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Residential solar photovoltaic (PV) and battery storage systems guideline

DRAFT

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Standards New Zealand

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Technical Advisory Group representation

This specification was prepared by the P4790 – Solar PV and battery storage systems Technical Advisory Group. The membership of the committee was approved by the New Zealand Standards Executive under the Standards and Accreditation Act 2015.

The Technical Advisory Group consists of representatives of the following nominating organisations:

Electrical Safety New Zealand

Electricity Authority

Electricity Engineers' Association

Electricity Networks Aotearoa

Energy Efficiency and Conservation Authority (EECA)

Master Electricians

Sustainable Energy Association of New Zealand (SEANZ)

Taspac Energy

Wellington Electricity

Wellington UniVentures

WorkSafe New Zealand – Energy Safety

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Residential solar photovoltaic (PV) and battery storage systems guideline

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Referenced documents

Reference is made in this document to the following:

New Zealand standards

SNZ PAS 6012:2022	Smart home guidelines

Joint Australian/New Zealand standards

AS/NZS 1170:- - - -	Two-volume structural design actions set
Part 2:2021	Wind actions
AS/NZS 3000:2018	Electrical installations – Known as the Australian/New Zealand Wiring Rules
AS/NZS 4509:	Stand-alone power systems
Part 1:2009	Safety and installation
Part 2:2010	System design
AS/NZS 4777:	Grid connection of energy systems via inverters
Part 1:2024	Installation requirements
Part 2:2020	Inverter requirements
AS/NZS 5033:2021	Installation and safety requirements for photovoltaic (PV) arrays
AS/NZS 5139:2019	Electrical installations – Safety of battery systems for use with power conversion equipment

International standards

IEC 60050:- - - -	International Electrotechnical Vocabulary (IEV)
Part 903:2013	Risk assessment
IEC 61730:	Photovoltaic (PV) module safety qualification
Part 1:2023	Requirements for construction
Part 2:2023	Requirements for testing
IEC 62109:	Safety of power converters for use in photovoltaic power systems
Part 1:2010	General requirements
Part 2:2011	Particular requirements for inverters
Part 3:2023	Particular requirements for electronic devices in combination with photovoltaic elements
IEC 61215.1:2021	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 1: Test requirements
IEC 62746:	Systems interface between customer energy management system and the power management system

Part 10-1:2018	Open automated demand response
IEEE 2030:	Smart grid interoperability for energy technology
Part 5:2023	Standard for smart energy profile application protocol[1]

New Zealand legislation

Consumer Guarantees Act 1993

Energy Efficiency (Energy Using Products) Regulations 2002

Electricity Act 1992

Electricity Industry Act 2010

Electricity Industry (Levy of Industry Participants) Regulations 2010

Electricity Industry Participation Code 2010

Electricity (Safety) Regulations 2010

Privacy Act 2020

Radiocommunications Regulations (Radio Standards) Notice 2016

Residential Tenancies Act 1986

Websites

www.legislation.govt.nz

Latest revisions

Users of this specification should ensure that their copies of the above-mentioned New Zealand standards are the latest revisions. Amendments to referenced New Zealand and joint Australian/New Zealand standards can be found on www.standards.govt.nz.

Review of standards

Suggestions for improvement of this specification will be welcomed. Send them to the National Manager, Standards New Zealand, PO Box 1473, Wellington 6140.

[1] This United States Institute of Electrical and Electronics Engineers (IEEE) standard defines an application profile, which provides an interface between the smart grid and users. It defines the mechanisms for exchanging application messages; the exact messages exchanged, including error messages; and the security features used to protect the application messages. This standard focuses on a variety of possible architectures and usage models, including direct communications between an electricity distribution business (EDB) and consumers and prosumers, or between an EDB and flexibility provider (FP).

Foreword

This document has been prepared as guidance and is published as a publicly available specification (PAS).

It introduces the concept of solar technology, explaining the different types of systems, their key components, and how they interrelate.

The PAS provides advice on choosing an appropriate solar and/or battery-storage system aligned with your specific needs, explains the regulatory requirements for installing and/or connecting a solar system to the electricity grid, and explains what you need to know to sell surplus electricity back into the system.

The International Organization for Standardization (ISO) categorises publicly available specifications as documents that are not national standards but are produced by a national standards body to respond to a particular market need. A PAS represents either consensus in an organisation or industry or consensus of the experts within a specific working group.

ISO sets the maximum elapsed time for systemic review of a PAS as three years. In the case of rapidly evolving technologies and ongoing updates to international standards, it is generally accepted that the first review should occur within 18 to 24 months of the initial publication date. Additionally, ISO states that the maximum life of a PAS is six years, by which time the PAS should be converted to a standard. If the PAS is not converted to a standard by the end of this period, it should be withdrawn.

Standards New Zealand expects this PAS to be used by householders, government agencies – such as the Energy Efficiency and Conservation Authority (EECA) – suppliers and installers of distributed generation equipment, including energy service retailers.

Publicly Available Specification

Residential solar photovoltaic (PV) and battery storage systems guideline

1. Scope

1.1. General

This publicly available specification (PAS) sets out good practice guidance for residential solar photovoltaic (PV) and battery storage systems. Its primary objective is to provide sound advice on:

(a) The benefits of solar.

(b) How to maximise the performance of your solar installation.

(c) How to best save money and avoid common pitfalls.

1.2. Inclusions

(a) **Section 1 -** is an introduction to becoming energy secure. It covers the scope of this publication (inclusions and exclusions), definitions and abbreviations.
(b) **Section 2 -** discusses residential energy consumption and why it is important to transition to solar. This section covers how solar PV panels work and why they matter. The section also covers statutory installation requirements, including differentiating between legal and illegal installations.
(c) **Section 3 -** provides a comprehensive overview of participation in the New Zealand electricity market – how it works and what the regulatory compliance requirements to participate are. It discusses purchase and leasing arrangements, as well as introducing the concept of energy efficiency through home energy management systems (HEMS) and why they are crucial to solar PV installations.
(d) **Section 4 -** introduces solar PV technology and how it relates to the electricity system. It explains how to maximise the benefits and what the key components are, as well as providing a snapshot of the New Zealand solar PV market.
(e) **Section 5 -** teaches the homeowner about solar PV systems. It covers the key factors to consider when sizing and designing a solar system and includes discussion about PV oversizing, financial analysis and the limitations and risks of the current technology.
(f) **Section 6 -** is dedicated to solar panels. It provides a comprehensive explanation on composition, types, sizing considerations, tier ratings, warranties and panel efficiency, as well as installation connections and safety considerations.
(g) **Section 7 -** explains rooftop mounted solar PV installations, commencing with the question whether your roof is suitable for solar PV in the first place. The section covers access, panel orientation, and general installation safety aspects.
(h) **Section 8 -** covers ground-mount solar PV applications. It addresses supporting structures, panel height, orientation, safety, trenching of cables, and associated electrical components, and gives guidance on operation and maintenance.
(i) **Section 9 -** explains grid-tied solar PV systems (without batteries). It also covers inverter requirements, multi-phasing, essential load redistribution, installation guidance, and basic design considerations.
(j) **Section 10** explains grid-tied solar PV systems (with batteries). It introduces the concept of islanding (including unintentional islanding) and its significance to the network. This section also covers advanced grid-forming battery solutions as well as hybrid solar systems with batteries.
(k) **Section 11 -** explains off-grid solar PV systems, from design through to system architecture and key installation factors. It also provides sound guidance on use, operation, and maintenance.
(l) **Section 12 -** is dedicated to batteries. It discusses the different types available, charging protocols, and installation considerations, as well as discussing warranties and giving general guidance on maintenance.
(m) **Appendix A -** is a guide for the homeowner on choosing the most appropriate solar PV system for their needs. It does this by raising several key questions that encourage the homeowner to seek expert advice. This section also identifies other key factors a homeowner should consider before making a final solar investment decision.
(n) **Appendix B -** This section points to current standards and technical specifications as good-practice guidance for the various systems described within this PAS.
(o) **Appendix C -** provides valuable good-practice cybersecurity guidance for all suppliers and installers of residential solar PV and battery storage systems. It explains the importance of cybersecurity and ensuring

the protection of data for all devices, interconnected within the home and ultimately with smart-grid networks.

1.3. Exclusions

This PAS does not apply to other forms of household renewable energy generation, such as mini-wind or micro-hydro. It focuses on solar at the household level (including off-grid) and guides homeowners in getting the best value from solar. The PAS only considers the wider electricity system to the extent it can assist with this; for example, through offering preferential terms for electricity sent to the grid at certain times and, in the case of mini-wind or micro-hydro, how those forms of generation relate and compare to off-grid solar PV systems.

1.4. Objectives

This PAS will guide homeowners considering a solar installation. It will also help solar equipment suppliers and installers to understand industry-accepted good practice principles. Readers should refer to their local solar professional installer (many of whom are accredited by the Sustainable Energy Association of New Zealand (SEANZ)) for further expert advice and detailed product-specific technical information.

1.5. Interpretation

For the purposes of this PAS, the word ‘shall’ refers to requirements that are essential for compliance with this specification. The word 'should' refers to recommended practices.

1.6. Definitions

For the purposes of these guidelines, the following definitions shall apply:

AES-256	a widely used, strong symmetric encryption algorithm that uses a 256-bit key to encrypt and decrypt data, offering robust security for sensitive information.
Algorithm	A set of instructions for solving a problem or accomplishing a task. One example is a recipe, which consists of specific instructions for preparing a dish. Every computerised device uses algorithms to perform its functions in the form of hardware- or software-based routines
Alternating current (AC)	An electric current that reverses direction at regular intervals. In New Zealand, AC is delivered across the entire low-voltage residential electrical network at 230 V +/- 6% variance
Ampere (amp)	A unit of electric current
Application programming interface (API)	A set of definitions and protocols for building and integrating application software
Azimuth	Is the horizontal angle, measured in degrees, clockwise from north (0º), used in navigation, astronomy, and other fields such as solar panel positioning, to optimises Sunlight exposure, throughout its daytime trajectory.
Battery	A device or system that stores energy in one form or another allowing electricity to be produced or stored when required. Storage can be within a number of different means, including but not limited to electric fields, chemical changes, and pressure
Bifacial Nameplate Irradiance (BNPI)	This refers to the test conditions used to measure the power output of bifacial solar panels, specifically focusing on the power generated from both the front and back sides of a bifacial solar panel under simulated sunlight.
Bluetooth	Wireless technology standard for exchanging data over short distances. ‘Bluetooth’ is a trademark owned by the Bluetooth Special Interest Group.

Break-before-make	A term that refers to isolators or changeover switches. It ensures that the current circuit being energised, is completely disconnected before the new circuit is connected – through its internal electrical contacts .
Controller area network (CAN) bus	In solar systems, a controller area network (CAN) bus is a communication protocol that allows various devices like inverters, batteries, and sensors to share data and control commands efficiently over a single network, enabling real-time monitoring and control. CAN is supported by the ISO 11898 series of international standards.
Charging	Re-energising a battery unit with electricity
Cloud computing	Using a network of remote servers hosted on the internet to store, manage, and process data instead of using a local server or a personal computer
Code	The Electricity Industry Participation Code 2010 – effectively the rules of the electricity market
Competent electrical worker	A person with the necessary knowledge, skills, and experience to carry out electrical work safely and to the required standards, demonstrated through a combination of training, education, and experience
Connectivity	The capability of a device to receive and react to external signals
Demand response or demand-side response (DR)	The process of consumers or their appliances adjusting electricity consumption during periods of peak demand, when electricity is scarce or electricity networks are congested, in response to time-based financial incentives. DR can consist of interrupting demand for a short duration or adjusting the intensity of demand for a certain amount of time by reducing or shifting loads or storing energy
Digitalisation	The application of information communication technologies across the economy, including the energy sector, to achieve desired outcomes such as improved safety, efficiency, and productivity
Direct current (DC)	An electric current of constant direction. This distinguishes it from alternating current (AC
Distributed energy resource (DER)	Electricity supply or demand resources (for example, solar PV, home battery units) or load that can be controlled within customer premises
Electrical safety certificate (ESC)	A legally recognisable statement that the connected installation or part installation is safe to use following prescribed electrical work. It may be used for other purposes, including auditing and investigations.
Electricity	Electrical energy, measured in kilowatt hours (kWh)
Electricity distribution business (EDB)	A publicly or privately owned company that supplies electricity line function services to any other person or persons. This may be either a local network (which is directly connected to the transmission grid) or a secondary network (which is indirectly connected to the transmission grid through another EDB(s)). These companies provide rules for connecting to their network that customers must comply with

Electricity market	A market in which generators sell their electricity into a pool, and retailers or purchasers buy electricity for resale or self-consumption. In this market, prescribed rules set out the structure, price discovery, security, and integrity of the electricity market
Ethylene Vinyl Acetate (EVA)	A common encapsulant material – normally, a thin, transparent layer that protects solar cells from environmental damage and ensures long-term performance by acting as a sealer and adhesive.
Extra low voltage (ELV)	A range of voltages up to and including 120V DC or 50V AC
Flexibility	The ability of connected residential devices (or networks of devices) to communicate with each other and determine the 'least cost' combination of demand to optimise energy use
Flexibility (in electrical systems)	The capability of an electricity system to respond to upward or downward changes in the supply–demand balance in a cost-effective manner over a period ranging from a few minutes to several hours
Flexibility provider (FP)	A service provider that manages electrical energy demand (consumption) or export (generation) on behalf of a group of customers and offers on-call or planned demand-reduction services to the electricity market, grid owner, or networks
Frequency	The rate, in seconds, at which a current changes direction. It is measured in hertz (Hz), an international unit of measure, whereby 1 Hz is equal to one cycle of AC electricity per second. For New Zealand, electrical AC is delivered at 50 Hz
Fusing	Over-current and short-circuit protection; it can be achieved by a fuse or miniature circuit breaker (MCB)
Home energy management system (HEMS)	A smart home system consisting of a network of devices that can be controlled via one hub or interface. A HEMS can encompass multiple services or be dedicated to a single service category (for example, a smart lighting system or a smart security system). Smart home technologies encompass appliances, systems, and other supporting or enabling technologies
Incentives	Normally government initiatives used to help shift a technology-based market in a desired direction. In the case of smart home appliances and electric vehicles, incentives can encourage a change in consumer purchasing behaviour over a relatively short time. These incentives often come in the form of grants, tax exceptions, or other initiatives that would, for example, assist a government in meeting its international climate change obligations
Ingress protection (IP) rating	The rating of a product, defined by the International Electrotechnical Commission (IEC) standard 60529, that indicates the degree of protection an electrical enclosure offers against solid objects, dust, and water. These ratings are represented by 'IP' followed by two digits: each digit signifies a specific level of protection
Internet of things (IoT)	A system of interrelated computing devices, mechanical, and digital machines or objects that have unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction

Interoperability	The capability of different electricity networks, smart devices, or smart device systems to connect and exchange data or instructions seamlessly
Kilowatt hour (kWh)	A unit of energy equivalent to the energy transferred or expended in one hour by one kilowatt of power. On electricity invoices, where electricity consumption over a given period for all home appliances and devices are all measured in kWh
Learning algorithm	A process or method used to extract patterns from data collection (for example, from sensors and controls) to identify and adapt appropriate solutions or applications for a device or system. An example is a 'smart' thermostat fitted to an electric hot water cylinder that maps usage patterns by volume and time of day
Lithium-ion battery	A type of rechargeable battery that uses the reversible intercalation of Li+ ions into electronically conducting solids to store energy. This technology is currently standard in electric vehicle and home battery systems – it offers good energy density, power, and fast-charging ability
Message queuing telemetry transport (MQTT)	A lightweight, publish–subscribe, machine-to-machine network protocol for message queuing. It is designed for connections with remote locations that have devices with resource constraints or limited network bandwidth, such as on the IoT. It must run over a transport protocol that provides ordered, lossless, bidirectional connections (typically TCP/IP). It is an open OASIS standard and an ISO recommendation (ISO/IEC 20922)
Multiple earthed neutral (MEN) system	The New Zealand variant of the internationally defined TNC system of supply of electricity in which the neutral is connected to earth at the source of supply (being either the generating station or the substation from which electricity, at the voltage at which it is delivered to the consumer, is derived), at points on the supply system, and at every installation connected to that system
Network	The owner/operator of the system of lines that deliver electricity to your installation. This may be a local network or a secondary network
Nominal (statutory) voltage	The value assigned to a system or circuit of a given voltage class for the purpose of convenient designation. The actual voltage can vary above or below this value. In New Zealand, the nominal low-voltage setting is 230 V +/- 6%, measured at the point of supply (typically the property boundary)
Open automated demand response (OADR)	Open automated demand response (OADR 2.0a/b) is an open access, highly secure, two-way information exchange model and global smart grid standard.[2] OADR 2.0 standardises the message format used for DR, flexibility, and DER (for example, solar PV and home battery system) management so that signals can be exchanged in a uniform and interoperable fashion among network providers, FPs, HEMSs, and 'smart' residential devices. In 2023, OADR 3.0 was introduced. It is not intended to replace the OADR 2.0a/b profile specifications; rather, it

[2] See IEC 62746-10-1.

provides an additional, simplified way to add OADR functionalities in current, as well as different and new, scenarios

Pascal (Pa) The Pascal (symbol: Pa) is the unit of pressure in the International System of Units (SI). It is also used to quantify internal pressure, stress, Young's modulus, and ultimate tensile strength. It is an SI coherent derived unit - defined as one newton per square metre (N/m^2).

Power Rate of generating, conveying or consuming work or energy, including electricity (electrical energy)

Power conversion equipment (PCE) The collection of solar PV system components that convert solar energy from the solar array to electricity; for example, inverters, controllers, and power-condition monitors, including all associated isolation and protection equipment

Prosumer A consumer with a small-scale, distributed electricity generation facility, which gives them the choice to produce at least some of their electricity needs and potentially sell the excess back to the grid (network)

Real time A state in which information is available simultaneously as an event occurs, or immediately after collection

Retailer (electricity) An entity that purchases and or sells electricity to another party

Sensor A device which detects or measures some type of input from the physical environment (for example, voltage and current, daylight, temperature, motion, or pressure)

Short message service (SMS) A text messaging service component of most telephone, internet, and mobile device systems. It uses standardised communication protocols that let mobile phones exchange short text messages, typically transmitted over cellular networks

Smart grid An electricity network that enables the two-way flow of electricity. It employs communication technology to transfer real-time information that electricity providers and end-use devices can respond to.

A smart grid can:

(a) Better facilitate the connection and operation of electrical load and generators;

(b) Increase the economic efficiency of electricity networks and generation, maintaining a cap on prices;

(c) Allow consumers to play a part in optimising the electricity system’s operation;

(d) Provide consumers with greater information and options for how they use their electricity supply;

(e) Significantly reduce the environmental impact of the whole electricity supply system;

(f) Maintain and improve electricity system reliability, quality, and security of supply

Smart home A residence with a network of smart devices that can react to external signals from electricity retailers or FPs. Smart home devices and networks operate using open communication protocols such as OADR

	2.0 that enable consumer devices to communicate with any suitably configured FP
Smart home device	A device that can connect to a communications network (directly or through a hub or central interface) and be controlled remotely or set to be controlled automatically based on user preferences and sensor inputs. Smart home devices include (but are not limited to) DR-enabled devices
Smart meter	A meter that records electricity consumption in intervals of an hour or less and communicates that information at least daily to the electricity provider for monitoring and billing purposes. A smart meter is a component in advanced metering infrastructure (AMI). AMI differs from traditional manual read meters or automatic meter reading in that it has two-way communication between the meter and a central system. AMI functionality includes enhanced information measurement (for example, power conveyed import or export, voltage and current), remote reading, support for advanced pricing plans and payment systems, and remote electrical connection and electrical disconnection of electricity supply
Solar photovoltaic (PV)	Direct conversion of sunlight into electricity
Solar (thermal)	Solar thermal technology harnesses the sun's energy to generate heat and is primarily used for water heating applications
Standardisation	The implementation and development of technical standards based on the consensus of different parties that include industry, interest groups, standards organisations, and governments. Standardisation helps maximise compatibility, interoperability, safety, and repeatability
Standby mode	Mode in which the light source or other devices are switched off while still connected to a live power supply
Standby power	Electrical power consumed by a device in standby mode
Time of use (TOU)	A term to describe a pricing methodology whereby various prices apply during day, week, or month periods. The methodology provides a financial incentive for consumers to defer discretionary electricity consumption from high-price periods to low-price periods, thereby reducing electricity demand on networks and generators
Transport Layer Security (TLS)	TLS 1.2 and 1.3 (respectively) are protocols that provide secure communication over the internet by encrypting data, ensuring privacy and integrity, and are used to secure connections between web browsers and servers, or other applications. TLS 1.3 is an improvement over its predecessor, offering faster handshakes and more secure cryptographic algorithms.
Universal Plug and Play (UPnP)	This is a network protocol that enables devices to automatically discover each other and establish connections without manual configuration. UPnP automates port forwarding - allowing devices to automatically open and close ports as needed for network communication, while port forwarding manually maps specific ports to devices, offering more control but requiring more configuration.
Virtual Private Network (VPN)	This describes a secure, encrypted connection that allows you to connect to the internet through a remote server, masking your IP address and

	encrypting your data to enhance privacy and security, especially when using public Wi-Fi
Wi-Fi protected access 2 (WPA3)	The third generation of the Wi-Fi protected access wireless security protocol, from the Wi-Fi Alliance. Like its predecessor (WPA2), this version is designed to enhance the security of wireless networks, by offering stronger authentication and encryption methods than WPA2.

1.6 Abbreviations

Abbreviations have the following meanings:

A	Ampere
AC	Alternating current
API	Application programming interface
BESS	Battery energy storage system
BOS	Balance of system
CAN bus	Controller area network bus
CoC	Certificate of Compliance
CT	Current transformer
DC	Direct current
DER	Distributed energy resource
DG	Distributed generation
DR/DF	Demand response/demand flexibility
EA	Electricity Authority
EDB	Electricity distribution business (also known as an electricity network provider or lines company)
ELV	Extra low voltage
EMP	Electricity market participants
ESC	Electrical safety certificate
EWRB	Electrical Workers Registration Board
FP	Flexibility provider
GTI	Grid-tied inverter
HD	Heavy-duty
HEMS	Home energy management system
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers

Imp	Maximum power current
IP	Ingress protection
Isc	Short circuit current
ISO	International Organization for Standardization
kW	Kilowatt
kWh	Kilowatt hour
kWp	Peak capacity in kilowatts
LFP	Lithium iron phosphate
MCB	Miniature circuit breaker
MEN	Multiple earthed neutral
MFA	Multi-factor authentication
mm	Millimetre
MPPT	Maximum power point tracker
MQTT	Message Queuing Telemetry Transport
NIST	National Institute of Standards and Technology (USA)
NMC	Nickel manganese cobalt
OEM	Original equipment manufacturer
OTA	Over the air
Pa	Pascals
PAS	Publicly available specification
PCE	Power conversion equipment
PEW	Prescribed electrical work
PV	Photovoltaic
RCD	Residual current device
SDoC	Supplier Declaration of Conformity
SEANZ	Sustainable Energy Association of New Zealand
SoC	State of charge
SPD	Surge protection device
TLS	Transport layer security
TOU	Time of use
V	Voltage

VLAN	Virtual local area network
Voc	Open circuit voltage
Vmp	Maximum power voltage
VPN	Virtual Private Network

2. Becoming home energy secure

2.1 Introduction

Over the lifetime of a rooftop solar system (Figure 1), the electricity generated costs you less than the electricity you would have purchased from the grid. Another way to look at this is that once the system has paid itself off, you've effectively got free electricity from the sun.

