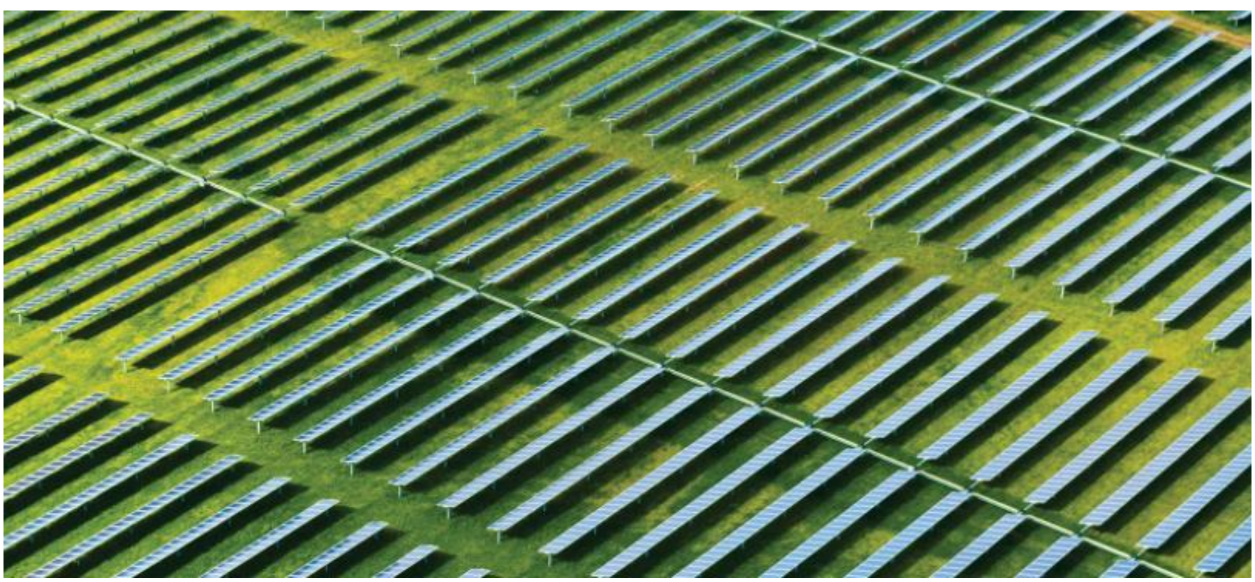
PURPOSE CAPITAL
IMPACT FUND

Solar

Research Paper

14th October 2021



Contents

1.0 Impact

1.1 Distributed generation – ICCC & Project Drawdown

Distributed generation

According to NZ's Interim Climate Change Committee Report: Accelerated Electrification - Evidence, analysis and recommendations - April 2019:

About 95% of distributed generation is from renewable sources such as wind, geothermal and hydro, and 'behind the meter' generation such as rooftop solar. These forms of decentralised generation play a role in reducing the amount of electricity that would otherwise have to be transmitted by the grid. This is particularly valuable when it can offset periods of peak demand when the grid is limited in some way (for example if a line fails during a storm).

For the above reasons, rooftop solar is a particularly interesting model given that it's part of a distributed generation model which is identified & ranked by Project Drawdown as number 10 out of the 80 solutions to climate change (Drawdown ranks solutions by Total Atmospheric CO2e Reduction [GT]).

Summary below from: Project Drawdown: Distributed Solar Photovoltaics

Rooftop solar panels are one example of distributed solar photovoltaic systems. Whether grid-connected or part of standalone systems, they offer hyper-local, clean electricity generation.

27.98–68.64	**$255–479.59**	**$7.89–13.53**
GIGATONS	**BILLION $US**	**TRILLION $US**
CO2 EQUIVALENT REDUCED / SEQUESTERED (2020–2050)	NET FIRST COST (TO IMPLEMENT SOLUTION)	LIFETIME NET OPERATIONAL SAVINGS

SOLUTION SUMMARY

Nineteenth-century solar panels were made of selenium. Today, photovoltaic (PV) panels use thin wafers of silicon crystal. As photons strike them, they knock electrons loose and produce an electrical circuit. These subatomic particles are the only moving parts in a solar panel, which requires no fuel and produces clean energy.

Small-scale solar systems, typically sited on rooftops, accounted for roughly 30 percent of PV capacity installed worldwide in 2015. In Germany, a leader in solar, rooftops boast 1.5 million systems. In Bangladesh, population 157 million, more than 3.6 million home solar systems have been installed.

Rooftop solar is spreading as the cost of panels falls, driven by incentives to accelerate growth, economies of scale in manufacturing, and advances in PV technology. Innovative end-user financing, such as third-party ownership arrangements, have helped mainstream its use. Yet, costs associated with acquisition and installation can be half the cost of a rooftop system and have not seen the same dip.

In grid-connected areas, rooftop panels can put electricity production in the hands of households. In rural parts of low-income countries, they can leapfrog the need for large-scale, centralized power grids, and accelerate access to affordable, clean electricity—becoming a powerful tool for eliminating poverty.

IMPACT:

Our analysis assumes that distributed solar photovoltaics can grow from 180 terawatt-hours of current electricity generation globally to a wide range of 6235–10100 terawatt-hours by 2050. This uncertainty of generation potential is linked to the different expectations of energy technologies on different future climate mitigation pathways intertwined with the role of electricity on the energy systems. That growth can avoid 27–69 gigatons of greenhouse gases emissions. With implementation costs reducing by the day, over the lifetime of distributed photovoltaic technologies, it could save US$7.9–13.5 trillion in associated operation, maintenance, and fuel costs.

1.2 Utility-Scale Solar Photovoltaics – Project Drawdown

Utility-Scale Solar Photovoltaics

Utility-Scale Solar Photovoltaics is a particularly interesting model given that it's identified & ranked by Project Drawdown as number 8 out of the 80 solutions to climate change (Drawdown ranks solutions by Total Atmospheric CO_2e Reduction [GT]).

Summary below from: Project Drawdown: Utility-Scale Solar Photovoltaics

Solar photovoltaics can be used at utility-scale—with hundreds or thousands of panels—to tap the sun's clean, free fuel and replace fossil-fuel electricity generation.

42.32–119.13	$-1.53–-0.29	$12.98–26.42
GIGATONS CO2 EQUIVALENT REDUCED / SEQUESTERED (2020–2050)	TRILLION $US NET FIRST COST (TO IMPLEMENT SOLUTION)	TRILLION $US LIFETIME NET OPERATIONAL SAVINGS

SOLUTION SUMMARY

The sun provides a virtually unlimited, clean, and free fuel at a price that never changes. Solar farms take advantage of that resource, with large-scale arrays of hundreds, thousands, or in some cases millions of photovoltaic (PV) panels. They operate at a utility scale like conventional power plants in the amount of electricity they produce, but dramatically differ in their emissions.

Solar farms can be found in deserts, on military bases, atop closed landfills, and even floating on reservoirs, deploying silicon panels to harvest the photons streaming to earth. Inside a panel's hermetically sealed environment, photons energize electrons and create electrical current—from light to voltage, precisely as the name suggests.

Bell Labs debuted silicon PV technology in 1954. At that time, photovoltaics cost more than US$1,900 per watt in today's currency. Since then, public investment, tax incentives, technology evolution, and brute manufacturing force have chipped away at the cost of creating PV, bringing it down to sixty-five cents per watt today.

In many parts of the world, solar PV is now cost competitive with or less costly than conventional power generation. In tandem with other renewables and enabled by better grids and energy storage, solar farms are ushering in the clean energy revolution.

IMPACT:

Currently just over 1 percent of global electricity generation is estimated to be from utility-scale solar PV. Our scenarios project that by 2050, this solution could represent 20–25 percent of the electricity generation mix, with generation levels of 9353–17740 TWh. We assume an implementation cost of $1733 per kilowatt and a learning rate of 21 percent. This results in cumulative first costs of US$3.4-5 trillion, but with a huge amount of lifetime operational savings of $13–26 trillion—one of the financial benefits of producing electricity without fuel. The significant increase of the solution use could avoid 44–119 gigatons of greenhouse gases emissions, depending on the climate mitigation ambition and electrification of demand-side sectors.

1.3 Agrivoltaics

1.3.1 Benefits of Agrivoltaics Across the Food-Energy-Water Nexus - NREL

The National Renewable Energy Laboratory (NREL) researchers express their thoughts on the benefits of agrivoltaics below.

Benefits of Agrivoltaics Across the Food-Energy-Water Nexus - NREL

Food and energy security need not be competing objectives. In fact, taking a holistic, integrated approach to food-energy-water decision making can increase resiliency of both food and energy systems.

In a recent article for Nature Sustainability, the U.S. Department of Energy's National Renewable Energy Laboratory's (NREL) Lead Energy-Water-Land Analyst Jordan Macknick and co-authors from the universities of Arizona and Maryland investigated the potential benefits of co-located agriculture and solar photovoltaic (PV) infrastructure (dubbed "agrivoltaics") on food production, irrigation water requirements, and energy production.

Building Resilient Systems

Across the globe, reductions in precipitation and rising air temperatures are increasing vulnerabilities in both the agricultural and energy sectors. Water scarcity concerns are shaping conversations and driving action in the agricultural sector while extreme weather events are impacting energy systems worldwide, reducing the reliability of energy generation. As such, the resilience of the global energy system is of growing importance. Drought-proof technologies such as wind and solar photovoltaics can satisfy both resilience and sustainability concerns.

However, studies of ground-mounted PV installations with gravel groundcover have found increased temperatures surrounding solar arrays, creating a "heat island" effect. This is particularly problematic due to PV panel sensitivities to temperature increases and resulting consequences for performance.

The business-as-usual approach to PV installations is to employ gravel as ground cover. Swapping the gravel for vegetation via strategic planting can help counter the heat feedback loop.

Novel Ecosystems

Applying a model derived from low-impact urban design, researchers looked to the concept of "novel ecosystems," and how they might benefit renewable energy and food production systems in dryland ecosystems. Researchers considered the possibility of co-located agriculture and solar PV infrastructure to maximize crop yields, minimize water use, and produce resilient, renewable energy.

To test their concept, researchers planted three common plants (chiltepin pepper, jalapeño, and cherry tomato), representative of three different dryland environments, beneath PV panels.

During the three-month growing season, they monitored light levels, air temperature, and relative humidity using sensors mounted above the soil surface. They also measured soil temperature and moisture at a depth of 5 centimeters. Both the control and agrivoltaic systems received the same irrigation in two testing scenarios: daily irrigation and irrigation every two days.

Implications for the Food-Energy-Water Nexus

While impacts varied by plant type, the researchers found that the agrivoltaic systems held promising implications for food production, water savings, and renewable energy production. The reduction in direct sunlight exposure beneath the PV panels led to cooler air temperatures during the day and warmer temperatures at night, which allowed the plants under the solar arrays to retain more moisture than the control crops that grew in open-sky planting areas.

Results from in the study include:

Food production

- *Total chiltepin fruit production was three times greater in the agrivoltaic system compared to the control*
- *Water-use efficiency for the jalapeño was 157% greater in the agrivoltaic system*
- *For the cherry tomato, water-use efficiency was 65% greater and total fruit production doubled in the agrivoltaic system*

Water savings

- *When irrigating every two days, soil moisture remained approximately 15% greater in the agrivoltaic system*
- *When irrigating daily, soil moisture in the agrivoltaic system remained 5% greater before the next watering*

Improved renewable energy production

- *Traditional ground-mounted PV panels were substantially warmer during the day than those with the plant-based understory*
- *The agrivoltaic PV panels were cooler during daytime hours compared to the traditional panel array by approximately 9°C, allowing for better performance.*

The co-location of PV and agriculture could offer win-win outcomes across many sectors, increasing crop production, reducing water loss, and improving the efficiency of PV arrays. Adopting such synergistic paths forward can help build resilient food-production and energy-generation systems.

As Macknick notes, "The promising results of this work have broad implications for how solar development and farming across the globe could be integrated to provide mutual benefits."

1.3.2 Agrophotovoltaic IRENA – Future of Solar

International Renewable Energy Agency (IRENA) researchers express their thoughts on agrivoltaics below.

AGROPHOTOVOLTAIC - IRENA Future of Solar Report

Agrophotovoltaic (APV) combines solar PV and agriculture on the same land and consists of growing crops beneath ground-mounted solar panels. Although the concept was proposed long ago, it has received little attention until recently, when several researchers have confirmed the benefits of growing crops beneath the shade provided by the solar panels. These include higher electricity production, higher crop yields and less water used (Beck, M. et al., 2019). APV is a win-win situation for both crops and the solar panels. Many types of food crops, such as tomatoes, grow better in the shade of solar 4 http://solarheateurope.eu/2018/04/30/increasingly-popular-heat-and-power-from-the-same-roof/. *panels, as they are spared from the direct sun and experience less water loss via transpiration, which also reduces water use while maintaining the same level of food production. A key advantage for solar panels is that their efficiency is increased. Cultivating crops underneath reduces the temperature of the panels, as they are cooled down by the fact that the crops below are emitting water through their natural process of transpiration (Hanley, S., 2019). The project "Agrophotovoltaics – Resource-Efficient Land Use (APV-RESOLA)" has tested the APV concept, showing a land use efficiency of 160% in 2017 and 186% in 2018 and thus confirming earlier research results.*

The project is located in Germany, near Lake Constance, and consists of a 194 kW solar system on a 5 metre high structure above land used to grow celery, clover, potatoes and winter wheat (Tsanova, T., 2019). The project results show that in 2018 land use efficiency increased, with yields from three of the four crops grown under the panels achieving above the reference yield thanks to the shade under the solar modules, which helped them to better resist the dry conditions in 2018. In fact, solar irradiation beneath the PV system was approximately 30% less than the reference field, the soil temperature was lower even if the air temperature remained the same and the soil moisture was kept higher than the reference field in summer and lower in winter months. The project confirmed the applicability of APV in arid regions (given the exceptionally hot and dry conditions of 2018), especially in developing countries; it also calls for the exploration of APV's applicability under other climate conditions and with other types of crops (Tsanova, T., 2019).

1.3.3 Nature.com - Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands

Abstract from research paper off Nature.com: Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands

The vulnerabilities of our food, energy and water systems to projected climatic change make building resilience in renewable energy and food production a fundamental challenge. We investigate a novel approach to solve this problem by creating a hybrid of colocated agriculture and solar photovoltaic (PV) *infrastructure. We take an integrative approach—monitoring microclimatic conditions, PV panel temperature, soil moisture and irrigation water use, plant ecophysiological function and plant biomass production within this 'agrivoltaics' ecosystem and in traditional PV installations and agricultural settings to quantify trade-offs. We find that shading by the PV panels provides multiple additive and synergistic benefits, including reduced plant drought stress, greater food production and reduced PV panel heat stress. The results presented here provide a foundation and motivation for future explorations towards the resilience of food and energy systems under the future projected increased environmental stress involving heat and drought.*

1.3.4 Fitch Solutions Country Risk & Industry Research - Agrivoltaics

Agrivoltaic Systems Gaining Momentum Globally

Key View:

- *We expect agrivoltaic systems will gain traction globally over the coming years, with total installed capacity set to exceed 10GW+ by 2030.*
- *This will be driven by the several benefits of the co-location of solar power projects and agriculture. These include the creation of dual-revenue streams, the high suitability for areas with land use constraints, the creation of a beneficial microclimate and a potential reduction in operation and maintenance costs.*

1.3.5 Fraunhofer ISE – Agrivoltaics

Below excerpt from Fraunhofer Institute for Solar Energy Systems (ISE) – Agrivoltaics

Agrivoltaics denotes approaches to use agricultural areas simultaneously to produce food and to generate PV electricity. In this way, Agrivoltaics increases land-use efficiency and enables PV capacity to be expanded while still retaining fertile arable areas for agriculture.

Agrivoltaics technology has developed very dynamically in recent years and can be found in almost all regions of the world. The installed Agrivoltaics power increased exponentially from app. 5 MW in 2012 to app. 2.9 GW in 2018, with national funding programmes in Japan (since 2013), China (ca. 2014), France (since 2017), the USA (since 2018) and most recently Korea.

Quick-Facts: Agrivoltaics

- *Global installed power of app. 2.9 GW*
- *Technical potential in Germany of app. 1700 GWp*
- *Advantages:*
    - *enormous land area potential*
    - *less expensive than small rooftop PV systems*
    - *Additional benefits for agriculture including protection against losses due to hail, frost and drought*
- *Challenges:*
    - *dual land usage not foreseen in legal framework*
    - *no rights to EU agricultural subvention for farmers*
    - *no feed-in tariff according to the German renewable energy law*

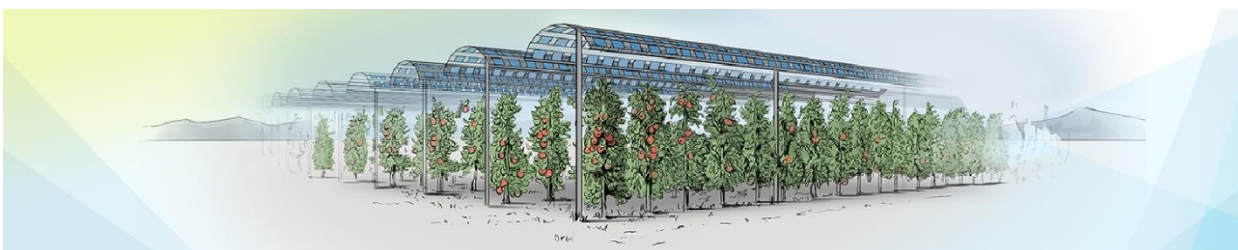


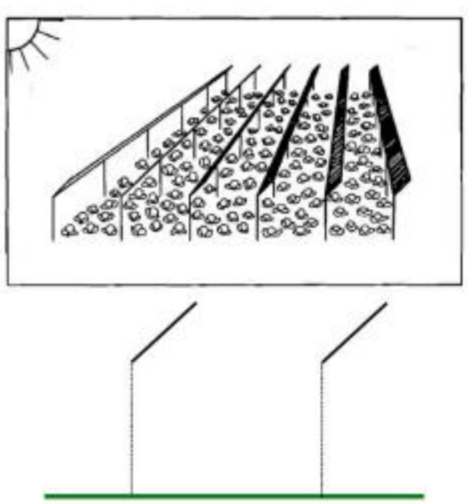
Image: The Agrivoltaic plant near Lake Constance in Heggelbach, Germany. Double usage of agricultural areas allows photovoltaics to be installed over fertile areas without eliminating these resources.

1.3.6 Agrivoltaics Report – MDPI Italian National Agency for New Technologies, Energy and Sustainable Economic Development, ENEA

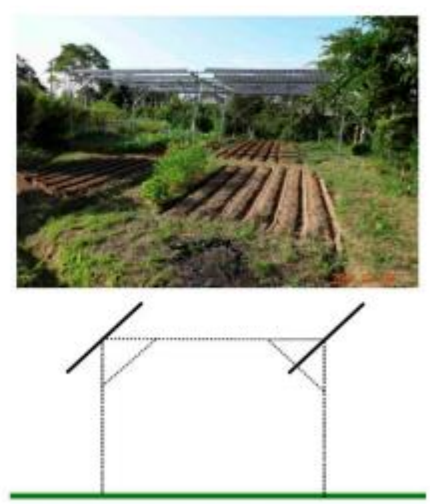
The **Italian government has committed €1.1bn to agrivoltaics** and expects to deploy 2 GW of agrivoltaics.

Below is the abstract along with several illustrations of Agrivoltaics from the report, Agrivoltaic Systems Design and Assessment: A Critical Review, and a Descriptive Model towards a Sustainable Landscape Vision (Three-Dimensional Agrivoltaic Patterns), commissioned by the Italian National Agency for New Technologies, Energy and Sustainable Economic Development, ENEA.

Abstract: As an answer to the increasing demand for photovoltaics as a key element in the energy transition strategy of many countries—which entails land use issues, as well as concerns regarding landscape transformation, biodiversity, ecosystems and human well-being—new approaches and market segments have emerged that consider integrated perspectives. Among these, agrivoltaics is emerging as very promising for allowing benefits in the food–energy (and water) nexus. Demonstrative projects are developing worldwide, and experience with varied design solutions suitable for the scale up to commercial scale is being gathered based primarily on efficiency considerations; nevertheless, it is unquestionable that with the increase in the size, from the demonstration to the commercial scale, attention has to be paid to ecological impacts associated to specific design choices, and namely to those related to landscape transformation issues. This study reviews and analyzes the technological and spatial design options that have become available to date implementing a rigorous, comprehensive analysis based on the most updated knowledge in the field, and proposes a thorough methodology based on design and performance parameters that enable us to define the main attributes of the system from a trans-disciplinary perspective



(a) Conceptualization designed by Goetzberger and Zastrow (1981)



(b) First model developed by Akira Nagashima in Japan (2004)

(**a**) Structure 4 m above the ground (**b**) Mono-crystalline PV arrays (**c**) Single-axis sun tracking system

Figure 3. Experimental agrivoltaic system in Montpellier, France. © C. Dupraz.

(**a**) Heggeslbach (Germany) (**b**) Heggeslbach (Germany) (**c**) Curacaví (Chile)

Figure 4. Experimental agrivoltaic systems installed by Fraunhofer ISE in Germany (**a**,**b**) and Chile (**c**). © Fraunhofer ISE.

(**a**) Pionlec (France) (**b**) Castelvetro (Italy) (**c**) Babberich (Netherlands)

Figure 5. First demonstrator projects developed by the following companies: Sun'agri in France (**a**), REM Tec in Italy (**b**) and BayWa r.e. in the Netherlands (**c**). © Sun'agri (**a**), REM Tec (**b**), BayWa r.e. (**c**).

(**a**) ICAR-Central Arid Zone Research Institute, Jodhpur (India)

(**b**) Aravali foothills, north Gujarat state (India)

(**c**) Hybrid Agrivoltaic System Showcase, Putra University (Malaysia)

Figure 6. Research pilot plants with low height PV mounting system. © P. Santra (**a**), B. Patel (**b**), N.F. Othman (**c**).

(**a**) Agrinergie system, Pierrefonds, Reunion Island (France)

(**b**) Next2Sun vertical system, Guntramsdorf (Austria)

(**c**) Next2Sun vertical system, Baden-Wurttemberg (Germany)

Figure 7. Commercial plants with ground-based PV mounting system. © Akuo Energy (**a**), Next2Sun GmbH (**b**,**c**).

(**a**) Fixed with different layouts

(**b**) Dynamic

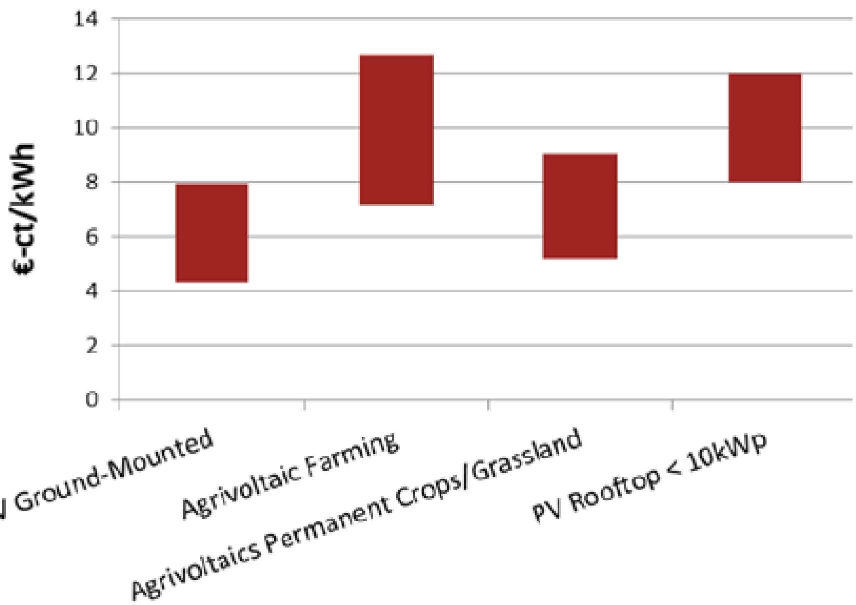
(**c**) Innovative PV solution

Figure 8. Approaches to integrate PV into greenhouse's envelope. © A. Yano [47] (**a**), A. Marucci [75] (**b**), M. E. Loik [87] (**c**).

