Solar energy

Energy Centre summer school in Energy Economics

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Outline

The resource

The technologies, status & costs

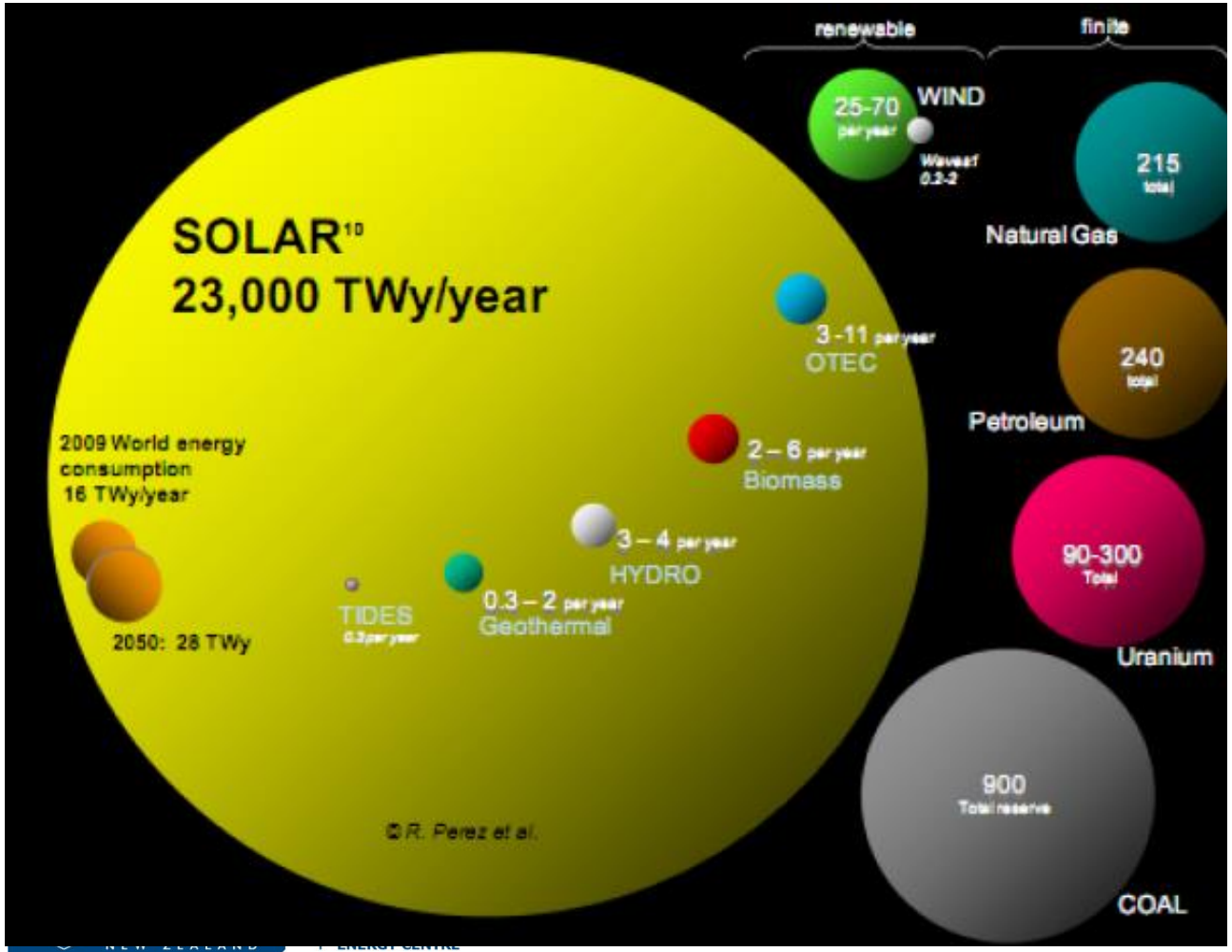
- (Solar heating)
- Solar power
  - Solar photovoltaic
  - Solar thermal (CSP)
- Costs

Solar energy in the world & New Zealand

Research at the Energy Centre

- Solar potential of Auckland rooftops using LiDAR data

The resource



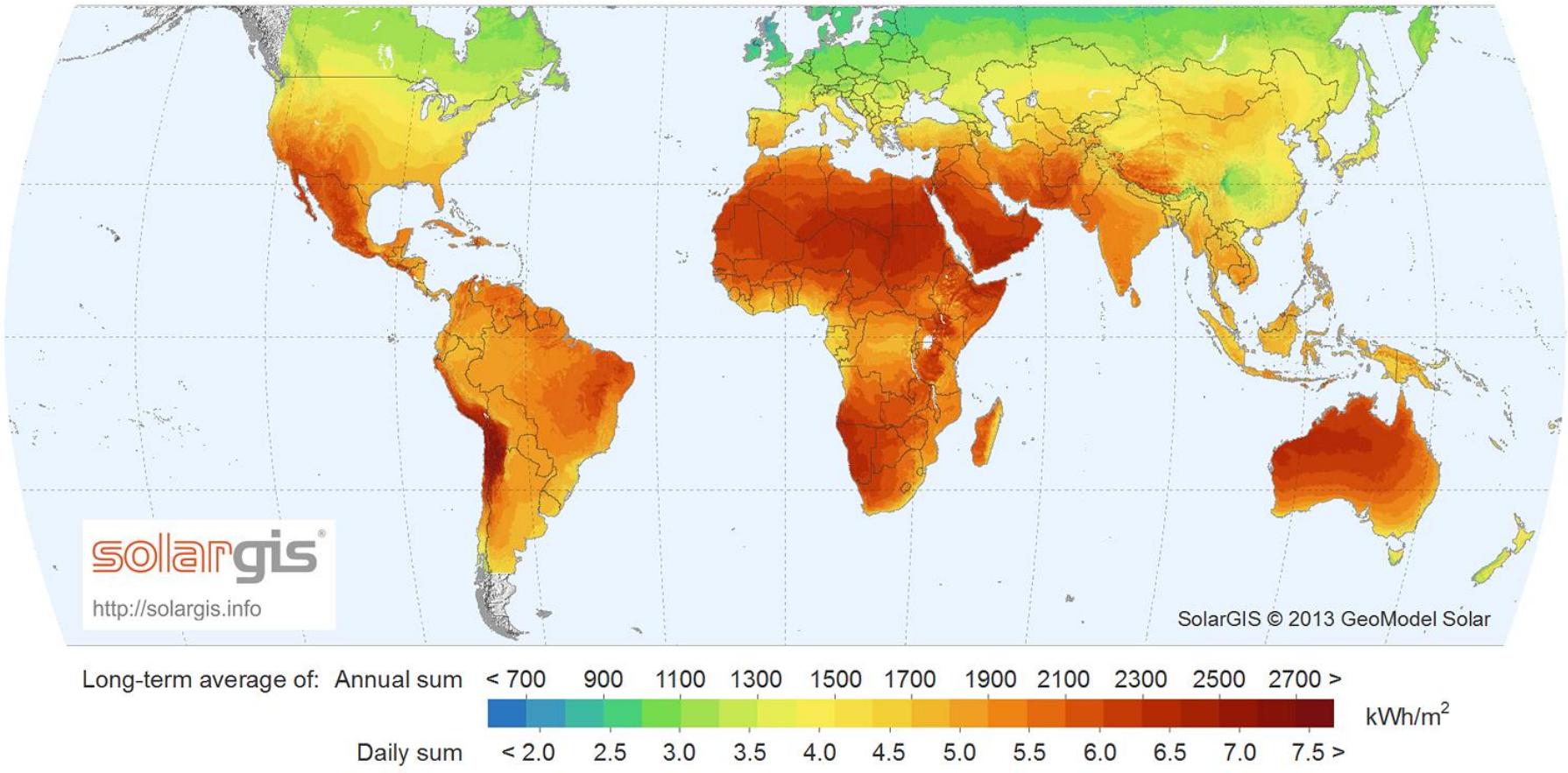
The figure compares the 2009 and expected 2050 annual energy consumption of the world to

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

(2) the yearly potential of the renewable alternatives.

- Sun ~ 1000 x world energy demand
- 6 hr of sun ~ 1 yr of world energy demand
- All petroleum < 4 days of sun
- All coal ~ 2 weeks of sun