If you're looking to install a rooftop solar system, you have the option either to buy the panels outright or to finance your purchase over a number of years. Many lenders offer low-interest 'green' loans for this purpose.

Figure 1 – Typical rooftop solar panels

2.2 Why should you transition to solar?

You may consider installing solar panels for several reasons, including the following:

(a) Drawing less electricity from the grid saves money on your electricity bills and allows you to avoid some of the effects of increasing electricity prices;

(b) Solar panels drive down the cost of energy consumption. Many people wish to be more self-sufficient. Although it is not financially feasible today to be completely off-grid, it is possible to supplement your energy requirements with cheaper solar PV and battery technology;

(c) Provided your solar system has the right components and is specified and installed appropriately, it may give you more resilience in the case of a severe weather event or natural disaster. Generating your own solar energy (with a backup system; that is, batteries) means you can keep refrigeration, lighting, and medical and communication devices running for some time without mains electricity;

(d) You may wish to contribute towards New Zealand's ambitions to use more sustainable and renewable energy.

Solar panels are not a one-size-fits-all solution. Sunnier places will enable more solar generation than areas with higher rainfall or more cloudy days. NIWA's sunshine hour history is a helpful resource in determining the most appropriate areas to install solar panels (see https://niwa.co.nz/climate-and-weather/mean-monthly-sunshine-hours). Additionally, solar generation is affected by individual housing factors, such as whether your roof space is north facing and whether the tilt of your roof is optimal. Even in the same suburb or street, household solar generation will differ between neighbours. It is therefore difficult to be certain about how long it will take to 'pay back' or return the investment you have made in solar technology. Local solar installers, many of which are accredited by the Sustainable Energy Association of New Zealand (SEANZ), can advise you on this.

To address the environmental impact of climate change, many countries (including New Zealand) are implementing policies to improve energy efficiency and reduce reliance on fossil fuels. This includes retiring or reducing our gas and coal power stations. To do this, New Zealand is now transitioning to electricity as its preferred energy source. New Zealand already has prominent levels of renewable hydro and geothermal generation, but as the demand for an all-electric economy grows, the country needs:

(e) More renewable sources; that is, more solar and wind power;
(f) More storage or flexible load to accommodate those sources;
(g) A significant boost in energy efficiency;
(h) An expansion of generation capacity.

Additionally, upgrading New Zealand's electricity infrastructure is essential as people increase their demand; for example, by charging their electric vehicles (EVs), or replacing gas heating and appliances with electric. Overall, the forecast is that electricity demand will increase quickly and steadily, while generation will become more variable or intermittent. This is because sources like solar and wind are only available when there is sunlight or when the wind is blowing.

Some households choose not to connect their generation, and some may even be completely 'off grid'. Others connect to local distribution networks (through their lines companies); when these participants both take electricity from the network (import) and send their generation into the network (export), a two-way flow is created. Original network design did not accommodate this two-way flow of electricity; hence, networks need upgrading, or electricity injected into a network may need to be restricted.

Solar PV can strengthen or support weak networks, especially when batteries are added. The distribution Business (Vector) applied this strategy from around 2016/2017, using 5 kW grid-tied inverters (GTIs) with batteries at end-of-line locations. This was a cheaper alternative to much needed network upgrades.

Most households (although not all) use most of their electricity in the evenings, when everyone is at home, and lighting, heating, and appliances are switched on. This is described as the 'peak', and it doesn't align with solar energy production, especially during winter months. As a result, households with the right solar installation may elect to use their generation to heat hot water (thermal solar), or, with solar photovoltaic (PV) panels, to export excess electricity during the day when consumption is low, to offset the cost of buying electricity at night when solar is not available. One way for households to reduce their dependence on the grid and enhance energy security is by installing rooftop PV panels, paired with battery storage.

Adding a battery to the system means that solar-generated electricity can be stored during the day (instead of being injected into the network) and used at night when there is no sunlight. This serves to improve self-consumption rates and, more importantly, provides continuous supply on essential circuits (for example, for refrigeration appliances and in-home medical devices).

While such an installation can provide a continuous 24-hour power supply for a household (for example, during a grid outage), its reliability depends on whether its size is appropriate and on careful management of both the solar array and the battery system. Your solar installer can advise you with this.

2.3 How solar PV panels work and why they matter

Learning the basics of how solar panels work will empower you to manage your home energy production, reduce your carbon footprint, and save on electricity bills. When the technology they employ is reliable and suited to New Zealand's often cloudy weather, solar panels are a practical option for those aspiring to a degree of self-sufficiency through renewable energy.

Solar panels work by absorbing sunlight (Figure 2), which releases electrons from atoms to create an electric current. Each panel is made up of PV cells, which convert sunlight into direct current (DC) electricity. This electricity then passes through an inverter, which changes it into alternating current (AC) to power your home.

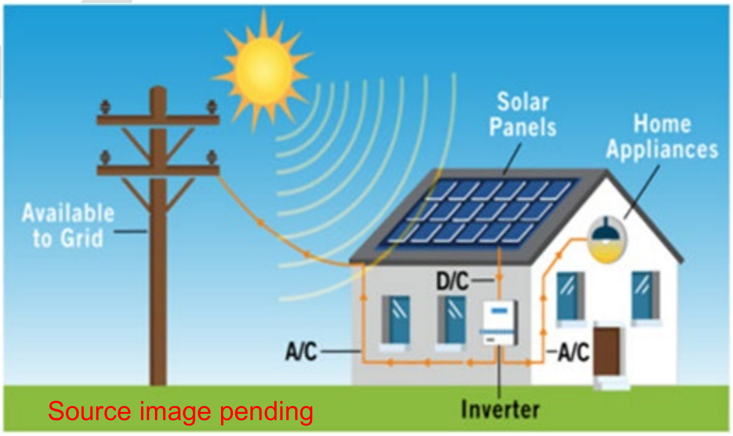

Figure 2 – Solar panel installation basics

In New Zealand, there are three main types of solar systems:

(a) Grid/network-connected without battery-storage;

(b) Grid/network-connected with battery-storage;

(c) Off-grid, not connected to a network at all, used in remote locations.

Note – There is more than one source of distributed energy generation available for the residential market. Others include mini-wind and micro-hydro. For more information on other options, refer to SNZ PAS 6012:2022 *Smart home guidelines*.

Solar panels pose particular electrical safety issues and must be professionally installed. For the best results, installations should generally be north-facing. However, depending on the orientation of the house, east- or west-facing arrays which can also work well. Installations should be properly tilted and kept free of shadows to optimise power generation by allowing them to capture as much sunlight throughout the day as possible.

Solar panels still work on cloudy days, but with reduced output. This must be taken into account if your goal is self-sufficiency, as a dull day can reduce generation to 5% of installed capacity.

To ensure you have electricity during cloudy weather, at night, or at any time sunlight is limited, it's wise to stay connected to the network and use a battery to save the extra electricity produced for use during the evening and morning periods. Your solar equipment provider can provide details on available battery storage options. If there is insufficient solar electricity available to charge the battery, the battery may instead be charged overnight, when the cost is lower. Active management of the battery and consideration of weather forecasts can assist with battery charge optimisation.

A grid-tied inverter requires mains voltage to function but can operate using a battery when mains power is unavailable. When a solar and battery system is properly configured, it can serve as an alternative power source during outages, including disasters. This set-up enables essential appliances – such as refrigeration, lighting, radios, and communication devices – to continue operating during extended periods without mains electricity.

Before installing solar panels, it's important to consult with your network provider to check that your installation will be connected to its system and to understand the technical requirements and associated costs. The network provider may impose limits on the amount of electricity that can be exported into the grid, or even the maximum amount of solar capacity that can be connected. A professional solar installer will typically handle this process on your behalf.

Note – Any installation connected without the network-provider's approval may interfere with the rights of other electricity users and can be disconnected.

2.4 Exporting excess electricity

The buy-back rate offered by electricity retailers for exported electricity is typically lower than the purchase rate for consumed electricity, because the purchase rate includes delivery costs, such as network losses, conveyance costs (network and transmission costs), and the retailer's operating margin.

When buying exported electricity from the consumer, the retailer will only pay its expectation of the market value for that electricity. The buy-back rate will not reimburse the conveyance costs.

It's important to consider feed-in tariffs and buy-back rates against the price of electricity that the retailer offers.

When using electricity generated from solar panels or batteries, there is no need to purchase electricity from the grid. This eliminates associated delivery costs. Therefore, the most valuable approach for consumers is to utilise the electricity produced on site.

2.5 Installation matters

Solar panels pose electrical safety issues and must be professionally installed by an electrician with a current 'endorsed' practising license. It is recommended that you discuss your needs with a professional solar installer; many such installers are SEANZ-accredited. They are trained to inform you of;

(a) The technical requirements and costs involved in connecting to your local network;

(b) The energy production and cost saving from the system(s) being proposed;

(c) The ongoing maintenance of the system;

(d) Any limits on the maximum amount of solar capacity that can be connected or exported into your local network. Your installer will normally undertake the application (on your behalf) with a local electricity distribution business (EDB) and will let you know about any capacity constraints that arise.

2.6 Illegal installations

The installation of solar panels or battery storage systems carries specific safety risks that, if not responsibly managed, could result in serious harm to individuals, significant property damage, or even loss of life. These risks stem from electrical hazards (shock), fire potential, and improper system integration.

There is widespread industry concern about the safety of non-compliant small 'off-grid systems'.

Further concerns have been raised about plug-in style balcony-mounted solar kits. These comprise a couple of panels and a small inverter that plugs into a normal wall socket. The issue is that the plugged lead is live, which is unsafe. This type of set-up is illegal in New Zealand under s 163(c) of the Electricity Act 1992.

To mitigate the dangers identified above, strict safety requirements govern solar and battery installations. These requirements encompass the competency of the installer, equipment standards to ensure the reliability and safety of components, installation standards to guide proper set-up and wiring, and connection standards to ensure safe integration with the electrical network the installation connects to. Adherence to these requirements is essential for safeguarding people and property while maintaining the overall stability and integrity of the electricity network.

Unsafe installations includes the connection of distributed generation (DG) that does not comply with the relevant requirements. Risks include, but are not limited to, the following:

(a) The potential for electricity to flow back into the connecting network unexpectedly, creating a shock risk for workers during outages;
(b) Electricity quality interference with other consumers;
(c) Poor wiring and connections;
(d) Overloading and overheating of appliances and components;
(e) High voltage in the installation;
(f) Live metal exposed to touch.

To avoid these dangers, homeowners should opt for professionally installed certified solar and battery systems that comply with the appropriate regulations. A small-scale solar set-up should be connected through a professionally installed GTI with the necessary safety protections.

3. Participating in the electricity market

3.1 General

Before diving into the details of electricity, let's cover the basics.

The electricity system that delivers electricity to your home comprises a pathway of assets, from generators to retail service providers. The key groups are as follows:

(a) Generator – produces the electricity;

(b) Transmission – reticulates electricity around the country;

(c) Distribution – delivers electricity from transmission to homes and business;

(d) Retailers – offer service plans and sell electricity to householders and businesses.

3.2 Supply and demand

In an electricity network, matching generation with demand is critical to maintaining the stability of the network. The role of matching supply with demand is the responsibility of Transpower, the operator of the transmission system (referred to in this context as the System Operator).

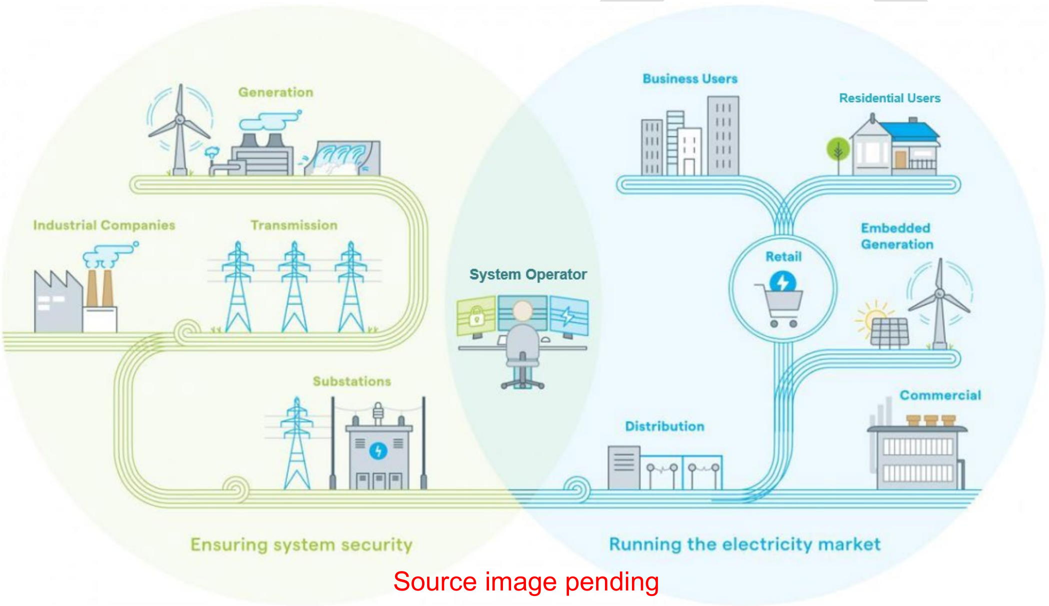

Figure 3 – New Zealand electricity market

3.3 What is the electricity market?

The financial transaction between generators and retailers can be made via direct arrangements or on the wholesale market. The wholesale market is a bit like an auction in which generators offer in, and then the System Operator selects and then dispatches the lowest bids required to meet the demand. The market works in half-hourly time intervals. The generators sell their electricity to the clearing manager at the prevailing wholesale spot price, and retailers buy electricity from the clearing manager, selling to most of their customers on a fixed pricing plan. Residential customers do not see the price fluctuations in the wholesale market.

The market is regulated by the Electricity Authority (EA). The EA is funded via a levy, paid for by customers on their electricity accounts.

3.4 The participation compliance requirements

There are three core compliance requirements for grid-connected generation (including solar PV):

(a) *Transaction arrangements for the exported electricity* – For grid-connected solar PV on homes and businesses, the electricity retailer pays a form of export tariff (buy-back price), thus negating the need for a householder to be involved in the wholesale market. The retailer needs prior notification, and this may require a metering upgrade, which will also be managed by the retailer.

(b) *Approval from the EDB you are proposing to connect to* – For electricity networks, the capacity available is the key consideration. For the homeowner, this application is normally handled by the installer or solar PV supplier. The EDB may place conditions on both the capacity and the operation of the inverter in order to connect.

(c) *Compliance with the Electricity (Safety) Regulations 2010.* This is the responsibility of the installer (an electrician with a current endorsed practising license). Upon completion of the installation, the electrician (or inspector) shall furnish the homeowner with a WorkSafe electrical safety certificate (ESC) – which is a legally recognised document certifying that a connected installation or part of an installation is safe to use after prescribed electrical work. This ESC is underpinned by a certificate of compliance (CoC) and a record of Inspection – which is the homeowner's proof that the installation meets regulatory requirements and is safe to operate. This also applies to off-grid systems. For grid-connected systems, the homeowner should also ensure that the system supplier sends the EDB a copy of the ESC.

Note – For grid-connected systems, the EDB also requires this documentation.

3.5 Guide to different pricing plans

3.5.1 General

Pricing plans in this section refer to purchase/leasing and pricing arrangements available in the New Zealand electricity market.

As of January 2025, at a high level, there are three different types of purchase/leasing arrangements and three energy retailer pricing plans for solar PV and battery systems. The following tables summarise these.

In Table 1, 'kWh' stands for kilowatt hours.

Table 1 – Purchase and leasing arrangements

Purchase option	Description	Payment model	Availability	Suitability
Power purchase agreement (PPA)	No/low upfront cost, agreement to buy all electricity (including energy not generated by solar PV system and battery) directly from provider	$/kWh for all energy consumed measured at the point of connection to the EDB	Readily available through most retailers	Best for those who prefer a predictable energy cost and a low upfront fee
Zero-cost solar	Similar to a PPA, but only to purchase energy generated by the solar PV system	$/kWh for energy generated by solar PV system only measured at the inverter within the installation	Only currently available in Australia	Best for those who prefer no upfront cost, and prefer to select their own energy retailer for energy not produced by the solar PV and battery system
Lease	No/low upfront cost, and a monthly instalment fee for the lease of the solar PV system for a fixed period of years	$/month for fixed term	Limited availability through solar suppliers	Best for those that prefer no upfront cost, don't want to own or maintain the equipment. They simply select their own energy retailer and enjoy the benefits of reduced energy consumption
Outright purchase	Purchase of the solar PV and battery system outright or via personal financing	Full payment or financing for the system	Readily available through solar suppliers	Best for those that want to own and maintain their system

Table 2 – Energy pricing options

Energy pricing option	Description	Payment model	Examples	Suitability
Export tariff	Sell excess electricity generated by solar PV and battery system back to the grid at an agreed fixed rate	Fixed $/kWh export rate	Genesis Energy	Best for large systems with lots of energy to export with a dedicated installation control point (ICP)
Hybrid plans (export and retail tariff)	A combination of an export tariff and regular retail plan	Payment for electricity used per fixed and variable rates; that is, $/per and $/kWh Credit for excess export at an agreed rate; that is, $/kWh	Mercury Energy, Genesis, Meridian, Contact	Most commonly available in the market
Time of use (ToU)	Pay and get credited different rates for electricity used/exported depending on the time of the day	Payment based on fluctuating ToU rates	Flick, Octopus	Ideal for homes with batteries that receive and use real-time information from electricity market

3.5.2 Classifying 'residential' consumers

Distinguishing residential consumers form other consumers has become more challenging with the rise of the multi-use home.

A residential connection is a supply to a consumer connection that is primarily used as a private dwelling (that is, a home) or intended for occupation principally as a place of residence. Residential households have similar capacity requirements and a common load profile, and electric hot-water load is often controllable by the EDB. Under the Residential Tenancies Act 1986, residential connections exclude hospitals, hostels, hotels, communes, or other temporary accommodations.

3.5.3 Net metering vs two-way metering

Retailers have different rates for imported and exported electricity. In New Zealand, electricity generated within an installation is first consumed by the consumer, and only the surplus above consumption is exported. This is also termed net consumption. Only electricity that flows through the revenue meter at the ICP is by retailers, within the invoicing process.

3.6 Energy efficiency

Energy efficiency often offers a better pay-back than solar PV, and it therefore should be your first consideration when you're looking to reduce your electricity bill. Examples include use of LED lamps, heat pumps for space and water heating, draught proofing, and thermal insulation. Consider the efficiency of appliances when choosing appliances such as fridges, freezers, washing machines, and dryers. Always look at the energy rating label on whiteware.

A more thorough way to optimise home energy use performance is to coordinate your electricity usage with a solar PV and/or solar PV and battery installation.

3.7 Home energy management system interoperability and why it is crucial to your solar PV installation

3.7.1 Introduction

A home energy management system (HEMS) provides supervisory control of smart appliances and DG such as PV technology. It controls the environment within a premises and integrates with external systems such as smart grids and flexibility providers (FPs).

A HEMS can also control shiftable household loads and storage batteries, to better match the solar PV output and enhance the value solar PV and battery systems provide. Examples include EV charging, hot water shifting, changing temperature settings on heat pumps, and time moving dishwashers and washing machines to operate within specific electricity price ranges.

A HEMS can operate on its own but will offer the greatest benefit to consumers when there is a healthy market for demand-reduction services. When such a market fully develops, there could be multiple parties interacting with a HEMS. For instance, a network provider could control capacity and voltage on its network, an electricity retailer could manage its electricity market purchasing costs, and an FP or aggregator could manage virtual power plants, provide reserves, or contract ancillary services within the network, all while interacting with residential HEMSs.

3.7.2 What is a smart grid?

A smart grid is a network that intelligently monitors and manages the transport of electricity from all generation sources to meet consumers' varying electricity demands. Though the New Zealand grid cannot currently automatically switch electricity around faults, it can isolate sections of the network and control power quality and electricity demand.

A smart grid can stand alone and manage aspects of a network. However, to control electricity demand there needs to be remote communications, pricing incentives, and equipment.

A smart grid works optimally when it is integrated with HEMSs or communicating directly with smart appliances. In this context, residential demand and generation can be sourced for DR or flexibility programmes to manage the network.

Smart grids provide a platform allowing networks to manage increasing demand requirements and reduce or minimise shutdowns during the replacement of aging infrastructure, as well as during routine maintenance. They can help achieve a more secure and sustainable energy future, as more decarbonised load is added to networks. They can also defer infrastructure investment, saving consumers future costs.

3.7.3 What is DR flexibility, and how does it relate to solar PV technology?

Solar PV systems with batteries can reduce the load of the home at peak times and take advantage of TOU tariffs. Future opportunities include reducing demand, through DR schemes, to support the grid. This is likely to be via a flexibility provider (FP), which will most likely offer suitable financial incentives to those who participate.

DR requires automated two-way communication between an FP and the home.

To participate in DR services, speak with an electricity market participant (EMP) about their available offers. Your system will need to be connected to the internet and configured to receive and respond to DR signals as agreed with your EMP.

The incentive paid to you for this service is often higher than that offered in a standard energy retail tariff, because in this case your system is playing an active role in maintaining capacity and/or power quality for the power grid.

An incentive structure might take the form of $/day for availability of the system plus $/event responded to, or it might take the form of a fixed $/kWh rate contributed during the DR event. This will vary depending on the EMP and the flexibility services they offer.

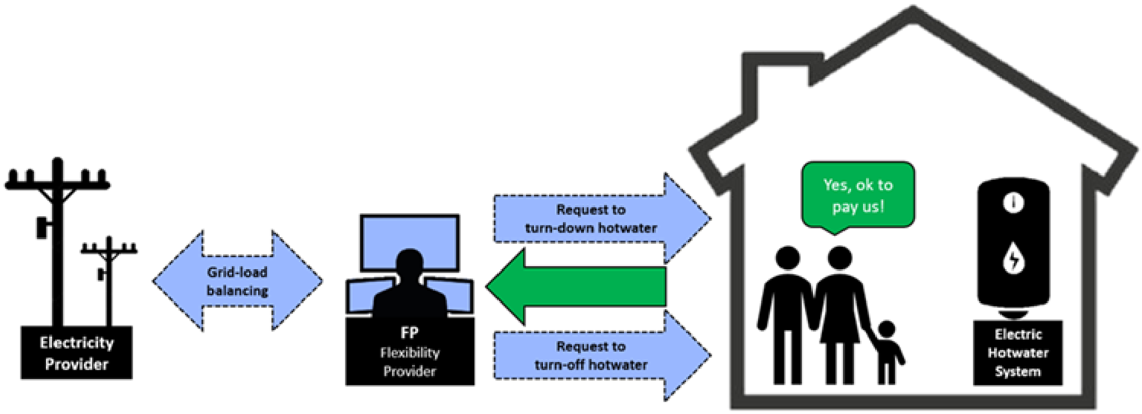

Figure 4 – Flexibility provider interface

3.7.4 Connectivity and communication protocols

Solar PV with battery systems are typically connected via Ethernet or Wi-Fi back to the router/modem used in your home for internet access. This provides you with near-real-time information on your system's historic performance and limited control functionality; for example, setting up schedules for charging your battery or configuring energy retailer plans or ToU settings. You typically access these through a mobile app a or web portal available from the original equipment manufacturer (OEM), your installer, or the provider that you purchased or leased from.

To participate in DR services, an additional configuration is made to connect your solar PV + battery system to the EMP. The EMP will connect with your system over the internet and potentially could temporarily override your configuration during a DR event.