1.3.7 Fraunhofer ISE - Agrivoltaics Guidelines for Germany – October 2020

[Fraunhofer ISE - Agrivoltaics Guidelines for Germany – October 2020]

Figure 30: Estimated average levelized cost of electricity (LCOE) for ground mounted photovoltaic systems and agrivoltaics, representation by Fraunhofer ISE, data from [3, 4, 23, 24]



1.3.8 Resources and Articles on Agrivoltaics

- First agrivoltaic research facility for carbon-neutral orcharding in Germany – Inceptive Mind
- Solar PV Magazine – AgriVoltaics Articles
- Agrivoltaics for strip farming – Solar PV Magazine

  Agrivoltaics for strip farming

  Vattenfall is leading a Dutch consortium in a research project to assess whether agrivoltaics is also compatible with strip cropping. The company's head of Solar Development NL, Annemarie Schouten, spoke with pv magazine about the first 0.7 MW pilot project under development in the northern Dutch province of Flevoland.

- Agrivoltaics to protect crops from heavy rainfall – Solar PV Magazine

  Agrivoltaics to protect crops from heavy rainfall

  BayWa r.e. and the Fraunhofer Institute for Solar Energy Systems ISE have built a 258 kW agrivoltaic system that hosts apple cultivation under four different crop protection systems. The system utilizes agrivoltaic technology with permanent, light-permeable PV modules that block rain, and tracking PV module tech that blocks rain only if necessary.

- Agrivoltaics for viticulture – Solar PV Magazine

  Agrivoltaics for viticulture

  French specialist Sun'Agri installed a pilot facility on five hectares in southern France in 2018. Its goal is to protect the vines from weather hazards and to improve the quality of the wine by lowering its alcohol content. The first harvest took place in mid-September.

- [Transparent solar panels for agrivoltaics – Solar PV Magazine]
  Transparent solar panels for agrivoltaics
  Romande Energie and Swiss research institute Agroscope are testing startup Insolight's transparent PV panels in an agrivoltaic project. The modules are replacing the plastic covers used to grow strawberries and raspberries.
  

- [French PV companies set up agrivoltaics association – Solar PV Magazine]
  French PV companies set up agrivoltaics association
  Sun'Agri, REM Tec, Kilowattsol and Altergie Développement et Râcines have announced the creation of France Agrivoltaisme, the world's first association for the promotion of agrivoltaics.
  

- Italy devotes €1.1bn to agrivoltaics, €2bn to energy communities and storage – Solar PV Magazine

  Italy devotes €1.1bn to agrivoltaics, €2bn to energy communities and storage

  The funds will be part of the EU Covid-19 recovery package. Overall, the Italian government expects to deploy 2 GW of agrivoltaics and 2 GW through energy communities.
- Agrivoltaics have an average LCOE of €0.093 per kWh in Germany

  Agrivoltaics have an average LCOE of €0.093 per kWh in Germany

  According to new guidelines by Germany's Fraunhofer ISE, agrivoltaic projects are already competitive with other renewable energy sources today. The lack of a proper regulatory framework, however, is currently preventing the dual use of arable land for food production and power generation from becoming a mainstream solution.

- Fraunhofer ISE – Agrivoltaics
- AgriInvestor.com – Fitch: More than 10GW of agrivoltiac capacity to be added by 2030
- YouTube Video: Just Have a Think - Agrivoltaics. An economic lifeline for American farmers?
- YouTube Video: Undecided with Matt Ferrell - Solar Panels Plus Farming? Agrivoltaics Explained
- The Fifth Estate - Agrivoltaics: growing opportunities for Aussie farmers
- Fraunhofer ISE - APV Guidelines for Germany – October 2020

1.3.9 PC Summary of Agrivoltaics

- Recognising that heading into the future we need to better utilise land, agrivoltaics provides a platform for the dual use of land.
- Benefits of Agrivoltaics could/may include:
    - land use efficiency,
    - higher crop yields (particularly in arid regions),
    - improve solar pv generation (cooler panels due to crops),
    - relevant to: dairy, grazing, apples, berries, grapes, other crops, etc,
    - protection from rain, hail, frost, etc,
    - water savings,
    - increase in per hectare returns for farmers &/or generators
- Lodestone appears to be the only utility scale solar farm in NZ going down the Agrivoltaics route making them the pioneers in this space in NZ.
- It is likely that Lodestone will build their solar arrays and that horticulturists &/or agriculturists will have an opportunity to lease the land off Lodestone and adapt their farming methods to best utilise/leverage Lodestone's solar infrastructure. Acknowledging that solar pv is going to play an increasingly important part of NZ's electricity generation profile, This presents an opportunity for NZ farmers/growers to innovate using agrivoltaics to improve farming/growing practises &/or improve per hectare returns.

1.4 Life Cycle Assessment of Solar

1.4.1 Carbon Footprint of Solar in NZ – Ecotricity domestic solar (via Solarcity/SolarZero products)

Ecotricity is a NZ electricity retailer that offers a carbon neutral certified electricity. For the year (01/04/2019 - 31/03/2020) their solar emissions were **0.0503 kgCO2e per kWh for domestic solar product** based on a weighted average of generation for each facility/type.

Table 3: Product carbon footprint summary by lifecycle activity for solar

Post Audit Totals		
Upstream	0.038	$kgCO_2e$/kWh
Core	0.013	$kgCO_2e$/ kWh
Downstream [2]	0	$kgCO_2e$/ kWh
Total inventory:	**0.0503**	**$kgCO_2e$/ kWh**

How does this compare to their other forms of renewable generation?

Ecotricity's product emissions for the year (01/04/2019 - 31/03/2020) were **0.0066 $kgCO_2e$ per kWh for hydro** (average across all generation at Pioneer Generation's Monowai, Roaring Meg and Teviot hydro generation facilities) and emissions were **0.0071 $kgCO_2e$ per kWh for wind** (average across Pioneer Generation's Flat Hill and Mt Stuart wind farms.

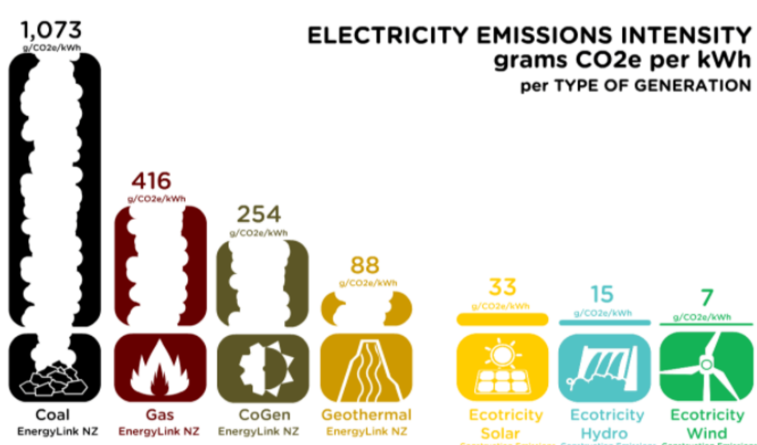
Table 1: Product carbon footprint summary by lifecycle activity for hydro (weighted average across selected generation sites)

Post Audit Totals		
Upstream	0.0025	$kgCO_2e$/kWh
Core	0.0032	$kgCO_2e$/ kWh
Downstream	0.00102	$kgCO_2e$/ kWh
Total inventory:	**0.0066**	**$kgCO_2e$/ kWh**

Table 2: Product carbon footprint summary by lifecycle activity for wind (weighted average across selected generation sites)

Post Audit Totals		
Upstream	0.0067	$kgCO_2e$/kWh
Core	0.0008	$kgCO_2e$/ kWh
Downstream	-0.0026	$kgCO_2e$/ kWh
Total inventory:	**0.0071**	**$kgCO_2e$/ kWh**

Figure: NZ Thermal Generation Emissions vs Ecotricity Construction Emissions



** Data Source: Energy Link NZ 12 months emissions 2020

1.4.2 Carbon Footprint of Solar in NZ – Emissions Accounting for Trust Horizon's Proposed Rooftop PV Installation – Trust Horizon / EPECentre Report

Below features an excerpt from the Executive Summary of the Electric Power Engineering Centre's (EPECentre of the University of Canterbury) Report titled: "Emissions Accounting for Trust Horizon's Proposed Rooftop PV Installation"

This report focuses on the benefits of installing a residential-scale or small commercial rooftop photovoltaic (PV) system both financially and in terms of the amount of carbon emissions offset.

The embedded emissions for rooftop PV systems installed in New Zealand were assessed using published database inventories and adjusted for New Zealand's location and electricity mix. ***PV systems using multi-silicon panels were found to have emissions in the order of 48 gCO2-e/kWh over the system's lifetime****. This is approximately a third smaller embedded emissions compared to* ***mono-silicon panels (71 gCO2-e/kWh) for the 3 kWp reference system****. Lower embedded emissions for multi-silicon panels are due to lower energy requirements at the ingot formation stage.* ***As the PV installation size increases, a gradual decrease in embedded emissions per kW peak is expected.*** *In the future,* ***PV embedded emissions are expected to decrease as cleaner energy is used in their manufacture. Additionally new technology is on the horizon with lower energy requirements such as perovskite-based solar cells that could provide a further pathway to PV sources with lower embedded emissions.***

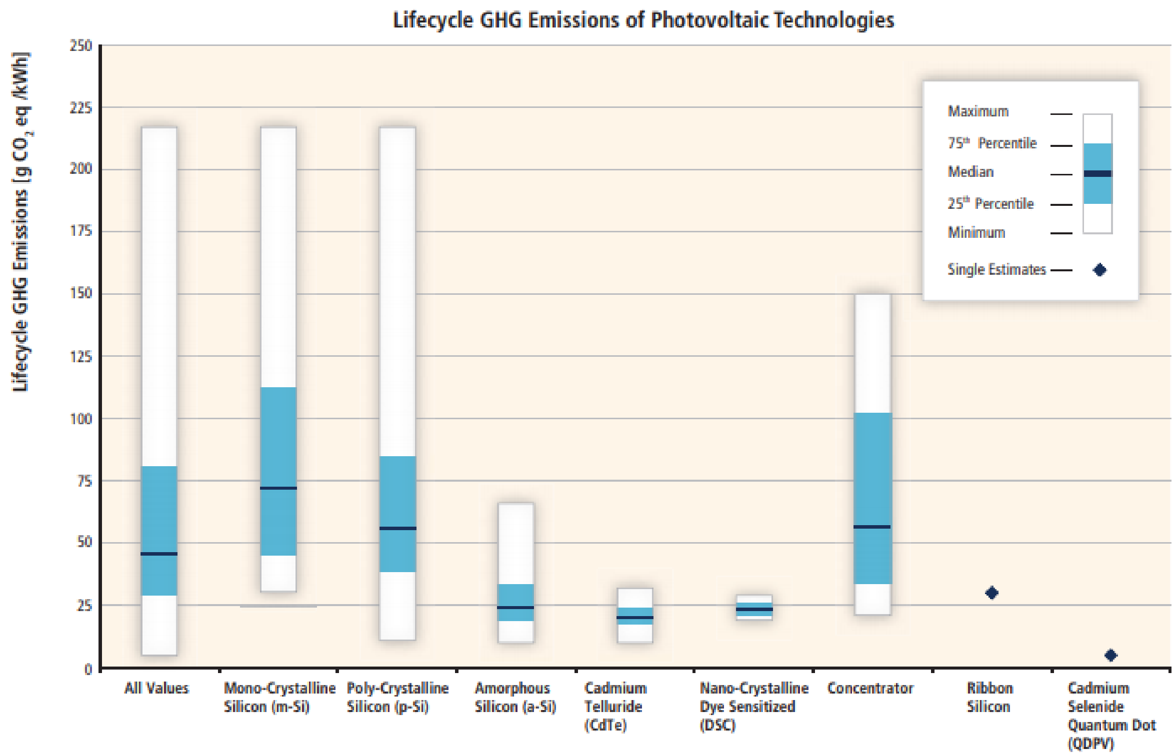
PV's ability to offset carbon emissions in New Zealand with an already high renewable proportion is open to debate. It is the view taken here however, that PV generation should be offset against marginal generation, the last and typically most expensive generation to be despatched. Natural gas power plants meet this criteria and are a non-renewable generation source that is anticipated to be required to balance the electricity mix for decades to come. ***Lifecycle PV emissions are an order of magnitude lower than the operational emissions of natural gas ~ 427 gCO2-e/kWh. PV installations were able to offset their embedded emissions in three to four years and had the potential to offset 13-14 tonnes of CO2-e/kWp over their thirty-year lifetime.***

Financially the small commercial PV systems are expected to provide a positive Net Present Value, assuming an estimated system cost of NZ$2.6/Wp, and application of the Treasury prescribed discount rate of 5%. The solar generation profile matches Trust Horizon's load profile well, providing high self-consumption, the best route to profitability with low buy-back rates for excess generation. The smallest PV system had the shortest payback times and highest rate of return. Given that the larger PV installations are more attractive from an emissions offset point of view, a more mid-size PV installation in the 6 kWp to 12 kWp range may provide a balance between financial return and carbon emissions offset.

1.4.3 Lifecycle GHG Emissions of Solar pv Technology - IPCC

The Intergovernmental Panel on Climate Change (IPCC) has conducted research that allows us to compare the CO2e emissions footprint of solar relative to other forms of generation.

Figure: IPCC: Lifecycle GHG Emissions of Photovoltaic Technologies



	All Values	m-Si	p-Si	a-Si	CdTe	DSC	Concentrator	Ribbon Silicon	QDPV
Estimates:	124	30	56	12	13	4	6	2*	1
References:	26	9	15	3	3	1	2	2	1

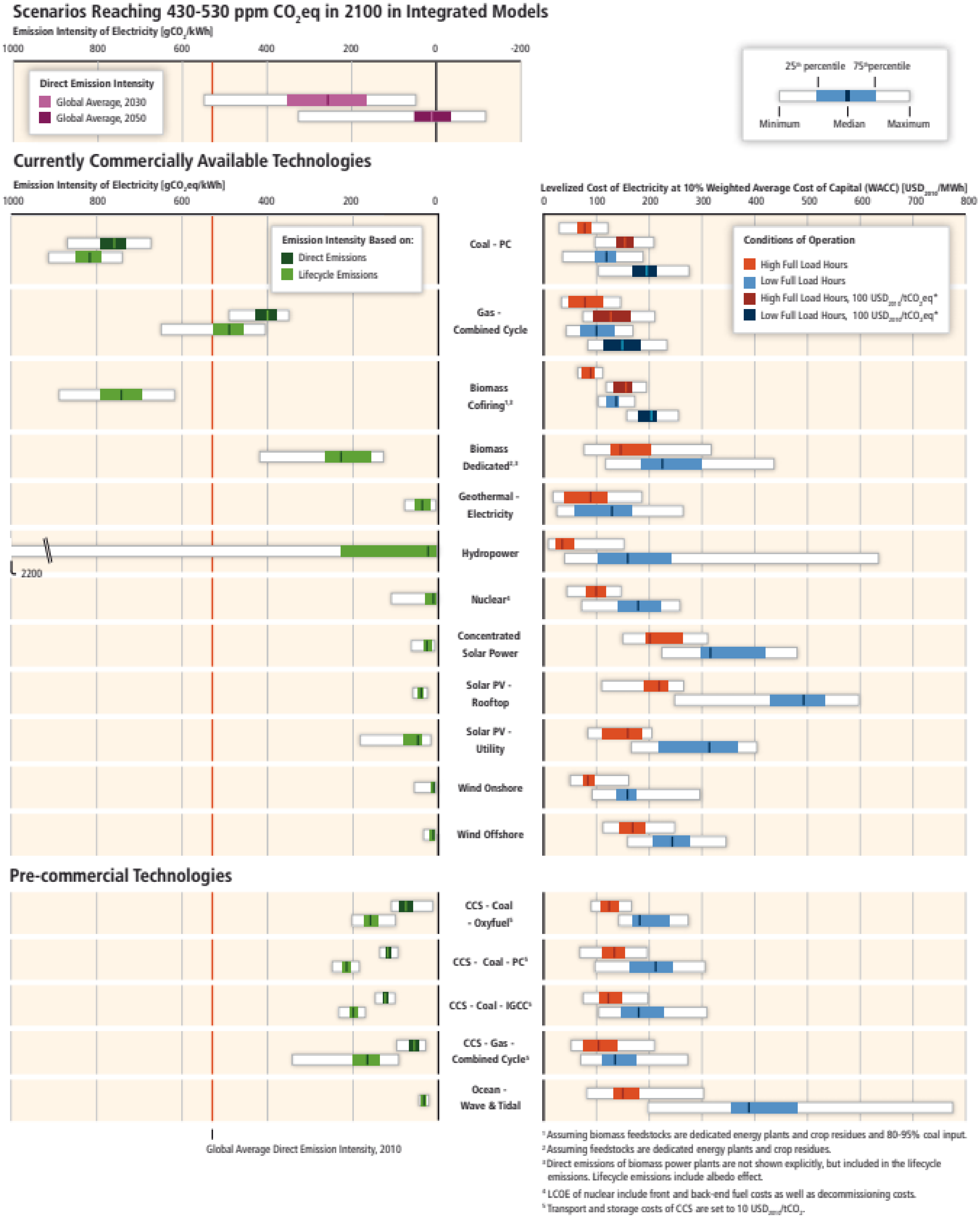
*same value

Figure 3.14 | Lifecycle GHG emissions of PV technologies (unmodified literature values, after quality screen). See Annex II for details of the literature search and citations of literature contributing to the estimates displayed.

1.4.4 CO2e Emissions Footprint of Solar relative to other forms of Generation - IPCC

The Intergovernmental Panel on Climate Change (IPCC) has conducted research that allows us to compare the CO2e emissions footprint of solar relative to other forms of generation.

Figure: IPCC: Emission intensity of electricity [gCO2 eq/kWh] of currently commercially available technologies



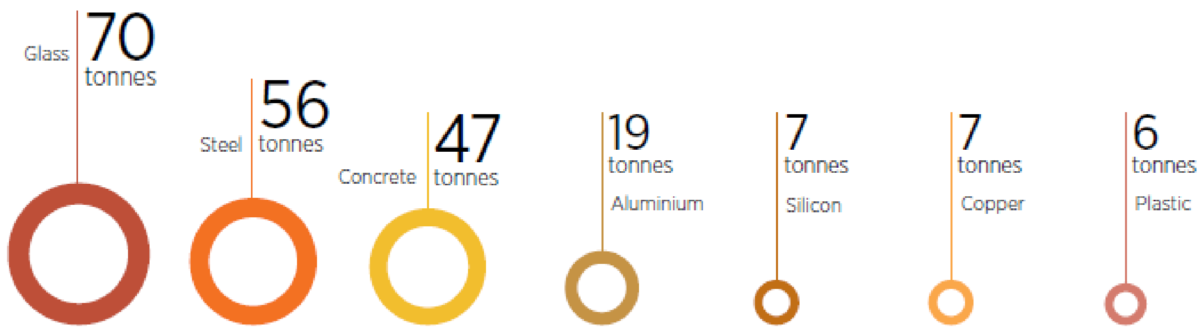
1.4.5 Solar End of Life – Kea Energy

Kea Energy own and operate a 2MW solar farm in Marlborough and claim *"Our intention is to keep the panels as long as economical and then sell on to hobbyists, for up-cycling."*

1.4.6 Materials required for a Solar PV Plant - IRENA

The International Renewable Energy Agency (IRENA) research on the [Materials required for a 1MW solar PV plant](#) below.

Figure: [Materials required for a 1MW solar PV plant - IRENA](#)



Source: IRENA (2017b).

1.4.7 What It Takes To Realize a Circular Economy for Solar Photovoltaic System Materials - NREL

One of the major concerns with solar is the materials involved in the manufacturing of the panels and what happens to the panels at the end of their life. The National Renewable Energy Laboratory (NREL) analysts express their thoughts on this topic below.

What It Takes To Realize a Circular Economy for Solar Photovoltaic System Materials

NREL Analysts Advance Understanding of Options, Opportunities To Repair, Reuse, or Recycle Solar Photovoltaic System Materials

April 2, 2021

Rapidly increasing solar photovoltaic (PV) installations has led to environmental and supply chains concerns. The United States relies on imports of raw materials for solar module manufacturing and imports of PV cells and modules to meet domestic demand. As PV demand increases, so will the need to mine valuable materials—a motivation for domestic reuse and recycling.

Moreover, decommissioned PV modules could total 1 million tons of waste in the United States by 2030, or 1% of the world's e-waste. This presents not only waste management concerns but also opportunities for materials recovery and secondary markets.

"Responsible and cost-effective management of PV system hardware is an important business and environmental consideration," said Taylor Curtis, sustainability analyst at the National Renewable Energy Laboratory (NREL). "Repair, reuse, or recovery of this equipment would reduce negative environmental impacts, reduce resource constraints, and stimulate U.S. economic growth."

Curtis and a team of NREL researchers have been leading ongoing analysis of how to manage retiring PV modules in support of the laboratory's vision of a circular economy for energy materials. The team conducted legal- and literature-based research and interviewed solar industry stakeholders, regulators, and policymakers. They published a series of NREL technical reports, narrowing in on options and opportunities for PV equipment reuse and recycling.

Technical, Economic, and Regulatory Factors for a PV Circular Economy

Today, there is little incentive for private industry to invest in PV recycling, repair, or reuse due to current market conditions and regulatory barriers. In the United States, only one manufacturer has implemented a "takeback" program to reuse or recycle retired PV modules. Although there are a growing number of U.S. third-party recyclers that accept PV modules, most companies only recover bulk material and leave behind high-value materials such as silver, copper, and silicon—according to one report in the study.

In the future, the U.S. industry for recovered PV materials from modules alone could total $60 million by 2030 or $2 billion by 2050. PV equipment recycling could increase supply chain stability and resource security, decrease manufacturing costs, enhance a company's green reputation, provide new revenue streams, add tax benefits, and create American jobs.

To help spur private investment in the early stages of new and expanded PV market opportunities, the analysts recommend government-funded R&D and analysis to help relieve some of the market and regulatory uncertainty associated with the reuse and end-of-life PV options. R&D could focus on designing PV modules to be more easily repaired, reused, or recycled, as well as on the associated cost-effective services and business models.

Policy is also critical to a PV circular economy, ensuring the safe handling, storage, treatment, transport, reuse, recycling, and disposal of PV equipment. However, NREL analysts found that existing interconnection, fire, building, and electrical regulations in the United States could directly prohibit reusing PV modules or inverters for grid-tied applications.

In the United States, PV equipment such as modules that are destined for resource recovery are often regulated the same way as equipment destined for disposal. Therefore, there is no incentive to recycle, especially when disposal costs less. Used PV equipment that is accumulated or stored before recycling or disposal may be regulated as solid waste or hazardous solid waste. U.S. waste laws vary by jurisdiction and mandate specific handling, storage, and transport requirements. Transporters of PV equipment may *be subject to U.S. Department of Transportation hazardous materials regulations with specific packaging, documentation, and other transit-related related requirements. If PV equipment is shipped abroad, it may be subject to international treaty requirements and export regulations.*

Based on their analysis, the NREL team recommends a multifaceted regulatory approach that places responsibility across the value chain. Consistent, clearly defined federal, state, and local regulations could mandate and incentivize secondary markets. These laws could prohibit disposing PV modules, provide an exemption from stringent regulation, or require reuse. For example, Washington state has a policy that requires PV manufacturers to take back or recycle modules at no cost to consumers. It also allows modules to be regulated under less-stringent solid waste requirements if they are recycled.

Best Practices for End-of-Life PV Management

In another report in the research effort, NREL analysts dig deeper into alternatives for managing retiring PV systems. The best option for each system that is being decommissioned is determined by estimated costs to refurbish or repower, and the projected revenue from continued operations.

If a system is operational and has not suffered extensive damage, it might be possible to extend the performance period. This involves extending permits and the utility and interconnection agreement. While there is no capital investment with this option, there are higher operation-and-maintenance costs to repair aged equipment.

Refurbishment is an option with detailed physical and electrical inspections and necessary repairs. This could cost about $500 per kilowatt. If a system has suffered storm damage, the cost could exceed $750 per kilowatt. Refurbishment is more difficult because parts of old systems are increasingly hard to find and operation-and-maintenance providers may not have the expertise to work with older systems.

