THE GREAT SOLAR OPPORTUNITY

How new technologies and data-driven approaches are unlocking the next era of solar energy.

SOLSTICE AI

Introduction

"Solar energy is now the primary driver of global electricity system growth.

Yet solar is also highly variable — and this variability introduces serious challenges for the energy systems of the future. As solar becomes the dominant source of electricity, the infrastructure that manages it must become far more intelligent. The next era of solar is not defined by capacity alone, but by coordination, visibility, and foresight.

Fortunately, new technologies are emerging that can transform solar from an intermittent resource into a predictable, dispatchable, and manageable component of the energy system — a foundational requirement for a stable, renewable grid. By 2030, the global opportunity for improved solar forecasting will exceed AU$80 billion per year, growing rapidly alongside the accelerating deployment of solar worldwide."

Dr Julian de Hoog, Solstice AI co-founder and CEO

$100M+

Australian solar farms, rooftop solar installations, VPPs and energy traders are losing hundreds of millions of dollars every year due to inaccurate weather forecasting and a poor understanding of cloud characteristics

$38m

Across all Australian utility scale solar farms, just a 10% improvement in solar forecasting accuracy would generate an extra $38 million per year in profit

10%

Large regions throughout Australia have ~10% more rooftop solar capacity than is recorded in official Government databases

$80bn

The global solar forecasting opportunity will reach AU$80 Billion per year or more by 2030

Executive Summary

Falling costs, advancing technology, climate commitments, and electrification across industry and households are accelerating the deployment of solar at unprecedented scale. Global solar capacity exceeded 2.2 TW in 2024 and is expected to surpass 7.1 TW by 2030 — more than tripling in just six years.

This growth is reshaping electricity systems. Solar is clean and abundant, but also **variable, highly distributed, and only partially visible to market and network operators**. This increases the need for more accurate short-term solar generation forecasts across the entire energy value chain.

At utility scale, solar farms must navigate weather-driven volatility, network constraints, curtailment, and increasingly dynamic bidding conditions. Co-located battery storage is now becoming standard — but unlocking its full value depends on accurate forecasts of future solar output. A 10% improvement in solar forecast accuracy enables revenue increases of AU$5.11 / MWh, implying a global solar forecasting opportunity of AU$9.5 Billion per year.

Behind the meter, rooftop solar is now the largest and fastest-growing "generator" in many regions, yet much of its capacity is invisible to system operators. Improving visibility into where and how much energy is being produced is now essential for efficient market operation and grid stability. New actors such as virtual power plants (VPPs), which aggregate households into flexible fleets, rely heavily on accurate solar forecasts. For VPPs alone, the global forecasting opportunity is estimated at AU$720 million today, growing to AU$2 billion by 2030.

In wholesale markets, price formation is increasingly driven by renewable variability. A small number of high-price intervals often determine quarterly trading outcomes: last year in Australia, battery energy storage systems obtained 36% of their annual revenue in just seven days, i.e. 2%, of the year. Knowing when cloud bands will reduce supply has become a material financial differentiator for retailers, asset operators, and trading desks. Globally, the solar forecasting opportunity for energy traders is estimated at $16.7 Billion per year.

Across all these domains, **solar intelligence** — the ability to measure, predict and coordinate solar generation — is becoming **strategic infrastructure**. New technologies are enabling this shift: high-resolution overhead and satellite imagery, real-time device telemetry, and AI models that can learn cloud dynamics and region-specific behaviour.

Australia sits at the forefront of this transition. With the world's highest rooftop PV uptake and rapidly expanding VPP adoption, Australia is a living laboratory for the high-solar grid of the future. Solutions proven here will scale globally.

1.