The connection between your system and the EMP would use either OADR or IEEE2030.5 open standards-based communication protocols. If you are planning to participate in a DR scheme, it is important to purchase a system that supports one of these. If you are unsure, confirm with the OEM or your installer.

4. Introducing solar PV technology

4.1 General

Solar photovoltaic (PV) technology allows households and businesses to generate electricity directly from sunlight. It is a clean and renewable energy source that reduces reliance on the national grid and can help lower electricity costs. As solar technology advances and battery storage becomes more affordable, more New Zealanders are considering solar PV as part of their energy solution.

4.2 How solar fits into the electricity system

A solar PV system can operate on its own, supplying power directly to a home or business. However, many systems are also connected to the wider electricity network. When a solar system produces more energy than is needed, the excess can be sent back to the grid, and in some cases, homeowners can receive a credit or payment for this exported electricity. Conversely, when solar panels aren't generating enough – such as at night – electricity can still be drawn from the grid.

Many solar PV systems now include battery storage, which acts as a flexible in-home energy source. Batteries store excess solar energy for use when sunlight isn’t available. This allows homeowners to use more of their own solar power, shift energy consumption to times when electricity prices are higher, and even provide backup power during outages.

4.3 Key considerations before installing solar PV

Before installing a solar PV system, there are several important factors to consider:

(a) *Network connection requirements* – Solar systems and/or batteries cannot be connected to an electricity network without approval from the network owner. Networks set technical standards to ensure that these systems do not interfere with voltage, current, or frequency stability. It is important to check with your distributor about its connection requirements and the required standards approvals for components.

(b) *Regulatory requirements* – If your system will feed electricity back into a network, you will need to follow the application process outlined in Part 6 of the Electricity Industry Participation Code 2010.

(c) *Pricing plans* – Your electricity retailer may have specific pricing plans for exported electricity. You may find that you will receive greater benefit from another retailer.

(d) *System sizing and energy use* – The times you produce the most electricity will not always match the times you use the most power. Using battery storage or shifting electricity use to align with solar generation can maximise efficiency and savings.

(e) *Local council requirements* – Generally speaking, solar PV installations do not require building consent (see s 43 of the Building Act 2004). There are some exceptions to this; for example, if the PV panels also form the roof cladding. Regardless of whether or not a building consent is required, all work must comply with the New Zealand Building Code. In some cases, a resource consent, rather than a building consent, could be required – for example, if the property is in a special interest or heritage zone.

4.4 Maximising the benefits of solar PV

By combining solar panels with smart energy management and battery storage, households can increase their use of renewable energy and reduce electricity costs. Managing when energy is used – for example, by running appliances during the day or storing solar energy for peak evening use – can improve savings and help balance electricity demand across the grid.

Whether you are looking to install solar PV for cost savings, energy independence, or sustainability, this chapter will provide a foundational understanding of how solar systems work, how they interact with the wider electricity network, and what to consider before making an investment.

4.5 Market snapshot

4.5.1 Introduction

New Zealand's solar PV market is growing rapidly as more households, businesses, and large-scale projects invest in solar energy. While solar currently makes up a small percentage of the country's electricity generation, its potential is significant.

4.5.2 Current market size

As of 2024, New Zealand has over 300 megawatts of installed solar capacity. Most of it comes from small-scale rooftop systems, on homes and businesses. However, interest in larger commercial and utility-scale solar farms is increasing, and several new projects are in development.

4.5.3 Future growth potential

With falling technology costs, improved battery storage, and increasing electricity demand, solar PV is expected to expand quickly. The New Zealand Climate Commission and energy sector forecasts suggest that solar could provide 10–15% of total electricity generation by 2050, up from less than 1% today.

4.5.4 Key drivers of growth

Key drivers of growth include:

(a) *Declining costs* – The price of solar panels, batteries and installation continues to drop, making solar more affordable;

(b) *Energy independence* – Households and businesses are adopting solar to reduce reliance on the grid and lower power bills;

(c) *Grid flexibility and decarbonisation* – Solar, combined with batteries and smart technology, can help manage peak electricity demand and support New Zealand's transition to 100% renewable energy;

(d) *Government and industry initiatives* – New policies, incentives, and market reforms are helping integrate more solar into the grid.

While solar PV won't meet all of New Zealand's electricity needs alone, it is becoming an important part of a more flexible, resilient, and low-carbon energy system.

4.6 Key solar components

Solar power systems convert sunlight into electricity using several key components. The main parts that make up a typical solar system are:

(a) *Solar panels (PV modules)* **–** These capture sunlight and convert it into DC electricity. Panels are usually installed on rooftops or ground-mounted in sunny areas;

(b) *Inverter* – This converts the DC electricity from the panels or battery into AC electricity, which is what most appliances use;

(c) *Battery (optional)* – This stores excess energy for use when the sun is not shining, such as during the night or on cloudy days;

(d) *Charge controller (if using batteries)* – This regulates the flow of electricity to prevent overcharging or deep discharging of the battery;

(e) *Home smart power meter* – This measures electricity production and usage, helping track savings and grid exports;

(f) *Grid connection (if applicable)* – This allows excess power to be sent to the electricity grid or allows the system to draw power when solar is not generating enough.

Figure 5 illustrates the main components and connections of a typical residential small-scale solar PV installation. The generation output connects through a DC/AC power inverter to the consumer's switchboard and directly supplies household appliances. Any instantaneous power imbalance (either over or under) between the generation output and household appliance demands flows through the home smart power meter, to or from the distribution network.

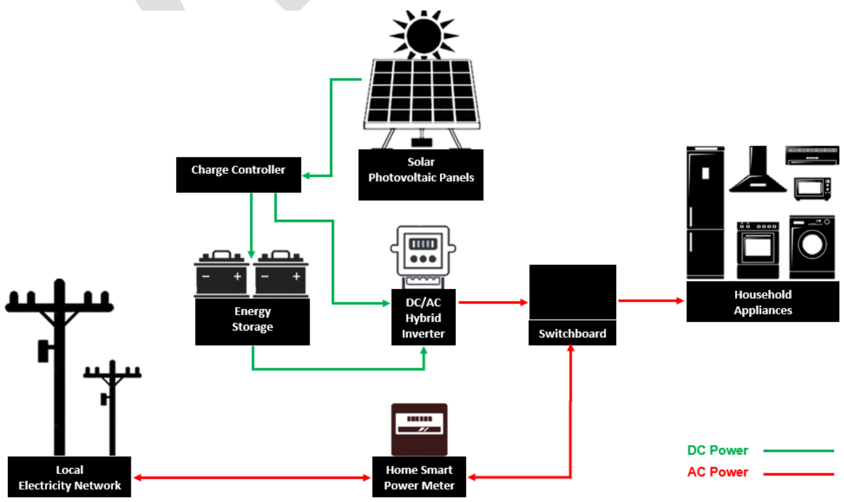

Figure 5 – Typical small-scale solar installation components

Distributed generation can take many different forms. The most common forms are the following:

(g) Solar PV;

(h) Wind turbines;

(i) Micro-hydro systems;

(j) Batteries (energy storage).

This PAS focuses on solar- and battery storage-related equipment.

5. Learning about solar PV systems

5.1 General

This section introduces the basics of how solar PV systems work, their key components, and the benefits they offer. It will also explore common installation options, factors that affect system performance, and important considerations for anyone looking to invest in solar power.

Whether you're new to solar energy or looking to deepen your understanding, this chapter provides a solid foundation to help you make informed decisions about solar PV systems.

Figure 6 – Typical rooftop solar panel system

5.2 Choosing a quality solar system

When installing a solar system, it's essential to choose high-quality components from reputable manufacturers. Look for good warranties and local support to ensure reliability. Equally important is selecting a trustworthy solar company or installer. Solar systems are long-term investments, so you should choose a provider you can rely on for many years.

5.3 Sizing your solar system

Determining the right size for a solar system depends on various factors. Priorities will vary based on the system type. Grid-tied systems don't need to cover all a home's electricity needs, as the network you are connected to supplies any shortfall. Off-grid systems should generate enough electricity to meet most or all a home's power demands.

Key factors to consider when sizing a solar system include the following:

(a) *Cost* – A larger system may have a higher upfront cost but can offer better long-term savings;

(b) *Electricity usage* – Reviewing past power bills helps determine the right system size. For off-grid set-ups, a detailed load assessment is necessary;

(c) *Available space* – The number of panels that can be installed depends on roof space, or land, for ground-mounted systems;

(d) *Network restrictions* – EDBs may impose limits on inverter size or the amount of power that can be exported to the grid;

(e) *Oversizing PV* – Many modern solar systems include more panel capacity than the inverter's output rating. Since panels rarely operate at their peak efficiency, extra panels help maximise energy production during cloudy days and winter. A common oversizing range is 100–150%. This needs to stay within the specifications of the power conversion equipment (PCE).

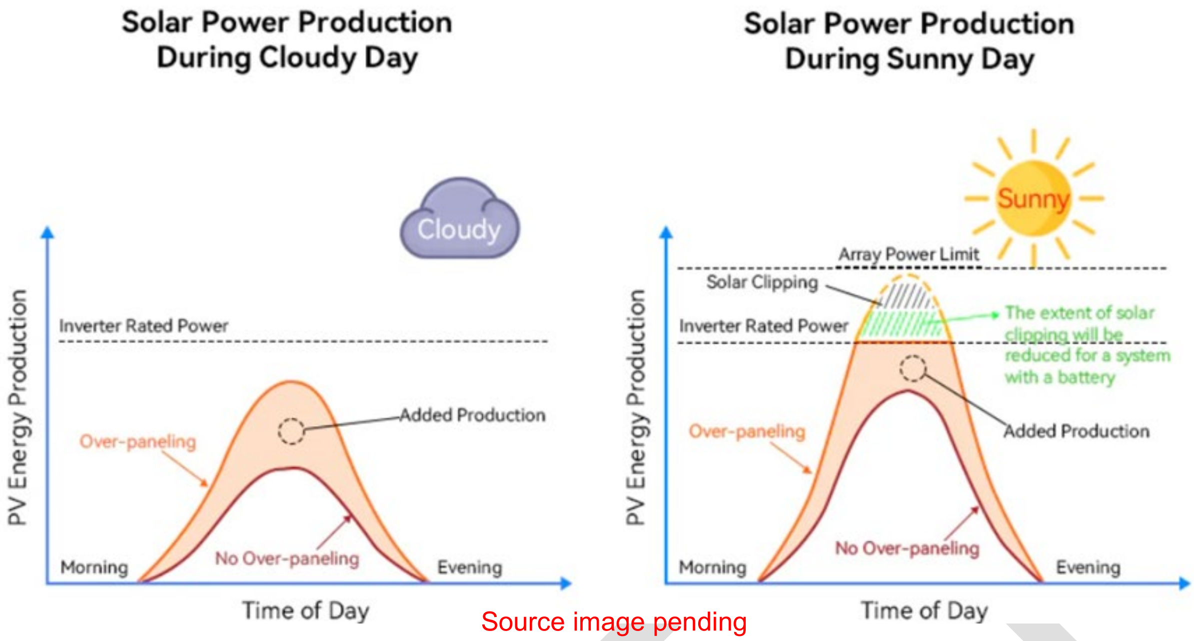

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Figure 7 – Advantages of PV oversizing

Since solar panels are relatively inexpensive, it often makes sense to install the largest system that fits the homeowner's needs within these constraints. Most EDBs will evaluate the capacity to host, based on the maximum power ingestion into their network.

Typical system specifications include the following:

(f) *Solar panel output* – Peak capacity in kilowatts (kWp); for example, 6.6 kWp;

(g) *Inverter output* – Maximum continuous power in kW; for example, 5 kW;

(h) *Battery storage capacity* – Stored energy in kilowatt hours (kWh); for example, 10 kWh.

5.4 Designing a solar system

5.4.1 Introduction

A well-designed solar system should be planned using industry-standard solar design software. This ensures accurate and efficient placement of panels. A professional solar designer should handle the process to ensure up-to-date and reliable results.

A solar design report (Figure 8) typically includes:

(a) A diagram showing panel placement on the roof or ground;

(b) A monthly breakdown of expected solar power generation;

(c) The percentage of the home's electricity needs met by solar versus the grid (or a generator for off-grid set-ups);

(d) Estimated energy losses due to shading or other factors;

(e) Financial projections, including the expected payback period and cost savings (for grid-tied systems).

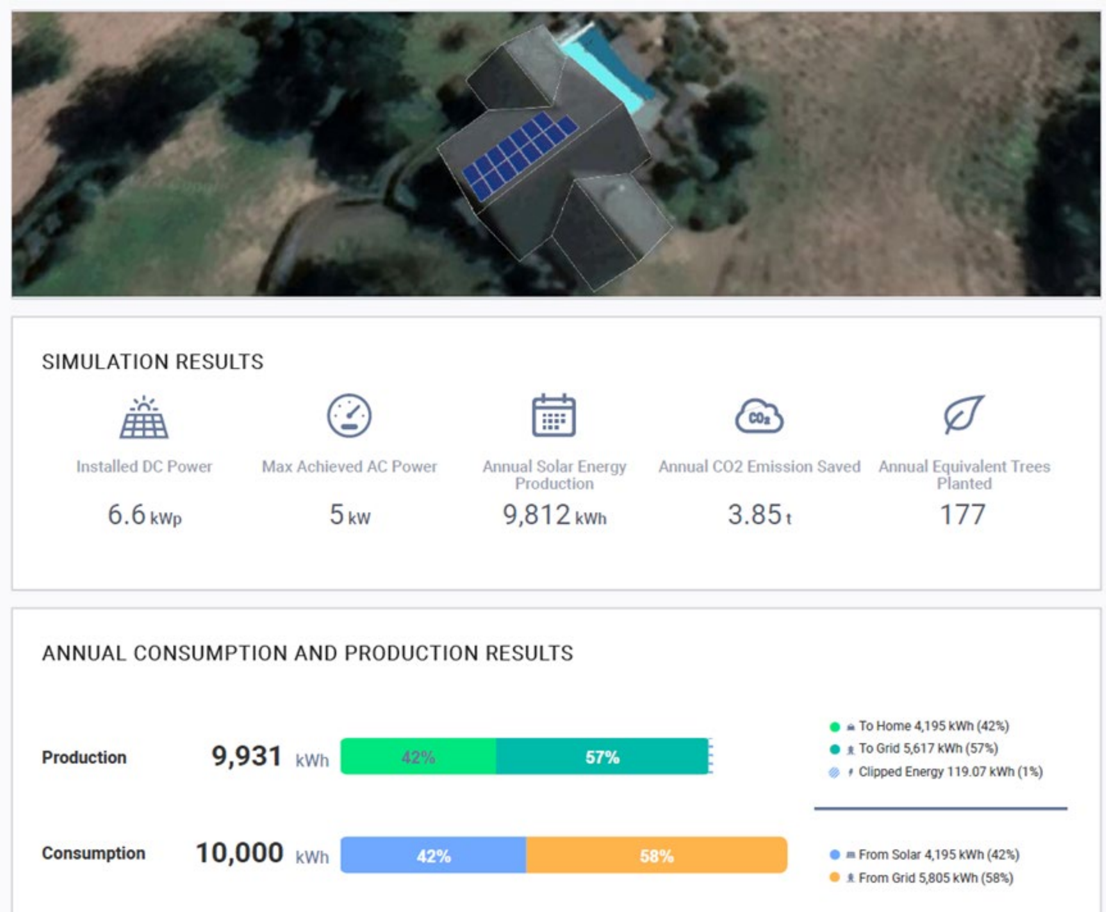

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Figure 8 – Solar design report key elements

5.4.2 Albedo effect

The term 'albedo effect' expresses the ability of a surface to reflect sunlight. It is generally expressed as a coefficient between 0 and 1, where 0 represents a totally absorbing surface (all light is absorbed), and represents a totally reflective surface (all light is reflected).

Surfaces with a high albedo reflect much of the incident light, while those with a low albedo absorb more. In practice, it is complex to evaluate the power gain due to bifaciality. For transparent bi-glass modules installed on residential roofs, where exposure of the rear surface to light is low, the power gain will be around 5%. For transparent bi-glass modules installed with an optimised slope on a white-coated reflective flat roof, it can be as high as 30%.

The general rule for maximising rear panel production is simply to move the rear panel as far away as possible from its support and to install the panels above the most reflective background possible.

5.4.3 Financial payback

One of the main reasons homeowners invest in solar is to save money. To get an accurate estimate of financial payback, calculations should be based on real data. Key factors include:

(a) Total system cost (including installation);

(b) Interest on loans (if financing is used) or incentives received;

(c) Total electricity consumption and how much solar power is used on site;

(d) Electricity rates: The cost of power imported from the grid and the price received for excess power exported;

(e) Battery storage and energy management tools that influence savings;

(f) Inflation and maintenance costs over time.

A typical grid-tied solar system pays for itself in four to eight years (Figure 9). However, this depends on various factors. If the estimated payback falls outside this range, a deeper analysis should be undertaken to identify the cause of that.

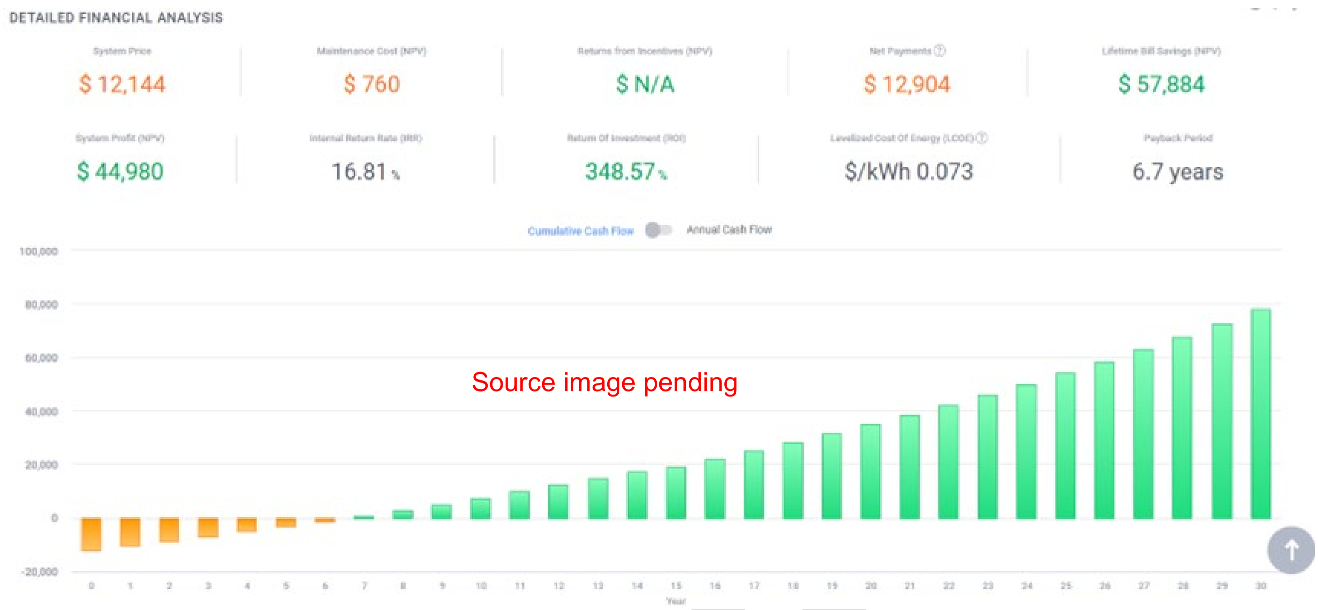


Figure 9 –Typical solar payback analysis

5.4.3 *Long-term support*

Solar systems are designed to last 20–30 years or more, so long-term support is crucial. Since solar technology is complex, homeowners should ensure they have reliable support in place. Support typically comes from multiple sources:

(a) *Solar installer* – The primary point of contact for installation and maintenance;

(b) *Equipment distributor* – Provides warranty support and handles repairs;

(c) *Manufacturer* – Backs up warranties and supports installers and distributors;

(d) *Industry bodies (for example, SEANZ, Electricity Engineers' Association)* – Support industry standards and help resolve disputes.

Choosing the right installer and manufacturer ensures that the solar system remains reliable and efficient for decades.

5.5 Limitations and risks of the current technology

Table 3 outlines some key limitations and risks homeowners need to be aware of before installing a system.

Table 3 – Solar panels limitations and risk

Limitation	Risk
Quality issues	The biggest risk for homeowners is buying a solar system of low quality, by reason of either poor-quality components or bad installation. Unfortunately, some sellers import cheap, non-compliant solar equipment into New Zealand. To avoid this, homeowners should choose reputable suppliers and installers (see Appendix A – Choosing a system that is right for you).
Rapidly evolving technology	Solar technology is constantly improving: new advancements regularly hit the market. This shouldn't be a reason to delay investing in a system. A high-quality solar system installed 5–10 years ago will still be performing well today, likely having already paid for itself while continuing to save money.
Upgrading challenges	Over time, it can be hard to find compatible parts for expanding or upgrading a solar system. For example, matching new panels with older ones or finding a battery that works with an outdated inverter may be difficult. That's why it's

	important to carefully consider future needs when designing a system. Homeowners should discuss potential upgrades with their installer from the start.
Insurance considerations	Solar installers should have public liability insurance, to cover any potential damage during installation. Homeowners should also check that their home insurance policy covers their solar system. Many insurers now include solar in standard policies.
Orphaned systems	In Australia, over 4 million solar systems have been installed, but an estimated 600,000–700,000 are now 'orphaned' – meaning the original installer or company has gone out of business, leaving the system without support. New Zealand's solar market is more stable; it hasn't experienced the same boom-and-bust cycles. However, the Australian experience highlights the importance of choosing quality products and ensuring there's ongoing support available.
Grid limitations	Currently, New Zealand has relatively few solar systems connected to networks. However, as more are installed, there may come a point at which the electricity network reaches its capacity for connecting new solar systems. Future investments in the grid will help increase this limit. Right now, there's still plenty of capacity for more solar in New Zealand. This issue does not affect off-grid solar systems.

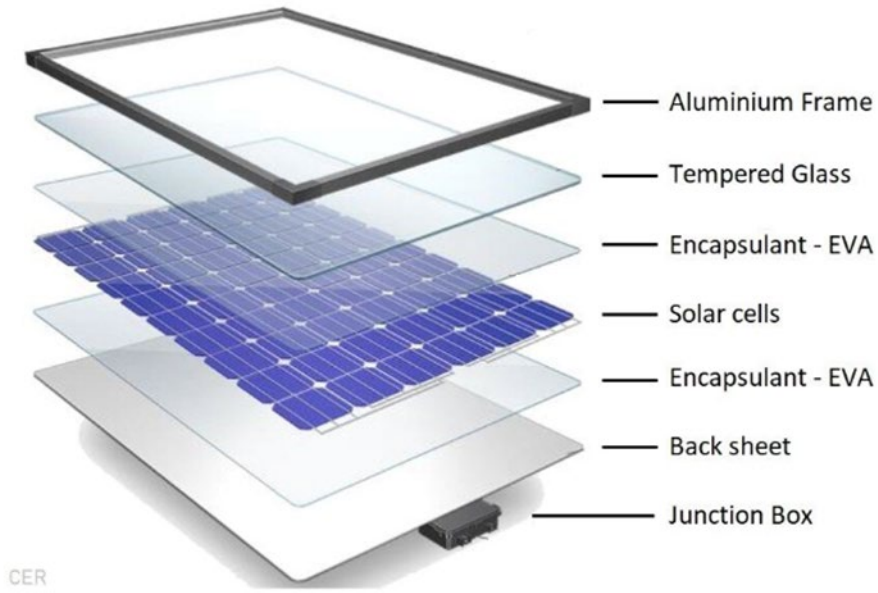
6. Solar panels

6.1 General

Each solar panel is made up of multiple solar cells, which are created by cutting a solid block of crystalline material into thin slices and shaping them as needed (Figure 10). These solar cells are connected in a series to increase the panel's voltage, using either thin wires or special conductive glue.