The resource



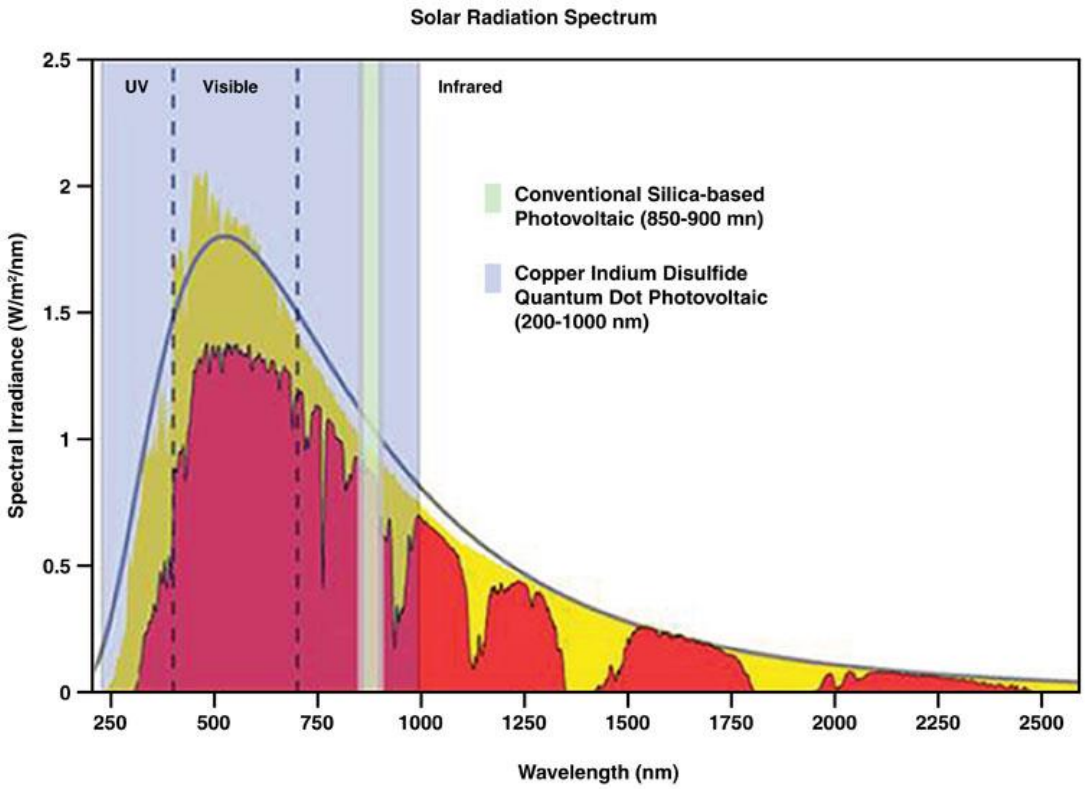
The resource

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

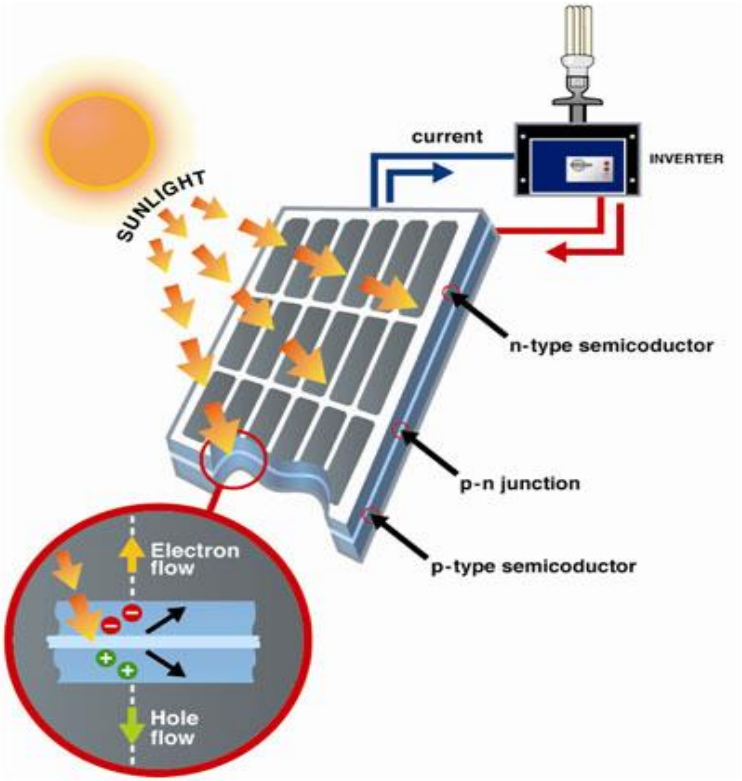


Capturing solar energy

- Heat – through absorption
  - Pools
  - Sanitary water
  - Drying (water evaporation) e.g. crops, other foods
  - Passive space heating
  - Mechanical work -> electricity (solar thermal electricity / concentrating solar power)

- Photoreaction
  - Photosynthesis
  - Photovoltaic effect

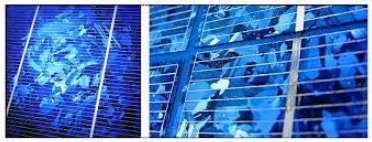
Solar photovoltaics (PV)



- Absorption of incident photons to creates electron-hole pairs.
- Electron-hole pairs will be generated in the solar cell (provided that the incident photon has an energy greater than that of the band gap).
- The pair is separated by due to the electric field existing at the *p-n* junction -> electrons flow one way, holes the other

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:

94% of global production in 2016

Efficiency: 16-18%.

Thin films (a-Si, CdTe, CIGS)

6% of global production in 2016

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

Efficiency: 12-16%

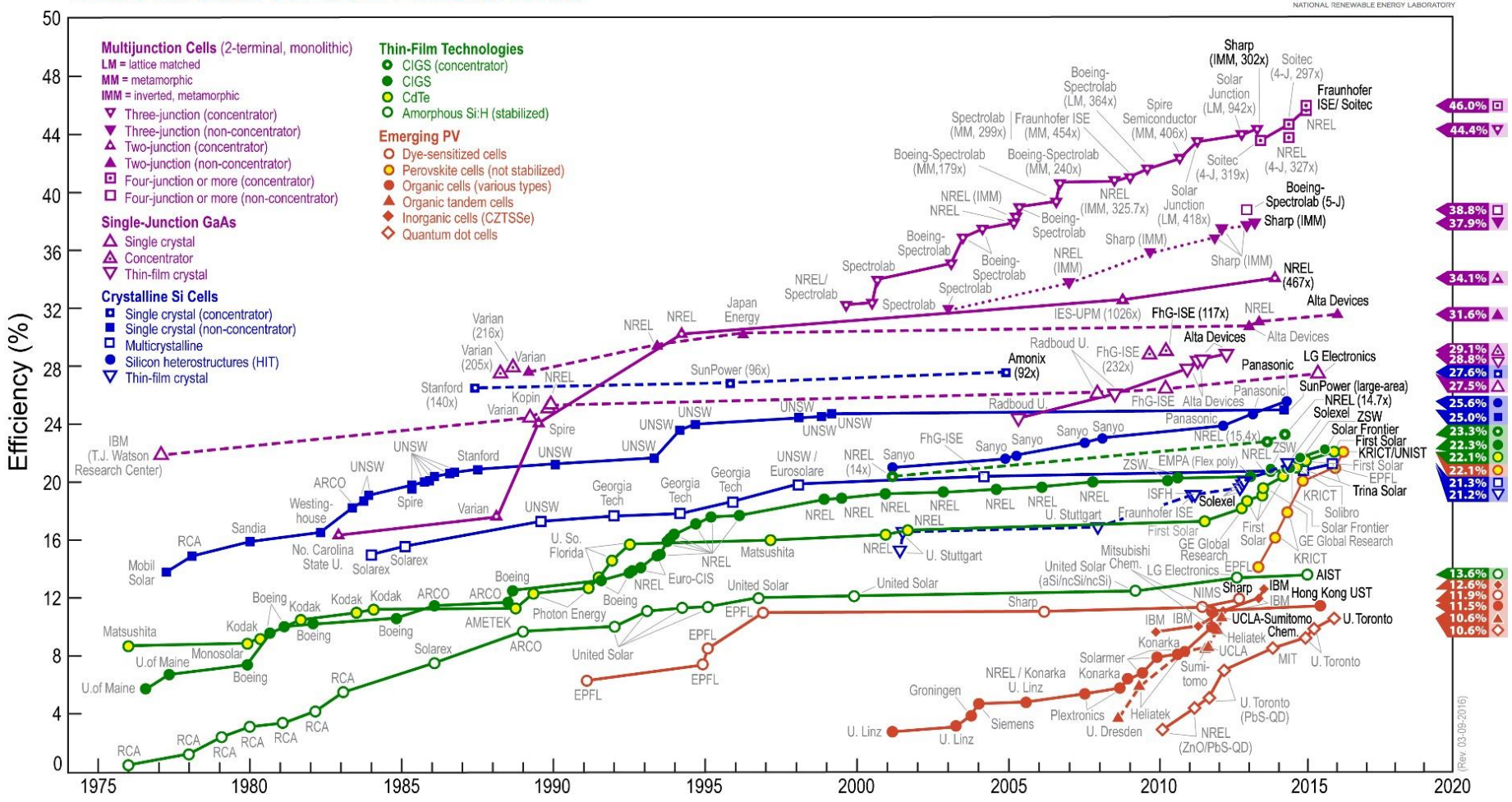
Concentrating solar PV / advanced thin films

Still under development!

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

Efficiency: 20-60%

Best Research-Cell Efficiencies



Environmental, health and safety challenges

Silicon based PV – similar hazards to microelectronics industry

- Silane gas (explosive), silicon tetrachloride (extremely toxic), sulphur hexafluoride (GHG 25000 x CO_2), sulphur dioxide (acid rain) used in Si production process
- Sodium hydroxide, potassium hydroxide (dangerous to eyes, lungs, skin) used to remove sawing damage on silicon wafer surfaces
- Hydrochloric, sulphuric, nitric acid, hydrogen fluoride (corrosive chemicals) used to remove impurities

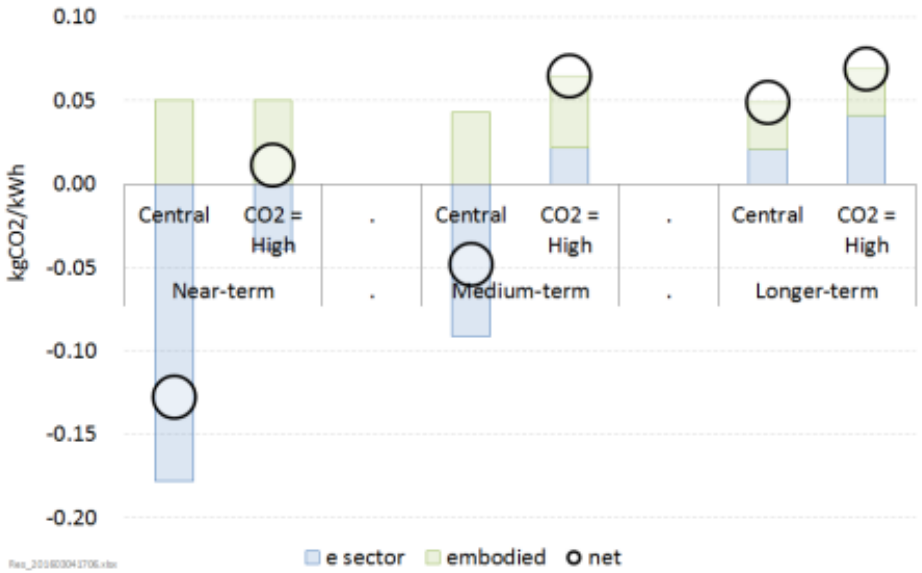
These are all well known chemicals that can be handled safely **if** appropriate environmental and occupational health and safety standards are in place.

We don't have the best product yet!

Is solar an environmentally friendly choice for New Zealand?