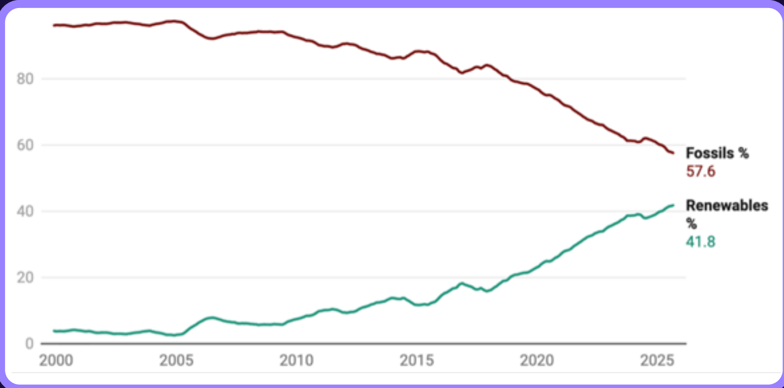
1.1 The electricity generation of choice to meet the global push for electrification

The world is electrifying at an unprecedented pace. Many established industries, transport and homes are all switching from fossil fuels to electricity. New and fast-growing industries are emerging, such as green metals and data centres that power AI.

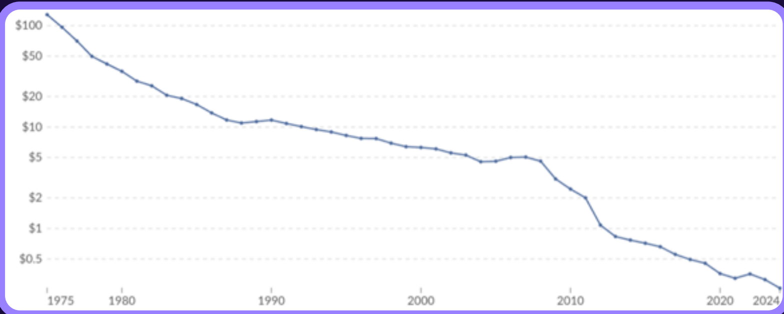
To satisfy this demand for electrical energy, **demand for renewable generation is exploding, and solar is leading the charge.**

Several powerful trends are driving this growth:

- **Economics:** the cost of solar modules has fallen by over **90%** in fifteen years.
- **Security:** governments and corporates across all global markets seek local, renewable energy resilience.
- **Technology:** improved efficiency, digital monitoring, and smarter inverters make solar easier to deploy and manage.
- **Policy:** net-zero targets are now embedded in most major economies.



Energy generation in Australia's energy markets [1]

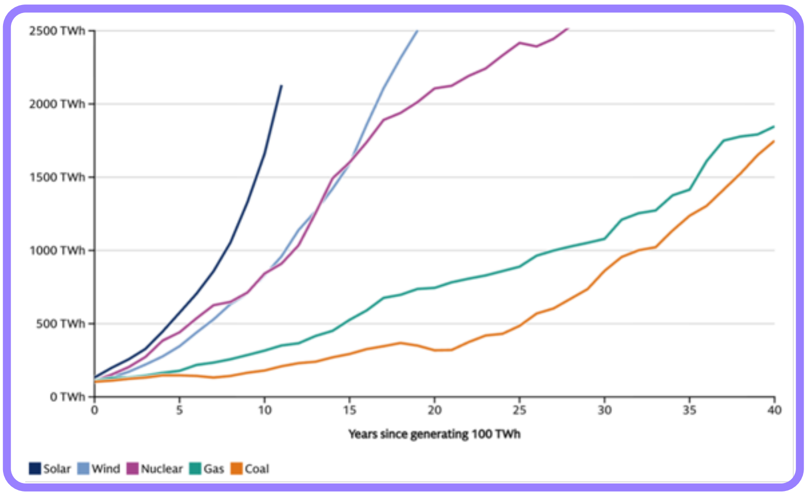


Solar photovoltaic panel prices, in US dollars per watt, adjusted for inflation. [2]

In South Australia, one of the world's most advanced renewables grids, there are now "unprecedented levels of interest in connecting the network, for both load and demand, from industries such as mining, green steel, desalination, data centres and new renewable energy projects. Active interest in new load connections in the short to medium-term currently exceeds 2,500MW" – which is **almost double the current average grid demand** of 1,300 MW [31].