Some older PV systems can be repowered. This entails redesigning the system and installing a new PV array and inverter(s) to rebuild or replace the power source. Repowering often costs 80% of the total plant value. A repowered PV system is new in almost all respects and can leverage existing land-use, permitting, utility interconnections, and power purchase prices.

If it does not make economic sense to repair or refurbish a system, decommissioning might be the right option. This entails removing the PV module and other equipment and restoring the land or roof to the original condition. This ranges from $300 per kilowatt to $440 per kilowatt.

Tax implications can also drive decisions because contracts are often structured so that projects are eligible for tax credits and depreciation.

What Is the Current State of U.S. Policies and Initiatives for PV Recycling?

A final report in the series analyzes federal and state regulations (existing, pending, and historic) that explicitly address PV module recycling in the United States.

The analysts did not find any federal statutes or regulations that explicitly address PV module recycling. However, state- and industry-led policies have started to emerge related to end-of-life PV management concerns. These state- and industry-led policies use their own frameworks tailored to specific options for retiring PV modules and thereby impact different parts of the solar value chain.

Some states, such as New Jersey and North Carolina, passed laws in 2020 to require the study of end-of-life PV management options to help develop options for legislative or regulatory considerations. This research could also provide valuable, publicly available information about the costs and liabilities associated with PV recycling and resource recovery opportunities. In addition, California has enacted universal waste regulations, which address the end-of-life management, transport, storage, accumulation, and treatment of discarded PV modules.

As of May 2020, Hawaii has pending legislation that would require a comprehensive study of issues related to PV module recycling and end-of-life management. Rhode Island has pending legislation that, if enacted, would create a PV module manufacturer stewardship and takeback program. California also has pending legislation to study and recommend policies that would ensure PV module reuse or recycling at end of life.

Learn More

"A circular economy for solar PV materials will involve everyone across the value chain, from project owners and financiers to manufacturers," Curtis said. "Together, the industry can ensure that liabilities like hazardous materials are avoided and end-of-life management extracts the most economic value and makes the least environmental impact possible." Learn more about NREL's vision for a circular economy for energy materials.

1.4.8 End of Life Management of Solar PV - IRENA

The International Renewable Energy Agency (IRENA) perspective on the end-of-life management of solar pv below.

END-OF LIFE MANAGEMENT OF SOLAR PV

Despite the growth of solar PV and its bright future, the sun sets on even the best panels. As the global PV market increases, so will the need to prevent the degradation of panels and manage the volume of decommissioned PV panels. The sections below explore innovative and alternative ways to reduce material use and module degradation, and opportunities to reuse and recycle PV panels at the end of their lifetime. The framework of a circular economy and the classic waste reduction principles (reduce, reuse and recycle) can also be applied to PV panels.

REDUCE: MATERIAL SAVINGS IN PV PANELS

The best option is to increase the efficiency of panels by reducing the amount of material used. Whilst the mix of materials has not changed significantly, efficient mass production, material substitutions and higher-efficiency technologies are already happening thanks to strong market growth, scarcity of raw materials and reduction of PV panel prices. Research is progressing towards reducing the amount of hazardous materials, as well as minimising amount of material per panel to save costs. PV material *availability is not a major concern in the near term, although critical materials might impose limitations in the long term. In addition, higher prices will improve the economics of recycling activities and drive investment for more efficient mining processes, such as extraction of metals used in the PV manufacturing process (i.e. silver, aluminium, copper and tin). R&D for PV is focusing on reducing or substituting different components used for solar PV panels, namely: c-Si panels (glass, silicon, etc.), CIGS panels (glass, polymer, aluminium, etc.) and CdTe panels (glass, polymer, nickel, etc.) (IRENA and IEA-PVPS, 2016).*

REUSE: REPAIRING PV PANELS

Most PV systems were installed in the last six years. A six-year-old panel today has aged by an equivalent of 20% of its expected average lifetime of 30 years (IRENA and IEA-PVPS, 2016). If flaws and imperfections are discovered during the early phase of a PV panel's life, customers can claim guarantees for repair or replacement and insurance companies may be involved to compensate for some or all of the repair/replacement costs. When replacement happens, quality tests to check electrical safety and power output – such as flash test characterisation and a wet leakage test – can be undertaken to recover some value from a returned panel through resale. Repaired PV panels can also be resold as replacements or as used panels at a reduced market price of approximately 70% of the original sales price, and partly repaired panels or components might be sold on the second-hand market (IRENA and IEAPVPS, 2016).

RECYCLE: DECOMMISSIONING AND TREATMENT OF PV PANELS

Future waste management of installed PV systems largely depends on their type and size. For example, whilst the small and highly dispersed nature of rooftop PV systems can add significant costs to dismantling, collection and transport of expired PV panels, waste management of large utility-scale PV applications is logistically easier. Currently PV waste quantities are very moderate, which reduces the economic incentive to create dedicated PV panel recycling plants. End-of-life PV panels are therefore typically processed in existing general recycling plants. However, in the long run constructing dedicated PV panel recycling plants could increase treatment capacity and maximise revenues thanks to better output quality, and could also increase the recovery of valuable constituents. Recycling technologies for PV panels have already been researched for the past 15 years and now the main challenge is to keep abreast of ongoing cell and panel innovations to obtain the best possible results at acceptable costs (IRENA and IEA-PVPS, 2016).

*Given the estimated growth of PV panel waste volumes, the management of end-of-life PV panels is worth examining, along with the associated **socioeconomic and environmental benefits** (IRENA and IEA-PVPS, 2016). The value creation stemming from end-of-life PV management involves:*

- ***Unlocking raw materials and their value**. The extraction of secondary raw materials from endof-life PV panels could create important value for the industry. PV panels have an average lifetime of 30 years, and they build up a large stock of embodied raw materials that will not become available for recovery for some time. As such, recovered raw material can be injected back into the economy and serve to produce new PV panels or other products, thus increasing the security of future PV supply. Rapidly growing panel waste volumes over time will stimulate a market for secondary raw materials originating from end-of-life PV panels.*
- ***Creating new industries and jobs in the PV sector**. The acceptance of future PV panel waste management systems depends on co-operation among the different players across industry, such*

as waste management companies, utilities, governments, producers, etc. End-of-life PV panel management holds the potential to develop new pathways for industry growth and offers employment opportunities for different stakeholders. Similarly, the PV recycling industry will necessitate trained staff with specific skills and knowledge, education and training programmes.

2.0 Market

2.1 Levelised Cost of Electricity (LCOE), Capital Costs, Returns, and the Future of Solar

2.1.1 Levelised Cost of Electricity (LCOE) – Lazard Investment Bank

The primary consideration for new power generation is what is called the Levelised Cost of Electricity production (LCOE). This is an analysis looking at the long-term cost of installing a new generation plant, running that plant and accounting for all other costs incurred.

The result is a dollar cost per megawatt over the plant's productive life. It takes account of everything – land purchase, plant installation, licensing costs, fuel, infrastructure to deliver electricity to a grid, carbon costs, labour – pretty much every cost that will be incurred over the multi-decade life of the plant.

Figure: [Levelised Cost of Energy Comparison – Unsubsidized Analysis – (Lazard Investment Bank)]

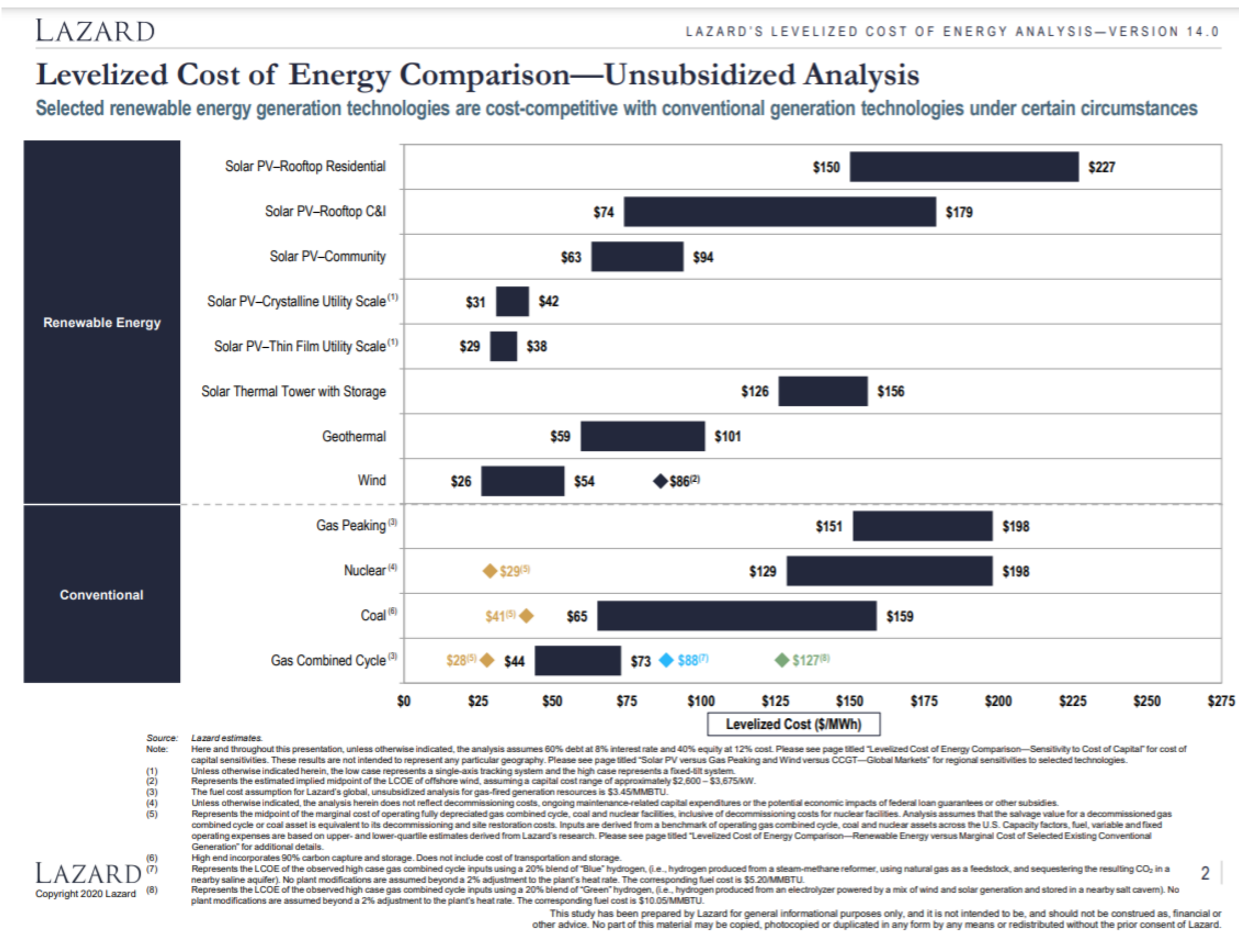
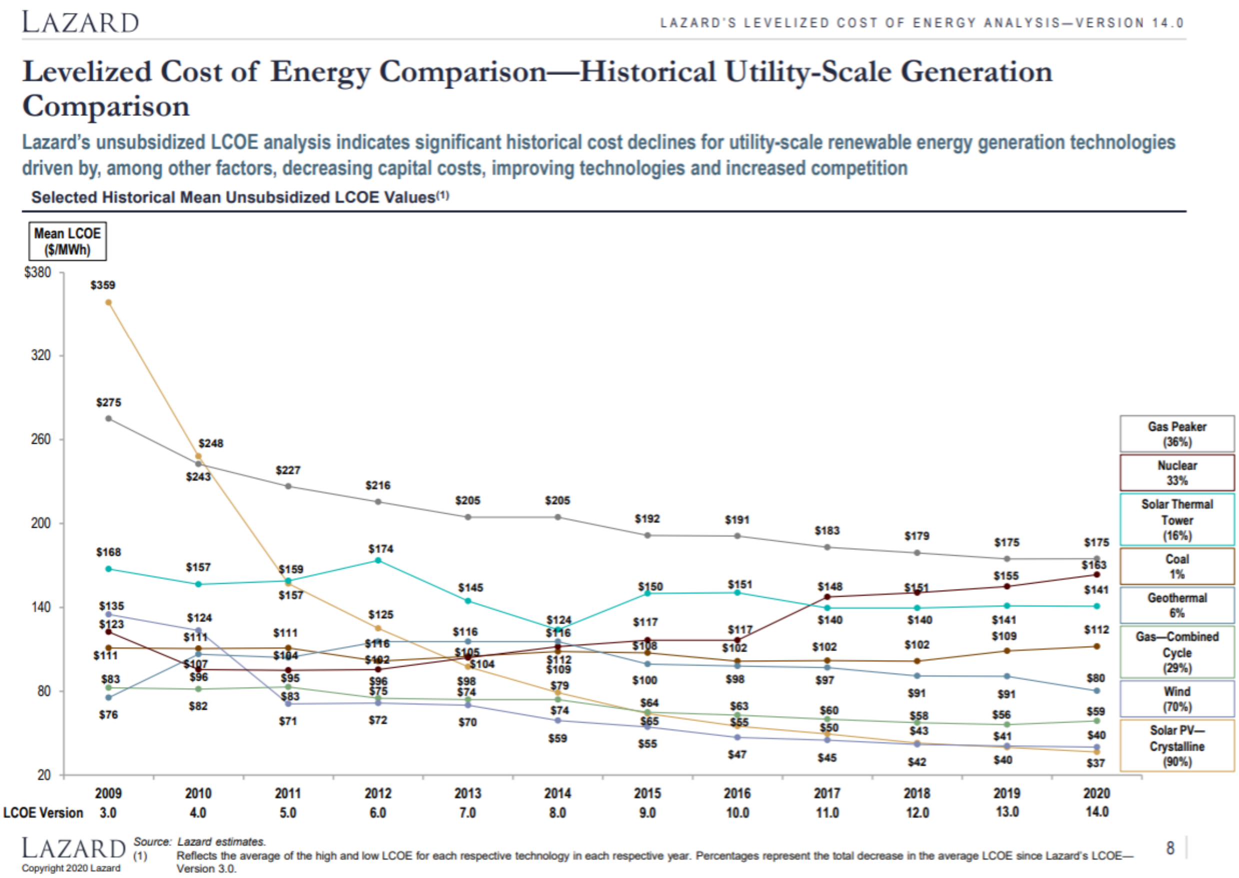
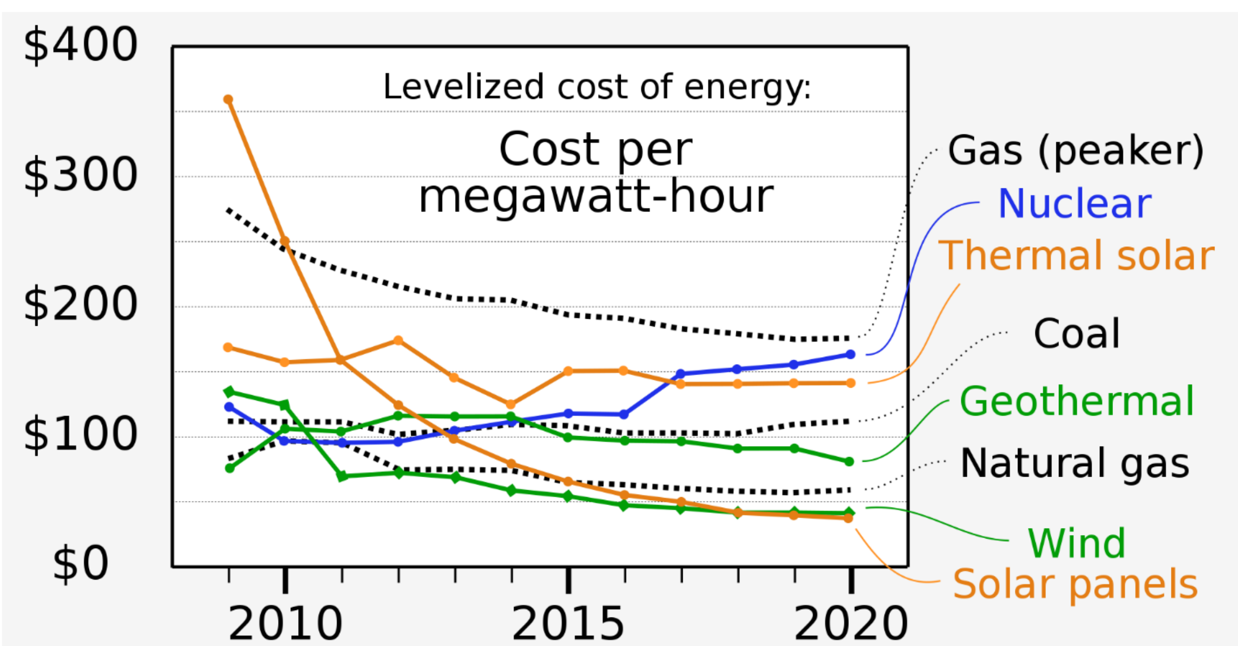


Figure: [Levelised Cost of Energy Comparison – Historic Utility Scale Generation Comparison – (Lazard Investment Bank)]

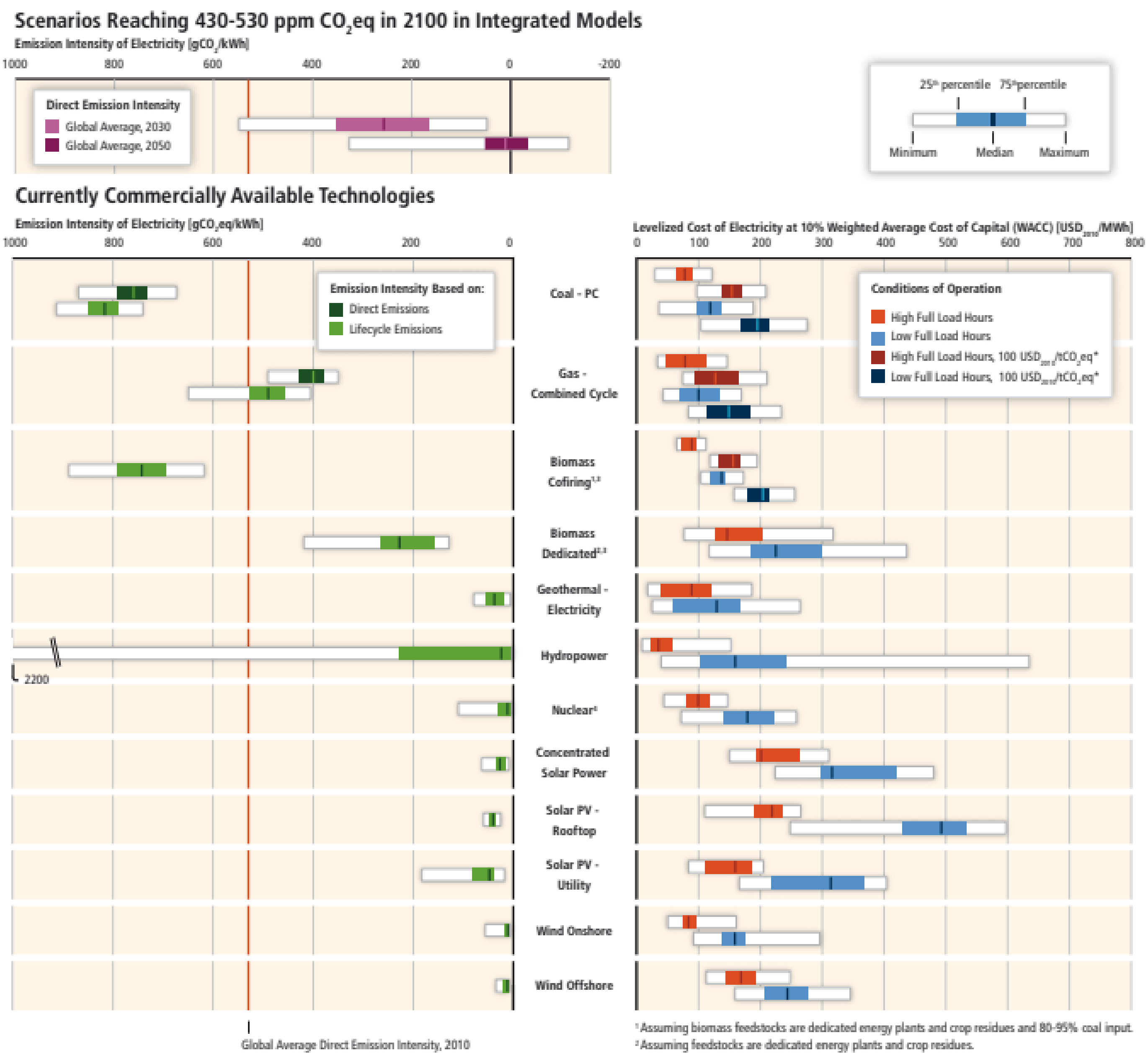




2.1.2 Levelised Cost of Electricity (LCOE) of Solar relative to other forms of Generation - IPCC

The Intergovernmental Panel on Climate Change (IPCC) has conducted research that allows us to compare the Levelized Cost of Electricity of solar relative to other forms of generation.

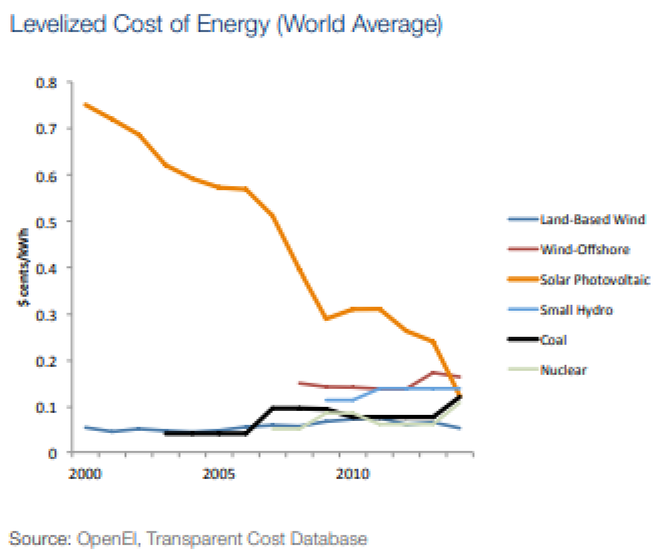
Figure: [IPCC: LCOE of electricity [$/kWh] of currently commercially available technologies]



[1] Assuming biomass feedstocks are dedicated energy plants and crop residues and 80-95% coal input.
[2] Assuming feedstocks are dedicated energy plants and crop residues.
[3] Direct emissions of biomass power plants are not shown explicitly, but included in the lifecycle emissions. Lifecycle emissions include albedo effect.
[4] LCOE of nuclear include front and back-end fuel costs as well as decommissioning costs.
[5] Transport and storage costs of CCS are set to 10 USD_{2010}/tCO_2.
[6] Carbon price levied on direct emissions. Effects shown where significant.

2.1.3 Levelised Cost of Energy (World Average) – World Economic Forum

Figure: Levelised Cost of Energy (World Average) – World Economic Forum



2.1.4 Levelised Cost of Energy (NZ Comparison) – MBIE

MBIE's Interactive Levelised Cost of Electricity Comparison Tool

This tool calculates an estimate of the levelised cost of electricity generation (LCOE) for each potential generation project in MBIE's Generation Stack. The Generation Stack is used by MBIE in energy and climate modelling such as Electricity Demand and Generation Scenarios (EDGS).

How the Interactive Levelised Cost of Electricity Comparison Tool works

The Interactive Levelised Cost of Electricity Comparison Tool ranks the projects from lowest to highest LCOE and the resulting curve is a simplified representation of the long-run marginal electricity generation costs in New Zealand. It is important to note that this simplified long-run marginal electricity cost curve does not take into account additional capital cost of meeting peak demand. The long-run marginal cost is the incremental cost incurred when additional electricity generation capacity is added to the system in the long run.

Using default assumptions, the tool says that for the current point in time, the next generation plants likely to be built are either wind or hydro. The combination of declining wind technology costs and low discount rates caused the LCOE of wind to reach as low as $54 per MWh. However, the tool does not allow for the falling cost of both wind and solar in the future.

Note: The LCOE is the average minimum price at which the electricity generated by the asset is required to be sold for in order to offset the total costs of production over its lifetime.

Pre-tax discount rates

As of 18 September 2020, the Treasury recommended real pre-tax discount rates in the range of 5% to 6% per annum to be used in economic analyses.