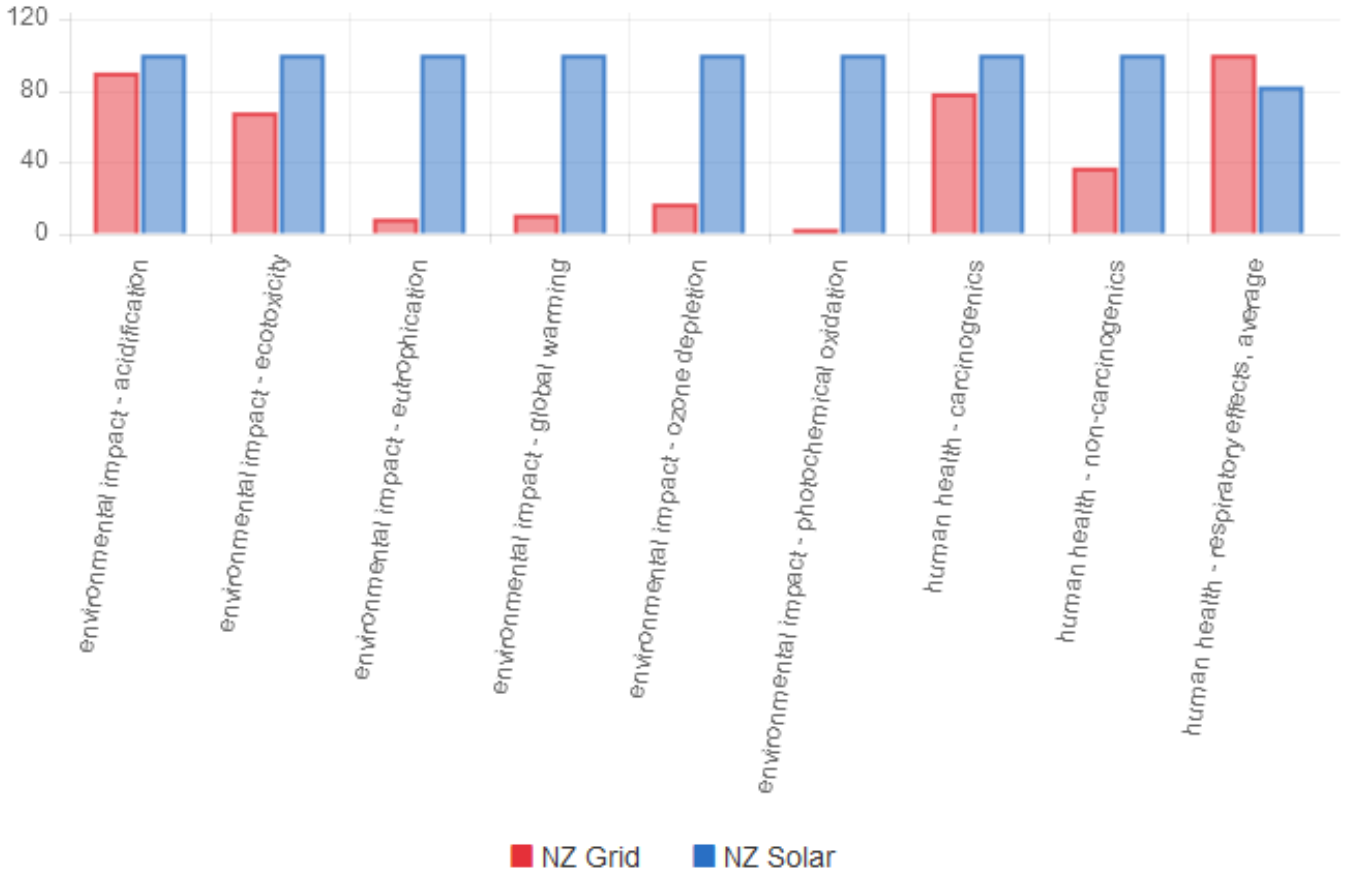
Background:

Figure 2: Lifetime emissions impact of solar PV

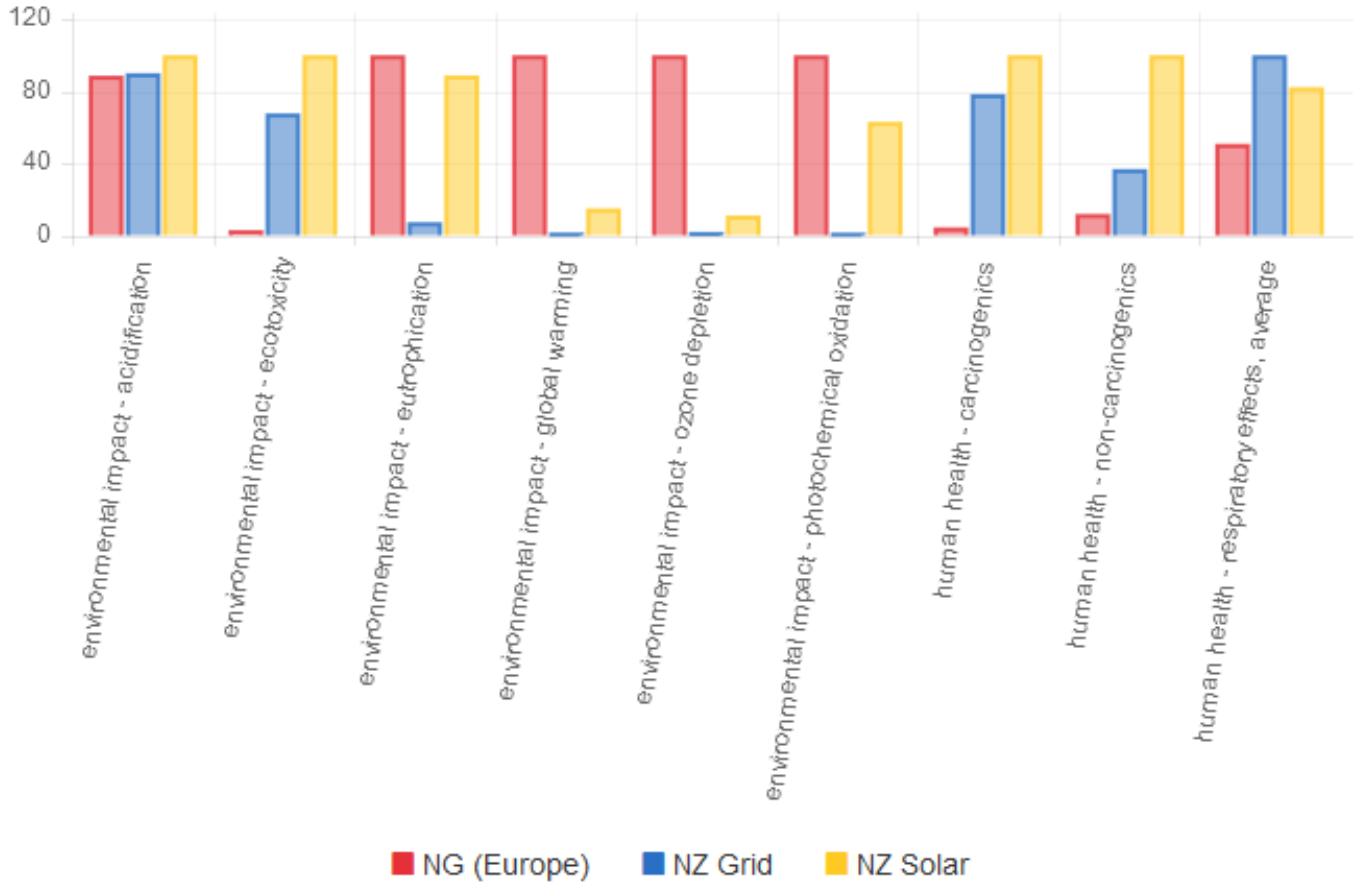


Source: Concept Consulting Group Ltd, 2016.

Life cycle assessment exercise

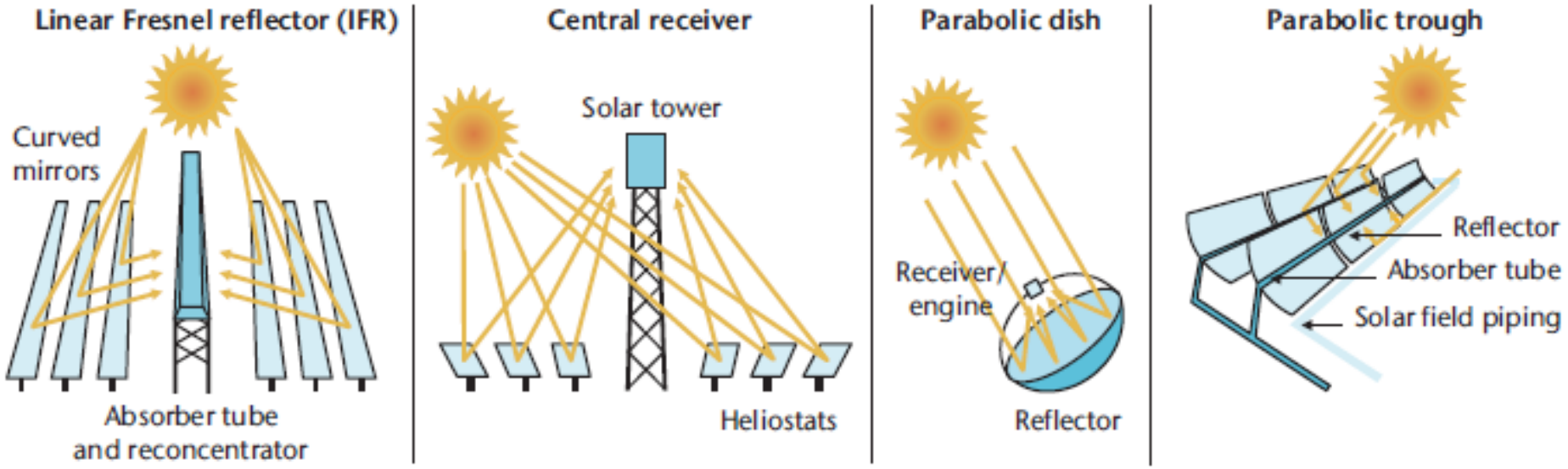


Life cycle assessment exercise, including natural gas



Concentrating solar power (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.



Large solar power plants

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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

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Save for later

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

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Dubai launches world's largest Concentrated Solar Power project

Shaikh Mohammad Bin Rashid launches world's largest single-site Concentrated Solar Power project

Published: 17:49 September 16, 2017
Staff Report

"the largest single-site project will generate 700 megawatts (MW) of power when completed"

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country to supply most of its energy from renewables

Ouarzazate solar power plant provides 160MW of its ultimate 580MW
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China builds world's biggest solar
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ANDHRA PRADESH

With Kurnool solar park, State takes a giant leap

V. Raghavendra

ORVAKAL (KURNOOL DT.), APRIL 29, 2017 00:00 IST
UPDATED: APRIL 29, 2017 04:43 IST

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Futuristic:Principal Secretary Ajay Jain at the mega solar power plant in Kurnool district on Friday.U. SUBRAMANYAMU_SUBRAMANYAM

Of the 1,000 MW installed capacity, it started generating 900 MW

Photograph: Tom Phillips for the Guardian

Tom Phillips *in*
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2. Datong Solar Power Top Runner Base – 1000MW – China

With 1GW Phase I completed and a Total capacity is 3GW in 3 phases. Datong Solar Power plant in China has the potential to be the largest solar plant in the world once completed. According to government statistics, from July 2016 to January 2017 , Datong generated a total of 870 million watts of electricity, equivalent to more than 120 million watts per month of power generation.