To reduce the impact of shading, solar panels include bypass diodes, which are built into the panel's wiring. Solar panels come in different designs. The most common types are as follows.

(a) *Framed solar panel* – This is the standard type. It has an aluminium frame that helps with mounting and a toughened glass layer on top to protect the solar cells. The cells are enclosed in a protective material - Ethylene Vinyl Acetate (EVA), and a plastic back sheet covers the rear. Junction boxes and short cables with connectors are attached to the back for easy wiring;



Source image pending

Figure 10 –Typical solar panel construction

(b) *Bifacial solar panel* – This has an extra layer of toughened glass on the back instead of a plastic sheet. It allows light to reach the solar cells from both sides, which can boost electricity production if the panel is installed on a raised frame or ground mount. If the panel is mounted flat on a roof, the extra power gain is minimal. Bifacial panels may also offer other benefits, such as improved fire resistance;

Note – For more technical information, see Appendix B.

(c) *Frameless solar panel* – This is usually a bifacial panel, without the aluminium frame. They are often chosen for their sleek design, but they need special mounting systems;

(d) *Thin-film solar panel* – This type does not have a frame. It is made by applying a thin PV layer onto a flexible backing. This type of panel is generally more affordable, but it has a shorter lifespan and warranty. Thin-film panels are rarely used for homes; they are more common on mobile applications like campervans and caravans;

(e) *Building-integrated photovoltaics* – In this type, solar cells are built into roofing materials such as solar tiles. These tiles function as both a roof covering and an electricity generator. Although this technology has been available for over 30 years, it is not widely used in New Zealand, due to its high cost, complex installation, and other challenges.

6.2 Types

When selecting solar panels, several important factors should be considered. Table 4 sets these out.

Table 4 – Solar panel selection factors

Factor	Consideration
Cell technology	Solar panels use silicon cells: the two most common types are monocrystalline and polycrystalline. Monocrystalline panels are generally considered superior due to their higher efficiency, and they are now the dominant technology.
Cell size and quantity	The number and size of cells in a panel affect its power output: (a) More cells increase voltage output; (b) Larger cells increase current output; (c) Half-cut panels (where cells are split in two) improve efficiency and reduce shading issues.
Size and weight	A standard residential solar panel is less than 1.8 m x 1.2 m and weighs under 25 kg, making it manageable for installation and suitable for most rooftops. Larger commercial panels are not recommended for homes, because they require more space, may not fit residential inverters, have shorter warranties, are heavier (requiring two people to lift), and are more prone to wind damage.
Efficiency	Residential solar panels typically convert 20–25% of sunlight into electricity. While efficiency is improving, advancements happen gradually and take time to reach the market.
Warranty	Solar panels come with two types of warranties: (a) Product warranty (10–25 years) covers manufacturing defects; (b) Performance warranty guarantees a minimum power output after a set period (for example, 90% output after 25 years).
Bloomberg New Energy Finance Tier 1 rating	Bloomberg New Energy Finance ranks solar panel manufacturers based on their financial stability (Tier 1). This rating does not measure quality directly but often correlates with reliability. Bloomberg does not rank manufacturers as Tier 2 or 3.
Appearance options	Solar panels come in various designs to suit aesthetic preferences. The following variations can be considered: (a) Frame colour: silver (natural aluminium) or black (anodised); (b) Frameless panels for a sleek look; (c) Bifacial panels (glass on both sides) that absorb light from both front and back; (d) Black or white back sheet: A black back sheet makes the panel look fully black but slightly reduces power output (by 5–10W); (e) Shingled cells: where thin strips of cells are glued together instead of using traditional metal wiring.
Quality testing	Independent laboratories outside of New Zealand - such as DNV, PV Lab, and TUV, test solar panels for durability and performance. Manufacturers often use these test results for marketing.
Price	Prices vary by manufacturer, but solar panels have become much more affordable in recent years.

6.3 Installation general considerations

6.3.1 Standards for solar panel products and Installation

When installing solar panels, it's important to follow the relevant standards:

(a) *AS/NZS 1170.2 – Structural design actions, Part 2: Wind actions* – This covers wind forces and how they affect structures, including solar panels;

(b) *AS/NZS 5033 – Installation and safety requirements for photovoltaic (PV) arrays* – This covers installation and safety for solar PV systems. This standard also refers to other international (International Electrotechnical Commission (IEC)) standards, which must also be followed.

6.3.2 Installation requirements

Before installation, the roof should be thoroughly checked. Any defects must be noted, and necessary repairs should be made. Since solar panels last over 25 years, the roof should be in good condition, to avoid costly repairs later. By adhering to the following valuable guidance, a solar installation will be safer and more reliable and last longer.

Source image pending

Figure 11 – Wiring of solar panels

6.3.3 Connecting solar panels

Solar panels are connected in the following ways.

(a) *Series connection (strings)* – Panels can be wired in series to increase voltage and power output, which helps reduce voltage loss over long cable runs:

   (i) All panels in a string must be the same type and specification, and face the same direction

   (ii) If one panel's output is reduced (due to shading, dirt, or damage), all the panels in that string will be affected. Bypass diodes inside the panels help reduce this impact;

(b) *Parallel connection (arrays)* – Strings can be connected in parallel to increase current and power output:

   (i) All strings should have the same number and type of panels

   (ii) Only do this if the connected PCE can handle the increased current.

6.3.4 Safety considerations

Installation of any solar panel system operating above extra low voltage (ELV) – defined as 120V DC or 50V AC – is considered high-risk work. In this case, panels must be installed by a competent electrical worker, as defined in definitions.

Other safety considerations include the following:

(a) *Overcurrent protection* – If the solar system includes batteries, PV fuses may be needed on each string. Never open PV fuse holders under load – this can cause a dangerous arc flash;

(b) *Voltage limits* – A residential system must stay below 600 V DC;

(c) *Short-circuit* safety – All components (cables, connectors, isolators, and PCE) must be able to handle at least 1.25 times the short-circuit current at maximum temperature;

(d) *Fire risks* – Loose connections, damaged cables, or faulty switches can create electrical arcs, which can cause fires. Use high-quality components and proper tools, and ensure moisture does not get into connections;

(e) *PV DC* isolators – These are used for system isolation, and placed near the PCE:

   (i) Their current rating decreases as array voltage increases

(ii) They must not be placed on rooftops in New Zealand

(iii) They should be lockable in the off position for safety.

(f) *Array isolation* – There should be an isolation point near the solar panel array. The main PV DC isolator at the PCE should be turned off and locked before disconnecting this isolation point.

6.3.5 Solar panel cables and connectors

Solar panel cables and connectors include the following:

(a) *PV connectors* – Most solar panels use Staubli MC4 connectors. Only plug together the same type and brand, to plug together to avoid fire risks;

(i) Staubli MC4 EVO2-A is also compatible with standard MC4

(ii) Cheap copies exist, but mixing different brands can cause failures and fires;

(b) *PV cables* – Special double-insulated, UV-resistant cables designed for solar systems:

(i) Common sizes are 4 mm² and 6 mm²; other options include 2.5 mm², 10 mm², and 16 mm²

(ii) Do not use intermediate joints – cables shall be continuous from the panels to the PCE

(iii) Voltage drop should be less than 3% from the panels to the PCE;

(c) *Cable protection* – PV cables inside buildings must be run inside heavy-duty (HD) conduit labelled 'solar' every 2 metres:

(i) Openings must be sealed properly to prevent water damage

(ii) In attics, cables must be installed safely to avoid hazards for firefighters.

6.3.6 Earthing (grounding)

Solar panel frames and mounting structures must be earthed (grounded), except if the system operates below 120 V DC (ELV). The minimum earth cable size is 4 mm², running alongside the PV cable inside the conduit. The earth cable must be continuous all the way back to the main switchboard's earth bar.

6.3.7 Lightning protection

Solar panel cables can pick up electrical surges from lightning, which can damage the system. Installing surge protection devices (SPDs) near the PCE can help protect the system.

6.3.8 Combiner boxes

Combiner boxes are pre-wired units that help manage multiple panel strings. They typically include string fuses, SPDs, and PV DC isolators for added protection.

7. Rooftop applications

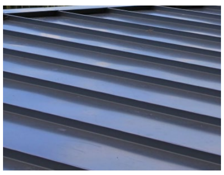
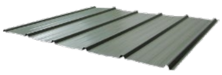
7.1 General – Is my roof suitable for solar PV?

Solar panels are usually installed on rooftops, using a specially designed racking system. Before embarking on any rooftop solar PV installation, it is important for the homeowner and installer to determine whether the existing roof and cladding system is suitable for the installation.

Not only is this an opportunity to assess the condition of the existing roof, its supports and its ability to take additional load, but it is also necessary to determine in advance what type of racking support system will be required.

Table 5 provides a useful guide on common roof types in New Zealand residences and their suitability for a rooftop solar PV installation.

Table 5 – Typical New Zealand roof systems

Roof type (cladding)	**Appearance** Source images pending	**PV installation suitability**	
Concrete/clay tiles		Difficult	This requires tile hooks or hanger bolts to mount the framing on the underlying structure. Tile breakages are common – ensure spare tiles are handy before beginning.
Corrugated iron		Very suitable	Framing brackets can often be screwed into joists beneath the cladding, making use of existing screw holes.
Decramastic (pressed steel tiles)		Possible	This requires tile hooks or hanger bolts to mount the framing on the underlying structure. The risk of asbestos exists in pre-1990 Decramastic installations.
Flat membrane		Most difficult and expensive	Due to the risks associated with breaching the integrity of the waterproof membrane, this is not recommended as a retrofit solution. It is a preferable solution if done as part of a new build or roofing system replacement.
Slate/schist tiles		Difficult	This requires tile hooks or hanger bolts to mount the framing on the underlying structure, and there is a chance the tiles will break. Installation typically takes three times longer than on a corrugated iron system.
Standing seam		Suitable	Special brackets are required to fasten to the standing seams.
Trapezoidal (long-run)		Very suitable	This has similar fixing arrangements to corrugated iron.

Typically, racking systems (Figure 12) consist of two aluminium rails per row of panels, which are securely fastened to the roof structure using multiple attachment points. The rails run parallel to each other, usually spaced between 800 mm and 1200 mm apart, depending on the roof structure. The panels are then clamped to the rails at four points to keep them secure.

Source image pending

Figure 12 – Typical rooftop racking systems

7.2 Access and safety

7.2.1 Introduction

Some roofs can be accessed safely with a ladder, but others may require scaffolding, roof edge protection, or mechanical lifts. During installation, installers should wear safety harnesses secured to anchor points. A detailed safety plan should be in place before installation. The right footwear is important, to prevent slipping or roof damage, and extra caution is needed around skylights and other roof hazards.

7.2.2 Roof zone

The outer 600 mm of a roof is an edge zone and experiences stronger wind uplift. This may require additional attachment points for the panels. Panels should not be too close to the roof edge and never overhang. Additionally, installers should ensure access for regular cleaning of the panels and set the panels back from gutters, to prevent water splashing over them.

Source image pending

Figure 13 – Roof zone

7.2.3 Wind zone

Installers should determine the wind zone of the installation site and design the mounting system accordingly. Other factors, such as terrain type and history of strong winds, should also be considered.

Source image pending

Figure 14 – New Zealand wind zones

7.2.4 Panel orientation

Panels can be installed in portrait or landscape orientation. This choice depends on available space, structural attachment points, ease of wiring, and aesthetics.

Source image pending

Figure 15 – Panel orientation

7.2.5 Tilt and azimuth

North-facing panels produce the most energy, but east and west orientations should also be considered.

The ideal panel tilt is typically equal to the site's latitude, but the roof angle usually determines the actual tilt. Steeper angles boost winter generation but increase wind uplift risks. For flat roofs, tilt frames may be necessary. A solar design app should be used to assess energy production based on tilt and orientation.

7.2.6 Roof area

Panels can be installed on different roof sections, but each section must be large enough to fit a full string of panels. The number of panel groups is limited by the available PV inputs on the connected inverter (PCE).

7.2.7 Roof attachments

Racking systems are usually attached to the roof substructure (purlins or rafters). If this isn't possible, specialised attachment systems for the roof cladding can be used.

Some commercial systems mount panels without rails, but these are not typically used for residential projects.

7.2.8 Panel spacing and clearance

Panels should not touch each other – mounting clamps ensure a small gap. A gap of about 100 mm between the panels and the roof helps prevent debris build-up and allows for cooling airflow, improving efficiency.

7.2.9 Service pathways

Panels should be arranged to allow space for maintenance and cleaning. For large solar arrays, dedicated pathways should be included for easy access. Panels should never be walked on: this can cause micro-cracks that reduce efficiency.

7.3 Cable management

Conduits should be securely attached to the roof or racking. Cables must never touch the roof and should be fastened using proper clips or stainless-steel ties. Sharp bends should be avoided to prevent damage to the insulation.

7.4 Anodising

Most solar racking is made from aluminium. Standard aluminium is common, but anodised (black-coated) aluminium is available for aesthetics (5-micron coating) or marine-grade durability (20-micron coating).

7.5 Earthing (grounding)

Solar arrays above ELV must be properly earthed. Earth clamps attach the grounding cable to the rails, ensuring all metal parts are conductive. If the racking is anodised, special washers may be needed for conductivity.

7.6 Roof penetrations

Solar cables and conduits often pass through the roof, requiring careful sealing to maintain waterproofing. Proprietary flashing products should be used to ensure a watertight seal. Cable penetrations are usually placed under the panels for better aesthetics and weather protection.

Whenever possible, existing roof screw holes should be used for attachments. Special fasteners or flashings may be needed (Figure 16), depending on the roof type.

Source image pending

Figure 16 – Typical flashing options

8. Ground-mount applications

8.1 General

Solar panels installed on the ground require a sturdy support structure to hold them securely. The panels can be set up in either landscape or portrait mode, and multiple rows may be used (Figure 15). This option is usually chosen when roof space is unavailable, too small, unsuitable, or shaded, or when the homeowner simply prefers a ground-mounted system.

Ground-mounted solar panels are more common in off-grid systems, as such systems often need larger arrays to generate enough power. These systems are typically installed in rural areas, where there's more open space.

8.2 Types of ground mount structures

8.2.1 Treated timber

Treated timber ground mount structures use posts set into concrete with a roof-like frame for mounting the panels.

8.2.2 Galvanised steel or aluminium

Aluminium rails may be added to make panel installation easier and for compliance with a manufacturer's instructions. You can either reuse a suitable generically designed support system or engage a structural engineer to design a custom system. Prefabricated, factory-made structures are built to standard specifications. Steel posts are either rammed or set in concrete at a specific depth. Other structural components are then attached.

8.2.3 Key factors to consider

Key factors to consider include the following:

(a) *Wind resistance* – The structure must be designed to withstand specific wind speeds for safety and durability;

(b) *Angle* – Panels are usually tilted between 25 and 35 degrees. A steeper angle can improve winter energy production (important for off-grid systems) but also increases wind resistance;

(c) *Orientation (direction)* – North-facing panels produce the most energy, but site conditions may require them to face east or west instead. Multiple structures can be set up at different angles to capture morning or evening sunlight;

(d) *Height* – The lowest part of the panels should be at least 600 mm off the ground, to prevent shading from grass and dirt splashes from rain. The highest point depends on the panel size, arrangement, and tilt angle;

(e) *Safety* – Cables must be well managed and protected. The structure should not be climbable by children, and animals should not be able to damage it;

(f) *Trenching for cables* – Solar cables should be enclosed in HD conduit and buried at least 500 mm deep. Electrical warning tape should be placed above the conduit in the trench. The ends of the conduit must be properly sealed to prevent damage;

    Note – See AS/NZS 3000, as there are other options with different depth and mechanical protection requirements allowed.

(g) *Electrical components* – Some installations may include combiner or fuse boxes. These should be weatherproof (ingress protection (IP)-rated) and UV-resistant. They should be mounted in a sheltered spot behind the panels, out of direct sunlight, and clearly labelled;

(h) *Building consent exemptions* – Some ground-mounted solar installations may not require a building consent. Further information can be found on the Ministry of Business, Innovation & Employment (MBIE)'s 'Building Performance' web page pertaining to 'Other structures' (see https://www.building.govt.nz/projects-and-consents/planning-a-successful-build/scope-and-design/check-if-you-need-consents/building-work-that-doesnt-need-a-building-consent/technical-requirements-for-exempt-building-work/14-other-structures).

Figure 17 – Example ground mount solar array

8.3 Guidance on use, operation, and maintenance

To keep your solar panels working efficiently, clean them regularly – especially if they are installed at a low angle or in a dusty environment. If you decide to clean them yourself, use only clean water without any chemicals or abrasive materials. Be cautious when accessing the roof, and never walk on the solar panels.

If inspection is included in your purchase agreement or arranged separately, a professional installer can inspect your system once a year. During this inspection, the installer will check key components such as earth bonding, cables, connections, conduit, and roof entry points.

If leaves or debris have built up under the panels, remove them carefully without disturbing the wiring.

9. Grid-tied systems without batteries

9.1 General

9.1.1 Introduction

A grid-tied solar system is a type of set-up that works together with the electricity network that supplies power to a home. This set-up is known as distributed generation (DG); it can also include batteries.

Note – Electricians with current practising licences intending to work on grid-tied systems are required to have additional endorsement for mains parallel generation systems (see the Electrical Workers Registration Board's web page 'Electrician (Endorsed Mains Parallel Generation Systems)': https://www.ewrb.govt.nz/registration/registration-new-zealand-experience-pathway/electrician-endorsed-mains-parallel-generation-systems/). This requirement extends to electrical inspectors; it comes into effect on 25 September 2025.

9.1.2 How it works

A grid-tied systems works as follows:

(a) *Use of solar power first* – The electricity generated by the solar panels is connected into the home's electrical installation, and because of this, it powers the home's electrical appliances and devices;

(b) *Getting extra power from the grid* – If the solar system doesn't produce enough electricity to meet the home's needs, the grid supplies the shortfall. The homeowner pays for this electricity at the agreed rate (import price);

(c) *Selling extra solar power* – If the solar system produces more electricity than the home needs, the excess power is sent back to the network. The homeowner may receive payment for this at the export price set by the electricity retailer.

9.1.3 Metering and installation

A special import/export meter (also known as a revenue meter) must be installed by the electricity retailer to measure the electricity both drawn from and sent to the grid. This meter is separate from any other solar system equipment. Homeowners should discuss applying for installation of this import/export meter with their solar installer well in advance, as wait times can be long, depending on the retailer.

Talk with your solar installer at the start of the process, to confirm who is responsible for paying for the meter upgrade.

9.1.4 Checking electricity supply before installation

Before installing a grid-tied solar system, it's important to understand:

(a) *The number of phases* – The type of electricity supply to the home (single-phase, two-phase, or three-phase) and how it is utilised (see clause 9.2 'Types of electricity connections');

(b) *The network power controls* – Some homes have systems like ripple control, which can affect how solar power is used;

(c) *The export limits* – Most EDBs set limits on how much solar power can be exported to the grid.

9.2 Types of electricity connections

9.2.1 Single phase (most common for homes)

Single phase is the simplest and most cost-effective type of solar installation: it typically requires just one inverter.

9.2.2 Two phase

Some homes have two phases from a three-phase supply or a dedicated two-phase set-up. A solar system can be installed on one phase, but the second phase won't benefit from solar.

In some cases, all electrical loads can be moved to the solar-powered phase, but this needs careful planning, including by checking cable sizes and transformer balance. Two-phase solar systems are custom-built and typically require two inverters.

9.2.3 Three phase

Three-phase inverters are available for these set-ups. An electrician should check that all three phases are properly connected and functioning before installation.

9.2.4 Ripple control (hot water control) considerations

Some homes have a ripple control unit, which allows the electricity provider to turn off certain appliances (like hot water cylinders) during peak demand times. In return for this control, EDBs may provide a network cost rebate to the customer.

Solar should not be connected to a ripple-controlled circuit, as it may cause the solar system to turn off unexpectedly.

Homeowners may prefer to connect their hot water system to the solar power supply, instead of relying on ripple control. This allows the heating of hot water with solar energy. Note that this primarily pertains to two-meter registers.

9.2.5 Export limits for solar panels

In single-phase systems, most EDBs limit solar exports to 5kW. Multi-phase systems typically have a 10-kW export limit (although some EDBs allow 5 kW per phase). Larger systems may be allowed if export power is restricted by the solar system to stay within these limits.

Note – Normally the system designer or installer will check the acceptable export capping level with your EDB.

9.3 System architecture

A GTI forms the heart of any grid-tied solar system. Strictly speaking, an inverter is a box of electronics that converts DC power to AC power, or vice versa. To convert electricity from DC (for example, solar PV) to AC (for example, grid/home), the DC is switched on and off at a fast variable rate and filtered to create an AC waveform.

The main power conversion is normally done in one of two ways:

(a) Early GTIs typically used a built-in transformer and used lower frequency switching to produce an AC output. These low frequency inverters are typically more expensive to manufacture, much heavier in weight, and typically 90–95% efficient. Their main advantage is having high peak power (surge) ratings and added safety with galvanic isolation between the PV DC input and the AC output;

(b) Since approximately 2015, most GTIs use a high-frequency non-isolated architecture. There is no bulky heavy transformer, and the switching frequency is higher. The main advantages are lower manufacturing costs, lighter weight, and higher efficiencies (typically 95–98%). Greater care needs to be taken during installation in this case, particularly regarding the PV wiring and earthing.

GTIs have additional functions, some of which are as follows:

(c) *Maximum power point trackers* (MPPTs) – These are the input circuits connecting a string of solar panels: there may be one or more. The number of separate MPPT inputs may determine how many different roof areas can be used to install solar panels. The MPPT circuit will accept the PV power by loading it in an optimal way to ensure maximum power production. Most MPPTs will do a regular sweep to establish the MPPT is maximising PV power production under present conditions. Solar panel strings/arrays need to be closely matched to the MPPT specifications;

(d) *Grid interface and management* – GTIs must be able to synchronise with the grid's AC, particularly as regards voltage and frequency. In the case of a grid outage, the GTI must disconnect from the grid and shut down the solar system. This feature is called anti-islanding; it ensures that a grid-tied solar system can never export power to a faulty grid, thus ensuring the safety of lines workers. If the grid voltage or frequency drift outside predetermined limits, the inverter will be programmed to respond appropriately. Included features allow the EDB control over the inverter under certain conditions. This function is used in Australia, but not in New Zealand (see AS/NZS 4777 – Grid connection of energy systems via inverters);

(e) *User interface* – Some inverters may have an LCD display, although many models do not have a display and will use a Bluetooth or Wi-Fi interface. This interface will typically have different access levels for installers and homeowners;

(f) *Remote monitoring* – Most GTIs will have the ability to connect to the internet using built-in Ethernet or Wi-Fi connections, or they may have optional dongles or cards for these purposes. Establishing an internet connection allows the inverter to connect to a manufacturer's web portal giving detailed performance and solar production information. There may be different access levels for installers and homeowners, and some systems will have remote abilities to perform inverter firmware upgrades and settings changes. Security is an important consideration when connecting an inverter to the internet;

(g) *Safety monitoring* – GTIs will also include mandatory safety monitoring features such as earth fault monitoring of the connected PV panel strings/arrays. Should a PV cable become pinched/nicked under the solar racking, or a similar fault, this can cause a leakage current from the PV panels to earth. The GTI will detect this leakage and generate an earth fault alarm. There may be other optional safety monitoring features, such as arc fault detection. A loose or damaged PV connection/cable can cause an arc to be generated which can lead to a fire. If the GTI has arc fault detection, it can issue a warning and cease solar production until the fault has been repaired. Note that on GTIs fitted with this feature, the feature may need to be turned on during inverter set-up and commissioning.