Read about the discount rates on the Treasury website(external link)

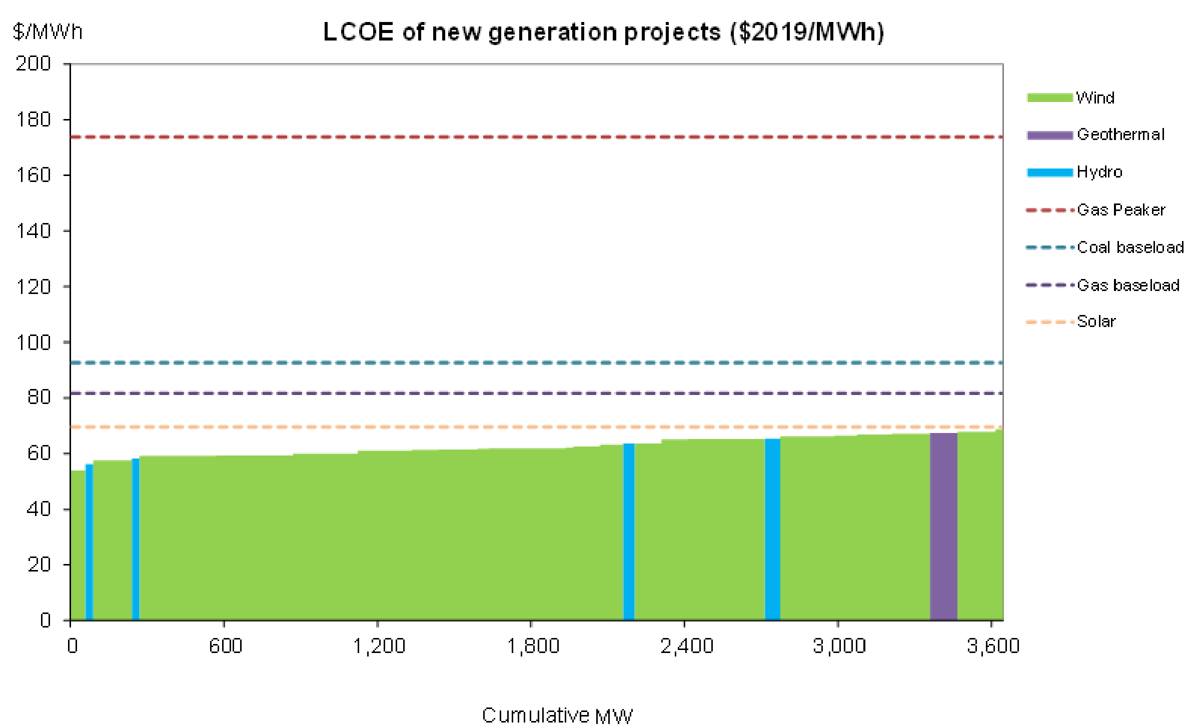
The default value of real post-tax discount rate in the calculator is 4.5% per annum. As the LCOE is sensitive to key assumptions such as discount rates and carbon tax, the tool allows users to perform sensitivity analyses by adjusting key assumptions.

Future plans

As there are no utility-scale solar installations in New Zealand, assumptions used in calculating LCOE for utility solar are based on overseas studies and hence the estimates are subject to large uncertainty.

In future MBIE is planning to build a Shiny app for this interactive tool and update the TWAP/GWAP parameter.

Graph: showing the Levelised Cost of Electricity Comparison of new generation projects



The graph shows the output of the Interactive Levelised Cost of Electricity Comparison Tool - the long-run marginal cost curve of electricity generation.

The results in the graph are illustrative only and are derived from using default assumptions.

The graph ranks the projects from lowest to highest levelised cost of electricity generation (LCOE).

If lower cost plants are built first, the majority of new build generation is wind.

The graph shows a situation where the levelised cost of electricity generation (LCOE) of wind ranges from $54 per MWh to $70 per MWh.

2.1.5 Levelised Cost of Energy (Solar & Wind) – IRENA

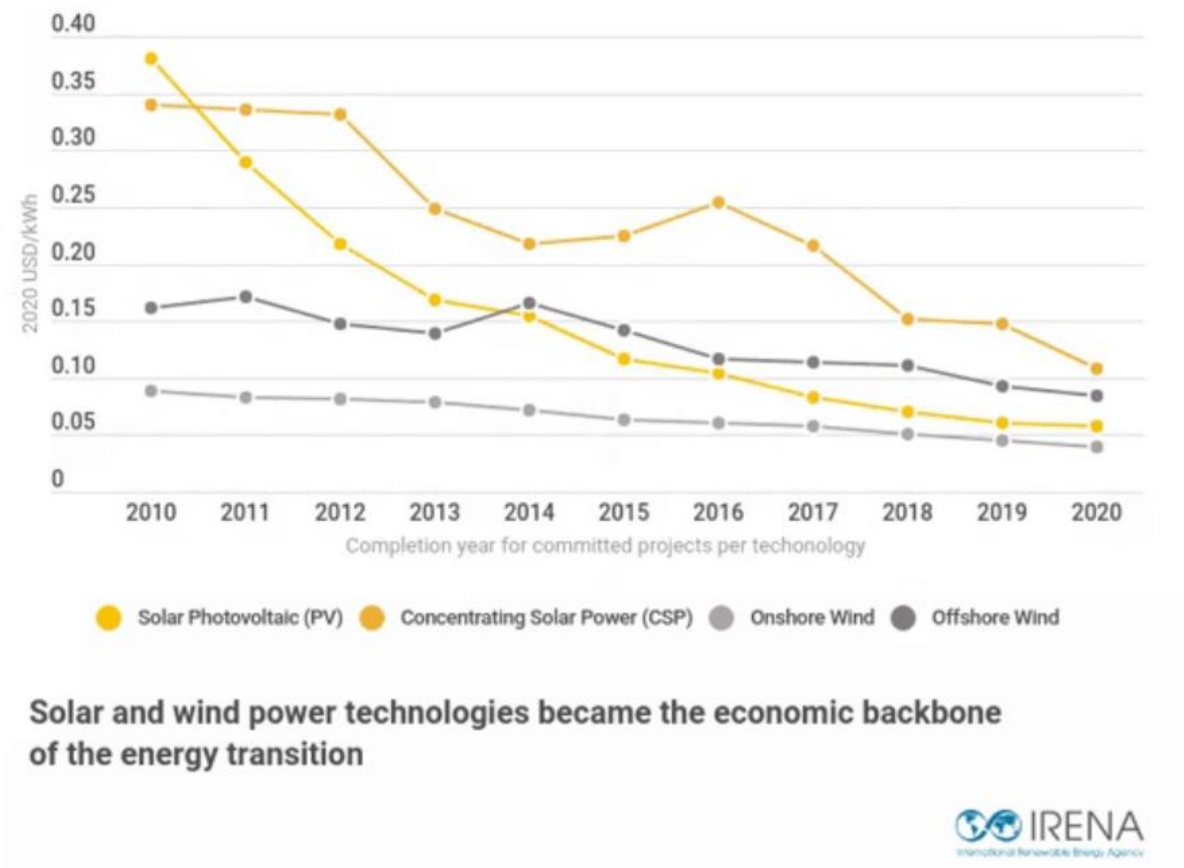
The International Renewable Energy Agency (IRENA) is an intergovernmental organization mandated to facilitate cooperation, advance knowledge, and promote the adoption and sustainable use of renewable energy.

The below is an extract from IRENA Press Release: Majority of New Renewables Undercut Cheapest Fossil Fuel on Cost

Renewable Power Generation Costs in 2020 shows that costs for renewable technologies continued to fall significantly year-on-year. Concentrating solar power (CSP) fell by 16 per cent, onshore wind by 13 per cent, offshore wind by 9 per cent and solar PV by 7 per cent. With costs at low levels, renewables increasingly undercut existing coal's operational costs too. Low-cost renewables give developed and developing countries a strong business case to power past coal in pursuit of a net zero economy. Just 2020's new renewable project additions will save emerging economies up to USD 156 billion over their lifespan.

2010-2020 saw a dramatic improvement in the competitiveness of solar and wind technologies with CSP, offshore wind and solar PV all joining onshore wind in the range of costs for new fossil fuels capacity, and increasingly outcompeting them. Within ten years, the cost of electricity from utility-scale solar PV fell by 85 per cent, that of CSP by 68 per cent, onshore wind by 56 per cent and 48 per cent for offshore wind. With record low auction prices of USD 1.1 to 3 cents per kWh today, solar PV and onshore wind continuously undercut even the cheapest new coal option without any financial support.

Figure: Solar and wind power technologies became the economic backbone of the energy transition



IRENA's report also shows that new renewables beat existing coal plants on operating costs too, stranding coal power as increasingly uneconomic. In the United States for example, 149 GW or 61 per cent of the total coal capacity costs more than new renewable capacity. Retiring and replacing these plants with renewables would cut expenses by USD 5.6 billion per year and save 332 million tonnes of CO2, reducing emissions from coal in the United States by one-third. In India, 141 GW of installed coal is more expensive than new renewable capacity. In Germany, no existing coal plant has lower operating costs than new solar PV or onshore wind capacity.

The IRENA Report "[Renewable Power Generation Cost in 2020]" clearly shows the reduction in LCOE that Solar has made over the last decade relative to other forms of generation.

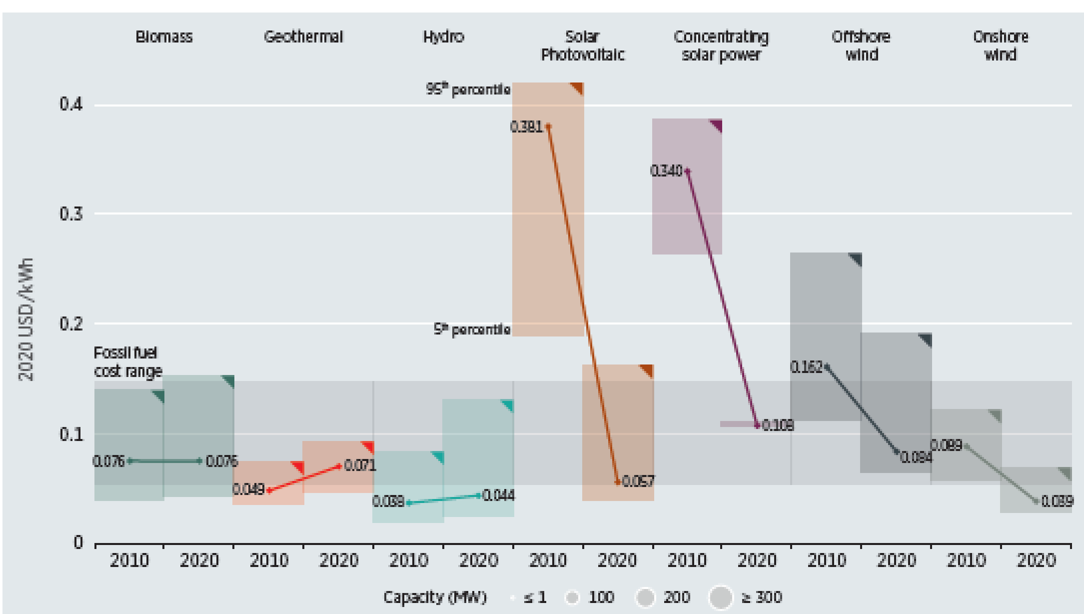
Table: IRENA Total installed Cost, capacity factor and levelized cost of electricity trends by technology, 2010 and 2020

Table H1 Total installed cost, capacity factor and levelised cost of electricity trends by technology, 2010 and 2020

	Total installed costs (2020 USD/kW)			Capacity factor (%)			Levelised cost of electricity (2020 USD/kWh)		
	2010	2020	Percent change	2010	2020	Percent change	2010	2020	Percent change
Bioenergy	2 619	2 543	-3%	72	70	-2%	0.076	0.076	0%
Geothermal	2 620	4 468	71%	87	83	-5%	0.049	0.071	45%
Hydropower	1 269	1 870	47%	44	46	4%	0.038	0.044	18%
Solar PV	4 731	883	-81%	14	16	17%	0.381	0.057	-85%
CSP	9 095	4 581	-50%	30	42	40%	0.340	0.108	-68%
Onshore wind	1 971	1 355	-31%	27	36	31%	0.089	0.039	-56%
Offshore wind	4 706	3 185	-32%	38	40	6%	0.162	0.084	-48%

Figure: Global LCOEs from newly commissioned, utility-scale renewable power generation technologies, 2010-2020

Figure ES.2 Global LCOEs from newly commissioned, utility-scale renewable power generation technologies, 2010-2020



Source: IRENA Renewable Cost Database

Note: This data is for the year of commissioning. The thick lines are the global weighted-average LCOE value derived from the individual plants commissioned in each year. The project-level LCOE is calculated with a real weighted average cost of capital (WACC) of 7.5% for OECD countries and China in 2010, declining to 5% in 2020; and 10% in 2010 for the rest of the world, declining to 7.5% in 2020. The single band represents the fossil fuel-fired power generation cost range, while the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.

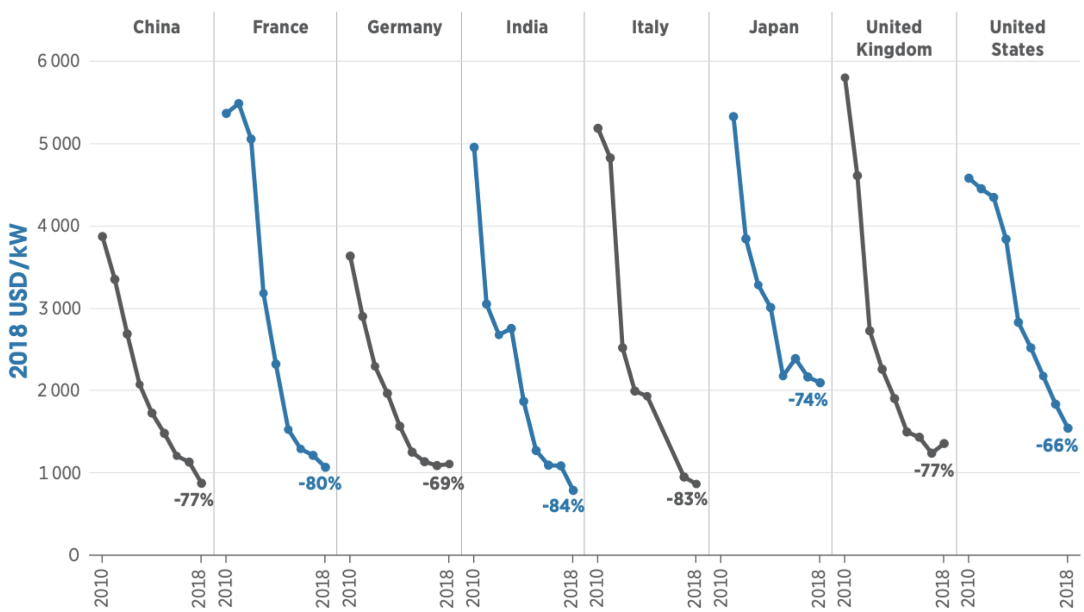
2.1.6 Future of Solar – LCOE – 2020 World Economic Forum Annual Meeting

The World Economic Forum states that the future looks bright for solar energy:

- *Over the past decade, the cost of solar has fallen dramatically.*
- *New technologies promise to increase efficiency and lower costs further.*
- *Solar energy will soon be unbeatable compared to fossil fuels.*

Figure

Figure 11: Total installed cost of utility-scale solar PV, selected countries, 2010–18



Source: IRENA (2019f).

2.1.7 Transpower Report "The Sun Rises on a Solar Energy Future" – Future of Solar in NZ & LCOE

Summary except below from Transpower Report - The Sun Rises on a Solar Energy Future"

The case for solar in our energy future

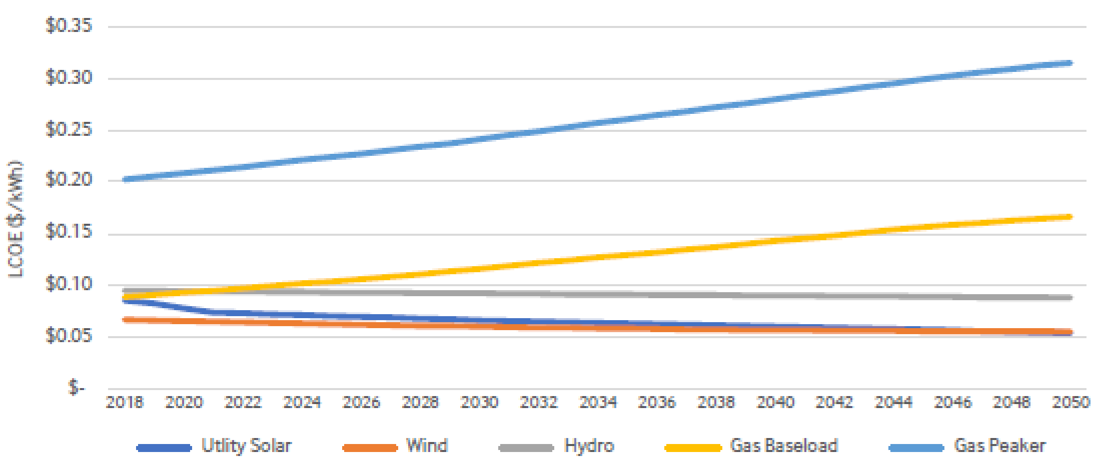
In 2017, solar became the leading form of new utility energy generation in the world.

The United Nations reports that in 2017, 98GW of solar generation was installed globally, exceeding the 70GW of new fossil fuel generation built the same year by 40 per cent. This represents a significant global shift – the first time since the industrial revolution that a renewable form of energy has outstripped the construction of conventional fossil fuel-powered electricity generation. This shift is the result of a long-

running trend of falling solar prices. Prices for solar installations have been helped at times and, in certain locations, by government subsidies but, stripping out all subsidies, utility solar is now on a pricing par with gas-fired peaking power stations. (It should be noted here that this is on a per unit of energy produced basis. However, this is not a direct like-for-like comparison as gas-fired peaking power stations produce power on demand, whereas solar produces variable energy output and varies by region.) Within the industry, looking at the real, underlying costs of energy sources is called a 'levelised cost of energy (LCOE)'.

Figure 1 below shows the levelised cost of energy for a range of electricity generation technologies1. With forecast carbon prices applied to gas-fired electricity generation, this graph shows that the cost of energy from gas-fired power stations will be double the price of energy from utility solar within a decade.

Figure 1: NZD cost of energy from different sources as technology and carbon prices evolve



The levelised cost of utility solar is expected to continue falling – by a further 24 per cent over the next 10 years, and by over 40 per cent by 2050. Based on what we currently know and believe, by 2050 utility solar is likely to be the world's cheapest form of energy – marginally cheaper than wind, which will also continue to fall in price.

The Massachusetts Institute of Technology has reported that the cost of photovoltaic solar cells has fallen by 99 per cent over the last 40 years. The installed cost per watt of solar energy has halved in Australia in the last six years.

The decreasing cost and steadily improving solar performance, as well as an increasing focus on sustainability and self-reliance, are now driving the mass adoption of distributed solar in homes and businesses, as well as grid and network connected solar farms.

Figure 6 : Levelised Cost of Energy compared to generation and retail prices ($/kWh)

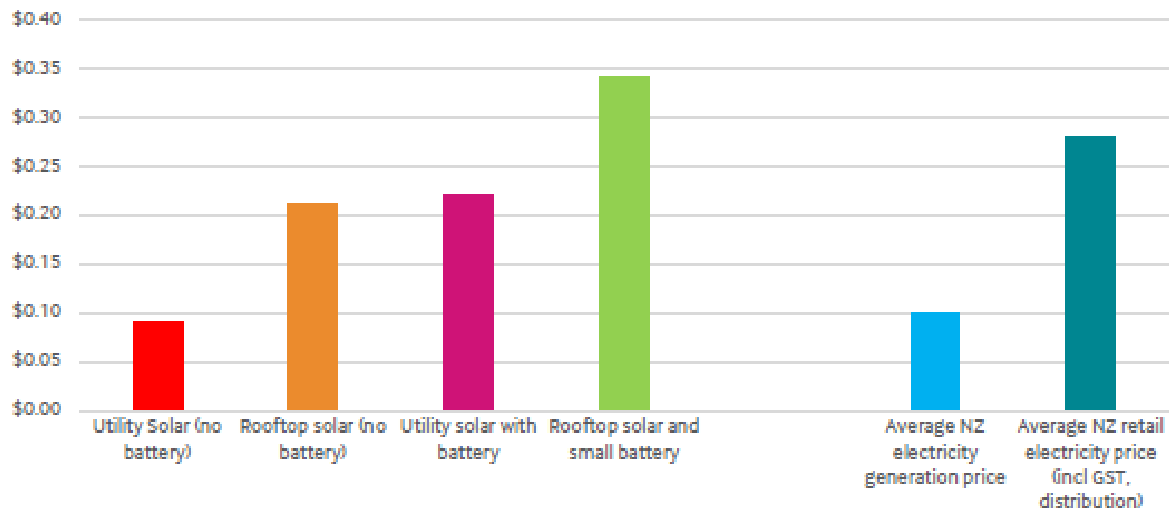


Figure 6 shows the average cost of energy produced. We compare utility and rooftop solar with and without batteries to the average New Zealand generation price and retail price. Note retail prices include the cost of distribution, transmission and retail. Without a battery, energy use must fit with times of generation. Average solar irradiation used for analysis. Generation price and retail price from Electricity Price Review First Report.

2.1.8 Future of Solar Report – IRENA – LCOE, Capital Cost, and other Info

Summary extracts from the IRENA – Future of Solar Report

Achieving the paris climate goals would require significant acceleration across a range of sectors and technologies. *By 2050 solar PV would represent the second-largest power generation source, just behind wind power and lead the way for the transformation of the global electricity sector. Solar PV would generate a quarter (25%) of total electricity needs globally, becoming one of prominent generations source by 2050.*

Such a transformation is only possible by significantly scaling up solar pv capacity in next three decades. *This entails increasing total solar PV capacity almost sixfold over the next ten years, from a global total of 480 GW in 2018 to 2 840 GW by 2030, and to 8 519 GW by 2050 – an increase of almost eighteen times 2018 levels.*

The solar pv industry would need to be prepared for such a significant growth in the market over the next three decades. *In annual growth terms, an almost threefold rise in yearly solar PV capacity additions is needed by 2030 (to 270 GW per year) and a fourfold rise by 2050 (to 372 GW per year), compared to current levels (94 GW added in 2018).*

Scaling up solar pv energy investment is critical to accelerating the growth of

Installations over the coming decades. *Globally this would imply a 68% increase in average annual solar PV investment from now until 2050 (to USD 192 billion/yr). Solar PV investment stood at USD 114 billion/yr in 2018.*

Increasing economies of scale and further technological improvements will continue to reduce the costs of solar pv. *Globally, the total installation cost of solar PV projects would continue to decline in the next three decades. This would make solar PV highly competitive in many markets, with the average falling in the range of USD 340 to 834 per kilowatt (kW) by 2030 and USD 165 to 481/kW by 2050, compared to the average of USD 1 210/kW in 2018.*

The levelised cost of electricity (LCOE) for solar PV is already competitive compared to all fossil fuel generation sources and is set to decline further as installed costs and performance continue to improve. Globally, the LCOE for solar PV will continue to fall from an average of USD 0.085 per kilowatt-hour (kWh) in 2018 to between USD 0.02 to 0.08/kWh by 2030 and between USD 0.014 to 0.05/kWh by 2050.