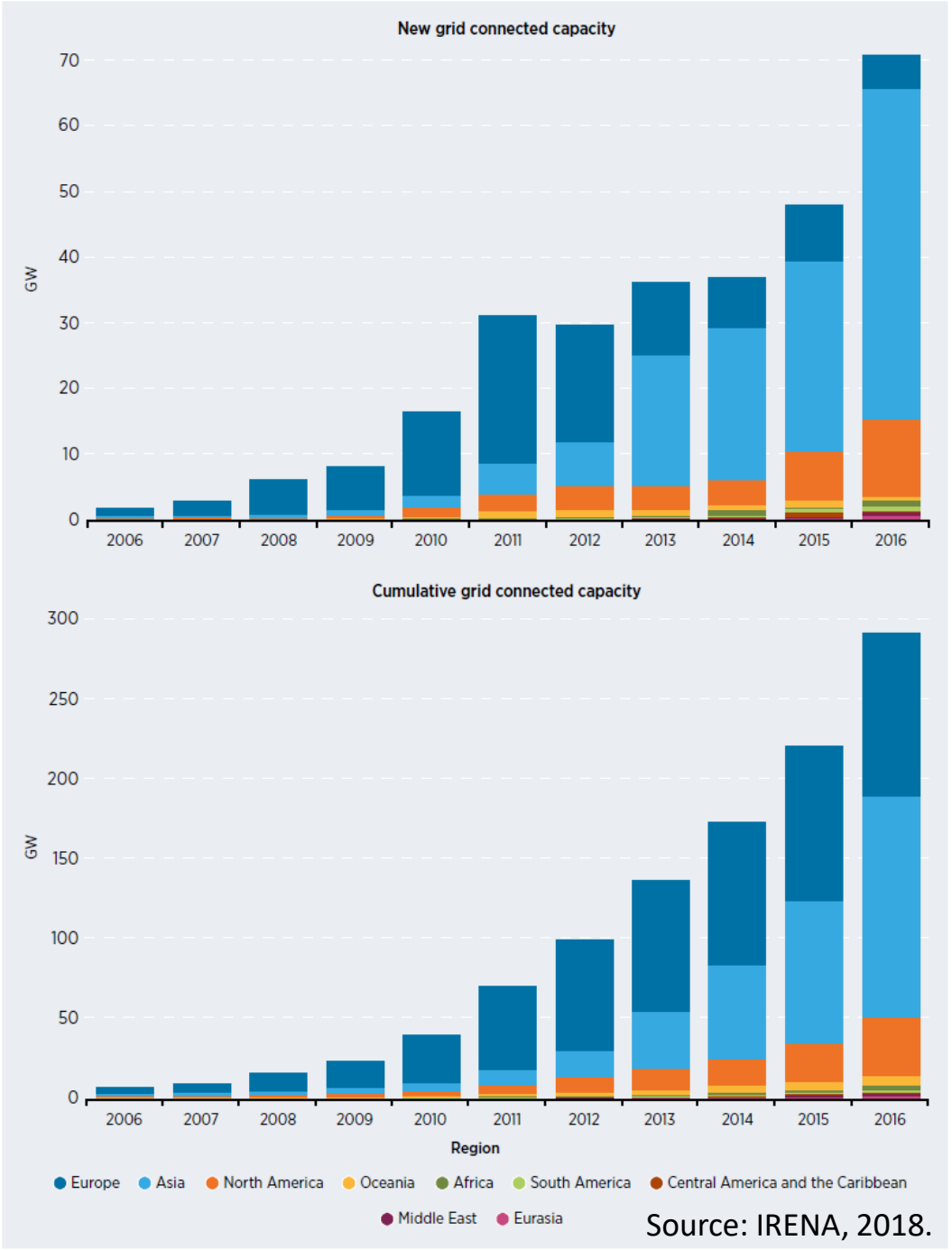
https://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations

1. Tengger Desert Solar Park – 1500MW – China

The 1547MW solar power was installed in Zhongwei, Ningxia is the world's largest solar array by far. Know as the "Great Wall of Solar" in China. The Tengger Desert is an arid natural region that covers about 36,700 km and is mostly in the Inner Mongolia

holds.

Solar PV in the world



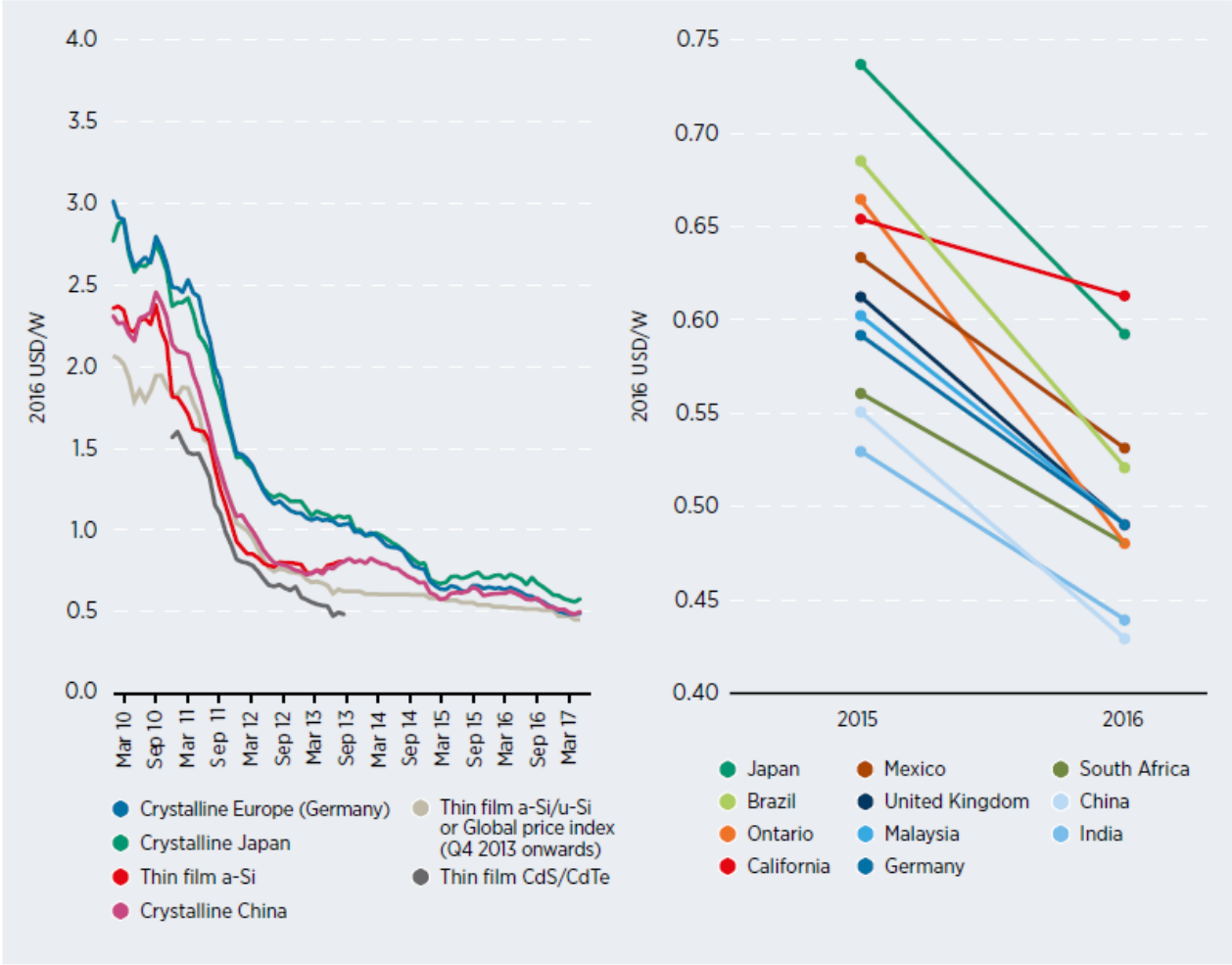
Source: IRENA, 2018.

PV Costs: Modules

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

European solar PV module prices by technology and manufacturer

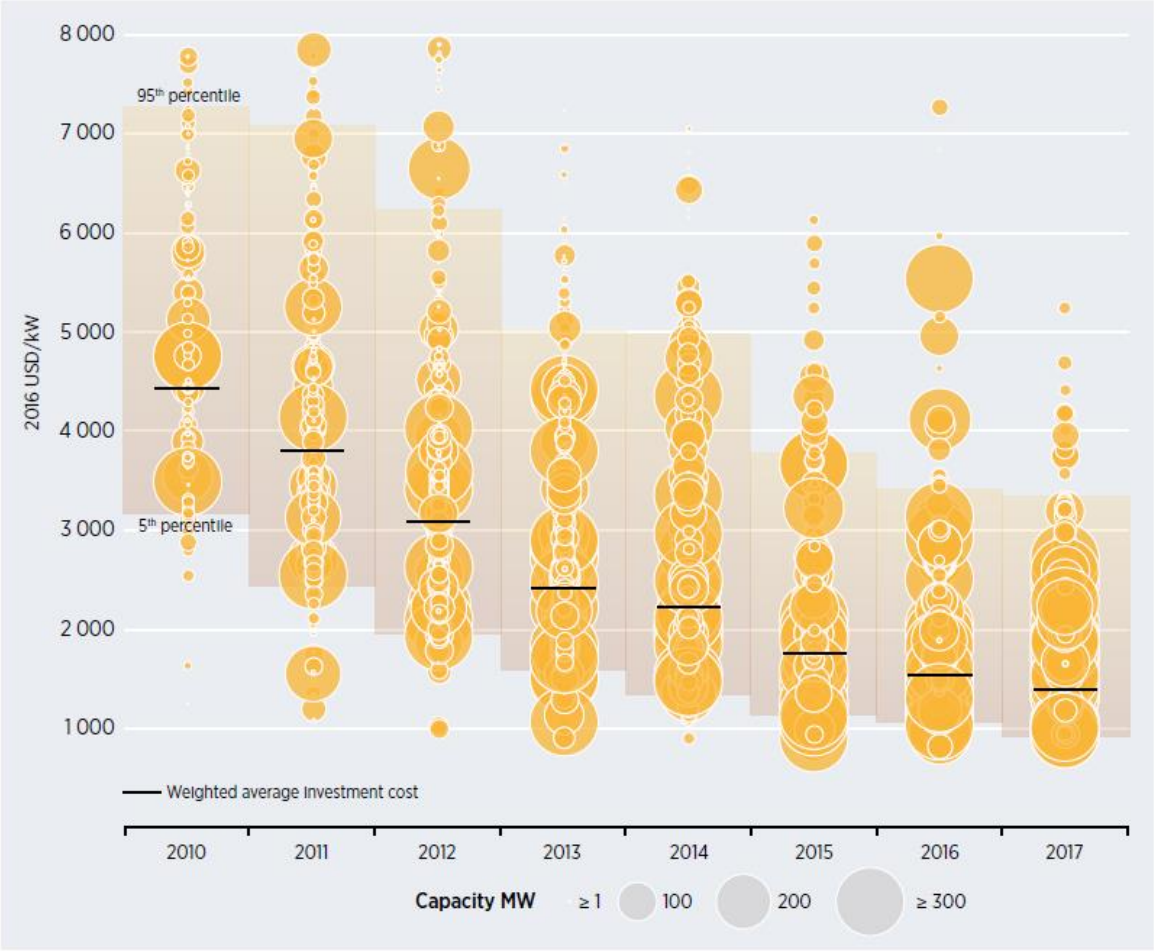
Average yearly module prices by market in 2015 and 2016



Source: IRENA, 2018.