Grid-tied inverters will generally be to one of three common designs:

(h) String inverters – These are the most common type of GTI. Strings or arrays of solar panels will be connected to the MPPT inputs, and all power electronics will be contained within one inverter box. The major advantage of string inverters is low cost and simplicity of installation. The main disadvantage is that when panels are wired in series, any individual panel that has reduced performance through shading, dirt, fault, or mismatch tolerance will reduce the power output of all panels in the same string. However, many modern string inverters will use software algorithms to help mitigate this drawback. The other consideration is safety – strings of solar panels will continue to produce significant voltage when the sun is shining, even when disconnected from the inverter. With expert installation and good quality product choices, string inverters are the most popular choice for grid-tied solar systems;

(i) *Micro-inverters* – These are smaller inverters that are installed underneath solar panels, typically with one unit for each solar panel. Additional elements such as a control or monitoring unit with grid disconnect relays will also be fitted. This can offer a more tailored approach, with each micro-inverter working to maximise the power production from a single solar panel. Very small solar systems can be built, which are scalable to larger systems. Micro-inverters allow the user to monitor the production and performance of each solar panel, and in the event of a micro-inverter failure, only one solar panel is affected. The main disadvantages are a higher purchase price and additional installation labour costs. Proprietary AC cable and connectors are normally used for the rooftop wiring, which can also add to the cost. In the event of a failure, the installer must access the roof and remove the solar panel to replace a micro-inverter;

(j) *Optimised inverters* – Here there is a single common inverter, and some of the electronics are contained in individual DC optimiser units installed under each solar panel. An optimiser is essentially a DC-to-DC converter; this has advantages such as maximising the output of each solar panel and facilitating panel-level monitoring. When the inverter is shut down or the panels are isolated, each optimiser will reduce its output to 1 V, making the system safer for installers and firefighters. Standard solar PV cable and connectors are used to wire the optimisers back to the optimised inverter, which will perform all other required functions. The main disadvantages are the higher purchase price and additional installation labour costs. In the event of a failure, the installer must access the roof and remove the solar panel to replace a micro-inverter.

When considering which inverter system best suits any particular home, there may be several suitable options, requiring careful consideration of which best meets the customers' needs and budget. Long-term maintenance, reliability, operation, and potential upgrade pathways also need to be considered.

An inverter meter will sometimes be installed at the main switch on the main grid feed to measure how much power is imported and exported to the grid. This meter may also include a current transformer (CT) sensor that is placed around the main live feed cable from the grid. It is essential that the CT be placed facing the correct direction, as indicated on the CT or its manual. This meter will usually be hard-wired back to the inverter using an RS-485 communications cable. The GTI will already know how much power it is producing; the addition of a meter allows it to see where the power is going. This enables the inverter to monitor import/export of power and self-consumption in addition to solar production, to build up usage history. A meter is also essential if a limit needs to be placed on export power, or where there is an accessory installed that requires this additional information (for example, a solar battery or hot water diverter). Note that this inverter meter is a different meter to the revenue import/export meter installed by the electricity retailer.

9.4 Installation considerations

The following standards should be followed for the products used and the installation of GTIs:

(a) AS/NZS 4777.1 – Grid connection of energy systems via inverters, Part 1: Installation requirements;

(b) AS/NZS 4777.2 – Grid connection of energy systems via inverters, Part 2: Inverter requirements.

Installation of GTIs is classed as high-risk work – GTIs must therefore be installed by an Electrical Workers Registration Board (EWRB)-registered electrician who has an endorsement for mains parallel generation systems (from September 2025). The installation must be recorded on WorkSafe's high-risk database and inspected by an inspector with both a current and an endorsed practising licence.

Prior to any solar installation, a detailed site survey should be completed by an experienced solar electrician. The main aspects considered by the electrician for inverter installation are as follows:

(a) *Type of grid connection* – Is it single or multi-phase? Is there any form of external control present, such as ripple control? Is the chosen GTI suitable for this installation, and does the customer understand any limitations on the solar system to be installed?

(b) *Mains cable and fuse sizing from the house to the point of supply* – Is the fuse-type and capacity appropriately rated for the maximum load demand of the house? Additionally, is the cable supplying the property in good condition and appropriately sized for the cable-length, current carrying capacity and voltage drop? On older homes built at a time when electrical standards were less onerous, and where many new electrical loads have been added, this consideration is especially important. Are there future plans to add additional heavy loads, such as an EV charger, swimming pool, or spa pool? Should there be any planned phase changes or transfer of loads onto a different phase? The implications of these changes should also be considered;

(c) *Condition of switchboard* – Many older homes have older-style switchboards that may need to be upgraded prior to solar installation. Older style switchboards can sometimes contain asbestos, sometimes have older-style fuses, and often lack any form of personal shock protection, such as residual current devices (RCDs). If required, upgrading a switchboard is best done prior to any solar installation;

Source image pending

Figure 18 – Typical switchboard imagery

(d) *Earthing* – Is the main earth rod and wiring back to the main switchboard in good condition? Is the multiple earthed neutral (MEN) link correctly installed in the right place? Grid-tied solar systems rely on the correct functioning of the main earth system for safety;

(e) *Location of inverter* – Ideally, the GTI should be installed close to the main switchboard in a suitable location, such as a garage. If this is not possible, other suitable locations should be considered. Many inverters will have a fan; the noise of this should be considered, so that the residents are not unduly affected. The ability to carry out a safe, neat, and tidy installation in a dry area should be considered, particularly considering all cable runs. These may be in the form of a hard-wired Ethernet cable or Wi-Fi, and this access should be considered. Many GTIs are rated for outdoor installation, but this should be approached with caution. If a GTI is installed outdoors, it should be in a sheltered location and out of direct sunlight. Extra care and attention should be paid to all cable entries and connections to the inverter. In addition, it should be noted that LCD screens generally have a short life span when exposed to sunlight;

(f) *AC cabling to inverter* – GTIs generate a considerable amount of power. The AC cable used to connect the inverter to the switchboard should be appropriately and generously rated. This cable run should be kept as short as possible. Any additional cable runs from the switchboard to the meter box should also be considered. GTIs export power to the grid by raising their output voltage slightly above the grid voltage, so that power flows outwards. Any resistance in a cable between the GTI and the grid transformer will result in unnecessary additional voltage rise; if the voltage at the GTI rises excessively beyond the AS/NZS 4777 limits, the inverter must disconnect from the grid and cease energy production;

(g) *Grid voltage* – The nominal AC grid voltage in New Zealand is 230V ± 6%. Should the grid voltage be excessive, it may cause a GTI to trip out, especially during times of high solar production. In these cases, it may be necessary to request that the EDB reduce the taps on the grid transformer to reduce the voltage. If there is a weak grid supply (for example, perhaps the house is at the end of a long thin supply line), this can be problematic for GTIs. There may be wide voltage variations from the grid, depending on the load or power exported, and it can be hard to find a balance. In these cases, the solution may be to upgrade the grid supply or to limit the export power from the GTI to the grid;

(h) *Cable entries to inverters* – GTIs will have several electrical and signal connections to the inverter – these may be in the form of conduit glands or direct connection using a multitude of different types of connectors. It is essential that all connections be safe, compliant, and neat, using the correct supplied and matching connectors. Any weather proofing and drain vents should be kept intact to maintain the inverter's IP rating;

(i) *Manufacturer's instructions* – It is very important that the installer read the inverter manufacturer's manual and follow all instructions. Particular attention should be paid to suitable mounting locations and required ventilation and clearances around the inverter;

(j) *Fusing and isolation* – All GTIs should have AC fusing and lockable isolation between the inverter and the switchboard. Fusing will normally be implemented using a miniature circuit breaker (MCB) in the switchboard – if the inverter is mounted close to and in line of sight of the switchboard, it's possible the inverter MCB can also serve as an isolator. A small MCB lock attachment can be used to lock it in the off position if required. Any fusing and isolation should only be on the live conductors; the neutral should not be switched;

(k) *DC PV cable to inverter* – There may be multiple PV DC connections to the inverter. It is very important that the correct polarity is observed on these connections, and that all connected PV strings/arrays are within the operating specifications of the inverter. The PV cables will normally be protected by heavy-duty solar conduit. If this conduit terminates before the inverter, suitable multi-hole glands should be used to seal the open conduit, and any exposed PV cables should be shorter than 300 mm. Many inverters have built in PV DC isolator switches; however, it may also be necessary to install external PV DC isolators;

(l) *Inverter earthing* – GTIs will often have two earth connections back to the switchboard main earth busbar. The first earth will be within the AC cable (usually three-core for single phase and five-core for three-phase) to the inverter's grid port. It is common for there to be a second earth cable from the switchboard earth busbar to the inverter case/chassis – this earth will usually also continue to earth bond the solar panel racking. This earth cable should be at least 4 mm^2 and be continuous; that is, if the inverter is removed for servicing, the PV racking should remain earthed;

(m) *Labelling* – All components of the solar system, switchboards, and meter box should be labelled clearly according to the requirements of AS/NZS 4777. This also specifies the inclusion of a site map at the installation indicating where all components are located.

9.5 Commissioning

The installer should allocate an appropriate amount of time and care to properly commissioning and setting up the inverter. This may be done by screen menus on the inverter or, more commonly, by a dedicated smartphone app. Some of the key functions to set up during the commissioning are as follows:

(a) *Firmware update* – The latest firmware should be installed on the inverter. It's best to leave automatic firmware updates turned off, as these can change settings and generate unexpected results over time;

(b) *Grid code standards* – The correct New Zealand grid code standards (AS/NZS 4777 series) should be applied. These relate to grid connection of energy systems via inverters – offering a wide range of operating parameters, which should not be changed (once set) and agreed to with the EDB;

(c) *Operation mode* – GTIs are often capable of several operating modes and parameters. The most appropriate mode to meet the customer's needs should be selected;

(d) *Features such as arc fault detection* – These should be enabled if required;

(e) *Alarms* – Settings should be made to direct alarm messages to the most appropriate bodies;

(f) *Export limit* – Any export limit required should be set;

(g) *Password* – The installer should set a password to prevent unauthorised changes that may cause the installation to become unsafe or non-compliant;

(h) *Meter* – Communication with the inverter (if fitted) should be set up and verified – ensure that any CT is pointing in the right direction and that reported power flows agree with measured results;

(i) *Wi-Fi or Ethernet* – The inverter should be internet connected and set up for remote monitoring; hard-wired Ethernet is the most reliable. Registration with the inverter manufacturer's web monitoring portal should also be completed;

(j) *Pairing* – For micro-inverters or optimisers, there will usually be a process for pairing the central control unit or inverter with all of the individual panel micros or optimisers. Communication is normally through the interconnecting AC or DC power cables;

(k) *User access* – An account and password will normally need to be set up to allow the end user limited access for monitoring purposes;

(l) *Testing and verification* – The PV system should be thoroughly tested and verified by the installing electrician, who should issue the CoC. It is good practice to attach all test results, SDoCs, and equipment certificates with the CoC.

9.6 Testing and verification

To ensure that product quality, efficiency, and durability ultimately lead to the longevity and performance expectations of the homeowner for their solar installation, it is important that solar equipment specialists make freely available all necessary product technical specifications and supporting documentation aligned to a specific installation.

This documentation normally takes the form of equipment datasheets. In the case of solar panels, it typically contains the following key information:

(a) *Power output* – This is measured in watts (W) under standard test conditions of 1000 W/m² solar irradiance at 25°C. Bifacial panels may list an extra BNPI rating showing additional power from the rear side. Many panels have a positive power tolerance (for example, rated at +0 to +5W);

(b) *Degradation* – Panels slowly lose efficiency over time, typically degrading by 0.3–1% per year. A long-term performance warranty ensures at least 90% of original output after 25 years;

(c) Voltage and current ratings:

(i) Open circuit voltage (Voc) – Maximum voltage when no load is connected. Increases in colder temperatures, which must be factored into system design

(ii) Maximum power voltage (Vmp) – Voltage when the panel is producing optimal power (always lower than Voc)

(iii) Short circuit current (Isc) – Maximum current when the panel's output is shorted. Increases with higher temperatures

(iv) Maximum power current (Imp) – Current when the panel is producing optimal power (always lower than Isc)

(d) *Maximum static load* – Panels are rated for wind and snow loads: for example, a front load (for example, in the case of snow) of 5400 Pa and rear load (for example, in the case of wind uplift) of 2400 Pa.

Considering the above factors will help you, in consultation with your preferred solar installation professional, to choose the right solar panels that balance efficiency, durability, aesthetics, and cost – tailored to your specific needs.

9.7 Inspection

No GTI should be permanently energised until after the system has passed its electrical inspection and the electricity retailer's import/export meter has been installed. The electrical inspector should issue a record of inspection and register the system on WorkSafe's high-risk database.

Note – In some instances, installations can be energised without an export meter if the network allows it. Clause 15.13 in the Electricity Industry Participation Code allows this for market settlement purposes.

9.8 Customer training and handover

When the solar PV system is up and running, training regarding the use, operation, and maintenance should be given to the end user. This should cover any remote monitoring that takes place. All manuals, documentation, and certifications should be handed over at this stage, along with clear contact instructions and procedures for technical support and service.

9.9 Guidance on use, operation, and maintenance

Grid-tied PV systems are generally very reliable when good quality equipment and installation practices are used. They generally don't require any input from the user and are relatively maintenance-free.

Most modern PV systems will be internet connected and will be capable of generating alarms or alerts if anything goes wrong. It is very important during the set-up and commissioning that all alarm and alert settings are directed to the system owner and/or installer, so that they can be addressed in a timely and efficient manner. A solar PV system has a very long-life span: there may be changes in home ownership and the existence or structure of support organisations during that time.

From a customer perspective, good system monitoring allows visibility of system operation and performance over time. Any major change in performance or faults reported should be notified to the solar company or installer. Electricity bills can show up system faults (for example, in the form of a sudden change in energy usage or export). However, allowance should be made for seasonal and weather variations.

Through remote monitoring of PV systems, solar companies and manufacturers can often diagnose issues remotely, reducing the number of site visits required. In some cases, issues can be resolved with remote firmware updates or changes to settings.

Where an inverter failure does occur that is covered by warranty, most quality manufacturers will efficiently and proactively express-ship a replacement unit to the installer. In some cases, the inverter manufacturer may even pay the installer a fixed labour charge to offset some of its labour costs. The installer may need to have done manufacturer training and be a registered authorised installer to be considered for compensation.

An annual inspection can be undertaken by an installer, if this is paid for or included in the sales agreement. Correct operation of the inverter and solar production should be verified. In addition, the grid islanding feature should be tested. Any labels that have deteriorated or fallen off should be replaced. The internet connection and remote monitoring should be verified – it is common for homeowners to change their wireless internet router and forget to update the inverter Wi-Fi settings.

10. Grid-tied systems with batteries and islanding capability

10.1 General

GTIs are also available as a hybrid model which allows the connection of a storage battery to the inverter. In this case, excess solar energy which would normally be exported to the grid is instead stored in the solar battery. This stored energy may be used to increase self-consumption, or to supply energy in case of a grid outage. It should be noted that not all hybrid inverters can provide backup power during a grid outage; this section is focused on hybrid inverters that do have backup capability.

It should also be noted that there are AC-coupled batteries available on the market that contain their own additional battery inverter. AC-coupled batteries do not require a hybrid inverter and can be added to most standard GTIs manufactured since 2015. There are advantages and disadvantages with AC-coupled batteries; these are discussed in more detail in section 12, titled ‘Batteries’.

The terms ‘battery-ready’ and ‘battery-capable’ can be very misleading terms; in many cases, they are misapplied to describe standard GTIs. Where an AC-coupled battery system could be added later, this does not imply that all standard inverters have some additional battery capability or functionality. Solar equipment providers and their customers must know whether the inverter offered is a standard GTI, or a higher-spec hybrid model capable of being directly connected to a DC battery.

There are several reasons why a hybrid inverter may be chosen. The main reasons are as follows:

(a) *It allows for future upgrading of a solar system through the addition of batteries* – Some hybrid inverter models allow the required hybrid features for adding batteries to be unlocked later, using software and subject to an additional fee being paid. If this is the case, it should be clearly explained, and the additional costs indicated at the time of purchase;

(b) *A hybrid inverter with batteries connected usually allows for the self-consumption of a higher percentage of solar energy before export to the grid* – When there is excess solar production, the additional energy is stored in batteries and can be used when solar production is not adequate to meet the home’s electrical loads;

(c) *In the event of a grid outage, many hybrid inverters are capable of supplying power to house loads* – The system may be capable of proving power to all loads or, more commonly, to select loads; these are often referred to as essential, backup, or critical loads. Most hybrid inverters can be set to maintain a minimum battery reserve capacity so that there is always some energy reserved in case of a grid outage. For most hybrid inverters, solar PV production and energy from batteries will be available during a grid outage;

(d) *Hybrid inverters often have the capability to be charged from the grid* – This feature may be used to import and store grid energy at a lower off-peak tariff and used at times when there is a higher tariff, thus saving money. Some hybrid inverters have predictive features allowing them to store extra energy from the grid to prepare for severe weather warnings and possible grid outages;

(e) *Some homes in New Zealand have a very weak or limited grid supply* – These homes will typically have a small main fuse, limiting the maximum power they can draw from the grid. Many hybrid inverter systems can top up or increase the amount of power available from the grid, by using PV power and battery-stored energy. In some cases, this feature can assist customers who face extra charges for exceeding their limit in using power from the grid. This feature is called peak shaving.

10.2 Islanding

10.2.1General

This section outlines the requirements and best practices for the integration of solar PV systems and battery energy storage systems (BESSs) in islanding scenarios in New Zealand. It provides guidance on both unintentional islanding (to ensure grid safety and stability) and intentional islanding (to enhance resilience and microgrid capabilities). These provisions align with relevant international and joint standards, including AS/NZS 4777.2:2020, and reflect New Zealand’s specific network conditions.

10.2.2 Unintentional islanding protection

Unintentional islanding occurs when a PV system with or without battery storage continues to supply power to a disconnected section of the grid. This can pose risks to network personnel, public safety, and system stability.

To mitigate these risks, all network and grid-connected electricity generation installations must include anti-islanding protection mechanisms. For PV and BESS installations these shall comply with AS/NZS 4777.2:2020. Requirements include:

(a) *Passive anti-islanding measures* – There must be continuous monitoring of voltage and frequency to detect loss of grid connection;

(b) *Active anti-islanding measures* – Inverters must introduce controlled disturbances and cease operation, if an unintentional islanding condition is detected;

(c) *Communications-based methods (for larger installations)* – Systems may be required to interface with network protection schemes, providing coordinated disconnection when necessary.

For installations exceeding 30 kW of inverter capacity, additional grid protection systems are required in accordance with industry standards, ensuring safe operation and disconnection during grid outages or faults.

10.2.3 Intentional islanding and microgrid applications

'Intentional islanding' refers to disconnection of an installation from the network: it refers to a situation where a generation system either starts or continues to supply electricity within the installation itself.

Disconnection of the installation from the network could be due to a pre-planned event, a power quality event, or a loss-of-electricity-supply event. This approach is particularly relevant for resilience-focused applications, including remote communities, critical infrastructure, hospitals, and emergency response scenarios. PV and BESS systems can (if correctly configured) supply electricity to part of a residential installation when network electricity supply is lost, allowing some operation of essential circuits during outage and disaster events.

Key design and operational requirements for intentional islanding include the following:

(a) *System control and synchronisation* – Advanced inverters and control systems must manage seamless transitions between grid-connected and islanded modes, ensuring stable operation;

(b) *Battery storage and load balancing* – Adequate energy storage capacity is required to maintain power supply, particularly in the absence of solar generation;

(c) *Black start capability* – Systems must include provisions for independently restoring power after an outage;

(d) *Safe reconnection to the grid* – Islanded systems must only reconnect when synchronisation with the main grid is achieved, ensuring frequency and voltage alignment.

New Zealand's distribution networks and regulatory framework already support islanding of installations, but further regulatory development is required for microgrid deployment. International best practices, such as those demonstrated in Australian microgrid projects, should inform standardisation efforts, regulatory updates, and investment in grid-forming inverters and smart control systems.

10.2.4 Advanced grid-forming battery solutions

As distributed energy resources (DERs) expand, grid-forming BESSs will play a crucial role in enhancing both grid stability and microgrid operation. These systems can:

(a) Provide synthetic inertia and frequency control to stabilise the grid;

(b) Enable islanded operation of distribution feeders during outages;

(c) Support peak demand reduction and network resilience.

10.2.5 Hybrid solar systems with batteries

Careful design is required for hybrid solar systems with batteries. Some of the main considerations are:

(a) *PV sizing* – PV arrays on hybrid systems will generally be larger to ensure that excess solar energy is available for charging batteries, especially in winter;

(b) *Inverter sizing* – Depending on whether the home requires full load backup or partial backup, the inverter AC power rating needs to be carefully considered. The inverter power also needs to meet the EDB's requirements for grid connect. If an inverter is used that is too small for the backup loads, it will overload and trip out when power is most required;

(c) *Battery sizing* – The capacity of the battery needs to be large enough to store a substantial amount of excess solar PV energy and meet the home's energy needs for an agreed time. Hybrid inverters will also require a minimum size battery to allow them to deliver the full backup power required. Any system is only as good as its weakest link;

(d) *Multi-phase hybrid GTIs* – These are generally available in single and three-phase models. For two-phase grid connections, custom systems can be built using separate components. With multi-phase systems, it can be important to have common battery banks and PV arrays, so that each phase can draw the energy it needs. If a multi-phase system is built up using multiple single-phase systems, limitations may occur where a particular phase has excess PV energy or storage, and another phase has no availability. It is common to see hybrid systems installed on only one phase of a multi-phase supply; there are advantages and disadvantages to this approach;

(e) *Essential loads* – Clear decisions regarding which loads, or AC circuits will have backup power are required, unless the entire home has backup power (often an expensive option). At the switchboard, the essential load circuits need to be kept physically separate from the main loads and carefully marked as such. Typically, the following loads will be classed as essential during a grid outage:

(i) Fridge or freezer circuits

(ii) Lighting

(iii) Water pump or septic tank pumps

(iv) Gas pilot lights

(v) Internet routers

(vi) Some essential power outlets

(vii) Security systems

(viii) Garage door openers;

(f) *Heavy electrical loads* – Hot water elements, stovetops or ovens, EV chargers, spas or swimming pools, electrical resistive heaters, and so on are normally considered for partial home backup. They should be left connected on the grid side of the inverter. In this way they will benefit from solar PV production and battery storage, except during a grid outage. Otherwise, these types of loads may overload, or trip a hybrid inverter during a grid outage, leaving the home without any power.

10.2.6 System architecture

There are several potential arrangements for hybrid grid-tied solar systems. Some hybrid inverters will have a high-voltage battery connected on the PV side of the inverter. More commonly, most hybrid GTIs have additional terminals for the connection of DC batteries and an additional AC backup port. Figure 19 shows the most common arrangements.

Source image pending

Figure 19 – Grid-tied system architecture

Depending on the model of hybrid inverter used, the power flows may be different. Some models will allow the PV power to be much greater than the inverter AC rating. For example, on a 5 kW AC rated inverter, there could be 10 kW of PV power, with 5 kW going to charge the DC battery and the other 5 kW going towards the AC loads or grid.