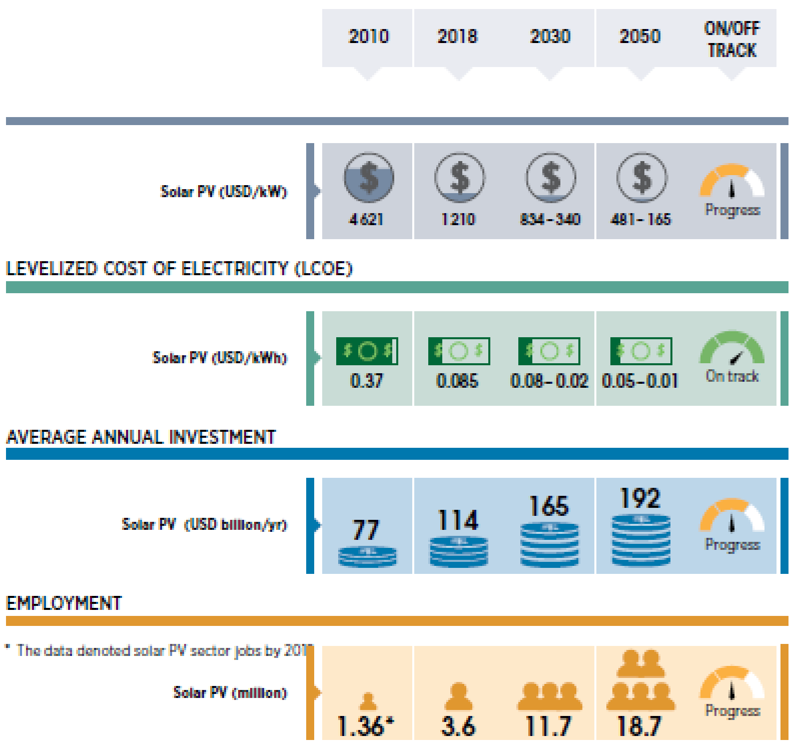
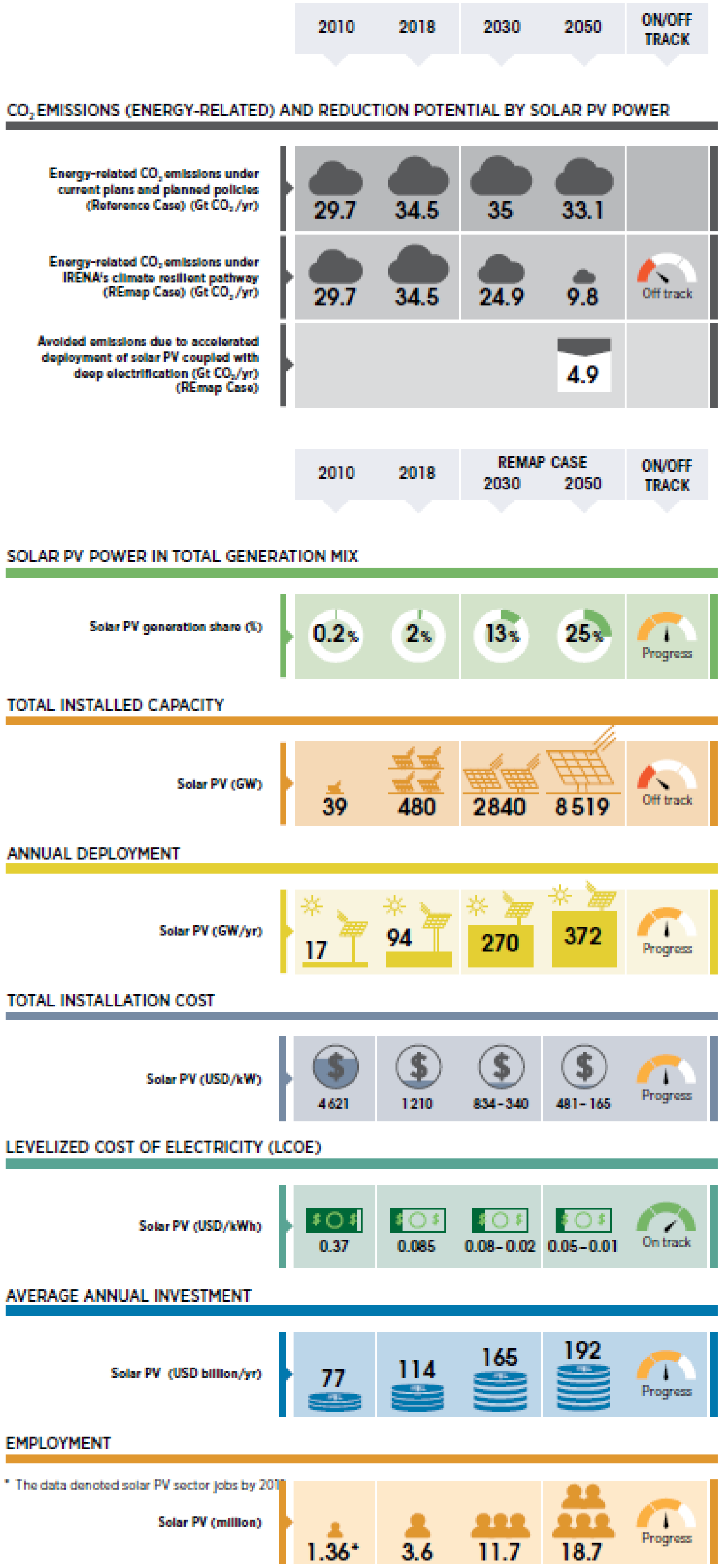


Figure ES 1. Status and future of solar photovoltaics (PV) - Tracking progress to accelerate solar PV deployment to achieve Paris Climate targets



Scaling up electricity from renewables is crucial for the decarbonisation of the world's energy system.

Solar, along with wind energy, would lead the way in the transformation of the global electricity sector.

Figure : Renewables and efficiency measures, boosted by substantial electrification, can provide over 90% of the necessary CO_2 emission reductions by 2050

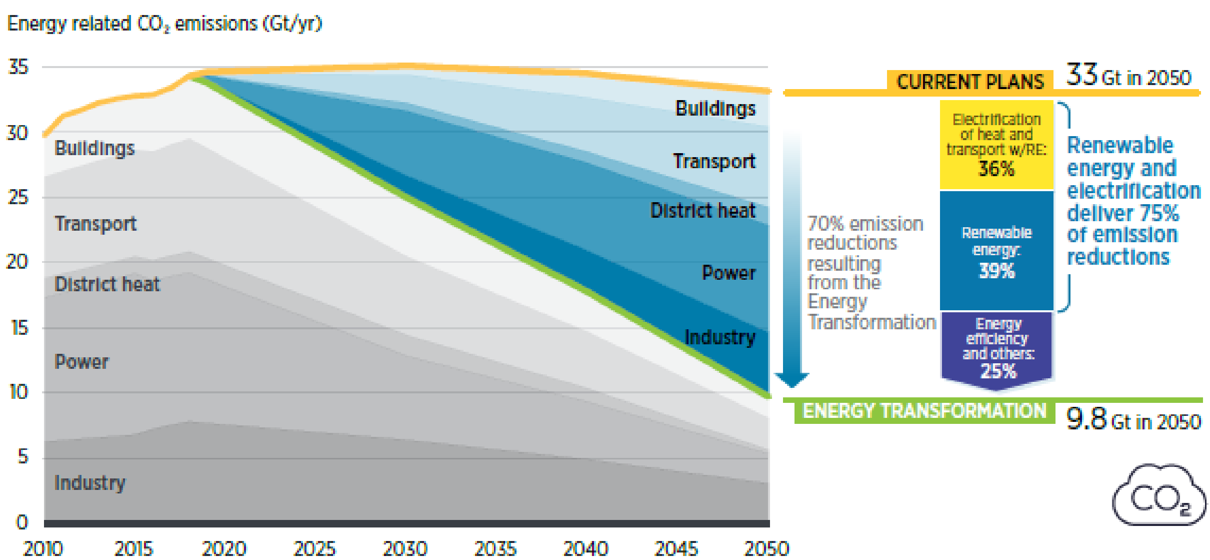
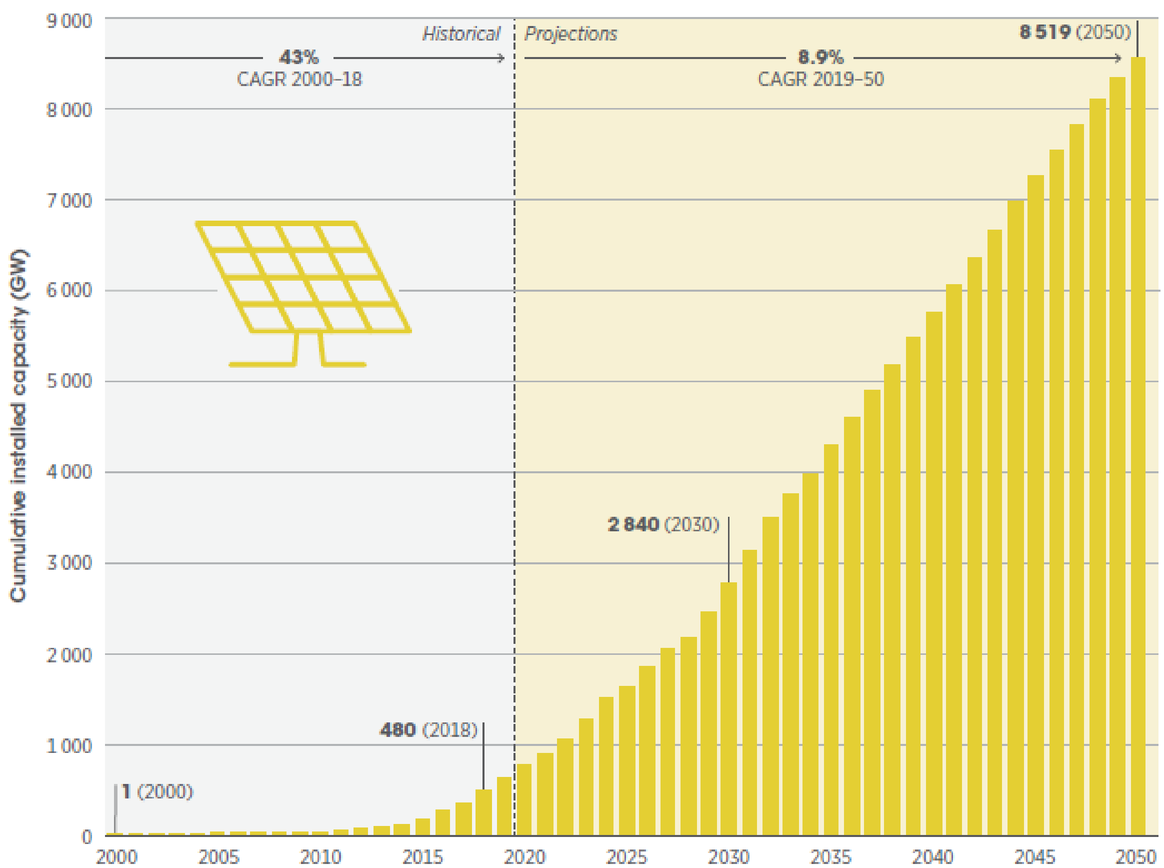
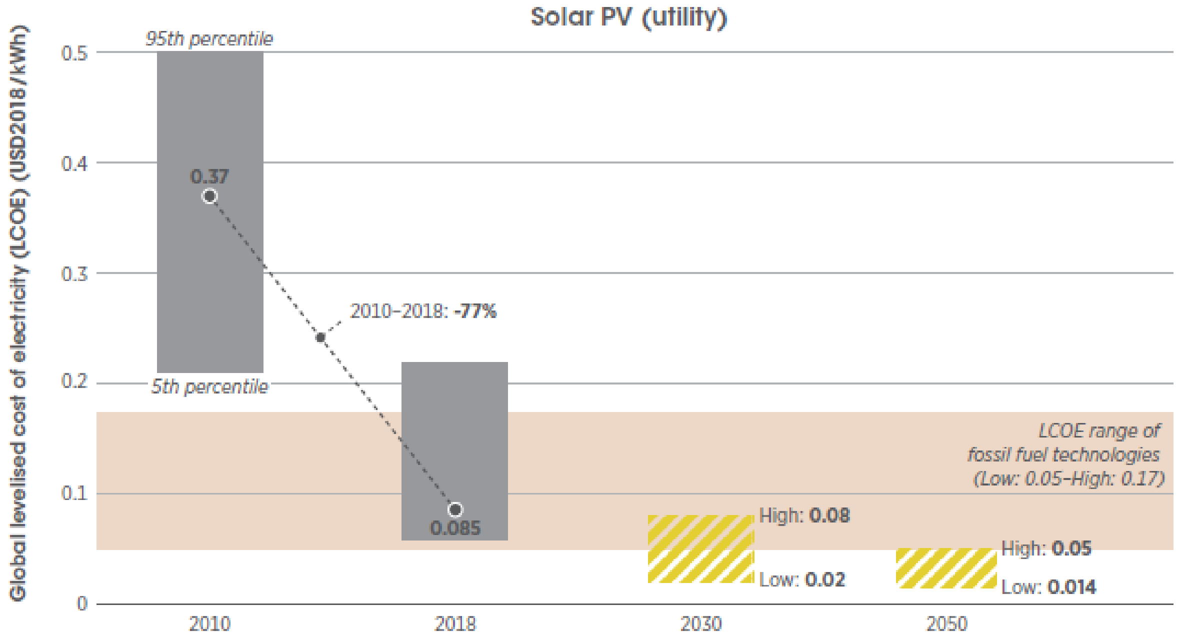


Figure : Compared to 2018 levels, cumulative solar PV capacity is expected to grow sixfold by 2030, with a CAGR of nearly 9% up to 2050



Sources: Historical values based on IRENA's renewable energy statistics (IRENA, 2019c) and future projections based on IRENA's analysis (2019a).

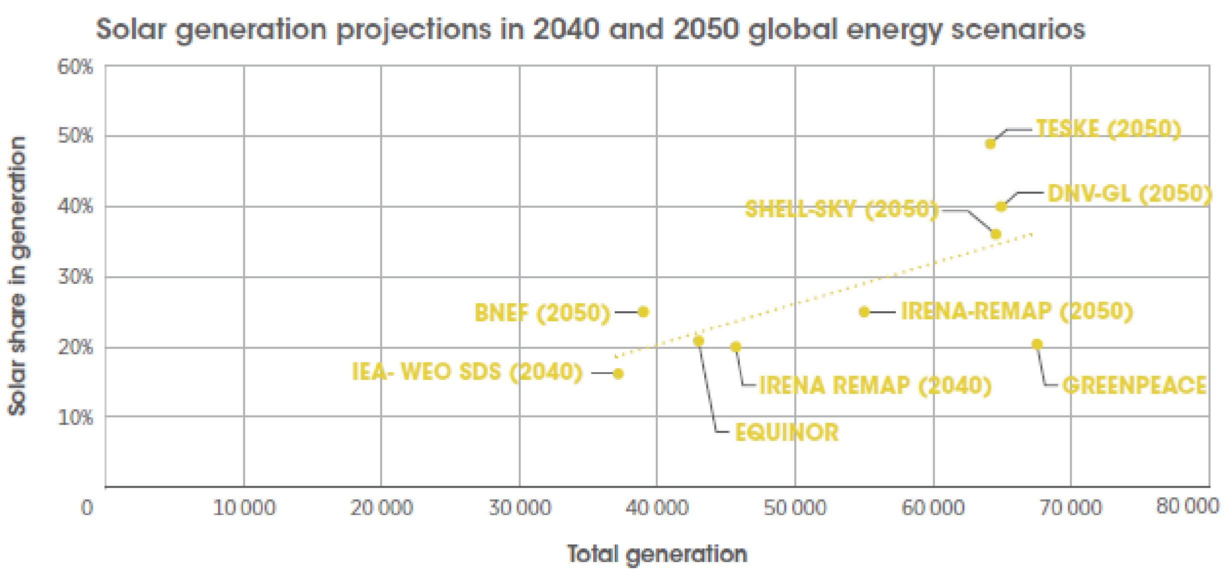
Figure : The levelized cost of electricity (LCOE) for solar PV is already competitive now compared to all fossil fuel generation sources and would be fully competitive in a few years.



Note: Historical data represent cost of new installations in a specific year and future projected value denotes the range in which the global weighted average LCOE of utility-scale solar PV projects fall by 2050; the capacity factor is assigned to projects that come into operation in a specific year and remains same through the life cycle of a project; LCOE for fossil fuel technologies refers to new capacity/new deployment.

Sources: Historical data based on (IRENA,2019c) and future projections based on IRENA's forthcoming report: Solar and wind cost reduction potential to 2030 in the G20 countries (IRENA, forthcoming a)

Figure: Solar generation projections in 2040 and 2050 global energy scenarios



2.1.9 Operation & Maintenance - IRENA – Future of Solar

5.3 OPERATION AND MAINTENANCE

An operation and management (O&M) system is a key component of a solar plant, as it ensures that the PV system will be able to maintain high levels of technical and economic performance over its lifetime (SolarPower Europe O&M Task Force, 2018). In addition, the O&M phase is the longest in the lifecycle of a PV project, as it typically lasts 20–35 years. As such, ensuring the quality of O&M services is essential to mitigate potential risks.

Innovations and improvements, including more data-driven solutions, are becoming increasingly important because they help O&M services to keep up with market requirements. Important trends in O&M innovation can be grouped in two main categories: 1) smart PV power plant monitoring; and 2) retrofit coatings for PV modules.

SMART PV POWER PLANT MONITORING

Drones for intelligent monitoring of solar PV

The exponential growth seen in PV markets has led to the development of large-scale power plants, which has increased demands for better tools for inspection and monitoring. Normally, the process of monitoring is done by conducting manual inspections; however, these can be replaced by intelligent systems, such as drones. Drones are becoming highly suited to the solar industry due to a wide range of surveillance and monitoring capabilities, the possibility of long-range inspection and easy control. In recent years they have become popular for their capability to monitor large-scale solar parks in less time than by human inspection. With the help of sensing elements, drones efficiently capture the necessary data and send them to the cloud for analysis in less time and in more accurate form (Kumar et al., 2018).

PV plant power output forecasting

Electricity generation from PV plants is limited by the variable nature of the sun's radiation. The growing penetration of PV into electricity markets creates the need for new regulations to guarantee grid stability and the correct balancing of electricity demand and supply (SolarPower Europe O&M Task Force, 2018). The ability to predict PV production is therefore an essential tool to capture economies in a market with a high penetration of non-predictable energy. Currently simulation models and meteorological forecasting resources for specific PV plants are well proven technologies. Algorithms that are able to match weather forecasts with PV plant characteristics are being used to predict energy production on an hourly basis for at least the next 48 hours.

In this context, short-term data collection represents a valuable opportunity to improve PV plant yield forecasting, and improvements in communication procedures between devices (i.e. modules, inverters, sensors, etc.) would contribute to improving intraday forecasting, calculation of performance expectations, and exchange with the energy grid (SolarPower Europe O&M Task Force, 2018). Solar monitoring is indeed a key component in asset operation; however, the process is often difficult, mainly due to two factors. First are frequent failings in communication between devices and the cloud or data centre infrastructure. To overcome this challenge, the Internet of things (IoT) represents a valid solution for PV systems, as it is an interoperability environment where all devices in the field are connected to each other and spontaneously show themselves as available to be connected to the system (SolarPower Europe O&M Task Force, 2018). Second is the lack of proper standardisation of terminology and languages used by all communicating devices. In this regard, efforts are being made throughout the whole PV market to increase standardisation of communication, which will improve the security level, options for communication, and configuration costs for solar monitoring (SolarPower Europe O&M Task Force, 2018).

2.1.10Operation and Maintenance Costs - IRENA

Operation and Maintenance Costs (IRENA Renewable Power Generation Costs in 2020 Report)

The operation and maintenance (O&M) costs of utility-scale solar PV plants have declined in recent years, driven by module efficiency improvements, which have reduced the surface area require per MW of capacity.

At the same time, competitive pressures and improvements in the reliability of the technology have resulted in system designs that are optimised to reduce O&M costs. Improved O&M strategies that take advantage of a range of innovations have also driven down O&M costs and reduced downtime. Such innovations stretch from robotic cleaning to 'big data' analysis of performance to identify issues and preventative interventions ahead of failures.

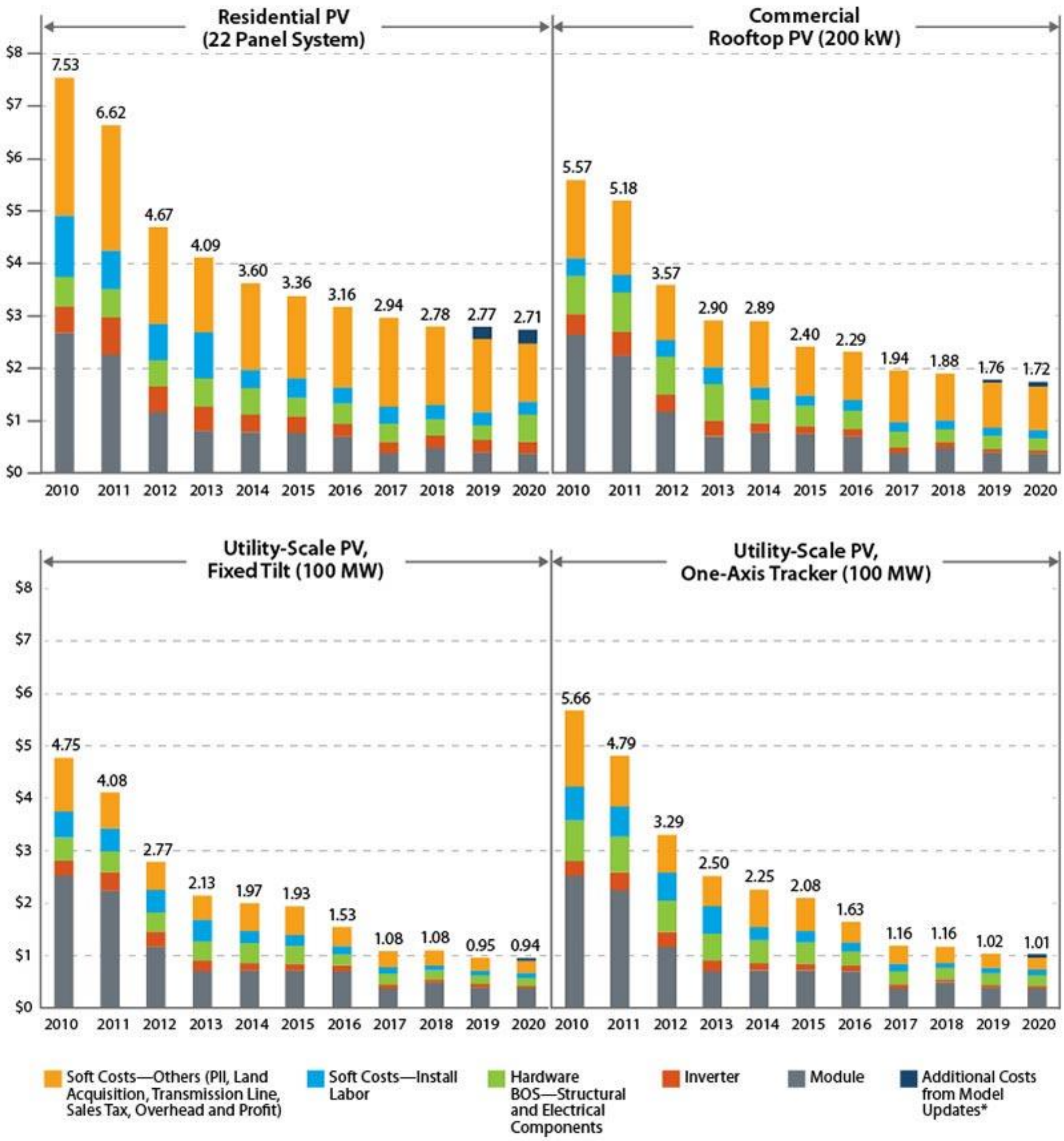
For the period 2018-2020, O&M cost estimates for utility-scale plants in the United States have been reported at between USD 10/kW/year and USD 18/kW/year (Wiser et al., 2020; Bolinger et al., 2019; Bolinger et al., 2020; EIA, 2020; NREL, 2018; Walker et al., 2021). Recent costs in that country seem to be dominated by preventive maintenance and module cleaning, with these making up as much as 75% and 90% of the total, depending on the system type and configuration. The rest of the O&M costs can be attributed to unscheduled maintenance, land lease costs and other component replacement costs.

Average utility-scale O&M costs in Europe have been recently reported at USD 10/kW per year (Steffen et al., 2020; Vartiainen et al., 2019), with historical data for Germany suggesting O&M costs came down 85% between 2005 and 2017, to USD 9/kW per year. This result suggests there has been a reduction of between 15.7% and 18.2% with every doubling of the solar PV cumulative installed capacity.