PV costs: installed

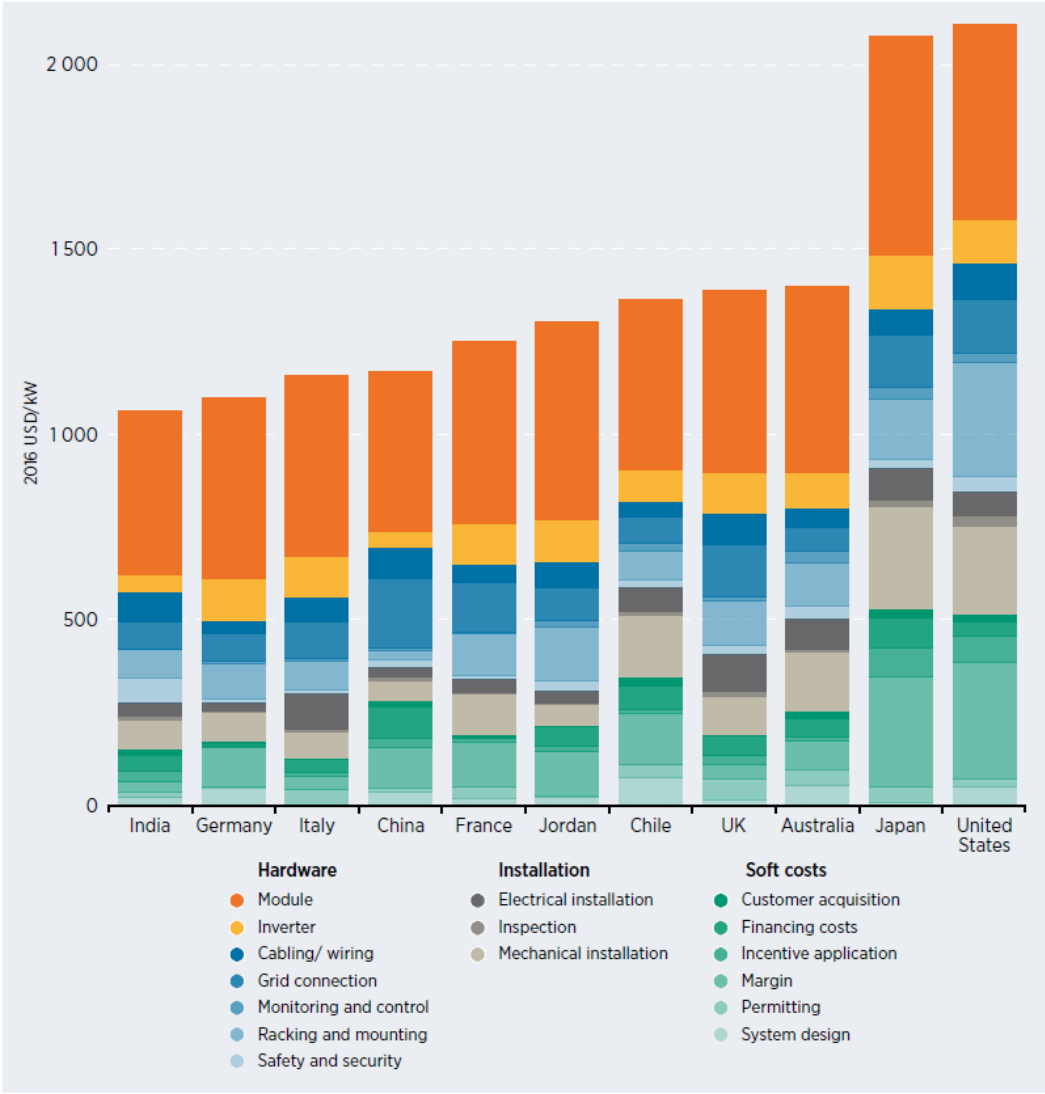
Total installed costs for utility-scale solar PV projects and the global weighted average, 2010-2017



Source: IRENA, 2018.