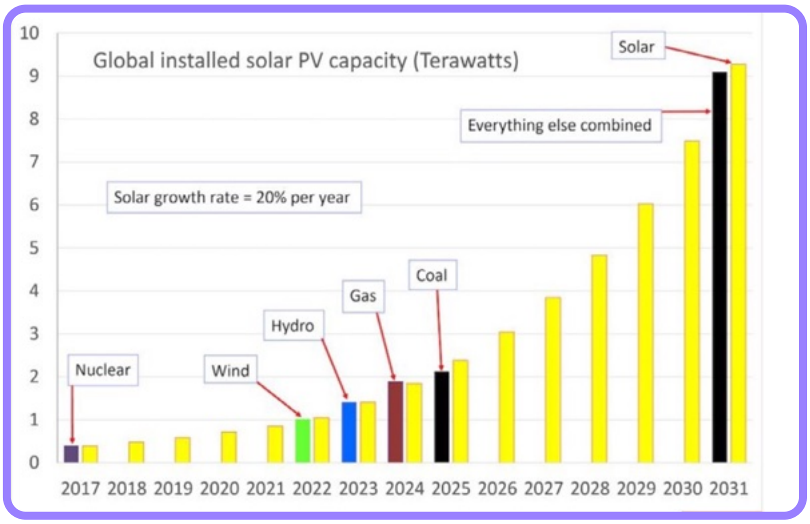
1.2 Quantifying and projecting solar growth

In 2024, the world added 452 GW of new solar capacity — representing **70% of all new global electricity generation** (more than coal, gas, nuclear, hydro, and wind combined) [3]. That represents a 33% increase on the previous year, a trend that is expected to continue for years to come. In fact, an analysis by Goldman Sachs confirms that the solar electricity generation surge is the fastest in the history of electricity, vastly outperforming growth of other technologies at similar stages in their lifecycle.



The solar electricity generation surge is the fastest in the history of electricity. Source: Goldman Sachs [7].

In total, global cumulative PV capacity grew to significantly over 2.2 TW by the end of 2024, up from 1.6 TW in 2023 [4]. Current trajectories suggest that installed capacity will exceed **7.1 TW** by 2030 — more than a **threefold increase in just six years** [5]. This is broadly split into 57% utility-scale, 23% industrial, and 19% residential (rooftop) [6].



Global generation capacity [8]. By 2031, the world will have more capacity to generate solar electricity than all other sources combined.

Using estimates of installed capacity, and applying a conservative capacity factor of 17%[1], we can therefore determine the total amount of solar energy generation: 3,276 TWh per year in 2025[2], growing to 10,573 TWh per year in 2030. For context: by 2030, solar PV will generate more than twice as much energy as the entire EU is consuming today.

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[1] *Installed capacity (TW) tells us how much solar generation could be produced at a given moment, but to understand* **annual energy output (TWh)** *we need to apply a* **capacity factor***. Capacity factor reflects how much a generator actually produces relative to its theoretical maximum — accounting for the facts that solar does not generate at night, varies by season, and is affected by cloud cover. Globally, solar PV systems show capacity factors in the range of* **10%–25%***, with a recent estimate placing the global average at* **16.2%** *[9]. In Australia — where solar resources are particularly strong — recent figures show an average of* **22.4%** *[10]. For conservative global modelling, we assume a* **17%** *capacity factor.*

[2] *Annual solar generation is calculated using: Annual Energy (TWh)=Installed Capacity (TW)×8,760 hours/year×Capacity Factor*

2.

The Integration Challenge: Managing Solar at Scale

As solar capacity accelerates, electricity systems are undergoing a fundamental structural shift in how supply and demand are managed. Solar is clean, low-cost and scalable — but it is also **variable**, **distributed**, and only **partially visible** to market and network operators. These characteristics are redefining how electricity is generated, traded, and managed across both large-scale systems and millions of behind-the-meter installations.

2.1 Utility-Scale Solar

Large-scale solar farms now make up a substantial share of generation in many regions, and their influence continues to grow. However, utility-scale solar introduces challenges that traditional power systems were not designed for:

Demand–supply balance: Solar production peaks in the middle of the day, often exceeding local demand, but drops rapidly in the evening — requiring fast-ramping dispatch from other generators.