For 2020, the solar PV LCOE calculations in this IRENA report assume utility-scale O&M costs of USD 17.8/kW per year for projects commissioned in the Organisation of Economic Co-operation and Development (OECD) member countries (a 3% decline from 2019). For projects commissioned in non-OECD countries during that year, USD 9.0/kW per year is assumed (a decline of 5% from 2019)4. These are the estimated, total 'all-in' O&M costs, so include costs such as insurance and asset management, which are sometimes not reported in all O&M surveys.

2.1.11Solar Installed System Cost Analysis (Capital Cost – [$/Wp]) – NREL

Figure: [Solar Installed System Cost Analysis – NREL]()



Other resources: [NREL - 2018 U.S. Utility-Scale Photovoltaics - Plus - Energy Storage System Costs Benchmark]()

2.1.12 EECA – Capital Cost analysis of Commercial-scale (rooftop) solar in New Zealand

EECA Report: Commercial-scale solar in New Zealand An analysis of the financial performance of on-site generation for businesses

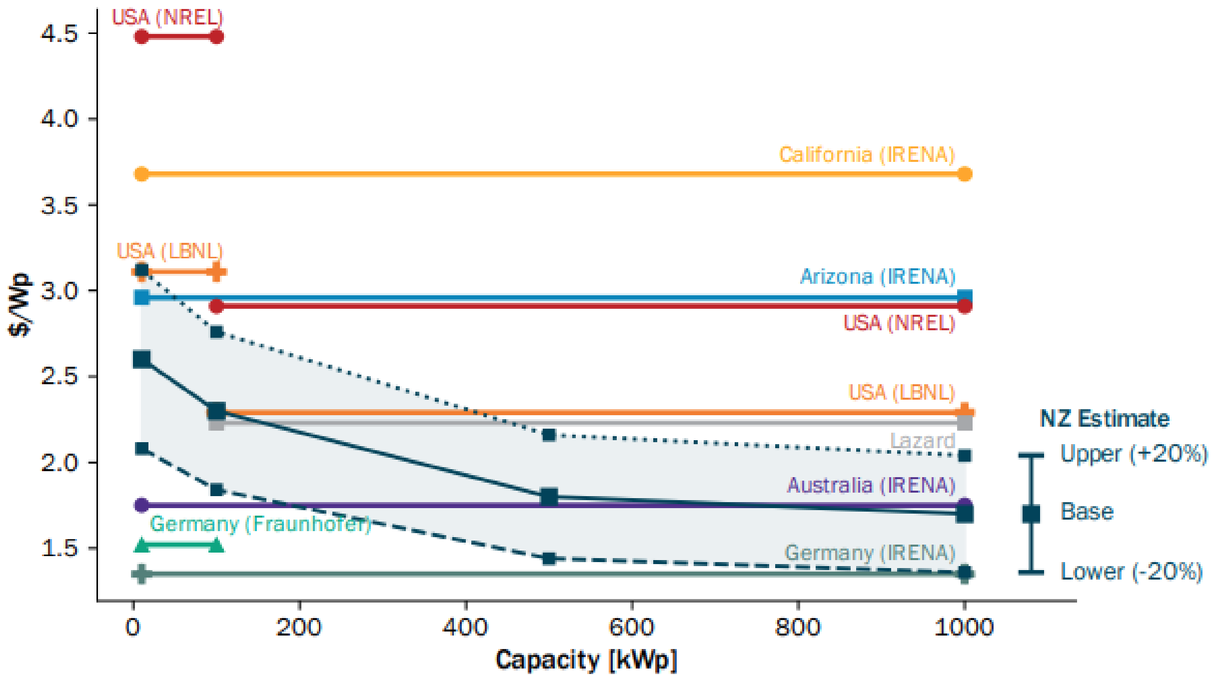


Figure 4: Per unit capital cost (NZD) at 2021 versus system size for commercial rooftop solar installations.

Table 29: IRENA commercial rooftop solar capital cost summary (NZ $/Wp), 2020 and 2021 projected.

Selected countries and USA states	Calendar year											
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Australia					3.97	3.10	2.73	2.34	2.18	2.04	1.89	1.75
China		4.46	3.48	2.96	2.32	1.96	1.79	1.71	1.31	1.06	0.98	0.91
Italy	7.55	6.44	3.63	2.87	2.82	2.19	2.01	1.83	1.65	1.59	1.47	1.36
Japan			7.32	5.88	4.36	3.38	3.29	3.17	2.90	2.77	2.56	2.37
Germany		4.88	3.16	2.69	2.36	1.77	1.89	1.80	1.76	1.58	1.46	1.35
United Kingdom							2.63	2.42	2.32	2.30	2.13	1.97
Arizona	9.82	8.68	7.65	6.06	4.99	5.36	4.80	4.34	3.75	3.46	3.20	2.96
California	9.07	8.75	6.94	6.47	5.12	4.98	5.16	4.90	4.47	4.30	3.98	3.68

NZ Rooftop Solar Capital Costs [$/Wp]

Table 2: Per unit capital cost (NZD) at 2021 for 10, 100, 500 and 1000 kWp system capacities.

Size (kWp)	Cost (NZ $/Wp)		
	Lower	Base	Upper
10	2.08	2.6	3.12
100	1.84	2.3	2.76
500	1.44	1.8	2.16
1000	1.36	1.7	2.04

Purpose Capital Analysis of EECA Capital Costs figures vs actual costs:

https://www.mysolarquotes.co.nz/about-solar-power/commercial/about-commercial-grid-connect/

$/Wp Analysis of mysolarquotes.co.nz data

[Wp]	Capital Cost (inc GST) [$]	$/Wp
10,000	$ 22,000	2.20
100,000	$ 180,000	1.80

https://www.eeca.govt.nz/assets/EECA-Resources/Research-papers-guides/Commercial-scale-solar-in-New-Zealand.pdf

$/Wp EECA Report:

lower	base	upper
2.08	2.60	3.12
1.84	2.30	2.76

My Solar Quotes Capital Cost Variance from EECA Report

lower	base	upper
-5.8%	15.4%	29.5%
2.2%	21.7%	34.8%

"Capital cost had the most impact, with IRR reducing about 20% when capital costs were increased 20%, **and IRR increasing about 35% when capital costs were reduced 20%**. Businesses may be able to access the lowest costs tested in this report, and with ongoing solar cost reductions, this will continue to make solar more attractive to commercial enterprises."

PCL's view is that actual NZ capital costs are 20% lower than the figures presented by EECA therefore it is reasonable to assume the actual IRR will be 35% higher than EECA's IRR figures.

2.1.13 EECA - IRR analysis of Commercial-scale (rooftop) solar in New Zealand

PCL's view is that actual NZ capital costs are 20% lower than the figures presented by EECA therefore it is reasonable to assume the actual IRR will be 35% higher than EECA's IRR figures.

An IRR analysis of Commercial-scale solar in New Zealand, by EECA in 2021:

A summary of average internal rate of return by load type and location is given in Table 10. These show a general trend towards higher IRRs in centres with higher solar capacity factors (from Table 7). However, it is difficult to say this definitively due to differences in distribution pricing between centres – this is discussed further in Section 5. Levelised cost of energy is summarised in Table 11. Average solar capacity, such that IRR is maximised, is given in Table 12. This helps explain the LCOE results, as per unit solar costs are higher at lower capacities, and decrease substantially at higher capacities, according to Figure 4. Average site load is summarised in Table 13. With all of these tables, the averages for each load type across all locations (rightmost column), and averages for each location across all load types (bottom row) will be biased by the load types and locations included in the sample, and should therefore be treated as broadly indicative only.

Locations are Auckland (AK), Hamilton (HN), Tauranga (TR), Napier (NR), Wellington (WN), Nelson (NN), Christchurch (CC), and Dunedin (DN).

Table 10: Average internal rate of return by load type and location.

Load type	AK	HN	TR	NR	WN	NN	CC	DN	**Mean**
Big box retail	4.3%	4.8%	5.3%	2.2%	2.9%	5.0%	5.8%	0.6%	**3.9%**
Retail	5.8%	4.2%							**5.0%**
Grocery retail	5.0%	3.5%	6.5%	3.0%	2.6%	5.8%	3.2%	1.1%	**3.8%**
Food market	5.1%				2.6%		6.8%	1.7%	**4.0%**
Cool store				4.6%		5.6%			**5.1%**
Greenhouse		6.3%							**6.3%**
Corporate office	6.5%				3.1%				**4.8%**
Retail warehousing	4.8%						5.7%		**5.2%**
Warehousing	6.3%		3.3%	2.0%			4.7%		**4.1%**
Production	6.6%								**6.6%**
Manufacturing	8.4%				3.3%				**5.8%**
Education	6.8%								**6.8%**
Waste water treatment	5.2%								**5.2%**
Water supply	6.8%								**6.8%**
Dairy farm							4.4%		**4.4%**
Mean	**6.0%**	**4.7%**	**5.0%**	**3.0%**	**2.9%**	**5.5%**	**5.1%**	**1.1%**	**5.2%**

Applying the 35% increase to the NZ mean IRR of 5.2% results in an IRR of 7%, which appears consistent with 'industry chatter' of 7-8% IRR for commercial rooftop solar (or higher in some circumstances).

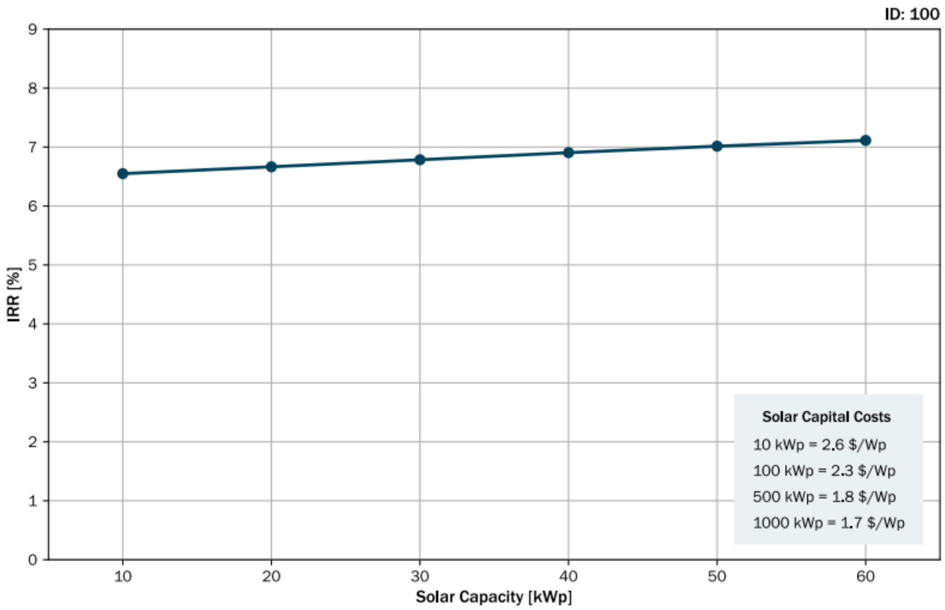


Figure 11: IRR versus solar system capacity for big box retail Site 100.

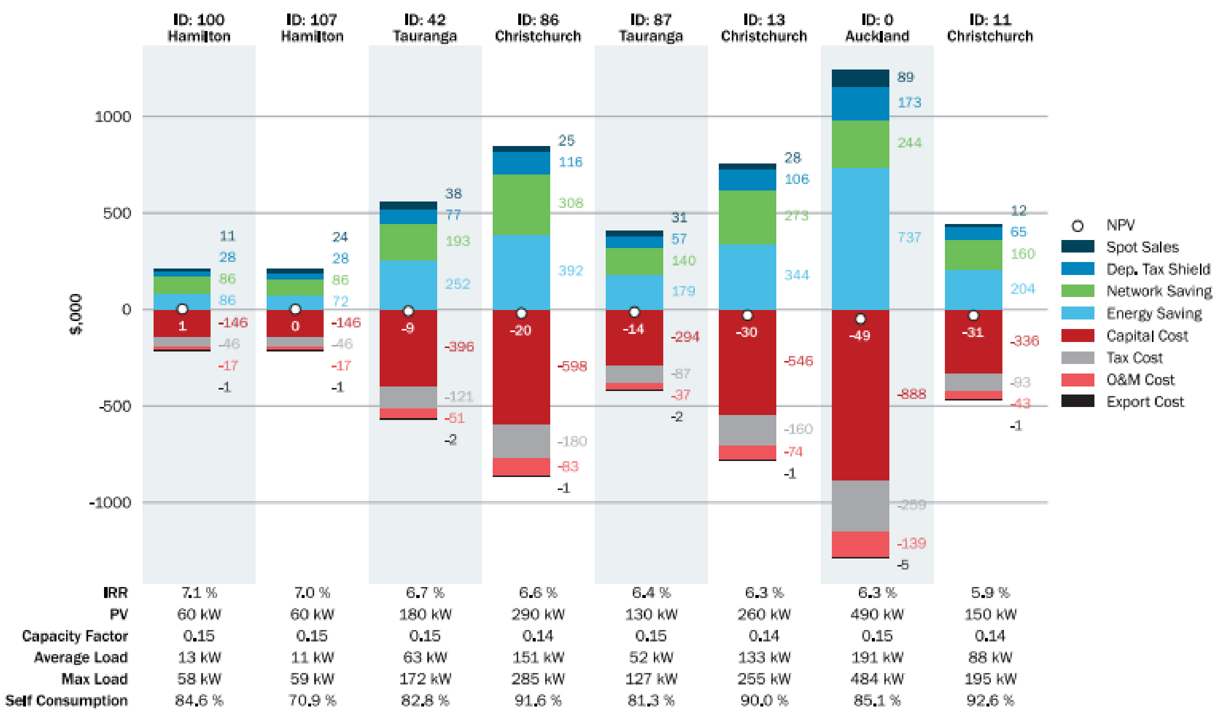


Figure 8: Financial results of analysis of solar at big box retail Site 100 and another seven sites in descending order of IRR.

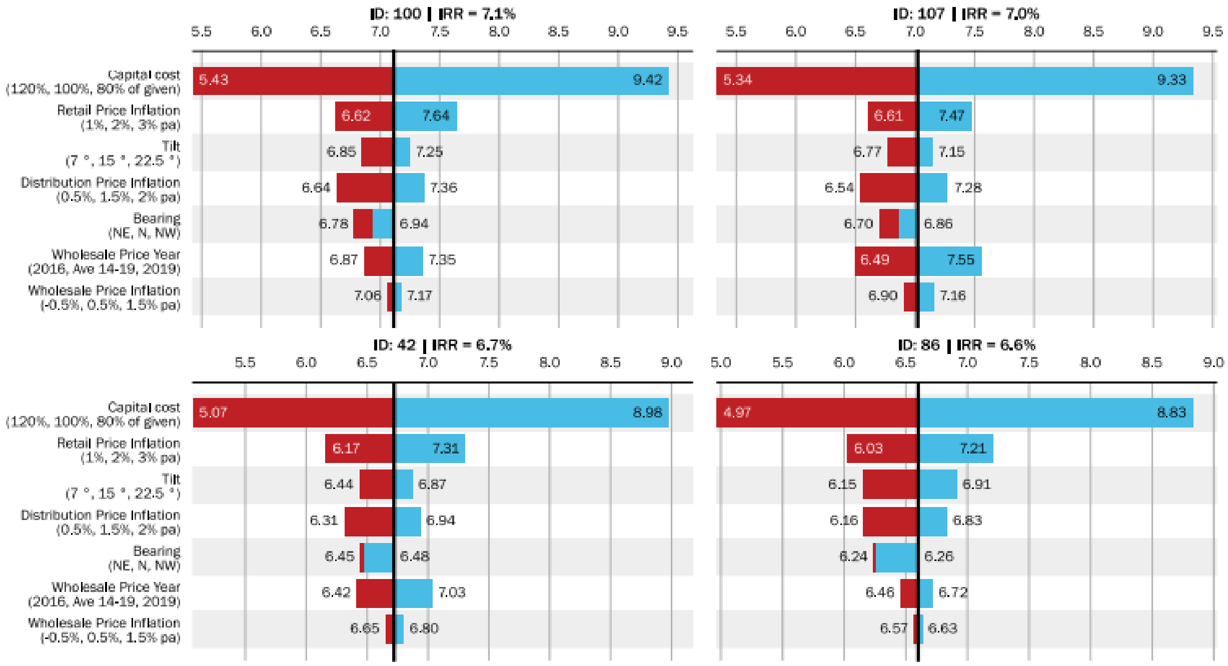


Figure 9: Sensitivity of IRR to inputs for big box retail Site 100 and three other sites.

2.1.14 Renewables Returns – World Economic Forum (Renewable Infrastructure Investment Handbook)

The below information is referenced from the World Economic Forums' "Renewable Infrastructure Investment Handbook: A Guide for Institutional Investors"

Figure: Target Returns Tables from WEF Renewable Infrastructure Investment Handbook

Renewable Infrastructure Investment Vehicles		
	Target Returns	Risks/Issues
Public debt (green bonds)	3-6%	Few "pure play" green infrastructure companies
Public equities	5-20%	Sector diversification limits
Infrastructure funds	7-20%	Fee structures, liquidity considerations
Direct project debt	6-10%	Illiquidity, deal pipeline
Direct project equity	12-18%	Illiquidity, deal pipeline

Insttutional Investor Presence in Renewable Infrastructure			
Item/Size (AUM)	Very large	Large	Medium
First investment in renewables	7 years ago	5 years ago	10 years ago
Commitment to renewables	$2bn to $3bn	$1bn to $2bn	$500mm to $1bn
Exposure	Direct investments	Funds	Public equities and funds
Returns	High single digits	High single digits	High single digits
Key constraint	Regulation pipeline	Regulation	Most opportties are in directs

2.2 Economics of Utility-Scale Solar in Aotearoa New Zealand – Executive Summary - Allan Miller Consulting Ltd for MBIE

Economics of Utility-Scale Solar in Aotearoa New Zealand - Forecasting Transmission and Distribution Network Connected 1 MW to 200 MW Utility-Scale Photovoltaic Solar to 2060

Executive Summary

This study contributes to the Ministry of Business, Innovation and Employment's development of the Electricity Demand and Generation Scenarios (EDGS). It does so by providing a forecast of potential utility-scale photovoltaic (PV) solar electricity generation in New Zealand, with accompanying detailed information such as size, location, and cost of each project. This provides an evidence base to inform energy sector and climate change policy, infrastructure providers, and the wider modelling community.

For a given location and design, utility-scale PV solar rate of return is most sensitive to electricity price and capital cost to build. From the absence of utility-scale solar development in New Zealand to date, the combination of electricity price and capital cost appear to have not guaranteed a suitable rate of return as yet. However, as the forecasts in this report show, capital costs for utility-scale solar are reducing and are now close to a point where rate of return becomes acceptable to consider building such plant. The forecasts also show that once that point is reached, the development of utility-scale solar could be extensive and rapid.

Utility-scale solar capital cost reduction is fuelled by a substantial worldwide PV industry that in 2018 produced and installed 103 GWp of solar modules – enough to meet New Zealand's annual electricity requirement by more than 3 ½ times.[1] This industry has grown substantially in the past 15 years and is expected to continue to grow according to International Renewable Energy Agency (IRENA) and International Energy Agency (IEA) forecasts. As the industry continues to grow, it improves production and installation techniques, leading to a lower module and system capital cost. Indeed, dramatic cost reductions are predicted by IRENA.

The exact timing of utility-scale solar development in New Zealand depends on several other factors in addition to electricity price and capital cost. These include:

- Location - irradiance varies substantially depending on location, mainly due to weather conditions but also due to latitude and topographic shading, and land availability in those locations (while there is ample land suitable for utility-scale solar systems, its availability will be constrained by alternative uses).
- Utility-scale solar system design - it is now economic to incorporate tracking systems to track the sun throughout a day, and to over-size module capacity to improve the inverter loading ratio and offset module degradation, thereby improving system capacity factor.
- Suitable electricity transmission or distribution infrastructure.
- Cost of capital and desired rate of return.

The scenarios investigated in this report illustrate the potential utility-scale solar build outcomes from changes in and optimisation of some of these factors. The modelling approach assumes that

[1] GWp is the peak power in giga watts that can be produced by a solar energy system, under ideal sunlight and temperature conditions. The actual power produced will vary substantially from the peak power as sunlight (irradiation) varies and module efficiency varies with temperature, shading, surface cleanliness, and degradation over time.

utility-scale solar is built if it is economic. This approach does not compare utility-scale solar with other generation technologies, so in that sense it is not a forecast of build, but rather a forecast of potential build. Scenarios were designed to primarily test sensitivity to electricity price and rate of return. The core scenarios, pertaining to results in this Executive Summary, are shown in the table below.

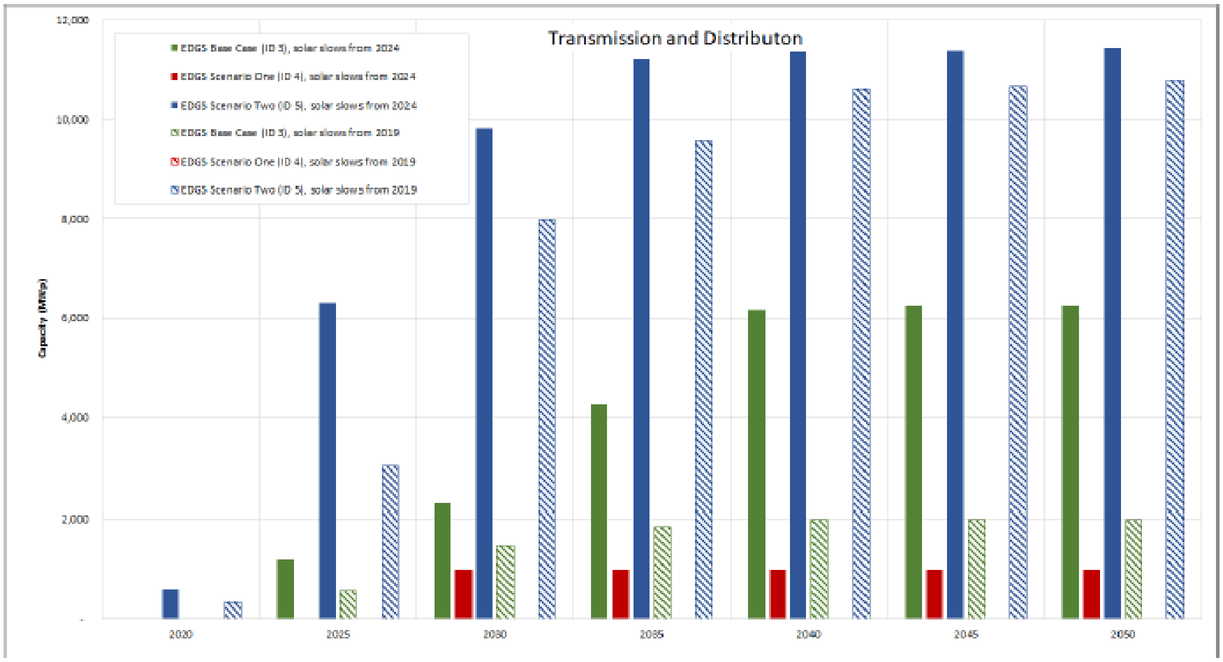
Price scenario parameters for the results shown in this Executive Summary - three core price scenarios consistent with the Ministry of Business, Innovation and Employment's Electricity Demand and Generation Scenarios.

ID	Name	Benmore Average Price (CY2020), $/MWh	General Price Inflation	Electricity price Inflation	Land value Inflation	O&M price Inflation	Wage Inflation	Nominal discount rate	Nominal IRR criteria for selecting potential site
3	EDGS Base Case	85	2%	2%	5%	2%	3%	7%	8.5%
4	EDGS Scenario One	85	2%	1%	8%	2%	3%	8%	9.5%
5	EDGS Scenario Two	85	2%	3%	3.5%	2%	3%	5%	6.5%

The rationale for the scenario parameters is explained in detail in the report. Briefly: (i) the 2017 electricity price from the 2019 EDGS scenarios is used with inflation adjustment. This is based on the long run marginal cost of new generation entering the market in the 2019 electricity demand and generation reference scenario; (ii) the Base Case scenario (ID 3) assumes electricity price increases at the same rate as inflation – and therefore the real price remains constant in 2020 dollars, consistent with the wholesale price indicator in the 2019 EDGS scenarios; (iii) land price inflation is set above the average dairy farm land price increases from 1978-2015 of 2.6% per annum; and (iv) the nominal discount rate is assumed to be 7% in the Base Case which is consistent with that used in the wind generation stack update report for EDGS. Since this study is exploratory in nature, parameters chosen for EDGS Scenario One and Two (ID 4 and ID 5) are quite extreme in order to provide a broad range of estimates of the potential solar sites.