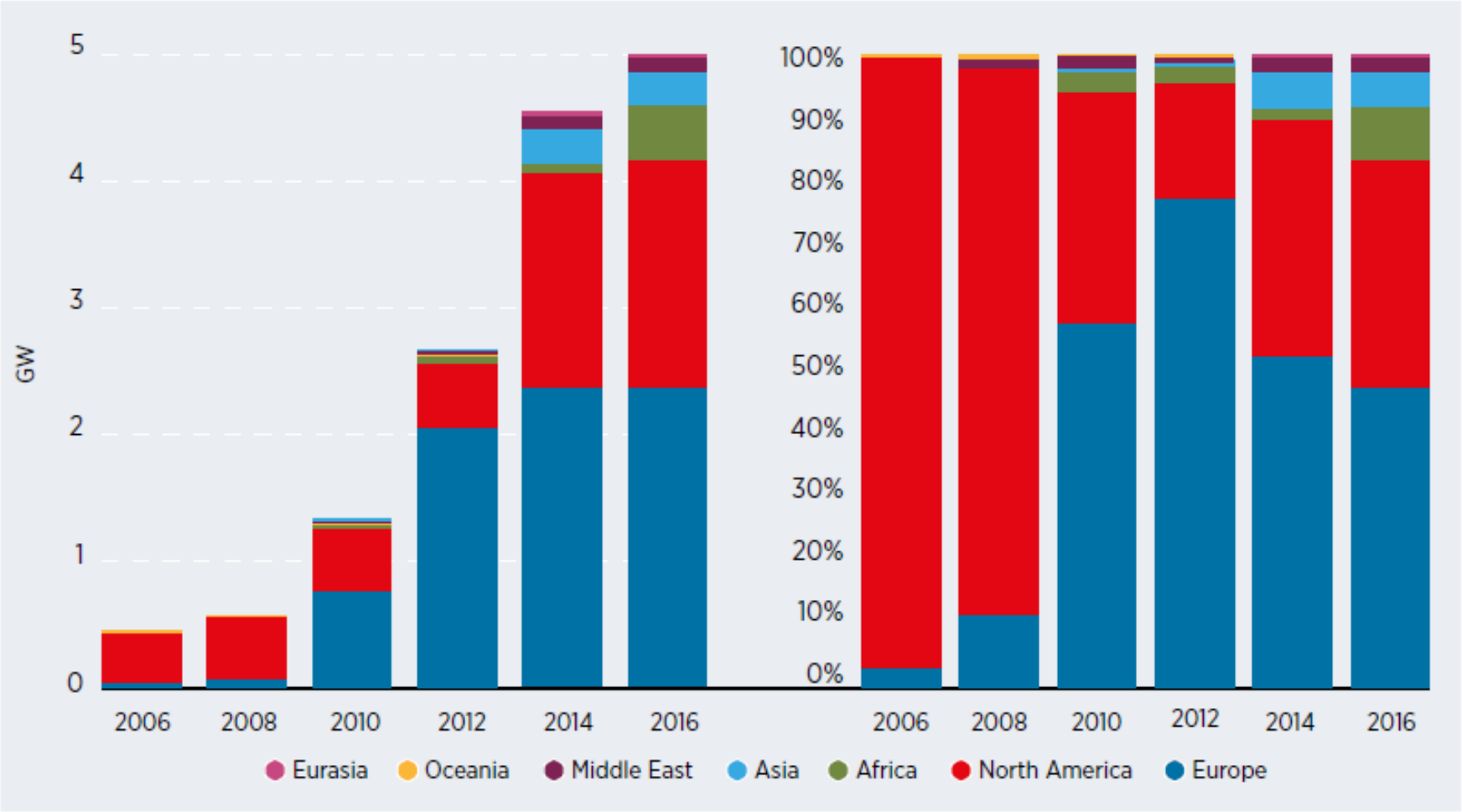
PV costs: breakdown

Detailed breakdown of utility-scale solar PV costs by country, 2016



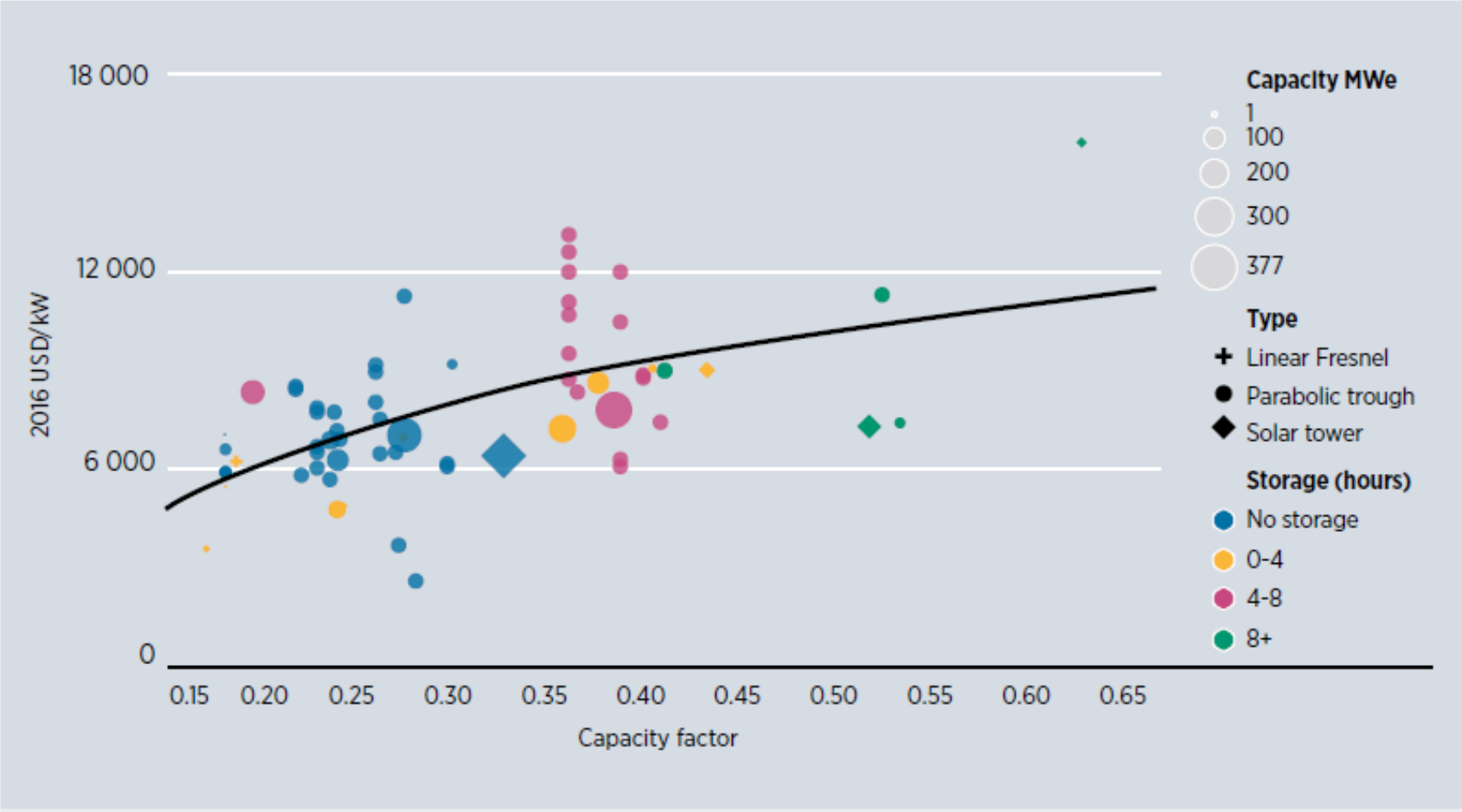
Source: IRENA, 2018.

CSP in the world



Source: IRENA, 2018.

CSP costs: installed and CF

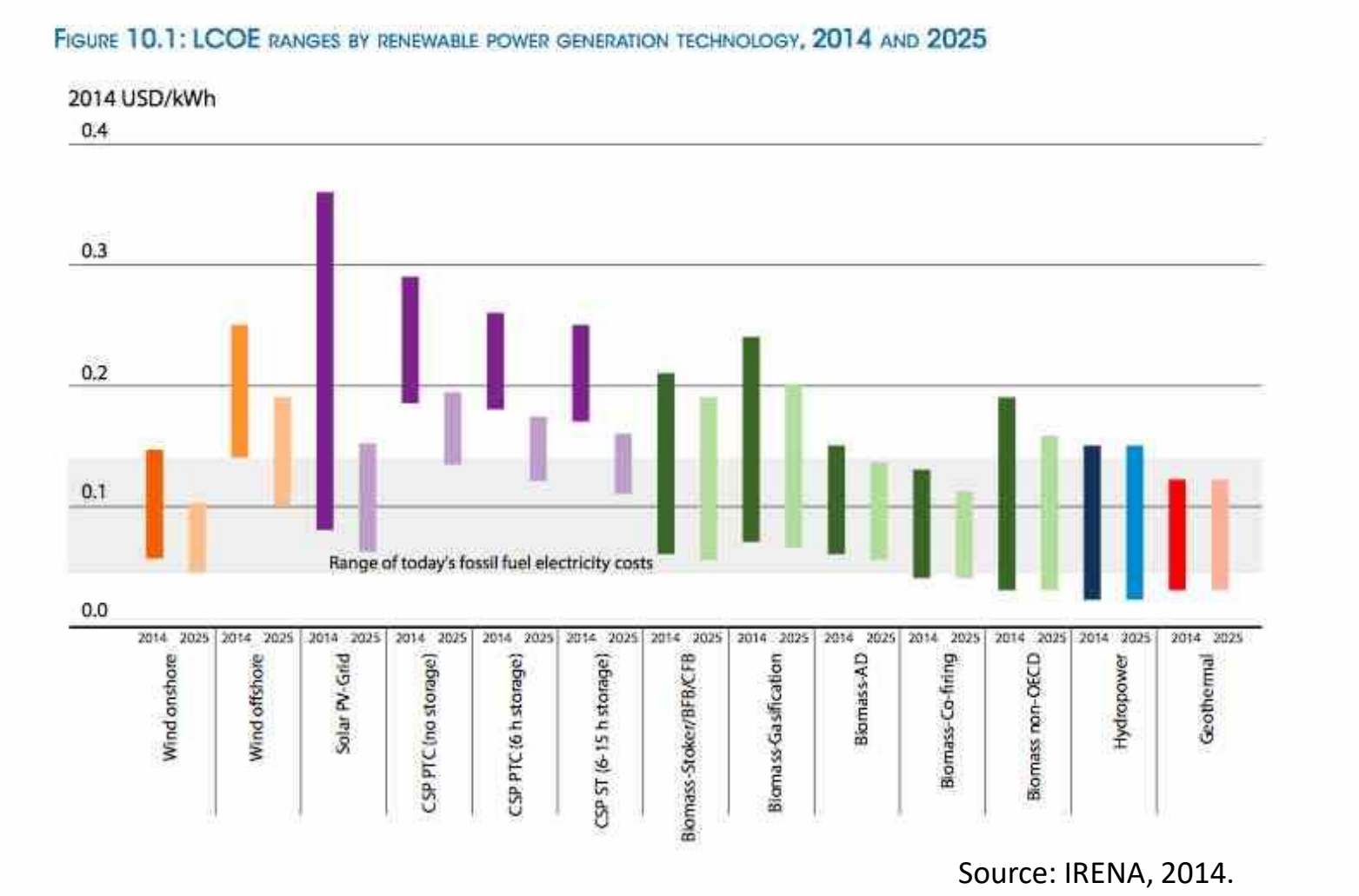


Source: IRENA, 2018.

CSP costs: installed (over time)

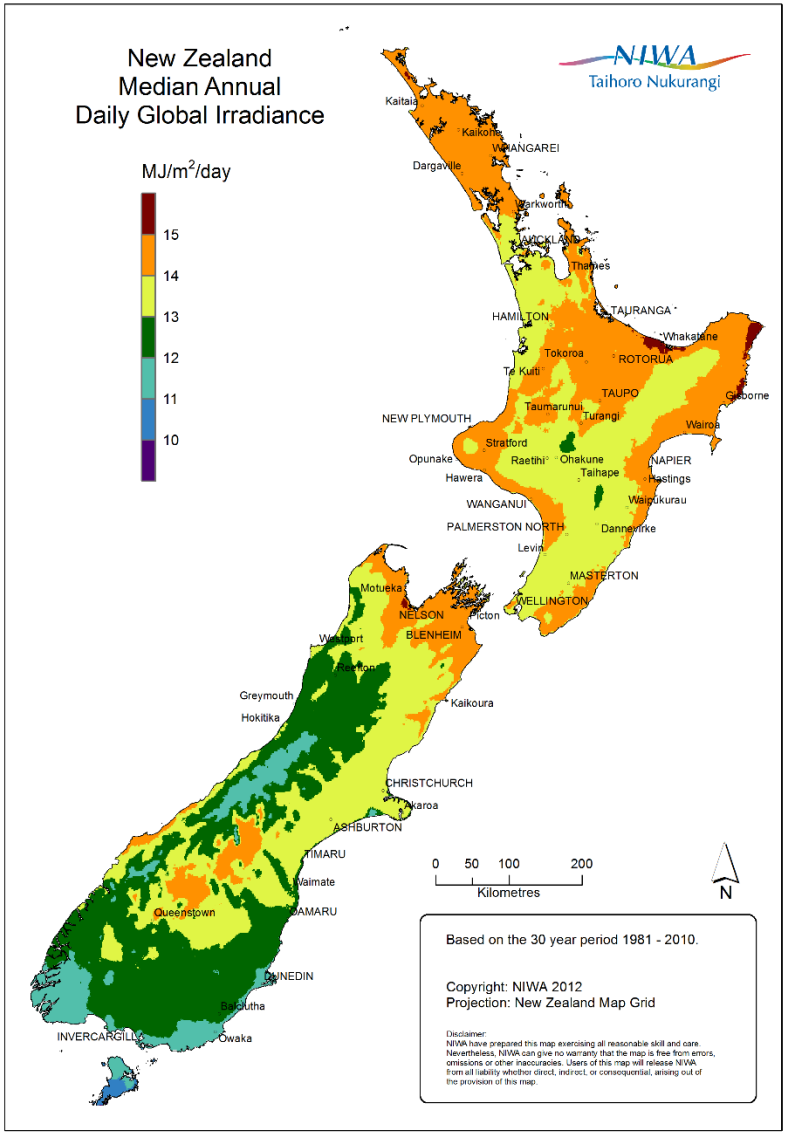
Source: IRENA, 2018.

Levelised cost of energy



Source: IRENA, 2014.