Source image pending

Figure 20 – Typical battery set-up

10.2.7 Installation considerations

Installation of a hybrid GTI with batteries and backup power is a more complex undertaking, and there are many additional installation considerations. For example:

(a) On homes where partial backup is being implemented, the installing electrician will carry out additional switchboard work to physically separate the backup load wiring, RCDs, and MCBs. In some cases, this may mean the addition of a new additional switchboard;

(b) There will be a second AC cable run from the switchboard to the hybrid inverter's backup port; this is to be appropriately sized and properly fused with isolation;

(c) It is essential that the backup AC circuit neutral conductor be hard-wired back to the switchboard main neutral busbar. During a grid outage, a hybrid GTI will open its AC port protection relays on all live and neutral conductors. A hard-wired neutral link is essential for the backup loads to ensure that the neutral always benefits from the protection of the main MEN link;

(d) Hybrid inverters may have internal switching to supply power to essential loads, or some models may require contractors to install additional wiring, and additional switchboard space should be allowed for;

(e) Should a hybrid inverter or the external contactors fail, the essential loads would have no power at any time. For this reason, it is a good idea to install a three-position transfer or bypass switch. The three positions are normally labelled 'solar', 'off', and 'grid'. This allows the hybrid inverter to be bypassed until it is repaired, and essential loads continue to have power from the grid;

(f) Some hybrid inverter systems will require an additional backup box, usually made by the same manufacturer to match the hybrid inverter. This additional box will usually form a type of load centre and contain control electronics and contactors for power switching or grid isolation;

(g) Some hybrid inverters will also allow for an additional generator connection and may also generate an autostart signal to the generator under certain circumstances. In the event of a grid outage, the generator will add to the electrical energy available from PV panels and battery storage, and can be used to recharge the batteries;

(h) Hybrid GTIs will always require their own meter, to see what energy is exported or imported at the main switch. This information can help determine whether to charge or discharge the battery and, depending on inverter settings, whether to import or export power;

(i) Multi-phase installations require extra care and attention – particularly regarding balancing of loads across phases. The architecture, the power limitations of each phase, and the type of revenue metering used in New Zealand should all be considered for these more complex installations;

(j) There are additional labelling requirements for these types of systems. Users and electrical workers should understand that some circuits will remain live – even during a grid outage or when the main switch is turned off.

10.2.8 Guidance on use, operation, and maintenance

Once correctly set up and configured, hybrid inverters should require no additional input from the homeowner. The householder's key responsibility is to ensure that backup loads never exceed the capability of the system: to do so would overload and trip the inverter or its AC circuit breaker.

11. Off-grid systems

11.1 General

An off-grid solar PV system is capable of supplying a home's electrical needs without any connection to an electricity network.

There may be many reasons why a homeowner may choose to go off grid. The usual motivating factors are lack of network availability in remote areas; the high cost of network connection, or high lines charges; and lifestyle choices.

Homeowners who choose to go off-grid take on a much higher level of responsibility. That is because the homeowner effectively becomes their own power company, carrying all responsibility for equipment and maintenance. In this situation, a good working relationship with an experienced and reliable off-grid installer becomes essential. Just as important is choosing very reliable, well-supported, and reputable off-grid equipment.

When a home is grid-tied, the homeowner can become accustomed to being connected to an almost infinite pipeline of energy. This can affect power usage habits and allows the use of energy-hungry appliances. Off-grid solar PV systems produce and store finite amounts of electrical energy: this requires a different mind-set and approach.

The first thing to consider before going off-grid is whether the power needs to be produced in the first place. To answer this question, a thorough analysis of the required loads and their efficiencies is a good starting point. Choosing energy-efficient appliances and lighting and shifting heavy loads to other forms of energy is also good practice.

11.2 System design

When it comes to off-grid system design, AS/NZS 4509.2 – Stand-alone power systems, Part 2: System design should be followed.

A detailed load sheet is needed to understand the requirements for any off-grid solar PV system. A load sheet lists all electrical loads and identifies the wattage for each and the run time. A diversity factor will need to be included, to allow for the fact that not all loads will be on at the same time.

From this exercise, it should be possible to establish the following key design targets:

(a) *Daily kWh consumption* – The PV array will need to be sized so that it is capable of producing at least this amount of energy on a typical mid-winter's day;
(b) *Peak demand* – The maximum power that the home will draw at any given time, when all loads and the diversity factor are allowed for, will determine the inverter's continuous power rating;
(c) *Days of autonomy* – The daily consumption multiplied by the number of days of autonomy will indicate the usable battery capacity required;
(d) *Generator sizing* – Most off-grid solar PV systems will require a backup generator for bad weather periods: in particular, in the event of system failure.

Running unsuitable electrical loads in an off-grid system that is not designed for them will result in a lot of generator run time, with high fuel consumption.

Other energy sources are commonly included in off-grid solar PV systems:

(e) *Wind energy* – This is a variable source of energy and difficult to predict accurately. There is a high level of maintenance required, and many wind generators fall into disrepair, as this essential maintenance is often neglected. Wind generators require a lot of extra protection and management circuitry, so that they are regulated and controlled in all wind conditions – this can add significant system cost. Additionally, solar panels have now reduced so much in price that wind generation is no longer cost-effective at a domestic level. There are many cheap wind turbines on the market, along with gimmicks such as vertical-axis wind turbines–. Most of these generally fail relatively quickly. Wind energy is a very specialised area of expertise, and only specialised companies with a long and successful track record of implementing reliable systems in New Zealand should be considered;
(f) *Micro-hydro* – This is a predictable and steady source of energy generation, as long as there is a suitable water resource with adequate flow and head. Good micro-hydro sites are rare; substantial effort is required to implement all of the civil engineering required. There are many successful micro-hydro sites in New Zealand; some have been producing energy 24/7 for more than 10 years. The constant energy production from micro-hydro can reduce the design requirements for battery storage, and a good site can open up the possibility of living a more energy-abundant lifestyle, with the possible inclusion of EV

chargers, under-floor heating, spa or swimming pools, and so on. Excess energy from micro-hydro needs to be dumped or diverted – hot water is a common way to use it.

Wind and micro-hydro energy sources are beyond the scope of this document and may also require additional consents. Any design incorporating these elements will need to be undertaken by a specialist in these fields.

11.3 System architecture

Off-grid solar PV systems (Figure 21) tend to use a more modular approach, typically being built up from a number of separate key components. It is vital that all the individual components work together, and match well, so that they form one cohesive system. Mixing and matching components from different brands can be problematic; they often will not communicate with each other. Choosing good quality off-grid brands, with long-standing and well tried and tested reputations within this niche industry is one of the keys to success.

The key components in an off-grid solar PV system are as follows:

(a) *Solar panels* – An off-grid solar PV system needs to produce all or most of a home's electricity needs, so it will require a larger PV array than a grid-tied PV system. If an off-grid home is being designed by an architect from scratch, then a large north-facing roof can be included to allow for the installation of a large solar PV array. If there is not enough suitable roof space for the installation of solar panels, ground mount arrays are commonly used. The solar panel array will need to be sized so that it can produce and store enough energy for all of the home's electrical loads on a typical mid-winter's day;

(b) *Charge controller* – The DC voltage from solar panels is not suitable for directly charging a battery bank, so it needs to be regulated by a solar charge controller so that the voltage presented to the battery bank is suitable and safe. An older type of charge controller using pulse width modulation is rarely used nowadays, as up to 30% of the PV energy is wasted. Today, a newer type – using maximum power point tracking – is most commonly used. Depending on the size and arrangement of the PV array, more than one charge controller may be required – this also gives some redundancy;

(c) *Batteries* – Off-grid solar PV systems must store solar energy produced during sunshine hours for use at night and during cloudy periods. A large battery bank capable of storing three days of autonomy is normally required. The battery bank is the single, most expensive part of an off-grid solar PV system and has a finite lifespan – so owners must always budget and allow for its eventual replacement. The most effective way to save money on the long-term cost of a battery-bank is to choose a high-quality, well-proven, and suitable brand. The battery bank must also be capable of delivering the high, continuous current required by the inverter;

Inverter – Conversion of the DC voltage from the battery bank to AC voltage (as required by the home's electrical load demand) is performed by an inverter. The inverter must be capable of delivering the peak load required by the home continuously, every day, for many years. This requires a very heavy duty and robust inverter design, which is also capable of handling high peak loads. All off-grid inverters must have galvanic isolation between the ELV batteries and 230 V AC output. Many off-grid inverters can also run in reverse, as a charger. These models are referred to as inverter/chargers. An AC generator can be connected to the inverter/charger, facilitating battery charging, where required;

There are two basic off-grid inverter topologies:

(i) *Low frequency with transformer* – These topologies are the classic tried and tested powerhouses behind most quality off-grid systems. This design has been long proven as a rugged and reliable solution for off-grid, and it has galvanic isolation by design, though the use of a heavy-duty built-in output transformer

(ii) *High frequency transformer-less* – Some manufactures are now introducing this lighter-duty topology into the off-grid market. The design is yet to be proven long term, and results to date from various manufacturers have been variable – some brands show promise, but some have failed very quickly or failed under heavier loads. It's very important to note than many inverters of this type do not have the required galvanic isolation and are, therefore, not compliant with regulations, or safe. All manufacturers' official documentation should state that the inverter has the required isolation – without this, you must assume it does not

(d) *Generator* – Off-grid solar PV systems should always have a backup generator, allowing the home to have AC power during extended periods of low sunshine. The generator should be configured so that it can supplement AC power through the inverter (using features such as power assist) and also charge the batteries. A transfer or bypass switch should be fitted in case of inverter failure – this allows the generator to directly power AC loads. It's common for off-grid generators to have a two-wire-autostart module fitted. This can allow the system to automatically turn on the generator when the batteries are low, or when AC loads are high;

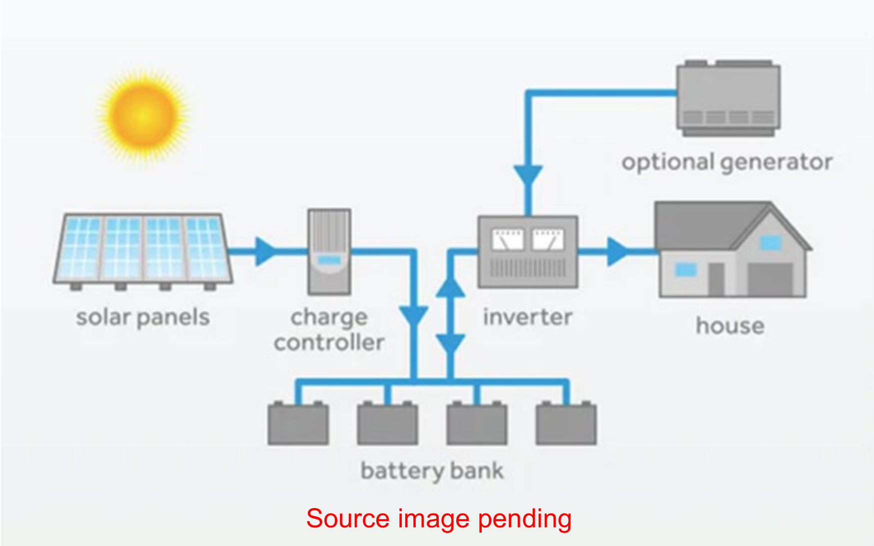


Figure 21 – Off-grid solar PV system architecture

(e) *Balance of system (BOS)* – A number of other key components are required to successfully implement a reliable, safe, off-grid solar PV system. The main BOS components are:

(i) *Busbar* – A positive and negative busbar is usually required to facilitate the interconnection of all components that are at battery voltage. The current flow through a busbar can be significant, and it must be appropriately rated

(ii) *Fusing and isolation* – All DC and AC components must have suitable fusing and isolation at all key points. This is required to provide overload and short circuit protection for all cables, busbars, and connected equipment

(iii) *Battery monitor* – This may be a separate item with an associated shunt where lead batteries are used; it allows the user to see the battery state of charge (SoC) and other parameters. In the case of Controller area network (CAN) bus-managed lithium batteries, this function will normally be integrated into the system, and the master battery will communicate the SoC (and other information) directly to the PCE

(iv) *System management* – Newer off-grid systems will normally have a dedicated management module. This can function like a brain for the system, communicating with all separate parts and coordinating all of the main functions. It will also usually also function as a user interface, allowing the homeowner to see the current state of operation and to control functions such as generator autostart

(v) *Remote monitoring* – Off-grid systems increasingly have facilities for remote monitoring. This allows installers to see detailed system and performance information remotely. In many cases, firmware updates and changes to settings can be made by installers, thus avoiding expensive call-out charges. Users can also have access at a different level for system monitoring without the ability to make major changes.

11.4 Installation considerations

When it comes to off-grid system installation, AS/NZS 4509.1 – Stand-alone power systems, Part 1: Safety and installation should be followed.

Off-grid solar PV systems have a higher level of complexity than grid-tied PV systems and require a higher level of skill and experience to implement well. An installer should be chosen who specialises in this area and is capable and willing to support the system over its lifetime. Off-grid systems are often installed in remote regions, and travel distances can be significant and costly. It is imperative to adopt best-quality equipment and installation practices.

The key aspects to consider when installing an off-grid solar PV system are as follows:

(a) *Location* – The off-grid PCE (Figure 22) and batteries will need an appropriate physical location that is protected from the weather, dry, spacious, and accessible, and that meets all relevant standards. There will need to be some physical separation between the batteries and the PCE to avoid any risk of fire or explosion. Ventilation and temperature management are very important for safety and reliability. A dedicated plant room or allocated space in a garage are commonly used. If there is no suitable non-habitable space available within a dwelling, a nearby shed is another suitable option. Off-grid systems should never be installed underneath a house in an area that is open to the environment. Flooding is another factor that should be considered;

(b) *Equipment cabinets* – Dedicated system cabinets are a popular option for off-grid solar PV systems, offering separate compartments for batteries and PCE. These allow for very neat and serviceable layouts and a high level of safety and compliance with standards. Lockable doors add to the security and safety of the equipment, and features such as weather protection, fan ventilation, insect screens, document pouches, lifting hooks, and plinths raised above flood level raise the standard of the installation to a much higher level. Analysis of PCE returned for repair shows that the leading cause of equipment failure is an environmental issue. Issues caused by moisture ingress and salt-mist corrosion are common. These can also generate significant safety risks. Insects regularly crawl inside equipment and will usually cause an electrical short circuit. Rats and mice are drawn to nest above warm PCE, and their discharges into the PCE comprise a regular cause of burnt-out circuit boards. These issues can be avoided by installing all equipment in a dedicated cabinet or shed in a weather-proof location with suitable insect and vermin proofing. The future reliability of the system is usually determined on day one – through proper equipment choices, good installation practices, and attention to detail;

(c) *Cable length* **–** All cable runs should be kept as short as possible, to minimise losses, and need to be trenched within HD conduit where required;

(d) *Cable sizing* – All DC cables should be double insulated and of a suitable type and size. DC currents can become significant in an off-grid system. All crimped connections should be checked – hold the crimp lug in a vice and lightly pull the cable to ensure that it does not slide out from the crimp;

(e) *Switchboard* – Off-grid systems will normally be wired to have the AC output of the inverter feed into a main switchboard. A suitable MCB is normally used as the main switch. The inverter does not have to be capable of tripping this main switch MCB, as the inverter will have a limited power output;

(f) *Earthing* – The main switchboard should be connected to a suitable earth rod, and have an MEN link fitted by the installing electrician. Many inverters will also have an inbuilt ground relay, which can serve a similar purpose for mobile applications. The inverter ground relay should always be turned off or disabled when an external MEN link is fitted in the main switchboard. Failure to do this is a very common mistake and leads to neutral currents flowing in the inverter earth cable, which is never permitted under New Zealand regulations;

(g) *Enclosures* – All PCE and metal battery cases/cabinets should be earth bonded back to the main earth busbar;

(h) *Electrical terminals* – All terminals should be covered, so that there is no risk of short risk of short circuits being caused by metallic objects or tools. There should be no touch risk or shock risk to users or installers on any part of the system;

(i) *Diversion loads* – These are commonly installed in off-grid systems. Typically, a second AC output on the inverter will be switched on when the batteries are above a preset SoC, and the other AC loads are below a preset level. This methodology is often used to control a hot water element;

(j) *Generator wiring* – This needs to be undertaken with care. For generators with a plug connection, the inverter must never be capable of sending AC power back along this power line – otherwise the plug terminals could be live and present a serious shock risk. On inverter systems where this risk exists, only fixed wiring should be used. There should be an AC isolation point fitted at the generator; this should also isolate any autostart signals from the off-grid solar PV system;

(k) *Generator bypass switch* – This switch should always be installed. It is also sometimes referred to as a transfer or changeover switch. This switch must be a break-before-make type and should not switch the neutral.

Figure 22 – Typical PCE arrangement

10.5 Guidance on use, operation, and maintenance

Off-grid solar PV systems require a higher level of user awareness and responsibility than any other type of PV system. Regular checks and maintenance are required to ensure that the system is always in good working condition. The typical monitoring and servicing tasks are as follows:

(a) *SoC* – Checking the battery SoC monitor will give a good indication of how much energy is available at any given time; users will typically make decisions on energy usage based on this reading;
(b) *Monitoring* – Online remote monitoring is very important for off-grid solar PV systems; it allows installers to view detailed system information easily and without an expensive site visit. The monitoring will also allow system history to be collected, so that long-term trends can be viewed;
(c) *Battery capacity* – Capacity will always fade over time; regular monitoring can record this capacity loss. It's important to pay careful attention to this aspect, so that expensive battery replacement can be planned for in advance;
(d) *PCE cleanliness* – All PCE should be kept clean and clear of any build-up of dust and other materials. This maintenance should be done in a safe manner, without exposure to any shock risk. Any filters should be regularly cleaned;
(e) *Cable condition* – All cables should be regularly checked to ensure that they are not damaged or frayed. Cables can be damaged by rodents chewing on them, or UV breakdown of insulation through the use of unsuitable cable types.

Many homeowners will add new electrical loads to an off-grid system over time, without consulting the installer or having due regard to the original system specifications and limits. During any planned maintenance by the installer, the system should always be reviewed to establish that it is still fit for purpose with regard to the present electrical loads.

12. Batteries

12.1 General

Batteries are a very common addition to grid-tied PV systems and can greatly enhance overall system performance and functionality. The additional cost of solar batteries can be significant, in many cases doubling the overall cost of the system. However, the advantages that batteries offer are significant. In addition to enabling solar PV systems to power homes during low sun periods and at night, they significantly increase the financial savings made over the lifespan of a solar system.

Batteries store and supply energy in the form of DC electricity. As a home's electrical loads use AC electricity, an inverter is required to convert from DC to AC and vice versa. However, some batteries, known as AC-coupled batteries, will have an additional battery inverter that is either built-in or external. Each system has its advantages. Figure 23 shows typical system configurations.

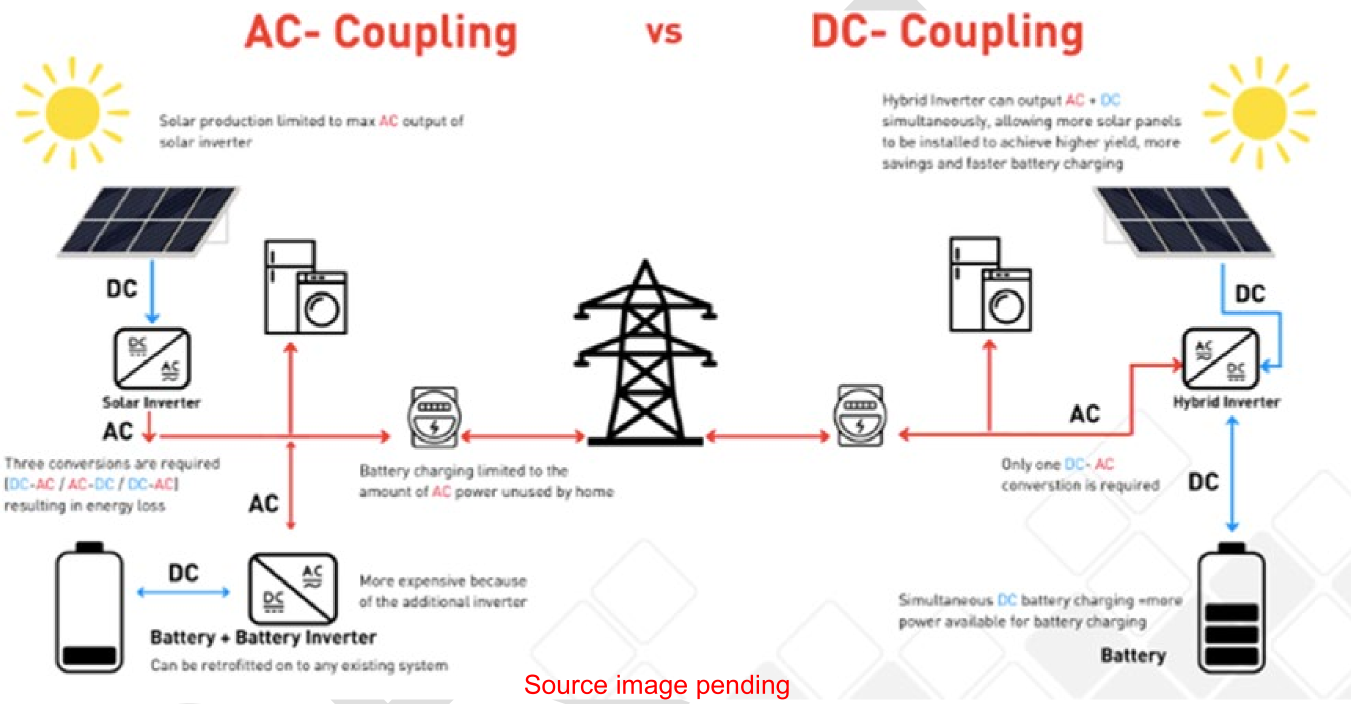


Figure 23 – Typical AC and DC system configurations

12.2 Types

A battery is a device that stores chemical energy and converts it to electrical energy. There are many different battery chemistries used, and there are variations with each chemistry type. The most common battery chemistries used for solar PV energy storage are lead-based batteries. These are commonly used for off-grid systems, more than grid-tied systems. They are usually made up of cells connected in series, each cell typically having a nominal voltage of 2.4 V.

12.3 Lead batteries

Lead batteries have been around for more than 160 years. They get their name from the lead plates that are used as electrodes within them. They are immersed in an electrolyte – typically sulphuric acid – thus forming a chemical reaction. Lead acid batteries were the first batteries that could be recharged and therefore used to store electrical energy. Lead-based batteries are relatively bulky and heavy, as they have a relatively low energy density, and very deep discharges will shorten their useful lifespan. These batteries are typically not discharged below 50%, so that they maintain' a reasonable life-span. This means that larger battery banks are required to increase usable storage capacity.

The efficiency of lead-based batteries is generally considered relatively low (typically 80–85%). Cold temperatures will reduce their performance, but they are still capable of charging and discharging at relatively cool temperatures. Lead batteries are relatively low tech, and they are considered rugged and easy to maintain or install. They will generally require good ventilation, and must not be installed in habitable spaces, as the gas that can be released during their operation can be explosive. As lead batteries age, they can suffer from sulphation of their plates – a chemical process that reduces the battery performance and is difficult to reverse.

Only deep-cycle lead batteries are suitable in solar PV installations; automotive or light-duty types should not be used.