Projections of solar capital costs are based on international studies of component cost by utility-scale solar system size, projected production and historical learning curves. Although worldwide solar module production has increased exponentially historically, this analysis assumes that the rate of increase will start to slow sometime in the next 10 years. As a result, capital costs reductions are also expected to slow. Two 'production scenarios' for this effect are included, with the slowing beginning at different years (from 2019 or from 2024). The reason for this is to investigate the forecast sensitivity to slowing worldwide solar production and the slowing of expected capital cost reductions.

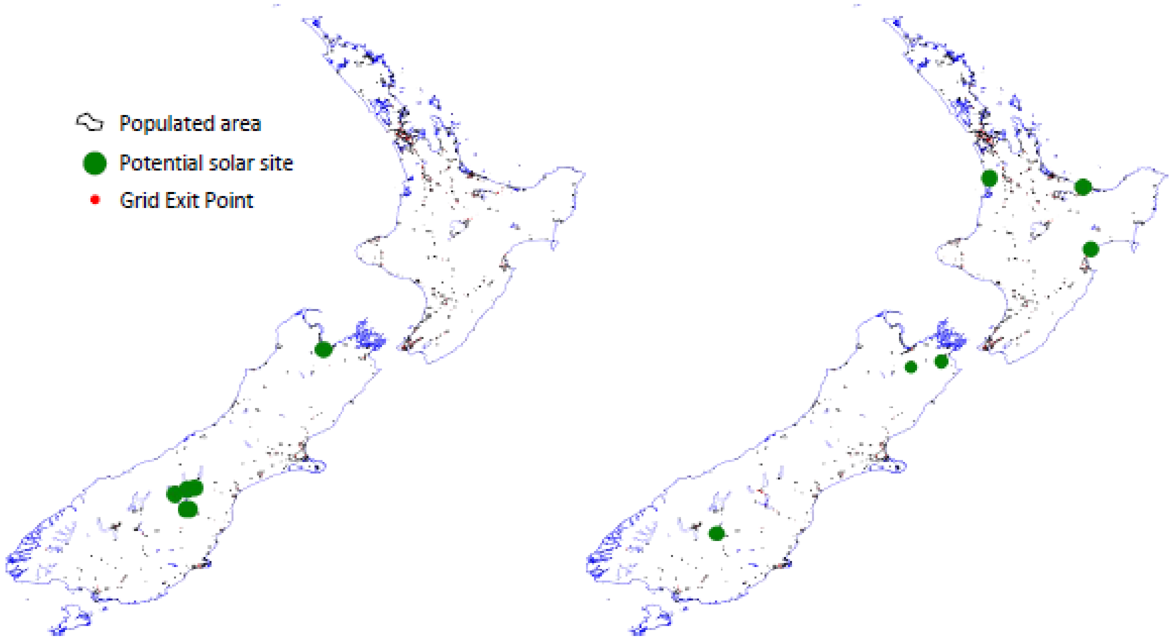
The following chart shows build forecasts for both transmission and distribution connected solar for the three price scenarios in the above table. In the chart the Base Case (solid green bar) requires a rate of return of 8.5% and incorporates strong land price inflation and medium electricity price inflation. Scenario One (solid red bar) requires a rate of return of 9.5%, has high land price inflation and low electricity price inflation. The Scenario Two (solid blue bar) requires a rate of return of 6.5% with moderate land price inflation and high electricity price inflation. The patterned bars are the same scenarios but with worldwide PV module production slowing from 2019. In all forecasts the capacity of distribution connected solar is about 5-15% of transmission connected solar.



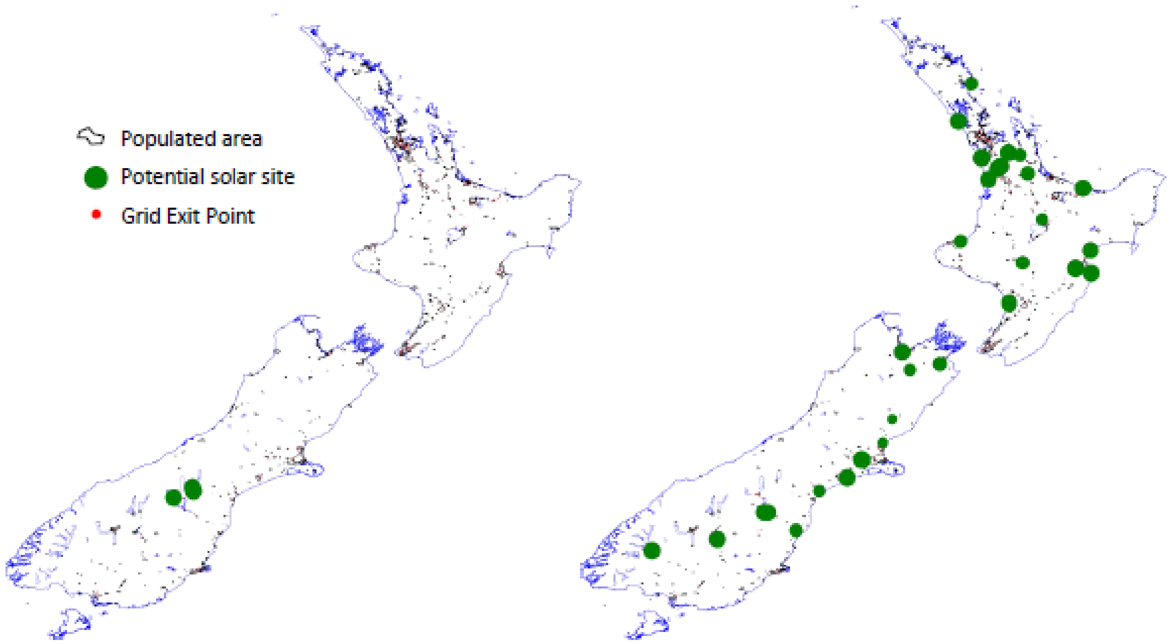
Transmission and distribution connected cumulative utility-scale solar system capacity. In all forecasts the capacity of distribution connected solar is about 5-15% of transmission connected solar.

As shown in this chart, the potential build differs significantly between scenarios, illustrating the sensitivity of utility-scale solar build to the economic assumptions. Nevertheless, it is worth noting that if and when utility-scale solar does become economically feasible, growth could be rapid, with major development possible in the space of 5-10 years.

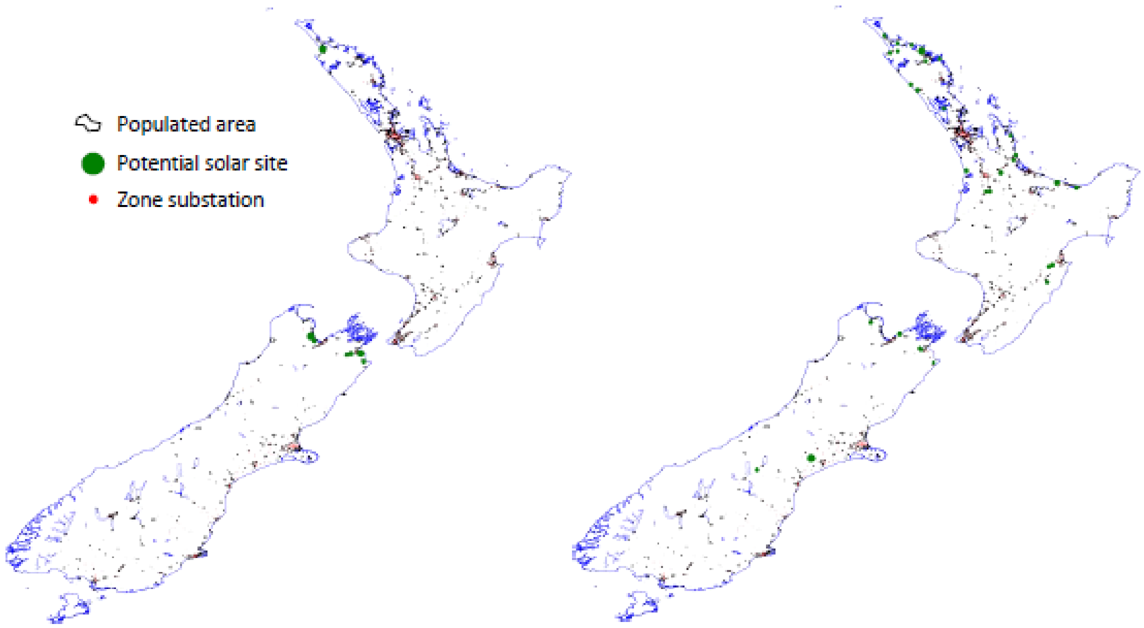
The approach used has considered utility-scale solar plant on a site-by-site basis, so by its nature has also examined where and when in New Zealand utility-scale solar systems are forecast to locate. This varies slightly between scenarios due to land price and electricity price difference. In general, the first forecast transmission connected utility-scale solar systems are forecast to locate (i.e. become economic) in the Mackenzie District and Tasman District, followed by Marlborough, Waikato, Hawke's Bay, Bay of Plenty and Central Otago as shown below. The first forecast distribution connected utility-scale solar systems locate (i.e. become economic) in the Far North District, Tasman and Marlborough, followed by the Bay of Plenty, Hawke's Bay, Waikato and Canterbury, as shown below.



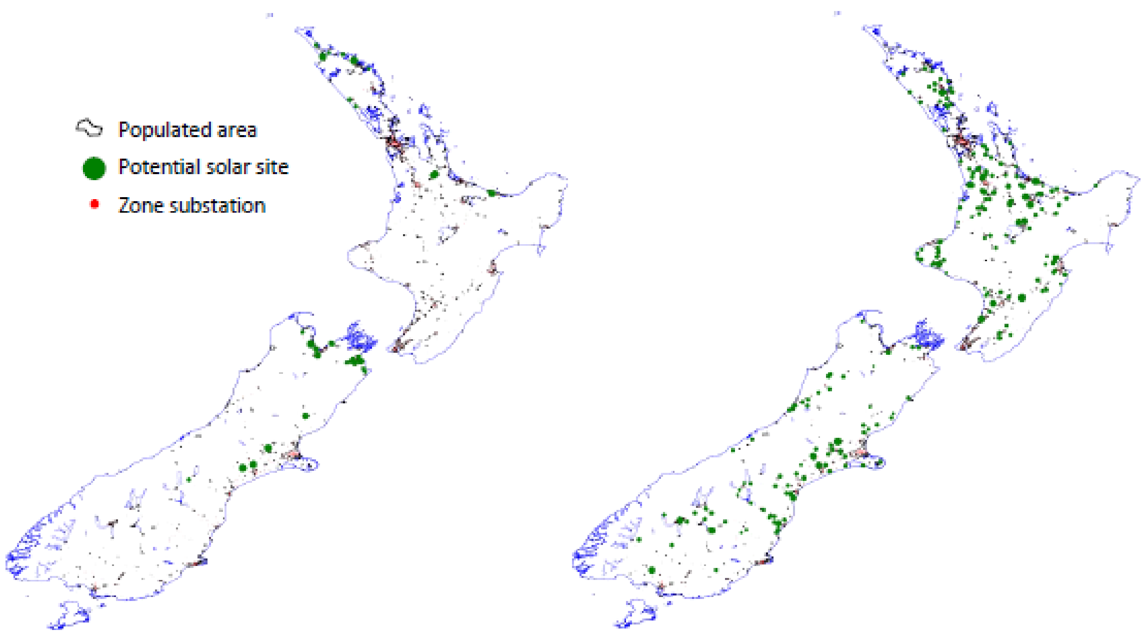
Transmission connected forecast utility-scale solar system locations in 2025 (left) and 2030 (right) EDGS Base Case scenario (the solid green bar of the above chart). This illustrates the areas where transmission connected utility-scale solar systems are most likely to locate first, due to a combination of high solar resource, higher location factors, suitable land at an acceptable price, and transmission grid. Solar capacity is represented by the size of the green dot (largest is 200 MWp).



Transmission connected forecast utility-scale solar system locations in 2020 (left) and 2025 (right) EDGS Scenario Two (the solid blue bar of the above chart). This illustrates the areas where transmission connected utility-scale solar systems are most likely to locate first in this scenario of lower cost of capital. Solar capacity is represented by the size of the green dot (largest is 200 MWp).



Distribution connected forecast utility-scale solar system locations in 2030 (left) and 2035 (right) EDGS Base Case scenario (the solid green bar of the above chart). This illustrates the areas where distribution connected utility-scale solar systems are most likely to locate first, due to a combination of high solar resource, higher location factors, suitable land at an acceptable price, and proximity to distribution network infrastructure with suitable capacity. Solar capacity is represented by the size of the green dots (largest is 20 MWp).



Distribution connected forecast utility-scale solar system locations in 2025 (left) and 2030 (right) EDGS Scenario Two (the solid blue bar of the above chart). This illustrates the areas where distribution connected utility-scale solar systems are most likely to locate first in this scenario of lower cost of capital. Solar capacity is represented by the size of the green dots (largest is 20 MWp).

The forecasts also show very high solar development in some scenarios, even with transmission and distribution capacity constraints accounted for. It may be questionable whether the wider electricity system could accommodate such solar capacity (for example, in terms of technical integration and managing and storing the daily and seasonal solar generation profile). This effect is being observed in Australia now, where there are far more new solar generation plants wanting to connect to the state grids than the distribution and transmission companies can deal with administratively and that the national System Operator is comfortable connecting. However, as mentioned above, a rapid rate of growth when the balance tips towards utility-scale solar systems becoming economic suggests the need for preparedness by network owners and operators.

When considering the forecasts in this report the following should be considered alongside them:

1. Capacity factor of a renewable generator is a particularly important consideration. Capacity factor is the measure of the resource available to a renewable generator, and its efficiency in converting that resource into saleable energy. For this it employs solar generating plant which comes at a considerable cost. Capacity factor is closely related to the solar resource, solar module efficiency and inverter characteristics. As discussed above, utility-scale solar system design can improve capacity factor; this study assumes all solar systems will employ increased inverter loading ratios and single-axis tracking. With these improvements the capacity factors of solar modelled throughout New Zealand range, conservatively, from about 0.12 to 0.20.

2. The forecasts must be viewed in conjunction with possible medium- to long-term electricity infrastructure changes. Infrastructure changes that will permanently increase or lower price and/or location factors are particularly important.

3. The large influx of solar capacity shown in some forecasts may also depress the wholesale electricity price at times when solar is generating, negating the incentive to develop a utility-scale solar project. While the forecasts do incorporate the reduction in location factor at a location from increased generation resulting in lower transmission losses, they do not incorporate the entire wholesale electricity market, and the effect of increased generation on real-time wholesale price. For these reasons, the very high forecast scenarios (the blue bar in the above chart / Scenarios 0, 2, 3, 5 and 8 in the report) are unlikely to eventuate.

4. The rates of return of utility-scale solar projects in other jurisdictions may be greater than what can be achieved in New Zealand. Solar projects in countries with better solar resource, such as Australia, California, the Middle East and northern Africa will produce more energy, potentially increasing rates of return. This is relevant, as the forecasts are based on utility-scale solar projects meeting an acceptable rate of return. For this reason, a range of rates of return are tested in the scenarios.

5. However, as solar development becomes saturated in other countries, solar investors/developers may look to New Zealand for development. Even if those countries are a long way off saturation, increasing solar deployment will drive more module production, reducing PV system prices further and thereby increasing rates of return in New Zealand. As discussed earlier, utility-scale solar forecasts are very sensitive to capital cost.

6. There is also the possibility that the cost of capital will decrease substantially in the near- to medium-term largely as a result of the coronavirus (COVID-19) pandemic declared while this study was being conducted. Consideration was given to adjusting some scenario parameters to account for economic disruption from the pandemic. However, this is a long-term study to 2060 and the parameters were therefore retained. Nevertheless, the report does investigate some of the forecast outcomes that may eventuate in a low cost of capital and electricity price inflation environment. Countering cost of capital reductions could be disruptions to supply chains of solar equipment resulting from the pandemic, possibly increasing its capital cost. While investigations of more recent capital costs show ongoing reductions in PV module and inverter costs, more recent data was not available at the time of writing to understand the impacts from the pandemic.

7. Since many PV components are imported, fluctuations in the New Zealand dollar could change the cost of systems in New Zealand. This may counter reducing rate of return requirements, although other generation technologies are likely to be similarly affected by exchange rate fluctuations.

8. Ongoing advances in other generation technologies, such as wind and geothermal, may see reductions in their capital costs. In turn they will continue to compete with utility-scale solar, and therefore the very large forecasts indicated in this report may not eventuate.

9. The lifespan and analysis of utility-scale solar used in this study was 25 years. This is a conservative assumption, as lifespans of modern modules are more likely to be in the range of 30 years, but they may attract a price premium.

10. The HVDC link transmission charges solely to South Island generators was removed as per the proposed new transmission pricing methodology published by the Electricity Authority in July 2019.

One of the key findings from this study is how rapidly utility-scale solar development could become economic in New Zealand. For example, if all economic utility-scale solar systems were built within the existing grid capacity, there could be several gigawatts of development in the space of 5-10 years. This growth would be fuelled primarily by the exponential growth in module production (a consequence of the large and growing solar industry). Moreover, such rapid growth could begin any time in the next 10 years.

Finally, further investigation of solar forecasts with a lower electricity price inflation combined with a lower cost of capital environment, shows lower overall solar capacity development. Nevertheless, the development may still be rapid and occur in the next 10-15 years.

2.3 Current Solar Landscape in NZ: Competitors & Various NZ Solar Models

2.3.1 Commercial Rooftop Solar - List of largest NZ solar installations known by Purpose Capital (installed, under construction, & proposed):

1. 1.166MW Foodstuffs North Island Distribution Centre (FNI to install NZ's largest rooftop installation at April 2020), system by Reid Technology, 6,000m^2 of panels estimated to generate 1.5GWh p.a. & the building is 75,000m² (Jan 2020)
2. 524kW Laminex Hamilton rooftop solar array (Sept 2020)
3. 422KW Mainfreight Auckland Depot (NZ's largest rooftop installation at April 2020), system by Reid Technology, Mainfreight building is 20,000m² (2020)
4. 411KW Yealands Wines, Blenheim rooftop solar installation, 10% of day time baseloads. (2016)
5. 315KW A&G Price, Thames, rooftop solar installation (Nov 2019)
6. 240KW Tarewa Shopping Centre Whangarei, rooftop solar installation (2014)
7. 170KW Mainfreight Hamilton Depot (NZ's 2nd largest rooftop installation at the time), system by SolarKing, Mainfreight building is 18,400m² (2015)
8. 153KW Misco Joinery, Christchurch. The largest commercial solar installation in Canterbury at time of install. Estimated 16.1% return on investment. 65% of total electricity needs (May 2019)
9. 150KW Energyworks (Engineering company in New Plymouth), system by Sunergise (May 2021)

It is apparent from the installations mentioned above, most of which occurred during 2019-2021, that Rooftop solar is commercially viable in a New Zealand context.

Foodstuffs NI Distribution Centre – Excerpt from Article (23April2021)

Quin says the decision to include just over 2900 solar panels on the roof was initially a bit of a cost-neutral, socially responsible move.

But soaring commercial power costs over the last six to nine months have made that decision look great in hindsight.

''There's been a seismic shift in power costs in New Zealand. There are examples of commercial power increases of 100 per cent and we didn't know that at the time we invested in solar for this building, but it's certainly good news we did,'' Quin says.

"That's been a massive shock to New Zealand businesses in particular and part of a cost profile that's looking increasingly difficult."

2.3.2 Solar Farms - List of largest NZ solar installations known by Purpose Capital (installed, under construction, & proposed):

Prior to 2021 there was no large/utility scale land based solar farms in NZ. Now there is a groundswell of projects and it's quite possible there are many other projects in the pipeline that aren't listed below.

1. Lodestone (PROPOSED) $300m 400GWh
2. 1000MW Total Future Investments by Far North Solar Farm Ltd over the next 5-8 years (PROPOSED)
   FNSF have several large-scale solar projects planned in Northland, including a power station on the outskirts of Kaitaia with 20ha of panels and an ever bigger solar farm with a 30ha panel area near Dargaville.
3. 500MW total Genesis Energy solar farm planned in North Island (PROPOSED). 300kw solar farm in the Northern Waikato to deliver 550 GWh p.a.
   Genesis Energy plans to build enough solar energy farms over the next five years to meet a little under 2 per cent of the country's current electricity demand. The company said it was finalising a joint venture with overseas solar firms to generate about 750 gigawatt-hours of solar p.a. "Solar makes sense on a number of levels and we believe there is an economic opportunity to develop utility-scale solar projects in New Zealand,"- Genesis chief executive Marc England
4. 26 MW solar farm at the Marsden Point Oil Refinery, (PROJECT ON HOLD)
5. 16MW Pukenui Farm by Far North Solar Farm Ltd, $30m, 12ha of panels on 15ha of land (UNDER CONSTRUCTION)
6. 10MW solar farm at Hawke's Bay Airport and Centralines planned next to the runway, expected to be operational by the end of 2021 (PROPOSED)
7. 2.1MW Kapuni, owned by Todd Corporation, system by Sunergise (May 2021)
   "It definitely proves that there is a case for large-scale solar farms in New Zealand, and that they can be economic," Sunergise general manager Paul Makumbe said. Makumbe said the company was constantly looking for new solar energy sites around the country.
8. 2MW Kea Energy Marlborough Solar Farm, $2.5m-$3m (March 2021)
9. 1MW Floating Solar, Watercare's Rosedale wastewater treatment pond (2020)

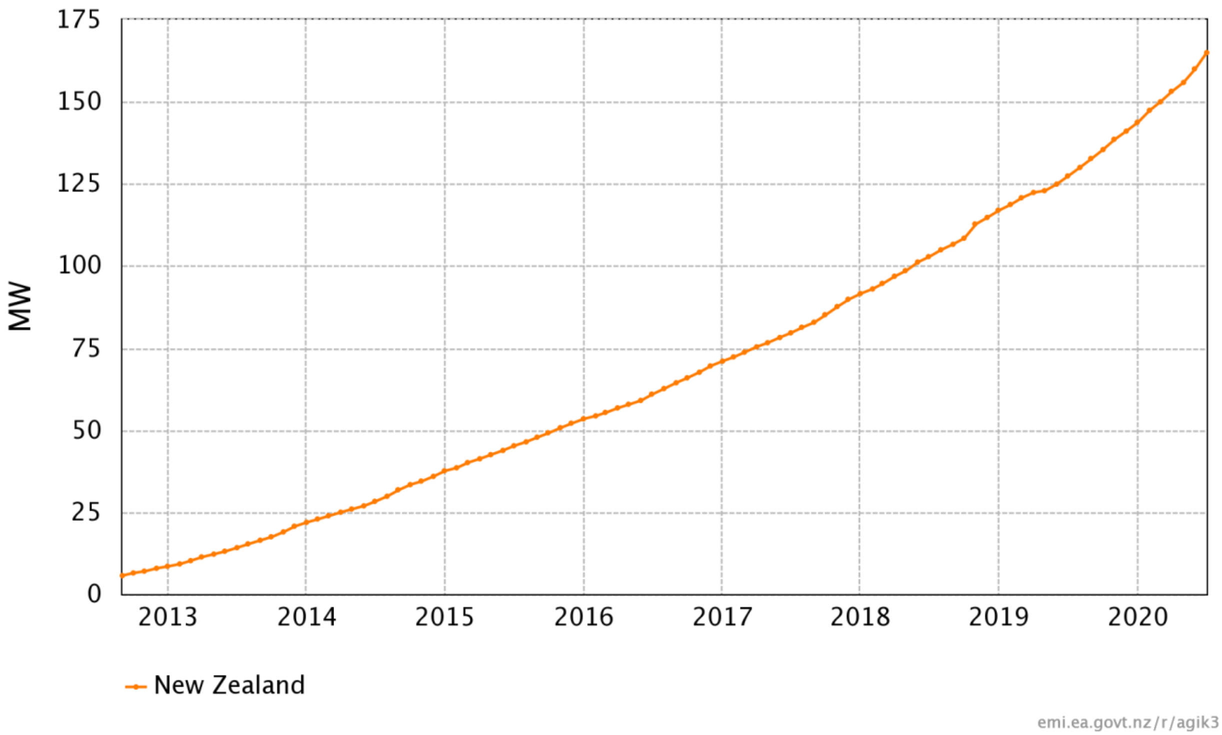
* Note: c.200MW - Name of party omitted for confidentiality reasons, this party has MoUs in place for c.200MW of ground mounted solar systems in NZ.