Solar energy in New Zealand



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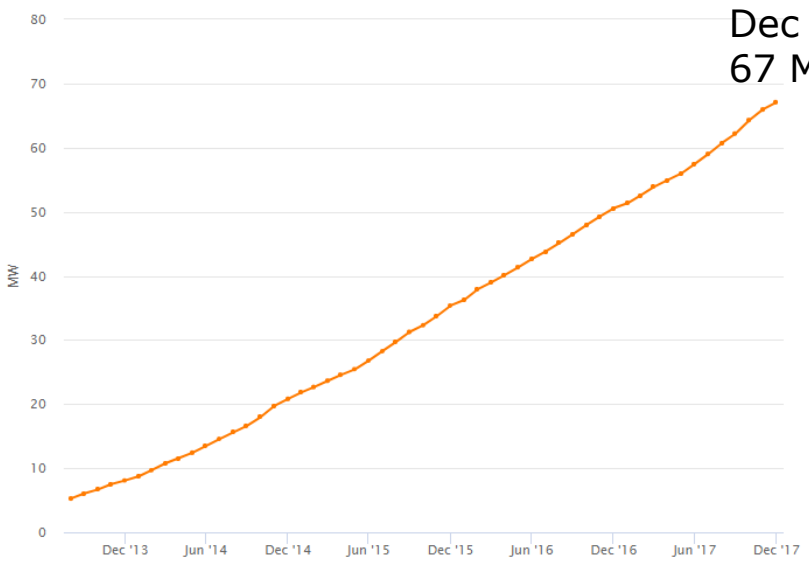
Installed solar capacity

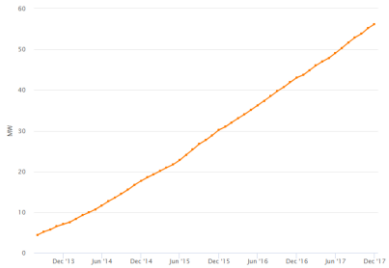
Installed solar capacity,
New Zealand



Dec 2017
67 MW

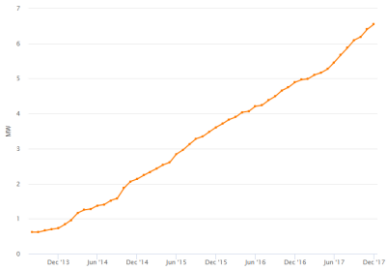
Source: Electricity Authority, Electricity Market Information, website visited Feb 2018.

Residential



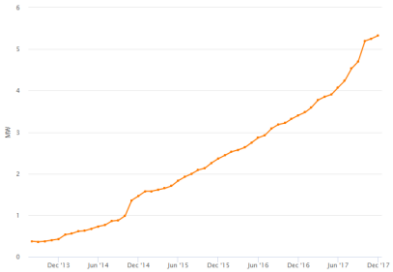
52.9 MW
15 411 ICPs

SMEs



6.5 MW
713 ICPs

Commercial



5.3 MW
508 ICPs

Industrial

5.6 MW
402 ICPs

Solar research at the Energy Centre

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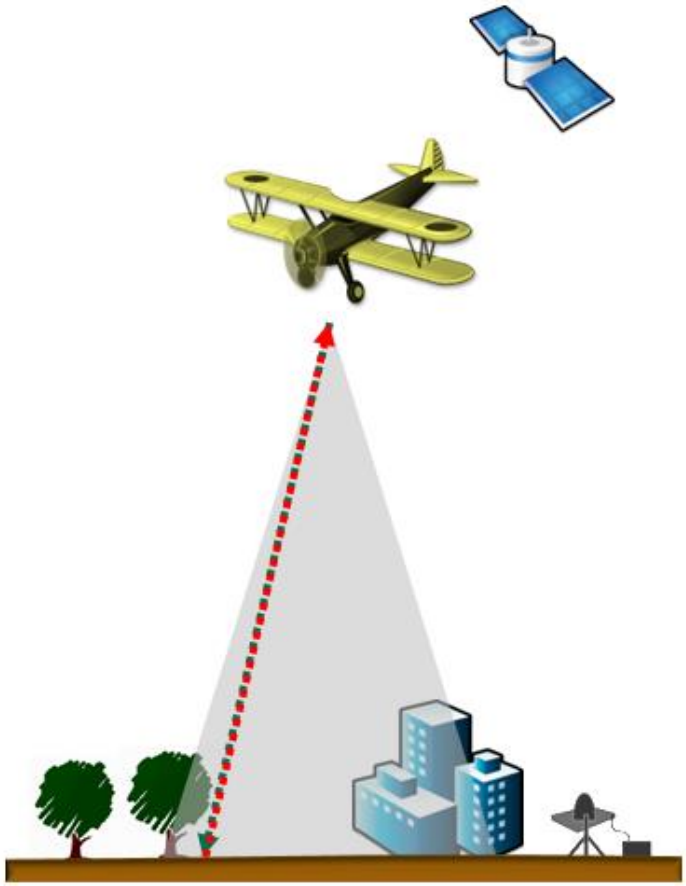
Solar potential in Auckland rooftops using LiDAR data



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.

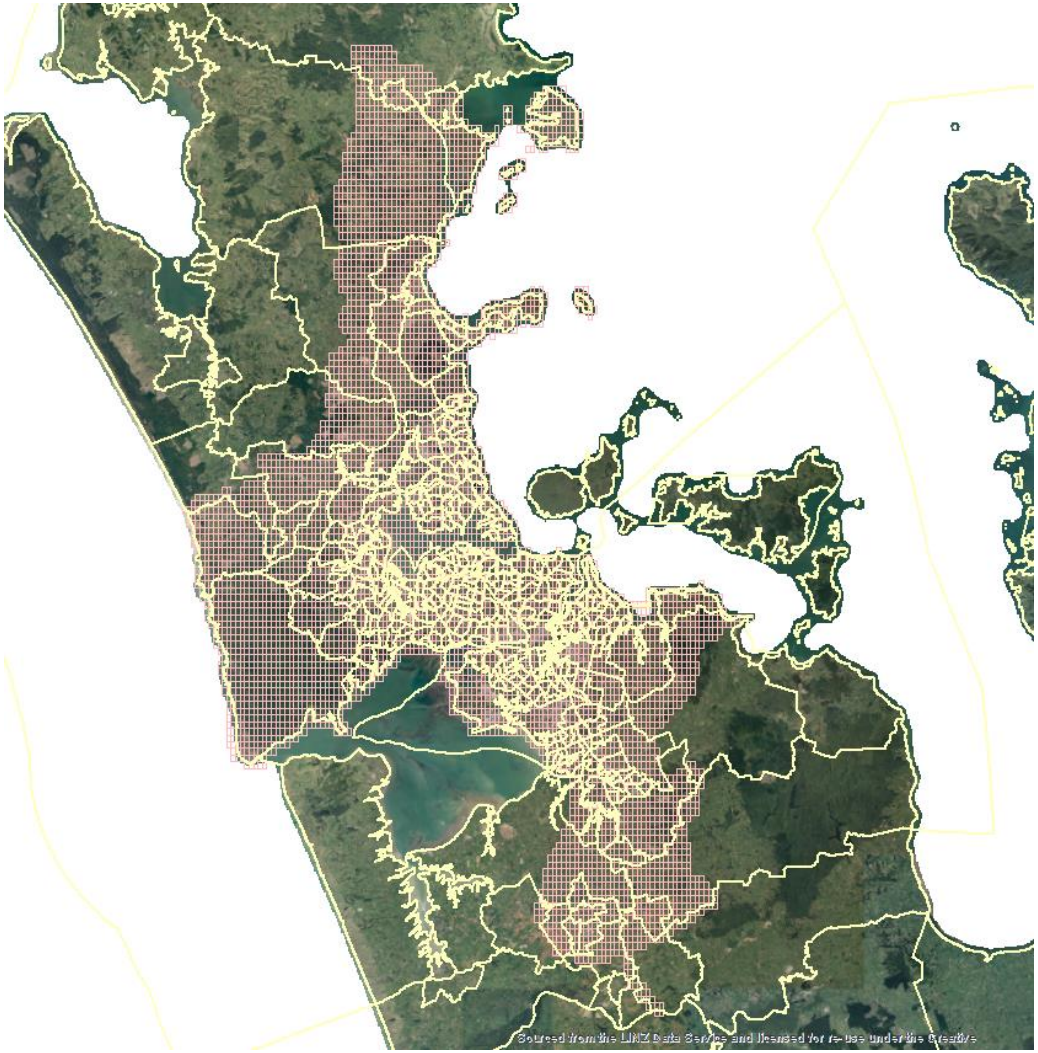
LiDAR data

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

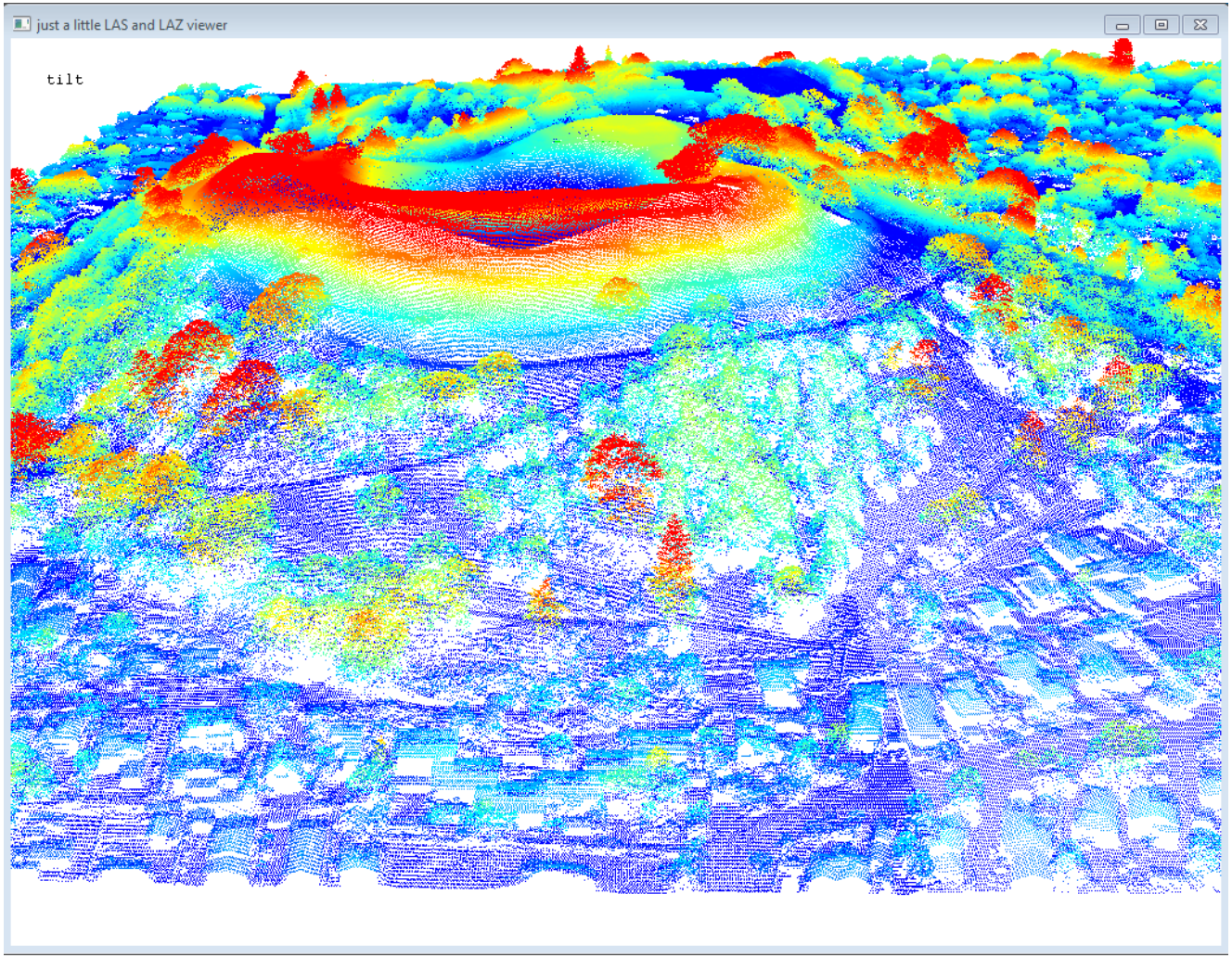
Flight info:
Altitude 900m, 1600m, 1000m
Scan frequency 36Hz, 45Hz, 42.9Hz