The main types of deep-cycle lead batteries used for solar energy storage are:

(a) *Flooded cells* – These can vent to the atmosphere and require regular topping up with distilled water. They must be kept upright, as the acid can spill out;
(b) *Absorbed glass mat* – These are a lower-cost sealed maintenance-free lead battery type with a limited lifespan;
(c) *Gel batteries* – These are a higher-quality sealed maintenance-free lead-based battery where silica is added to the electrolyte to give it a gel consistency;
(d) *Carbon lead* – In this case, an improvement is made to gel batteries by adding carbon to the lead plates that form the negative electrode. This slows down the sulphation process and thus extends the battery's lifespan.

It is important to note that even sealed lead batteries can vent gases when overcharged, so adequate ventilation needs to be considered for all lead battery types.

12.4 Lithium batteries

Another common battery chemistry is lithium batteries. These are almost always used for domestic grid-tied systems with backup; they are increasingly being used for off-grid installations.

The energy density of lithium batteries is relatively high, so they take up a lot less space. Their efficiencies are also excellent (typically 90–96%), meaning that less energy is lost in storage.

A longer lifespan is one of the major advantages of lithium batteries. It is not uncommon for a reputable brand to have an expected lifespan in excess of 15 years, or 8000 cycles. Depth of discharge is another major advantage. A typically good-quality lithium battery can be discharged to 95% depth of discharge (DoD) without suffering the sulphation damage that lead batteries can experience.

Note – Losses associated with charging/discharging are also referred to as churn losses.

Lithium batteries are normally made up of a number of individual cells which are wired in series to increase the overall battery voltage and may have several strings wired in parallel to increase capacity and charge/discharge current. Lithium batteries will normally include a battery management system, which will control functions such as battery charging/discharging rates, cell balancing, error reporting, and shut-down. Low temperature operation is a limitation: while lithium batteries can discharge to a small extent at low temperatures, their ability to accept charge can be limited from temperatures of around 10°C, and they may stop accepting charge completely at around 5°C.

Placing the batteries in an area that is temperature protected can mitigate these temperature effects. Some lithium batteries have built-in heating systems, which can extend their temperature operating range; however, these additional systems also consume some energy. Lithium batteries must be protected against excessively high temperatures – usually with fan ventilation. There are many types of lithium battery chemistry. The two most commonly used types for solar storage batteries are:

(a) *Nickel manganese cobalt (NMC) lithium batteries* – These are a compact type of battery with a high-energy density. However, they are not as thermally stable as lithium iron phosphate (LFP) batteries (see below) and require careful battery management. NMC batteries do not like being charged up to 100%, so manufacturers will often not use the full capacity of the battery cells;

(b) *LFP batteries* – These have gained favour as one of the most popular battery types for solar storage. While they do not have as high an energy density as NMC batteries, resulting in slightly bulkier batteries, the better thermal stability makes LFP batteries a safer choice for home installation.

Note – AS/NZS 5139 does include other chemistries; however, they are not in common usage.

12.5 New battery technologies

There are many old and new battery chemistries currently under development. It can take a long time for new battery chemistries to reach the market in a cost-effective, reliable manner, and in a form factor that is usable, made with commonly available raw materials.

Consumers and installers alike should be aware of companies marketing 'wonder batteries', making claims that defy the laws of physics, such as lifespans in excess of current battery technologies or efficiencies of 100% or greater. Independent analysis performed on the internal of the battery may reveal that cheap, low-quality lithium cells have been used, or that these are held together using low-quality materials such as a hot glue, with little in the way of battery safety or protection.

12.6 Design

The choice of a BESS at the design stage is crucial, to ensure that the complete system will meet its design objectives. Some key considerations are as follows:

(a) *Quality* – This is the single largest indicator as to whether a BESS will prove to be reliable, usable, safe, and long lasting. A BESS should be sourced from a reputable specialist solar supplier who can guarantee compatibility with the PCE. Where equipment is purchased from multiple vendors, the installer and homeowner may end up caught in the middle of multiple issues resulting from incompatible and failed systems. Buying cheap, low-quality batteries without warranty, or with limited support from the seller, may end up costing a householder more in the long run than a system with an initial higher price;

(b) *Voltage* – Voltages of BESS can vary widely. A nominal voltage of 48 V is the most common used for lead and lithium BESSs in residential installations. Other voltages, such as 12, 24, 36, 60, and 120, are sometimes required by some brands of PCE, although this is unusual. Voltages lower than 24 V should generally be avoided in residential installations, as the current can become very high. Many newer systems use higher-voltage batteries of between 150 and 600 V. These are potentially lethal and need much greater care during installation by a licensed electrician;

(c) *Capacity* – The storage capacity of a battery is usually measured in kWh and can be expressed in ampere (amp) hours (Ah). To convert from one to the other, multiply Ah by the nominal battery voltage and divide by 1000 to get the kWh storage. The capacity of a battery can vary, depending on how fast a battery is discharged, especially for lead batteries, whose capacities are often followed by a number such as C5, C10, C100, or C120. The ‘C’ refers to capacity, and the number is the hours over which the battery is discharged;

(d) *Usable capacity* – The useable capacity of a battery is normally less that its storage capacity, because any battery should only be discharged to a minimum DoD. A battery with a total storage capacity of 10 kWh and an allowable DoD of 95% will give a usable capacity of 9.5 kWh. When designing a complete system, the usable capacity should be used when determining the required storage. When sizing a BESS for grid tie with backup, adequate capacity should be ensured, not only to capture excess solar energy but also to ensure continuous operation of the system during a grid outage, and to meet load requirements. For off-grid solar systems, the recognised minimum storage is provision for three days of autonomy. The battery capacity chosen can be determined by the continuous charge and discharge ratings of the BESS – it should be capable of accepting the full power supplied by the connected PCE and supporting the PCE under full load. Under sizing BESS at the design stage will usually result in the system underperforming or even failing. It should also be noted that battery capacity diminishes over time; this should be allowed for in the design;

(e) *Compatibility* – It is essential to choose a BESS that has been tested for compatibility and approved by the PCE manufacturer. There are many parameters to consider, including battery chemistry, voltage, charge/discharge current, battery capacity, and communications. Some PCE manufacturers will have compatibility with a wide range of batteries, and others with only a single model of battery;

(f) *Battery communications* – Many battery parameters, such as voltage, temperature, SoC, health, alarms, and cell imbalances, should be communicated to the PCE. On lead-based battery systems, some of these functions can be accomplished using temperature sensors placed on the battery casings, and a shunt (small high-power resistor) normally placed close to the negative battery terminal. This allows the PCE to adjust charging parameters based on battery temperature and battery SoC On lithium BESSs there will be an established communication protocol, such as CAN bus, used for direct communications between the battery and the PCE. Extensive manufacturer testing is caried out to ensure safe and reliable operation between the battery and PCE, and communications testing is a major part of this;

Some lithium batteries do not have communication ports and are designed as lead battery replacements. These batteries need to have a shunt installed on the PCE side. This lack of communications can produce variable results; it means that there is no ability for the PCE to receive any alarms or messages from the battery and respond accordingly. In addition, the charge/discharge voltage curve for a lithium battery is very different to that of a lead battery, so it can be difficult for the PCE to accurately establish the true battery SoC based on shunt readings alone.

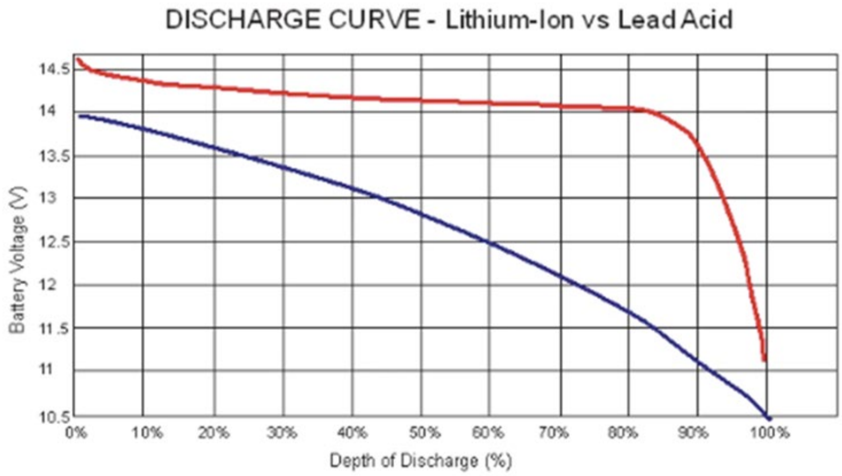


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Figure 24 – Typical battery lifespan-cycling for each chemistry

12.7 Charging protocols

For lead-based batteries, three-stage charging is normally used to prolong battery life. The key stages of charging are as follows (Figure 24 below also illustrates these):

(a) *Bulk charge* – This allows all available current to charge the battery until a pre-set voltage is reached – at this stage the battery will typically be about 85% charged;

(b) *Absorption charge* – This is the next stage, where the voltage is held steady, and the charging current is gradually reduced until the battery is almost fully charged;

(c) *Float charge* – This is the final stage, where the charging voltage is reduced to a steady level intended to keep the battery topped up.

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Figure 25 – Three-stage charging

12.8 IP rating

While lead batteries are relatively robust, they will still need to be housed in a suitable well-ventilated and weather-protected box or shed when installed outdoors. Lithium batteries are complex devices with many cells and complex electronic circuit boards. Lithium batteries come in a wide range of IP ratings: some models are suitable for outdoor installation in shaded and protected areas, where the local climate allows. Outdoor-rated cabinets for lithium batteries are commonly available.

12.9 Soft start/pre-charge

Inverters have large banks of capacitors placed across their battery terminal inputs to keep the DC battery voltage steady while they convert this voltage to AC. At startup of the system, these capacitors can draw very large currents, which can overload lithium batteries and cause their protection circuits to activate an overload warning. For this reason, many lithium batteries now have a soft-start or pre-charge feature whereby they will slowly charge the inverter capacitors to prevent an overload.

12.10 Warranty

Battery warranties can be complex; homeowners should read them carefully to fully understand the implications and conditions. Battery warranties vary according to their respective chemistry:

(a) *Lead batteries* – These will normally have a fixed warranty of between one and five years. There may be an additional pro rata warranty for some models, where a percentage of the battery's cost is credited, depending on the remaining number of months left on the warranty. Lead battery suppliers will usually examine returned batteries for damage caused by under- or overcharging, sulphation, and so on; these types of misuses are not normally covered under warranty. Failure due to incorrect design, installation, or misuse is common for lead batteries, hence the importance of getting these aspects correct;

(b) *Lithium batteries* – These typically have a 10-year warranty, for residential BESSs. The warranty period may also entail an upper limit on the number of allowed charge/discharge cycles, which could reduce the warranty duration. Lithium warranties will usually guarantee a minimum state of health for the battery by the end of the warranty period: 70% is a commonly used figure. Many battery warranties will only cover a credit for a percentage of the battery cost, depending on the battery's age at time of failure.

12.11 Independent battery testing

Some work has been undertaken on battery life cycle testing; further work is needed. The most significant independent battery testing relevant to the New Zealand market was undertaken by ITP Renewables at the Canberra Institute of Technology, funded by ARENA. Its research was carried out in three phases between 2016 and 2022, and while mostly focused on lithium batteries, it did also include some lead batteries and some emerging technologies. A large variety of commonly used BESS' were installed at the Canberra Institute of Technology under temperature-controlled conditions, and batteries were cycled by charging and discharging up to three times per day. This is a very high cycle rate for BESSs, but it provides valuable data for accelerated life cycle testing and reliability. There was a very high failure rate among some of the models tested. Among the many issues highlighted were challenges in commission batteries, unclear installation instructions, lack of clarity regarding charging settings, compatibility issues with PCE, and slow response times from manufacturers on service issues. Testing ended in 2022, when phase 3 had only been under way for a short time. All of the 12 reports from this testing are now publicly available (see https://www.deepcyclesystems.com.au/arena-funded-battery-test-centre-in-canberra/).

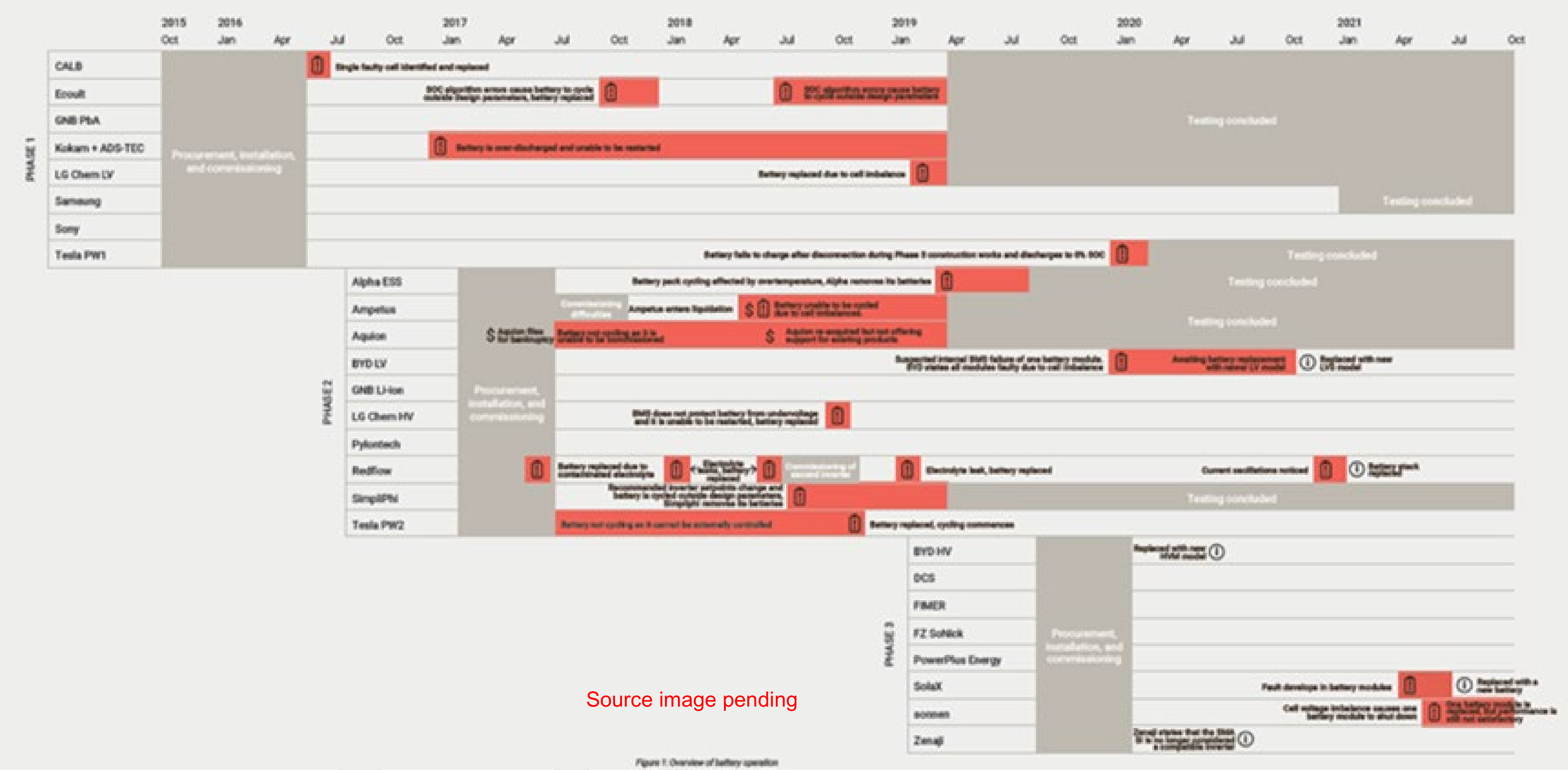

Figure 26 – Example battery testing summary

12.12 Installation considerations

The installation of BESSs must comply with AS/NZS 5139 – Safety of battery systems for use with PCE.

Batteries above ELV, defined as 120 V DC or 50 V AC, are classed as low-voltage work, in accordance with Schedule 1 of the Electrical (Safety) Regulations. They must be installed by an EWRB-registered electrician with a current practising licence. Further information regarding specific battery voltage classes is contained within the above standard. These are referred to as decisive voltage classes.

Most of the following installation guidance is covered in greater detail within AS/NZS 5139 for each BESS type. The key points to consider include:

(a) *Safety* – Regardless of the battery type and voltage, installers should be aware that the potential fault current from a battery can be very high – sometimes in the magnitude of many thousands of amps. Insulated tools should be used, and installers should avoid working on live systems if possible. AS/NZS 5139 provides guidelines for assessing the arc flash potential of a battery and guidance on the appropriate safety gear to wear for each installation;

(b) *Location* – There are a wide range of spaces in which BESSs should not be installed. These include habitable spaces; ceiling spaces; under stairs; within 600 mm of exits, windows, and other electrical installations; and escape pathways. Where a BESS is installed outdoors, it should be in sheltered location out of direct sun and in a suitably rated housing;

(c) *Ventilation* – All types of lead batteries require significant ventilation; passive ventilation is safer than forced fan ventilation, as there is less risk of sparking or igniting ventilating gases;

(d) *Exclusion zones* – There are exclusion zones around BESSs for any equipment not associated with the BESS: 600 mm to each side and 900 mm above. The same exclusion zone applies to off-grid PCE placed above lead batteries – this is not permitted unless the lead batteries are enclosed in a housing and ventilated away from the PCE;

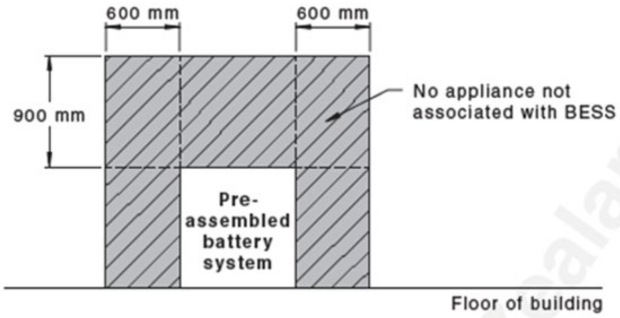

Figure 27 – Restricted zones for equipment not associated with the pre-assembled battery systems

Source: AS/NZS 5139

(e) *Fire rating of walls* – Where BESSs are being installed closer than 300 mm from a wall where there is a habitable space on the other side, then the wall should be constructed from a non-combustible material (such as brick/concrete), or a non-combustible lining should be applied to the wall extending 600 mm to either side of the battery and 900 mm above;

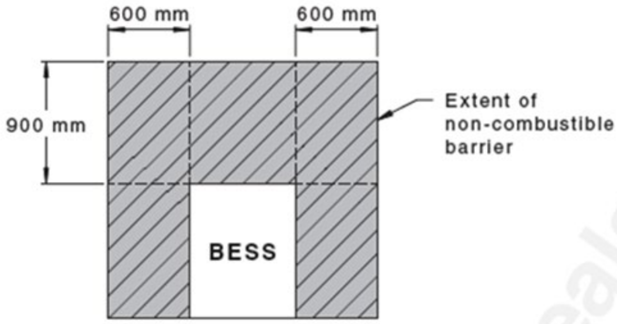

Figure 28 – Barrier zones for pre-assembled integrated BESS installed on or near a habitable room-facing wall

Source: AS/NZS 5139

(f) *Cable sizing* – DC batteries are usually installed as close as possible to their associated PCE. Depending on the battery voltage, the currents flowing can be very high and can generate unwanted voltage drops and ripple voltages at the PCE. Battery cable size needs to be carefully chosen according to manufacturer recommendations, length of cable, installation method, and fuse sizing, and to minimise voltage drops between the batteries and the PCE;

(g) *Fusing/isolation* – All BESSs require fusing and isolation between the batteries and the PCE. This can sometimes be built into the BESS but must always be accessible to a user without tools. For off-grid systems, the battery fusing/isolation must be external to the batteries and be placed at specified distances. Fusing/isolation is required to be two-pole in most cases, and must connect or disconnect both the positive and negative connections simultaneously;

(h) *Earthing* – Any metal cabinets or BESS housings should be earth bonded. It is unusual to earth the battery negative – this is normally left floating with respect to earth. Earthing the battery negative can generate unintended consequences; for example, if a non-isolated charge controller or GTI is also connected, the PV negative input will also become unintentionally earthed;

(i) *Battery monitoring* – Where a shunt has been installed along with a battery monitor, correct orientation and programming of the battery monitor will need to be undertaken. The battery monitor may require several complete charge/discharge cycles to calibrate itself accurately. If there is a facility to network the battery monitor to the PCE, this should also be installed;

(j) *Communications cables* – Where a CAN bus-enabled lithium battery has been installed with compatible PCE, a communications cable will need to be installed between the battery and the PCE CAN bus ports. There may also need to be terminating resistors installed. The wiring of this communication cable varies widely between manufacturers. They are rarely reversable – great care must be undertaken to install this cable the correct way around;

(k) *Battery settings* – Battery charging parameters on all charging devices should be correctly set. There are other battery settings to consider, such as temperature compensation, battery cut-out voltages, and multi-stage charging. A lot of PCE will have a selection of battery presets; however, all parameters should be checked to ensure that they correctly match the exact model and capacity of the battery installed. For lithium batteries with CAN bus, the PCE will often recognise a battery from its compatible list and choose the correct settings. However, the installer should also consider the backup settings the PCE will default to, in case of CAN bus communications being lost. Incorrect settings can lead to a very short battery life which is not covered by manufacturers' warranties;

(l) *Maximum charge/discharge rate* – Any given battery will have a maximum charge and discharge rate which should never be exceeded. Battery management system-managed lithium batteries can self-protect by disconnecting from the PCE in extreme circumstances, although this approach is less than ideal, as the system will crash unexpectedly with loss of power to house loads. For CAN bus-connected batteries, the BESS can communicate any issues with compatible PCE, and the PCE can adjust accordingly in most instances. For lead batteries, exceeding the charge/discharge rate will usually result in damage to the batteries, such as swelling, melted terminals, leaking electrolyte, overheating, and so on. Installers should ensure that the BESS design meets best practice so that these issues never occur;

(m) *Outdoor installations* – Greater care needs to be taken by installers when placing a battery outdoors. They should ensure that the battery or its cabinet is suitably IP rated and that the BESS is placed in a sheltered location out of direct sunlight. The ambient temperature range for the location should also be considered to ensure that it matches the BESS's temperature range of operation. Particular attention should be paid to all cable entries to the batteries, to maintain weathertightness.

12.13 Guidance on use, operation, and maintenance

12.13.1 Think safety

BESSs should always be kept clear of flammable items such as petrol cans, paint tins, cardboard, and paper. Neglecting to do this can generate significant safety issues and limit access for battery inspection and maintenance.

12.13.2 Battery lifespan

All BESSs have a finite lifespan. Installers/homeowners need to take note of any signs that a battery is beginning to fade in performance and capacity. Regular checks and essential maintenance are essential; batteries have a significant replacement cost and are therefore well worth maintaining.

12.13.3 Battery maintenance

Batteries require different types of maintenance, depending on their chemistries. Maintenance of lead batteries should be carried out as follows:

(a) Flooded batteries will require regular topping up with distilled water. These battery types usually need a monthly equalisation cycle – a period of higher-voltage charging when the battery's electrolyte can bubble and remove deposits from the plates. Sealed batteries can be damaged if excessively charged in this way, as any electrolyte that is lost and vented cannot be replaced;

(b) All lead battery types should be fully charged to a 100% SoC at least once per week. If solar PV energy production is not adequate to do this then an external charging source such as grid power or a generator should be used. If lead batteries are left for periods of time at a lower SoC, the plates will sulphate, and the batteries will permanently lose some capacity – this type of neglect is not covered by warranty;

(c) Lead battery terminals should be kept clean from any build-up, and all cables regularly inspected for any damage;

(d) On banks of lead batteries with multiple cells, maintenance can involve regular recording of individual cell voltages under known load and SoC conditions. In this way, trends in results can be observed and any weak cells with significant voltage variations picked up early.