** Note: 350 MW - HES Aotearoa, a joint venture between Hive Energy, Ethical Power Group and Solar South West, that they hope will lead to 350 MW of utility scale installations in NZ, their NZ Project Pipeline below however it's unknown whether there is overlap with any of the solar farms mentioned above.

Country	Project Name	Technology	Location	Capacity (MW)
New Zealand	HES 1	☼	Auckland	60
	HES 2	☼	Manawatu	90
	HES 3	☼	Timaru	32
	HES 4	☼	Waikato	15
	HES 5	☼	Ashburton	50
	HES 6	☼	Selwyn	88

2.3.3 Electricity Authority NZ - NZ Total Solar Capacity Installed (MW)

Figure: NZ Total Solar Capacity Installed (MW) – Source: Electricity Authority NZ



2.3.4 Solar Businesses - NZ

2.3.4.1 Lodestone

Lodestone Energy was founded to help the national effort to decarbonise New Zealand's energy sector.

Lodestone energy claims to be leading the development of New Zealand's largest ever solar project. This transformative project will see utility-solar farms constructed in five locations across Northland, the Coromandel and the Bay of Plenty. More than half a million solar panels will be placed over 500 hectares of land.

Lodestone Energy has secured sites near Dargaville, Kaitaia, Whakatane, Edgecumbe and Whitianga for the solar farms which it describes as "a massive turning point for the country's energy production". Combined, the farms will act as one giant power station, feeding electricity into local networks and complementing New Zealand's hydro, geothermal and wind resources.

Each solar farm will incorporate world-leading bi-facial modules and single axis tracking technology. This will see the panels rotate and track the sun as it travels across the sky. Electricity will be produced from both sides of the panel, allowing the capture of energy from reflected sunlight from the ground.

The farms will deliver approximately 400 GWh of valuable daytime, renewable energy to the New Zealand market, enough to power 50,000 New Zealand homes – or a city the size of Hamilton. The five solar energy farms in the upper North Island come in a at a cost of $300 million, which will together be capable of providing about 1 per cent of the country's electricity supply.

In addition to producing electricity, the farms will continue to support agriculture and horticulture production. The panels will be high enough, and spaced sufficiently, to allow farming and cropping to continue underneath.

The first solar farm, Lodestone Two near Kaitaia, is expected to be operational in the summer of 2022, with the construction of the four other farms completed by the end of 2023.

"Lodestone's developments, when combined with other renewable energy sources, are likely to drive power prices down to levels last seen in the early 2000 period. Renewables are lower cost than carbon-based generation and, if reaching 100% renewable electricity is achieved, consumers, embracing electrification will be winners" – Gary Holden, Managing Director, Lodestone Energy.

2.3.4.2 Genesis Energy

Genesis Energy very recently announced (a few months after Lodestone's announcement) they're planning 500 megawatts of grid-scale solar built on existing transmission connections in the North Island, including Huntly power station.

The generator retailer is finalising a joint venture with international developers to build enough solar over the next five years to generate up to 7500 gigawatt-hours of power a year. That's enough to power 185,0000 electric vehicles a year and Genesis plans to eventually back this up with battery storage as well.

"Solar makes sense on a number of levels and we believe there is an economic opportunity to develop utility-scale solar projects in New Zealand," - Genesis chief executive Marc England.

"We'll take advantage of key learnings from the recent surge in interest in solar in Australia, particularly equipment selection, cost efficiencies in the installation process and transmission connection risk."

The company intends to be a developer and not just a partner. England says its experience in consenting, land access, and grid connections – the latter two being especially big cost drivers – will complement its prospective JV partners' expertise.

"We'll probably become the pre-eminent solar developer in New Zealand."

2.3.4.3 Meridian Energy

Meridian claims to have "helped establish New Zealand's largest commercial solar programme, installing solar across Kiwi Property shopping centres in Christchurch, Palmerston North, Auckland and Hamilton."

Meridian's Commercial solar solutions for businesses:

1) ***Solar Power Purchase Agreement***

   For businesses that want no upfront capital costs.

   With a Meridian Power Purchase Agreement (PPA) gets you solar through monthly payments. We'll design, install and maintain a solar system for you. Your business won't need to put any upfront capital cost towards the solar system. Instead, we'll sell the power generated back to you at an agreed c/kWh rate for the lifetime of the PPA.

   After that, you'll be the proud new owner of your solar array. A solar PPA is invoiced monthly like your regular power bill, so it doesn't tie up capital you could use for your core business activities.

2) ***Solar Buy Now***

   For businesses that want to manage their own solar system.

   With a Solar Buy Now package, we'll do the hard work up front. After that, you'll own and operate your solar system.

   We can get you underway with a detailed solar assessment to give you the information you need to decide if solar is right for you. If it is, we'll help size a solar system to meet your business needs, building infrastructure and energy load.

   You'll get access to a competitive, all-inclusive quote you can rely on.

2.3.4.4 Far North Solar Farm

Far North Solar Farm Ltd (FNSF) has proposed 1000MW Total Future Investments over the next 5-8 years. FNSF have several large-scale solar projects planned in Northland, including a power station on the outskirts of Kaitaia with 20ha of panels and an ever bigger solar farm with a 30ha panel area near Dargaville. The Pukenui solar farm is expected to start supplying power by the end of the year.

The company behind the venture, Far North Solar Farms, is owned by a Melbourne-based company and Richard Homewood of Muriwai Beach.

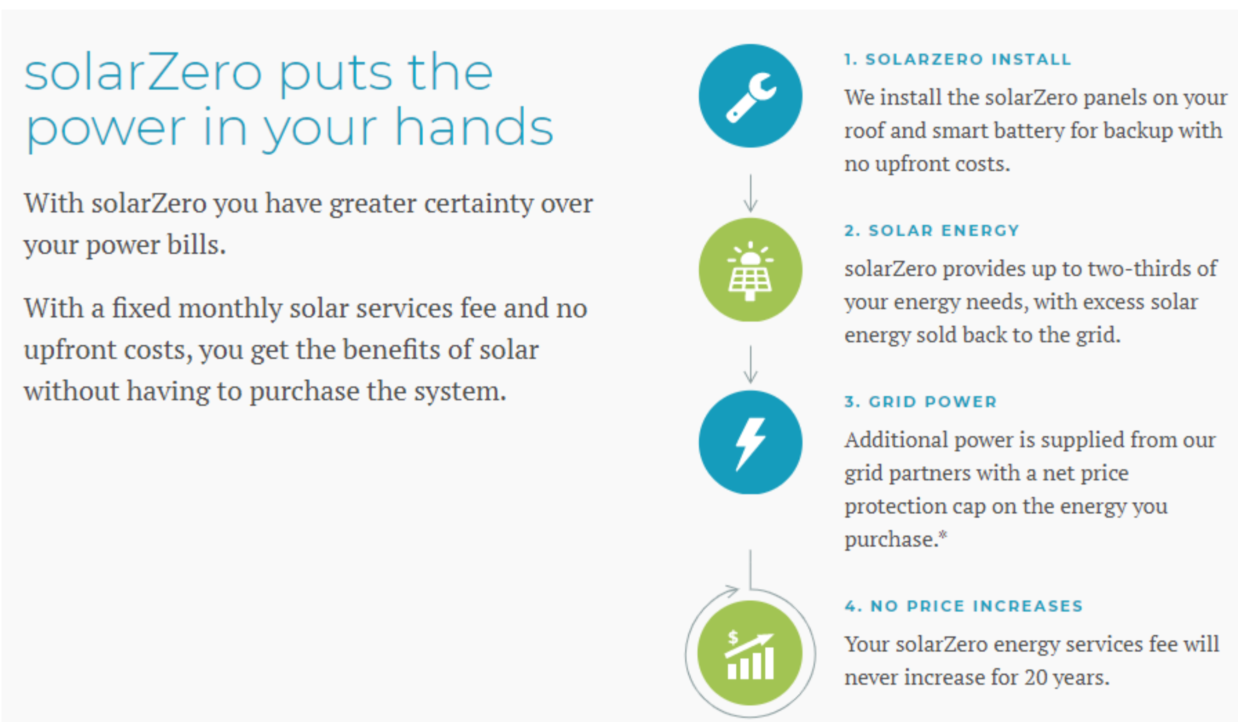
Funding for the FNSF Pukenui solar farm has closed. However, future investment opportunities are still open for investors.

2.3.4.5 SolarCity (NZ not USA)

Note: The NZ Solarcity is a completely unrelated company to Musk's $2.6B Solarcity company in the USA

Solarcity offers 'solar a as a service' for residential customers essentially a 'pay for power, not panels' model. They provide both panels and batterys and essential act as a utility company whose generation assets are on your house roof. However, it is known that Solarcity does some commercial solar as they got the solar contract for the Warehouse.

Solarcity Investors include ACC, K1W1, Pencarrow Private equity, and most recently NZGIF made a $10m investment. The NZGIF investment in SolarCity is to accelerate the growth of solar and battery deployment.



2.3.4.6 SolarBay

SolarBay is a $350m Renewable Energy Fund with a focus on Solar PV. Typical investment size range between $500,000 – $30 million, with smaller per site capital deployment possible for multi-site rollouts.

Solar Bay was founded in 2016 with the goal of providing renewable energy solutions to commercial and industrial users. Solar Bay now owns and operates a diverse portfolio of Solar PV, Battery Storage and Off Grid Renewable IPP.

Solar Bay can be thought of as a utility company that installs its solar electricity generation assets on businesses roofs (or on land next to a large energy user). To deliver this offering, SolarBay operates a Solar Power Purchase Agreement model where businesses don't put any upfront capital cost towards the solar system. Instead, SolarBay sells the power generated back to businesses at an agreed c/kWh rate for the lifetime of the PPA (typically 10-20 years). After the lifetime of the PPA, businesses be then own the solar array.

About Solar Bay

- Solar Bay is a Renewable Energy Investment Fund that invests in large scale solar projects.
- Solar Bay is a $350m Australian solar fund with a significant portion of that eligible to be installed in NZ
- Solar Bay investors comprise of 3 Australian family offices
- Solar Bay can be thought of as a utility company that installs its solar electricity generation assets on businesses roofs (or on land next to a large energy user).
- All solar systems are designed, installed, funded, operated, managed and maintained by Solar Bay.

Impact

- Rooftop Solar / Distributed Solar Photovoltaics (PV) is an important part of the solution to climate change.
- From a Financial, Environmental and Climate Change perspective, their solution allows renewable energy (low carbon energy / fossil free energy) to scale. They have created a win-win-win model for: Solar Bay, businesses, & the environment.

2.3.4.7 Sunergise (owned by Todd Corp)

Sunergise provides clean, reliable, cost-effective solar power services for businesses, communities and governments. They claim to be "Oceania's largest private operator of renewable energy assets."

Sunergise was founded in 2012 as the first pan-Pacific solar power utility by a group of entrepreneurs and veteran investors including ANZ Oceania CEO Bob Lyon.

“Our mission is to secure a brighter, more productive future for the people of New Zealand and the Pacific Islands by providing high quality, clean, affordable energy. Increasing solar in the energy mix helps to reduce crippling fuel import bills and protect the natural environment that entices visitors from all over the world. In partnership with our customers, Sunergise is rapidly accelerating the adoption and installation of solar PV panels in the Pacific region. Our solar power creates energy independence and protection from rising oil prices. As part of developing a business with sustainability at its core, we aim to make clean energy affordable to all.”

Sunergise began operations with the introduction of the world’s largest installation for a marina at Port Denarau in Fiji.

In 2014 The World Bank’s International Finance Corporation (IFC) took a stake in the business.

The Sunergise group is the leading solar power services company in the Pacific Island region, with a growing portfolio of solar projects in Niue, Nauru, New Zealand, Fiji, Vanuatu, Marshall Islands, Papua New Guinea and Solomon Islands.

In 2019 Todd Corporation via Todd Generation Limited took a majority stake in Sunergise New Zealand Limited and Sunergise International Limited.

The investment will boost solar power generation in New Zealand and the Pacific Islands.

To date over 13 MW of clean power has been installed and over 20 gigawatt-hours of electricity produced by Sunergise.

On 16 December 2020, Sunergise became the first in NZ to generate 1GWh of renewable solar energy.

Sunergise’s SunPlus™ product allows businesses to go solar without buying any panels.

SunPlus™ “Buy power, not panels.”

Using your available roof area or vacant land on-site, we design, finance, install and maintain a custom solar system. If you are grid-connected, we can cater for up to 100% of your daytime electricity requirements. If you are off-grid, Sunergise can offer a complete solution with storage and backup to meet your power needs.

The Sun provides us with enough energy in an hour to power the Earth for a year. That power that could be going to reduce your company’s costs. If you have a roof or vacant land, it’s time you put it to work for your business. With Sunergise SunPlus™, you can keep your capital where it belongs – invested in growing your business – while lowering your operating costs for the life of the agreement.

Invest in the savings

Sunergise assesses your site to determine the optimum solar PV system for your needs. Once you are happy with our proposal, we can install and maintain the system for zero money down. We offer an instant saving on your current power bill and fix your solar power rate for the longer term. With Sunergise SunPlus™, you pay less for electricity today and watch your savings grow over time as fossil fuel prices and grid electricity costs rise.

With SunPlus you simply pay for the solar power you use every month. It's just like your old utility bill, only more affordable. We service, monitor and maintain the system to ensure that it is working at maximum efficiency.

Here's how it works:

1. *We evaluate your building and power usage*
   We will look at your roof and your site to determine potential for solar, taking into account any aesthetic considerations.
2. *You get solar power for no capital outlay*
   Sunergise pay for the design, installation, insurance, and regular maintenance of the system.
3. *You get cheaper electricity now and your savings increase over time*
   As the cost of power increases, your Sunergise SunPlus™ spend remains at the original lower price.
4. *We guarantee the power output*
   Guaranteed, reliable power is better for business. Plus we can help manage your consumption and advise on other ways to save.

2.3.4.8 LightForce

Lightforce are suppliers & installers of Solar (& battery) systems for both residential and commercial applications. They have completed 6000+ residential installs.

Lightforce have partnered with financial institutions and can assist in the financing of commercial solar pv systems and claim they "endeavour to make the shift cash-flow positive over the lifetime of the system".

Also on their website, it indicates they are looking for landowners to partner with on a solar farm development (1 acre minimum):

If you have land and are interested in passive income exceeding 10% yield, Contact us to explore opportunities to partner on a Solar Farm development. With 25 years of guaranteed system performance, utility-scale Solar is a long term and environmentally friendly investment that really stacks up. With feasible blocks as small as 1 acre, you can help ensure the future of New Zealand's energy generation. Contact Lightforce via the below link to have a representative call to discuss options.

2.3.4.9 Tesla Solar: Solar Roof Tiles & Battery Packs

Tesla offers both solar and battery products. Their solar roof tile product is not at the stage of mass production/adoption.

2.3.4.10 Community Solar Models & P2P Solar

The Raglan Local Energy project is about working with partners Our Energy and the Raglan community to embrace new technology which will more efficiently utilise solar power with the ultimate benefit of decarbonising the supply of electricity.

Currently less than 1% of buildings have solar and for solar to be a commercially viable investment alternative economic models are required.

RLE integrates a real time peer-to-peer (P2P) matching system built by Our Energy using the OurPower retail platform to create a power retailer that focuses on changing customer behaviour to better utilise renewable energy.

The outcome will be a more cost effective system for generators which we hope will encourage further distributed solar installations. The RLE project is in the early stages but we have an ambitious goal of making Raglan New Zealand's first 'zero carbon energy community'.

2.3.4.11 Infratec

Infratec provides an experienced team of renewable development and implementation specialists. Clients include Transpower, Wel Networks, Watercare, Countdown, & Kainga Ora.

2.3.4.12 Kea Energy

Family run company based in Canterbury, New Zealand who generate their own 'environmentally friendly' electricity. They own, operate, maintain and manage hydro-turbines and solar generating plants, including the 2MW Marlborough solar farm.

Kea Energy offers PPA's to selected sites, these agreements cost the customer nothing and the customer allows Kea Energy to install PV panels, inverters and other associated equipment on some land or a roof. Kea Energy pays for the equipment and installation costs. The customer agrees to buy the power from the solar panels at a discounted rate from the Retailers.

Kea Energy also offer complete turnkey systems that can purchasing via Kea Energy. They claim that "if you buy a solar park from us we can also offer a competitive buy back rate for your power".

2.3.4.13 SOLAGRI

Solagri solar systems generate low cost solar electricity as a service on your farm. No capital investment is required. "Offering farmers capital-free solar as a service."

Solagri achieves competitive dairy farm energy prices by aggregating the purchase and installation of solar for many farms at once, and negotiating on behalf of its customers to drive down the cost of the electricity they get from the grid.

How it works:

- *We install a solar array at our cost on approx. 0.25 ha leased from your business*
- *Your property remains grid connected*
- *Solagri supplies 100% of your dairy shed's electricity needs, from both solar, as well as the grid, under a long-term Power Purchase Agreement (PPA)*

- *Your solar generated power price is locked in and pegged to inflation*
- *Solagri will use the purchasing power of our growing customers base to push down the cost of your power from the grid*
- *Your exposure to high energy prices caused by dry lakes and other market shocks is reduced*
- *Your business has improved cash flows and increased environmental sustainability*
- *We'll add a battery to the system once we have completed our R&D which will improve the efficiency of the solar and save you more money.*
- *We maintain the system at our cost*
- *Your shed gets a DC fast charger at no cost when you're ready to get an EV*

"The monthly energy bill for my shed is down around 10% with Solagri. It's the most profitable half hectare on the property." - Richard Stalker, Dairy Farmer, Rangiora

Agrisolar are now in the process of crowdfunding. You can follow their progress on Pledge Me and view their Information Memorandum.

2.3.4.14 Energy Democracy (a co-op model)

Energy Democracy approached Purpose Capital for investment in 2020. They establish locally owned renewable energy co-operatives and build, operate and maintain renewable energy parks for the co-ops. Energy Democracy claims to exist to democratise the transition to a low carbon economy, helping individuals to save power, save money, and save the planet.

2.3.4.15 Harrisons Energy Solutions

Harrison Energy Solutions are suppliers of Solar residential and commercial systems

2.3.4.16 Reid Technology

Reid Technology specialises in the design, supply and installation of large-scale solar power systems throughout NZ and the Pacific.

2.3.4.17 iGenerate

iGenerate is Solar supplier, part of the Lightforce family.

2.3.4.18 NZ Solar Professional Directory

A complete list of SEANZ members who install solar, battery and energy management system technology work to a strict SEANZ Code of Conduct can be found here: https://www.seanz.org.nz/directory

3.0 Key Risks: Assessment & Mitigation

A comprehensive risk framework for renewable investments from the WEF

https://impacttoolkit.thegiin.org/renewable-infrastructure-investment-handbook-a-guide-for-institutional-investors/

Risks	Description	Mitigation
Land purchase and site	Suitability of the project site (e.g. geology, security, pollution).	Thorough due-diligence; possible risk-transfer to EPC contractor; government has no obligation to speed-up permits.
Environmental and social	Environmental and social strategy (e.g. compensation for relocation).	Make sure contractor complies with permits/consents by including respective clauses in contracts.
Design	Design compliance with output/performance specifications; changes require consent by authorities.	Pass-through obligation to the contractors; project relief principles to be incorporated in contract.
Construction	Labour disputes, quality standards, IPR breaches, cost overruns.	Pass-through obligation to the contractors; some risks are exempted (e.g. force majeure)
Completion	Delays and cost overruns; failure to meet the scheduled commercial operation date.	Pass-through obligation (including delay obligation damages) to the contractors; independent engineer.
Performance/ price	Meeting output specification metrics and costs; private partner cannot add more panels beyond contracted under PPA.	Pass-through obligation to the contractors; in EM, repairs might be allowed.
Resource/input	Interruption of necessary supplies for the project operation; in EM, this risk might be shared with authorities in some cases.	Some risk can be passed-through to the contractors, for higher fees.
Demand	PPA does not contain a take-or-pay obligation, so only actual power sold will be remunerated.	Governments will stand behind obligations of the contracting authority.
Maintenance	Maintaining the asset to the appropriate standards, subject to cost overruns.	Pass-through obligation to the operation and maintenance contractors.
Force majeure	Unexpected events beyond control of parties, compromising performance.	Private partner is exempted from PPA obligations, but should seek insurance to mitigate loss of revenue and damages.
Currency and interest rate	Private partner assumes all currency and interest rate risks.	Hedging instruments.
Insurance	Private partner is responsible for taking insurance for the project; particular types of insurance might not be available.	Thorough due diligence, including an insurance advisor.
Political	Government intervention, seizure, or expropriation.	Contracting authority will bear expropriation risk; force majeure may be applied; political insurance is available.
Regulatory	Change in law or taxation.	Contracting authority will bear change in law (not in tax) risk; force majeure may be applied; insurance may be available.
Inflation	Costs rising above expected under PPA.	Hedging instruments.
Strategic	Conflicts of interest, changes in shareholding; original private partner must remain in control.	Create a holding company for the project; indirect mechanisms specified in shareholder agreement.
Disruptive technology	Unexpected displacement of current technology, more applicable during construction.	Adding clauses to EPC contract in order to take full advantage of new technologies.

Box 8. SOLAR PV PERFORMANCE UNDER EXTREME WEATHER EVENTS

Extreme weather events are clearly affecting the solar industry and are becoming the biggest cause of failure of any PV plant. Solar installations have to cope with different natural disasters and, as the frequency of such extreme events grows, the industry will have to find ways of surviving and adjusting to them. Indeed, design, construction and operational factors greatly influence a PV system's survivability from a severe weather event. As such, the industry's efforts are channelled towards both technical improvements and the development and application of updated codes and standards to keep up with the lessons learned from field experience.

Fire

There have been fire-related incidents involving PV systems in several countries, such as the United States, Germany and Japan. In the very rare cases where the PV system was the main cause and source of the fire, the main causes relate to ground or arc faults. However, regardless of the source of the fire, PV systems can affect the ability of firefighters to extinguish the flames. Common hazards include: electrical shocks, collapse of roof structures due to the additional weight of a PV system, and slippery glass surfaces on an inclined roof. Besides introducing guidelines for firefighters, countries have also produced guidelines on technologies, products and installation to mitigate fire hazards. These include, for instance, guidance on installation to reduce the incidence of fires and shocks (*e.g.* ground-fault circuit interrupters [GFCIs] and arc-fault circuit interrupters [AFCIs]) (IEA-PVPS, 2017).

Hurricanes and tornadoes

Recent storms have not only highlighted factors contributing to PV system survivability, but also those leading to failure (US DOE, 2018). Having good O&M practices is a key factor in survivability and pre- and post-storm measures can be applied to minimise damage and recovery time.

One of the most common causes of equipment loss are solar fasteners. An easy measure to prevent disassembly is to properly use twist fasteners with a true locking capability and highly effective hardware and then proceed to audit the results. Clamping fasteners, which are very practical and fast and easy to assemble, are not adequate for PV systems in extreme weather areas, as they can be easily damaged in high winds. In addition, since one clamping fastener is shared between two modules, the loss of one creates a domino effect and causes the loss of neighbouring modules. A solution to this is to fasten the module to the support structure through mounting holes, using fasteners with specific twist ratings. Module selection is also another important aspect, as preference should be given to modules that have the highest ratings in terms of resistance to pressure. Similarly, modules should be well supported by frame elements to avoid bending and twisting during strong winds. Solar racking with a three-frame rail system for module mounting provides greater rigidity and support than a two-frame rail. Trackers for solar arrays have also improved in design and no longer depend on steel to support them, but rather use control sensors to adjust the angle in relation to wind strength and safely position the panel during storms (US DOE, 2018).

POTENTIAL RISK	NATURE, LIKELIHOOD AND POTENTIAL MAGNITUDE OF RISK	STEPS TAKEN TO MITIGATE RISK	PURPOSE CAPITAL ASSESSMENT