Average point spacing:
minimum 1.5 points per m2

Vertical accuracy: +/-0.1m

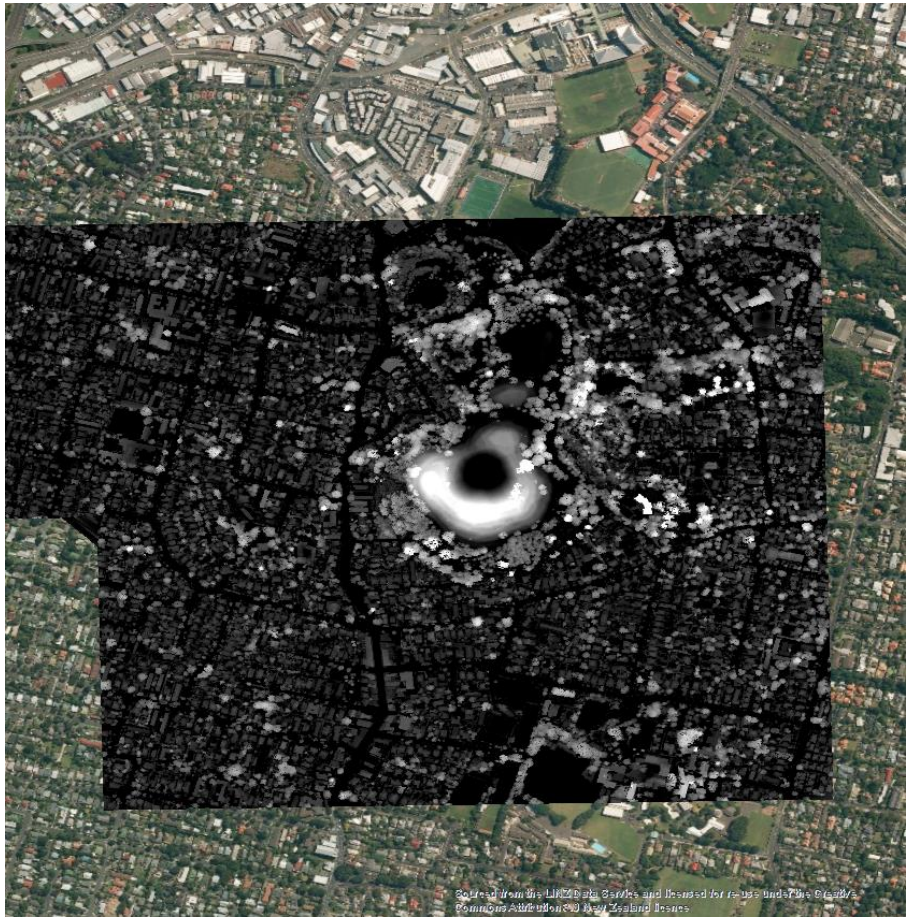


LiDAR data example

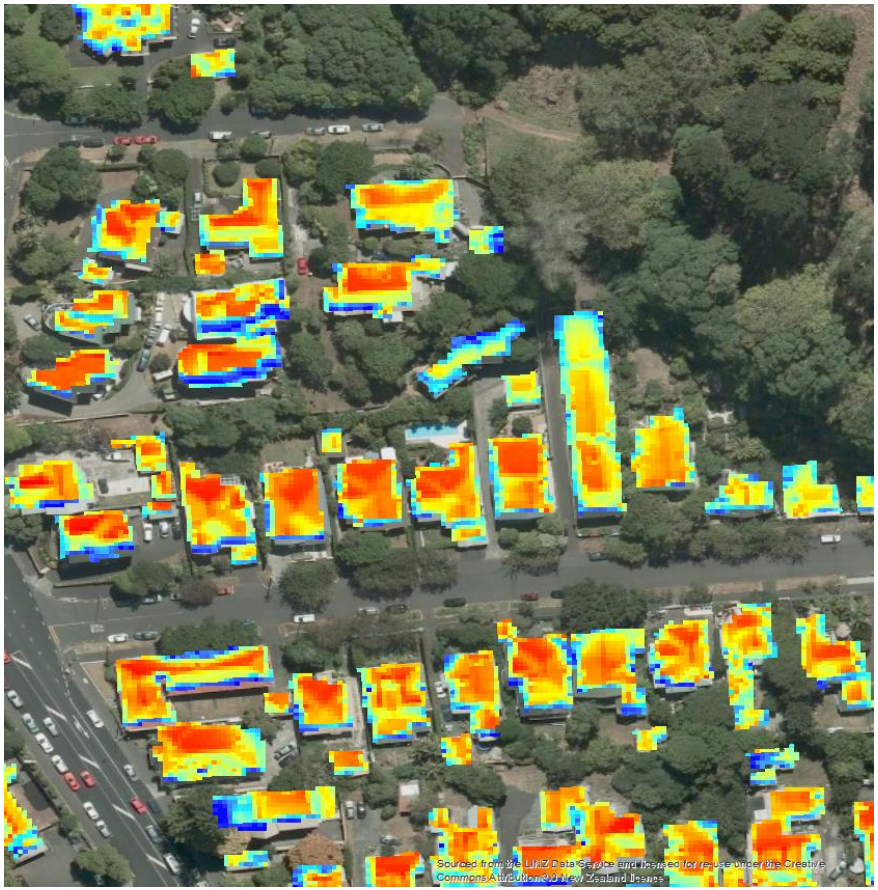


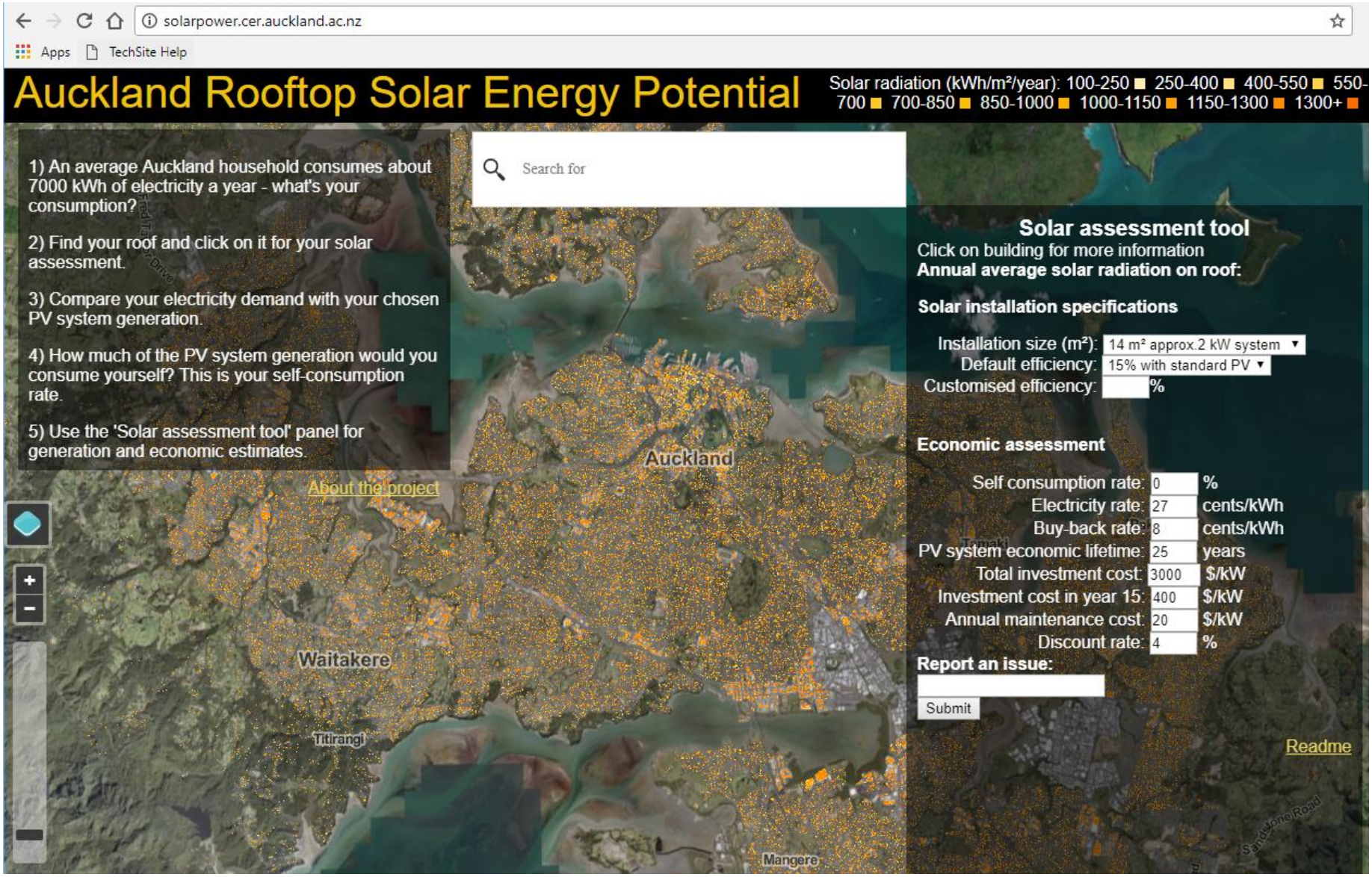
LiDAR -> Digital surface model

- Elevation data
- Resolution: 1 m^2



Solar potential





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Thank you!