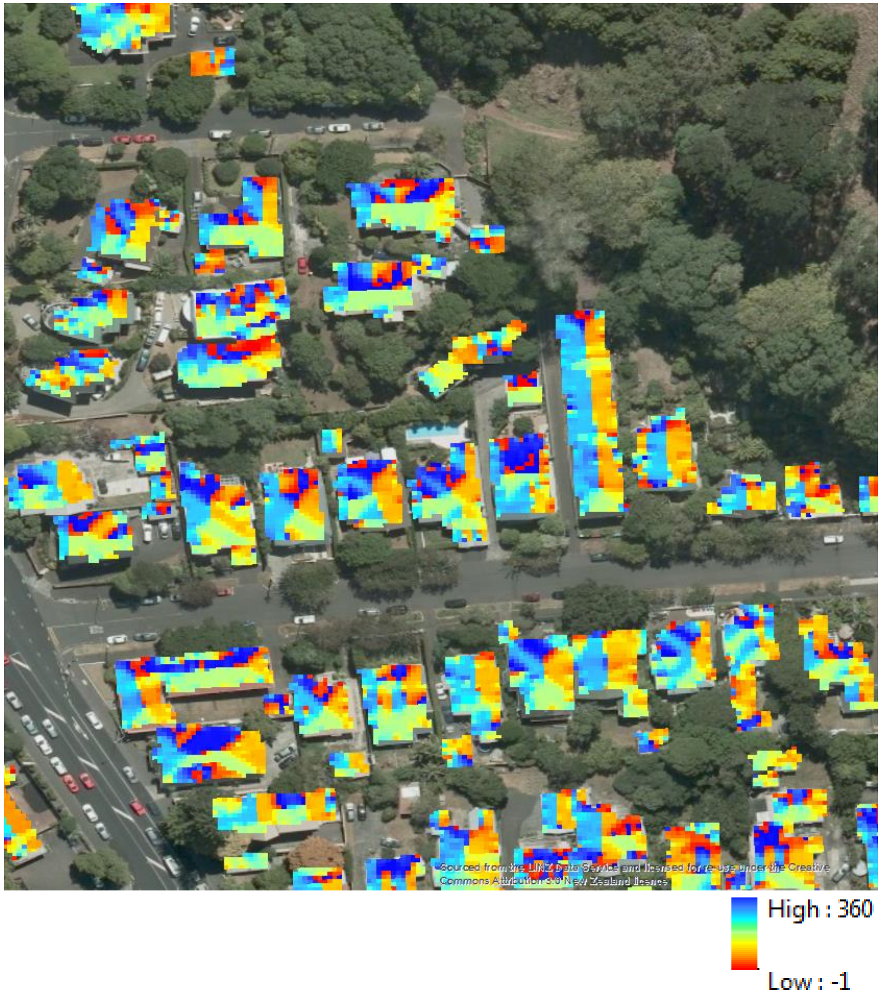
Choosing just rooftops for calculations



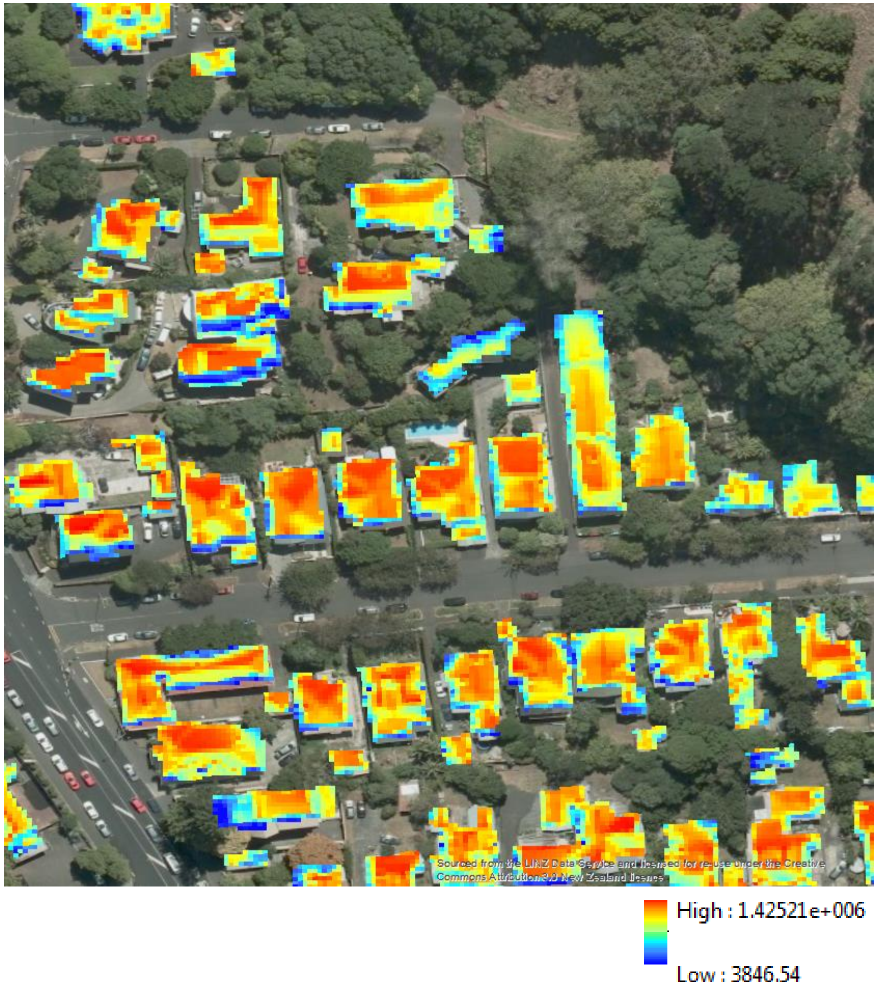
Calculating slope



Calculating aspect

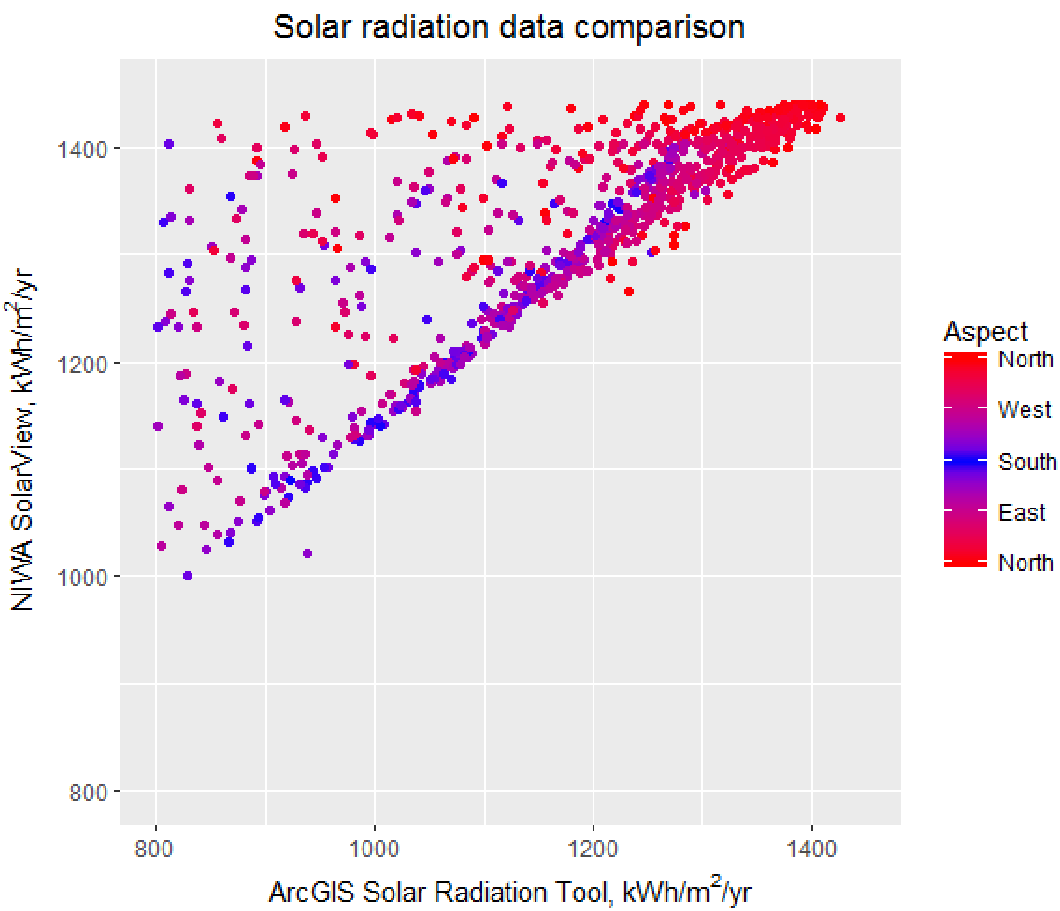


Calculating annual solar radiation



Comparing neighbourhoods

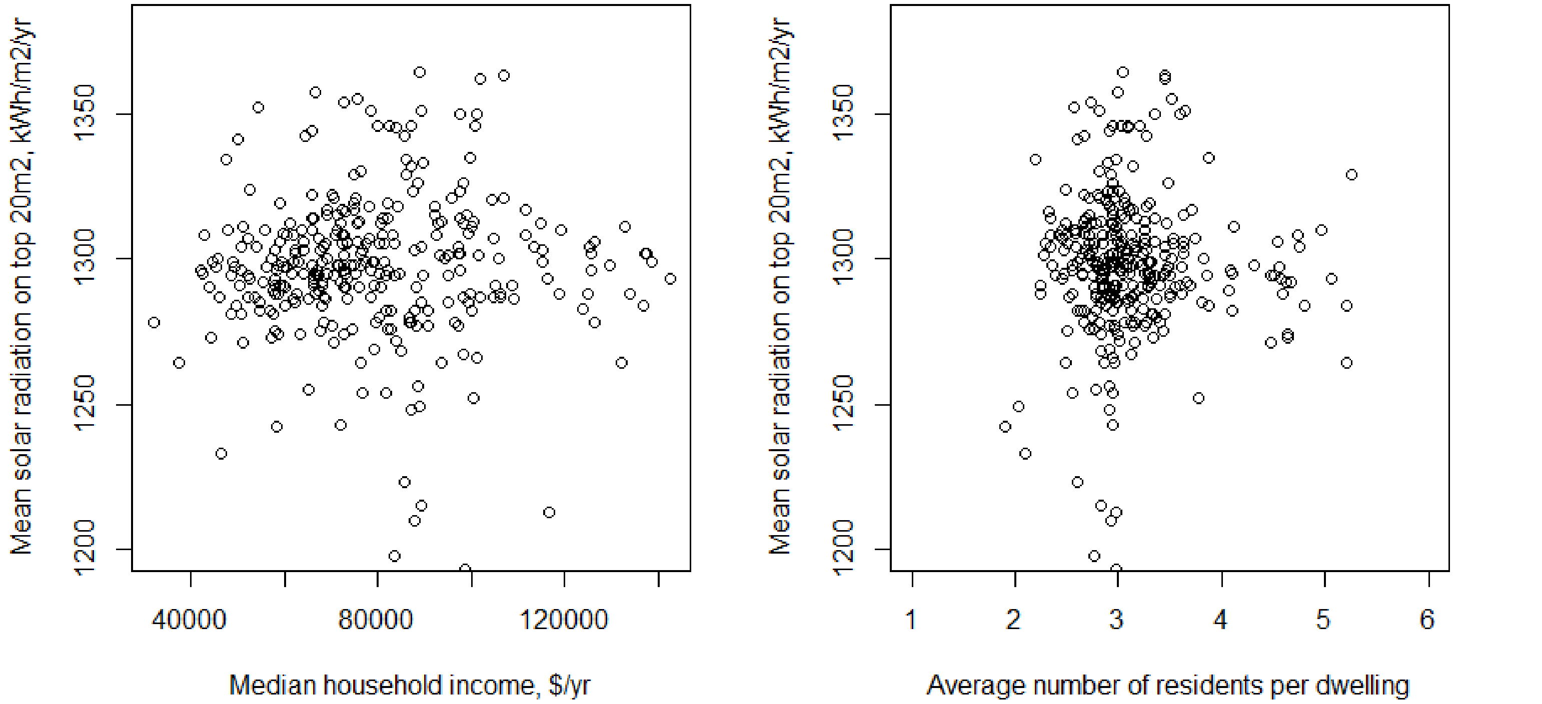
Comparison with NIWA's SolarView



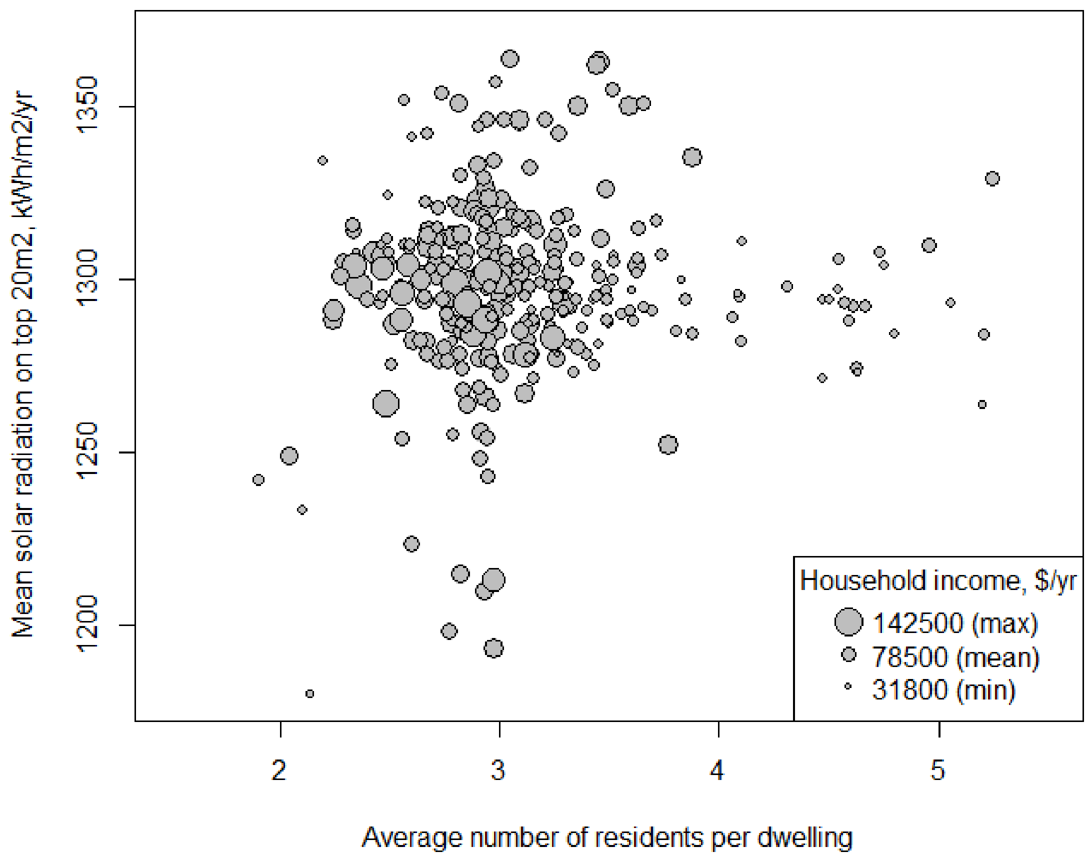
ArcGIS/SolarView

	North	East	South	West
Median	0.9535	0.9103	0.8640	0.9086
Max	0.9984	0.9580	0.9628	0.9676
Min	0.2900	0.3979	0.2794	0.3041

Comparing with income per neighbourhood and population density



Solar potential, income and residents per dwelling



Limitations

- LiDAR data represents a snapshot of the DSM; however, buildings and trees are not permanent
- Building footprints may be outdated; some buildings missed
- Not all points necessarily from rooftops, although there are methods to limit errors from this
- Resolution limitations (here 4 points per m2)
- ARCGIS solar radiation tools vs. NIWA's tool
- Statistical error for individual buildings

Key points

- LiDAR data can be used for detailed cityscape modelling
- Solar potential assessment can be used for policy design for renewable energy targets and/or market opportunities
- Future research can include
  - Comparison with property values, function, old vs new builds, …
  - Study implications on lines capacities
  - More detailed modelling of individual houses
  - App for visualisation of results for public use

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Thank you!