Maintenance of lithium batteries should be carried out as follows:

(e) Some lithium batteries require a regular full discharge and charge cycle to calibrate correctly and indicate an accurate SoC;

(f) For lithium batteries installed in outdoor cabinets, particular care should be taken to ensure the IP rating is maintained, and that fan intake filters are regularly cleaned. Grommets and plastic fittings can easily perish over time. Any lithium battery exposed to moisture or salt spray can be adversely affected and may become unreliable and dangerous;

(g) All batteries will slowly discharge over time when not in service – the rate of discharge will depend on the chemistry and battery brand. Manufacturers will usually give guidance as to how often a top-up maintenance charge should be performed for batteries not in service. If a system is not used, the batteries should be left on a float charge from the PV PCE or other source to maintain them;

(h) Lithium battery models have additional ports that allow detailed history and diagnostic information to be accessed using manufacturer-supplied software and cables. In the event of battery issues, these history logs and diagnostic data are invaluable in determining the cause of the issue, and this information is often required by the battery manufacturer if a warranty claim is being made. While some lithium batteries have their own internet connection and remote monitoring abilities, most remote monitoring is performed through the PCE. Depending on the PCE brand, there can be detailed battery information and history available for all battery chemistries. A much greater level of detail is available for lithium batteries that have a CAN bus communication with the battery. Remote monitoring is often a warranty condition for many lithium batteries;

(i) It is common for lithium batteries to have their firmware updated either locally or remotely, to fix known issues and make improvements. These improvements should only be undertaken by an experienced installer – when required.

12.14 Battery recycling

At the end of their useful life, batteries should be recycled to recover the many valuable materials contained within them and to prevent unnecessary environmental harm. Facilities to recycle lead batteries are very well established; it is generally possible to recover approximately 98% of the materials used. Lithium is a newer technology; however, New Zealand's recycling industry is now putting new facilities in place for the recycling of lithium batteries.

APPENDIX A – CHOOSING A SYSTEM THAT IS RIGHT FOR YOU

(Informative)

A1 General

Choosing the most appropriate solar PV system for your needs can be challenging. It requires careful consideration of several fundamental factors, many of which will require further professional advice.

To help navigate this process (in addition to advice outlined in section 4.3), this appendix is designed to guide the homeowner on the most important considerations during the early information-gathering phase of the decision process.

A2 What is the current condition of your electrical installation?

Those wishing to participate in the electricity market via a grid-tied system should consider the following questions:

(a) Is the mains cable entering your property of adequate capacity to transfer energy back to the grid?
(b) How many phases exist in your installation, and is there ripple control?
(c) Do you have a smart meter (import/export) designed for a grid-tied system? If not, one will need to be installed;
(d) Do you have approval from your local EDB to connect to its network? See the regulatory requirements outlined in 3.4.

A3 Is rooftop solar right for you?

In considering whether rooftop solar is the right choice, you should consider the following questions:

(a) Where do you live in New Zealand (for example, near the sea?). Think about corrosion;
(b) Are you in a high-wind zone area?
(c) Do you have internal roof cavity access?
(d) Will external roof access require scaffolding? Who will provide and install this?
(e) What is the condition and type of cladding applied to your roof? See Table 5, which indicates the types of roof cladding systems used in New Zealand, and consider the practicalities of installing a rooftop solar PV system;
(f) If rooftop solar is not a viable option for you, is a ground-mounted system worth pursuing? (always seek professional advice).

A4 Determining the size and type of system

In considering the size and type of the system you need; you should consider the following questions:

(a) When (over a 24-hour period, and a seven-day period) do you typically use the most electrical energy?
(b) How much electrical energy do you consume annually, and what does it cost (on average)?
(c) Is a professional solar equipment supplier or SEANZ representative located near you? They can guide you through the following technological factors:
    (i) Which solar panel technology is best suited to your specific needs: monocrystalline or polycrystalline? See A5
    (ii) Will your system be grid-tied or not?
    (iii) Following a review of your time-in-use energy consumption data and factoring in household lifestyle, is battery storage an important consideration for this installation?

Note – The assessment of peak winter demand from energy consumption data is useful for sizing battery systems, for periods when solar panels are inactive.

A5 Inverter considerations

Choice of inverter (micro- or string inverter) is also important, and worth discussing with your solar equipment specialist. Table A1 outlines the pros and cons of both, along with power optimisers.

Table A1 – Comparing string inverters, micro-inverters and power optimisers

	Pros	Cons
String inverters	Because they're located at ground level, access for maintenance and replacement is much easier. String inverters have a 15% lower system cost per kW than micro-inverters. The performance and monitoring benefits of micro-inverters can usually be achieved by adding DC optimisers to the solar panels (at an additional cost). String inverters usually have two DC inputs so can work for two separate solar arrays facing in different directions.	String inverters require an aesthetically and spatially suitable location in the home for the inverter, as well as a position that's close to a source of internet (Wi-Fi or Ethernet). It can be difficult to detect and isolate faulty solar panels. There's a higher safety risk in having a cable carrying up to 600 V DC from the roof to the inverter.
Micro-inverters	Unlike string inverters, which monitor the entire system's performance, microinverters enable monitoring of each individual panel's output. They offer real-time, panel-level performance monitoring, allowing users to track the output of each individual solar panel and identify any issues quickly Micro-inverters allow the maximum output of each panel, resulting in slightly better performance than a string inverter. They're particularly useful if there's any shading during the day or if the solar arrays are to be installed in more than two roof directions. Micro-inverters are also known to be safer. The DC is converted to 230 V AC at the panel, so there's no high-voltage DC cabling from the roof.	Micro-inverters are currently more expensive per kW than string inverters. They require a central hub device to be located somewhere in the home with a dedicated power point (or wired into the switchboard) so that they can communicate via the power lines. This also needs to be close to a source of internet (Wi-Fi or Ethernet).
Power optimisers	Power optimisers are module-level power electronics integrated into each solar panel. Like micro-inverters, they optimise the energy output of individual panels. In comparative studies, power optimisers have provided efficiency improvements of around 5% in partially shaded conditions compared to traditional systems. Their cost-effectiveness is a significant selling point, offering many of the benefits of micro-inverters, but at a significantly lower price. Power optimisers present a balanced solution for homeowners with tight budgets between cost and performance enhancement.	Unlike micro-inverters, power optimisers still rely on a central inverter to convert DC to AC. They regulate the voltage of each panel, ensuring that underperforming panels do not degrade the overall system performance.

A6 Lifespan considerations of a solar PV system

Solar panels are built to last around 25 years, though many silicon-based panels around the world are still functioning well beyond that. Typically, they come with two types of warranties: a 10-year product warranty covering defects and a 25-year performance warranty which ensures the panel's energy output remains within expected levels over time.

It's important to note that solar panels gradually degrade, meaning their energy output slightly declines each year. By the end of a 25-year performance warranty, most manufacturers guarantee the panels will still operate at about 80% of their original capacity. As technology advances, so do warranty offerings. Some manufacturers now provide 30-year performance warranties on certain solar products.

String inverters, which are commonly used in solar systems, generally last 12–15 years, although high-quality models can exceed 20 years. Most come with a 5- or 10-year warranty, and in some cases, you can purchase an extended warranty of up to 20 years. Since inverters typically won't last as long as the solar panels themselves, it's wise to plan for potential repairs or replacements during the system's 25-year lifespan.

Micro-inverters and DC optimisers have a longer expected lifespan, of 20–25 years, often with warranties to match. However, some micro-inverter manufacturers have recently shortened their standard warranties to 10 years.

Battery lifespan, on the other hand, depends on three main factors: usage (or duty cycle), type of chemistry (for example, lead-acid vs lithium-ion), and environmental conditions. Like solar panels, batteries lose efficiency over time. Most modern lithium-ion batteries come with a 10-year performance warranty, which typically guarantees 60–70% of the original storage capacity by the end of the warranty, depending on how heavily the battery has been used.

Figure 27 provides an example of how linear performance warranties often work for solar PV systems with a 25-year life span.

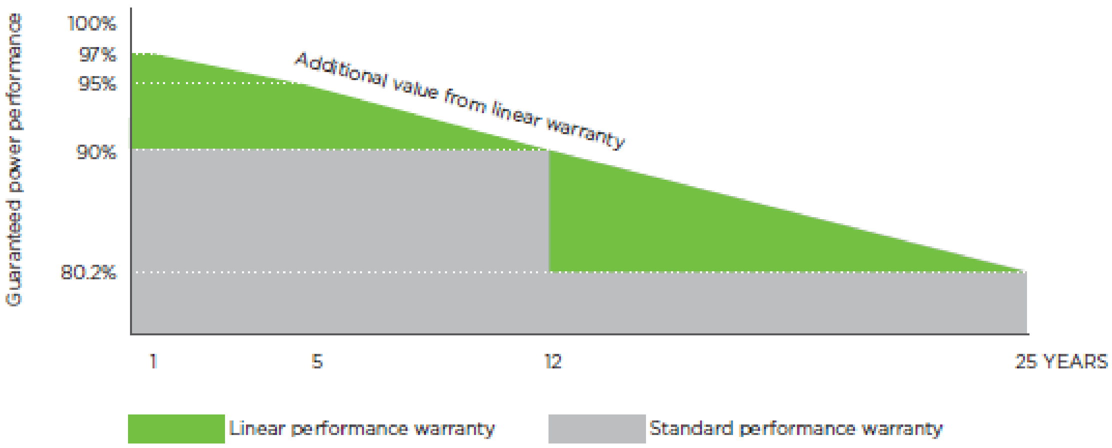

Figure A1 – Linear performance warranty examples

A7 How much will your solar PV installation cost?

Now you know what type of system you want, it's time to seek written quotations for your installation. These must clearly define which aspects of the installation have been included and which have been excluded.

Never make assumptions about coverage. If in doubt, always seek further clarification with a request for response in writing.

When it comes to quantifying the total cost of your solar PV installation, there are a number of additional factors to consider:

(a) Do you have adequate funds to cover the entire installation? If not, have you considered a 'green' loan, available from most commercial trading banks?
(b) Installation budgetary considerations include:
  (i) Allowing for scaffolding to install a rooftop system
  (ii) The cost of all solar PV system components – including all cabling, inverters, controllers, surge protection, and a specially designed solar panel racking system
  (iii) Any necessary roof cladding penetrations, including resealing/waterproofing and consenting
  (iv) Battery storage system installation (as necessary)
  (v) Electrical installation (labour component), including any EDB applications, possible smart metering installation, and any other regulatory consenting fees
  (vi) Additional electrical segregation of essential circuits necessary for the continuous operation of appliances, devices, and medical equipment (if any) in the event of loss of mains power at the distribution board
  (vii) Any potential distribution upgrade requirements.

Once you are satisfied with what you are getting and you have agreed on equipment lead times, the project installation timeline, and payment milestones, it is time to enter a contract with your professional installer and get the job done.

APPENDIX B – TECHNICAL SPECIFICATIONS

(Normative)

B1 General

This section summarises the compliance environment, including legal requirements, relating to the various types of solar PV and battery storage systems outlined in this PAS.

The purpose of conforming with the technical specifications listed in Tables B1 and B2, is to manage risk and provide the homeowner with confidence that the installation they are investing in meets expectations of equipment quality, performance, energy efficiency, safety, and cybersecurity.

Where a homeowner chooses to participate in the electricity market for example, by selling excess energy (when not needed, or surplus to their specific needs) back to the grid – they are lawfully able to so.

Table B1 – Legal requirements

Application	Compliance environment	Regulator	Regulatory instrument	Cited standard
All mains parallel generation system installations	Electricians require additional endorsement for mains parallel generation system installations. This extends to electrical inspectors, and these requirements come into effect on 25 September 2025.	MBIE –EWRB	n/a	n/a
Electricity market participation	All market participants in grid-connected generation (including solar PV) must comply with the Electricity Industry Participation Code 2010	EA	Electricity Industry Participation Code 2010	n/a
Electrical wiring and system components	Radio interference	MBIE – Radio Spectrum Management	New Zealand Radiocommunications Regulations (Radio Standards) Notice 2020	Table 1 - Radio standards
	• Electrical installation • Safety	WorkSafe – Energy Safety	Electricity (Safety) Regulations 2010	AS/NZS 3000 – Electrical installations – Known as the Australian/New Zealand Wiring Rules

Grid-tied inverters				AS/NZS 4777.1 – Grid connection of energy systems via inverters, Part 1: Installation requirements
				AS/NZS 4777.2 – Grid connection of energy systems via inverters, Part 2: Inverter requirements
Off-grid systems				AS/NZS 4509.1 – Stand-alone power systems, Part 1: Safety and installation
Solar panels				AS/NZS 5033 – Installation and safety requirements for photovoltaic (PV) arrays
Solar panels	Structural integrity requirements	MBIE – Building System Performance	New Zealand Building Code	AS/NZS 1170.2 – Structural design actions, Part 2: Wind actions

Table B2 – Good practice guidance

Application	Compliance environment	Regulator	Acceptable standards solution
APIs	DR scheme communication	EECA	OADR 2.0a/b and OADR 3.0 – Open automated demand response standard
			IEEE 2030.5 – Standard for smart energy profile application protocol
Off-grid systems	Stand-alone system design	WorkSafe – Energy Safety	AS/NZS 4509.2 – Stand-alone power systems, Part 2: System design
Battery systems	Installation and safety rules	WorkSafe – Energy Safety	AS/NZS 5139 – Safety of battery systems for use with power conversion equipment
Cybersecurity	Equipment information security management to align with the National Institute of Standards and Technology (NIST) protocols and/or SOC 2 Type II cybersecurity compliance framework of identify, protect, detect, respond, and recover	Government Communications Security Bureau – National Cyber Security Centre	ISO 27001 – Information Security
			SOC 2 Type II – A cybersecurity compliance framework developed by the American Institute of Certified Public Accountants that assesses an organisation's internal controls over a period of time (typically 3–12 months), demonstrating their ability to protect customer data and maintain user privacy
	Secure API standards		REST (Representational State Transfer) – A software architectural style for designing web services, emphasising simplicity and leveraging the existing HTTP protocol, and commonly used for building APIs
			ISO/IEC 20922 – Information technology — Message Queuing Telemetry Transport (MQTT) v3.1.1
			OAuth 2.0 – Open standard for authorisation that allows users to grant third-party applications access to their data on a service provider's website or application
			ISO/IEC 20648 – Information technology — TLS specification for storage systems

APPENDIX C – DATA CAPTURE AND CYBERSECURITY

(Informative)

C1 General

This appendix sets forth a comprehensive set of data capture and cybersecurity requirements designed for solar PV systems, both with and without battery storage. It provides guidance on secure connectivity, data handling, encryption, remote firmware updates, application programming interfaces (APIs), cloud-to-cloud data sharing, and a risk management framework.

The goal is to support robust, resilient, and interoperable systems that maintain the confidentiality, integrity, and availability of operational data while ensuring secure remote management and monitoring.

The evolution of solar PV systems into smart, networked installations has introduced a new paradigm in energy management. This appendix is intended for system owners, operators, and potential owners who must address cybersecurity concerns as these systems become more connected and data intensive.

Every solar installation, whether standalone or integrated with battery storage, must implement measures that not only capture performance and operational data but also protect it from unauthorised access and manipulation. This introduction frames the cybersecurity approach in a risk-based context, aligning with established guidelines such as those from the United States National Institute of Standards and Technology (NIST).

Figure C1 – Overview of cybersecurity in solar systems

Courtesy of the United States Department of Energy's Solar Cybersecurity Basics

C2 Connectivity

Solar PV systems today use multiple communication channels to transmit data from a site to remote monitoring stations. Whether the system uses wired Ethernet, Wi-Fi, or cellular networks, each connection must be designed to support secure and reliable communication. The connectivity architecture should support network segmentation, where operational networks are isolated from less secure networks to reduce risk.

A homeowner with a solar PV system can implement network segmentation, focusing on four key areas to improve security and ensure reliable communication between their solar equipment and monitoring systems.

(a) Use a separate network for solar equipment:

  (i) Create a dedicated Wi-Fi SSID: If your router supports multiple SSIDs (network names), set up one exclusively for your solar inverter, battery, and monitoring system

  (ii) Use virtual local area networks (VLANs): Some advanced home routers allow VLANs, which can isolate solar devices from regular home devices like phones and smart TVs;

(b) Enable firewalls and access controls:

  (i) Block unnecessary traffic: Configure your router's firewall to allow only necessary data transmission (for example, inverter communication with the monitoring portal)

  (ii) Restrict remote access: If your inverter has a web interface, ensure it's not accessible from the public internet unless using a secure method like a VPN;

(c) Disable unused network features:

  (i) Turn off remote access if it's not needed: Many solar monitoring systems offer remote access, but if you don't use it, disable it to reduce security risks

  (ii) Disable UPnP and port forwarding: These settings can make it easier for attackers to access your network;

(d) Regularly update firmware and change default passwords:

  (i) Update your inverter's software to patch security vulnerabilities

  (ii) Change default credentials for inverters, monitoring apps, and routers to strong, unique passwords.

C3 Security and encryption

Cybersecurity in solar installations encompasses the careful control of who can access system settings and data. Strong authentication methods, such as multi-factor authentication, are essential, and every access point should be secured with robust credentials. Security monitoring and logging are critical for detecting anomalous behaviour and ensuring that breaches can be rapidly investigated. The overall design should adhere to industry standards, such as those outlined in the NIST Cybersecurity Framework, to provide layered defences.

Protecting data both at rest and in transit is paramount. All communications between solar PV devices, local controllers, and cloud services must employ current encryption protocols such as transport layer security (TLS) to ensure that data cannot be intercepted or tampered with. Data stored on local devices or in the cloud should be encrypted using industry-standard algorithms like AES-256. Effective key management practices, including regular key rotation and secure storage, are essential components of a robust encryption strategy. Ask your equipment supplier and solar PV system cloud services provider about their encryption practices.

Ask equipment suppliers about compliance with ISO 27001; a globally recognised standard for information security management, often aligned with NIST, or SOC 2 Type II. Ensure your vendor has strong security controls in place.

C4 Data captured

Solar PV systems are expected to capture a wide range of data. This includes operational parameters like power generation, consumption metrics, inverter performance, and battery SoC, as well as environmental measurements such as irradiance, temperature, and weather conditions. Detailed logging of events – from routine operational changes to system alerts – is also essential for forensic analysis in the event of a cybersecurity incident. This continuous data stream not only helps in performance analysis but also in predictive maintenance and fault detection. For an example of how data flows are structured in IoT-based solar monitoring.

C5 Over-the-air updates

As solar PV systems evolve, firmware updates delivered over the air (OTA) are critical for addressing vulnerabilities and ensuring optimal performance. OTA update mechanisms must be designed with full cryptographic verification, so that only authenticated updates from trusted sources are installed. The update process should include features for rollback and recovery to mitigate the risk of installing a faulty update.

How to secure OTA updates for your solar system:

(a) Enable automatic updates (if available):

  Many modern solar inverters and batteries offer automatic firmware updates to fix security vulnerabilities

Check the system settings or mobile app to confirm updates are enabled.

(b) Verify update sources:

Only install updates from the official manufacturer's website or app.

Avoid third-party or unofficial firmware, as it could contain malware. If you receive an update notification, verify it with your installer or manufacturer before proceeding.

(c) Use a secure network:

Ensure the Wi-Fi network used for updates is secured with Wi-Fi protected access 2 (WPA2) or WPA3 encryption.

Avoid using public or unsecured Wi-Fi when updating the system.

If possible, keep the solar system on a separate network (VLAN) from personal devices.

(d) Check for cryptographic verification:

The solar system should digitally verify firmware updates before installation.

Check the manufacturer's documentation to ensure updates are signed and encrypted.

(e) Keep a backup plan (rollback feature):

Ask the manufacturer or installer if the inverter/battery supports firmware rollback in case of a faulty update.

If updates cause performance issues, contact the manufacturer for a fix or revert to a previous stable version.

(f) Monitor the system after an update:

After an update, check your solar monitoring app for errors, reduced efficiency, or connectivity issues.

If something seems wrong, report it to your installer or manufacturer immediately.

(g) Regularly review firmware status:

Every few months, check if your inverter, battery, and monitoring system are running the latest firmware.

Some brands require manual updates, so it's important to stay informed.

C6 APIs and data exchange protocols

Interoperability is a key requirement for modern solar installations. As a flexibility market evolves in New Zealand, electricity participants like aggregators/flexibility traders, energy retailers, distribution and transmission companies will want to integrate with your system for various reasons. APIs to facilitate this data exchange must be designed following industry standards such as REST or MQTT. Secure API endpoints are essential and should include strong authentication and access controls to ensure that only authorised parties can access or modify system data.

C7 Cloud-to-cloud sharing

Many solar PV systems now integrate with cloud-based platforms for advanced data analytics and remote monitoring. When data is shared between cloud services, secure communication channels must be maintained. This means that as a homeowner you should:

- *Use strong, unique passwords* – Avoid default or weak passwords for your monitoring app. Use a password manager to generate and store complex passwords;
- *Enable multi-factor authentication (MFA)* – If available, enable MFA (for example, short message service (SMS) codes and authenticator apps) to prevent unauthorised access;
- *Limit access permissions* – Some platforms allow multiple users (for example, installers and energy consultants). Grant access only to trusted people and remove unused accounts.

C8 Risks

Below is a risk table that summarises key cybersecurity risks for solar PV systems, along with a brief description, an assessment of likelihood and consequence, and recommended treatments or mitigation measures.

Table C1 – Key cybersecurity risks for solar PV systems

Risk	Description	Likelihood	Consequence	Treatment/mitigation
Unauthorised access	A hacker gains access to system settings or data due to weak passwords or unsecured remote access.	Medium to high	Unauthorised control of your solar system or operational disruptions	Enable MFA, use strong and unique passwords, disable remote access if unnecessary, and regularly review who has system access.
Data breach	Personal or system data (for example, on energy usage or home occupancy patterns) is intercepted or leaked.	Medium	Privacy invasion, potential financial fraud, or unauthorised profiling by third parties	Ensure your solar app/platform uses encryption (TLS 1.2/1.3 for data transmission, AES-256 for stored data). Limit data sharing with third-party apps. Regularly review privacy settings.
Firmware/software compromise (OTA updates)	An attacker injects malicious firmware via an unverified update, leading to system malfunctions.	Medium to low	System failures, lower energy production or permanent inverter damage	Only install updates from the official manufacturer, verify update sources, enable automatic security updates, and ensure a rollback feature exists for faulty updates.
API and data exchange vulnerabilities	Weak APIs allow attackers to intercept, modify, or misuse system data.	Medium	Unauthorised system control, data theft or integration failures with smart home devices	Limit API access to only essential services, check if your provider follows secure API standards (OAuth 2.0, MQTT with TLS), and disable unnecessary third-party integrations.
Cloud-to-cloud data sharing risks	Unsecure cloud integrations expose homeowner data during transmission.	Low to medium	Data tampering, inaccurate monitoring insights, or unauthorised access to system data	Ensure cloud platforms use encrypted connections, review privacy policies before linking services, and periodically check security settings for cloud integrations.
Insecure network connectivity	Unsecured Wi-Fi or outdated router settings allow attackers to intercept solar data.	Medium	Loss of data privacy, system hijacking, or connection disruptions	Use a strong Wi-Fi password, enable WPA3 (if available) encryption, set up a separate network (VLAN) for smart devices, and keep router firmware updated.

NOTES