Volatility: Cloud movements can cause output to change by hundreds of megawatts in minutes, affecting system frequency, interconnector flows, and unit commitment decisions.

Curtailment: During periods of high solar output and low demand, excess generation must be curtailed to maintain grid stability. In some markets, curtailment has reached levels that materially affect project economics.

Shift toward co-located storage: As curtailment and volatility increase, batteries are becoming a standard complement to utility-scale solar — to smooth output, avoid imbalance penalties, and capture price spreads.

Utility-scale solar is therefore no longer just about adding capacity. It increasingly requires **coordination** and **forecasting** to ensure the system remains stable and commercially viable.

On 14 September 2025, massive amounts of renewable generation had to be curtailed in Australia to maintain stable operating conditions. In fact, the amount of renewable energy that had to be shut off was greater than the total energy demand on Australia's electricity grid at the time [32]. Such events are becoming increasingly common, and such high levels of curtailment affect the long-term economics of solar farms (not to mention residential solar and storage). However, with effective forecasting they can be minimised, or the surplus energy can be effectively used for other purposes, instead of being wasted.

2.2 Distributed Rooftop Solar

Distributed, behind-the-meter solar is growing even faster than utility-scale solar, and in some regions now forms the **largest single "generator" in the system.** Yet it is largely invisible to system operators:

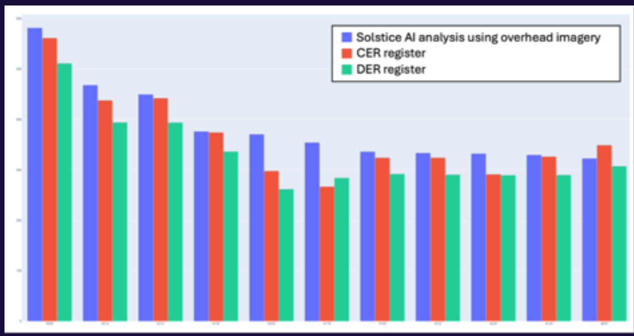
Limited visibility: Most rooftop systems do not report real-time output to the grid. Operators often see only the net load, not how much rooftop solar is generating behind it.

Incomplete capacity knowledge: Official installation registers are often outdated or inaccurate; actual installed rooftop capacity is typically significantly higher.

Zero centralised control: These systems behave according to the weather, not system needs. At scale, they influence voltage levels, reverse power flows, and local congestion.

Growing contribution: In markets like Australia, rooftop PV can supply up to or beyond 100% of local demand during mild weather conditions [11].

This creates a situation where a large part of the energy system is **unmonitored and uncoordinated**, yet increasingly determines how the grid behaves. The result is **complex operational challenges**, especially for network and market operators who must manage flows they cannot directly see.



Postcode-by-postcode comparison of solar generation capacity estimates (only the largest 11 postcodes, in terms of solar PV capacity, shown above)

In a recent analysis comparing official rooftop solar installation databases with high-resolution imagery and automated detection, Solstice AI identified ~10% more installed rooftop PV capacity than was recorded in official databases. Because these databases underpin regional planning, market modelling and solar generation forecasts, this finding highlights a significant gap in current visibility of distributed solar — and a major opportunity to improve system-level insight.

> **"Consumers are now not only responsive but also producers of electricity, introducing a layer of complexity to system operation that challenges established tools and frameworks.**
> **The rise of these hidden participants risks undermining the operational integrity of the system if not properly integrated."**
>
> *2025 National Electricity Market Review (The Nelson Review) [43]*

2.3 Price Volatility and Market Risk

As both large-scale and rooftop solar reshape the supply curve, the resulting market dynamics are dramatic:

Frequent negative price intervals: Midday price events are increasingly negative, particularly in high-solar regions.

Steep evening peaks: As solar output falls at sunset, prices can spike sharply, sometimes by orders of magnitude.

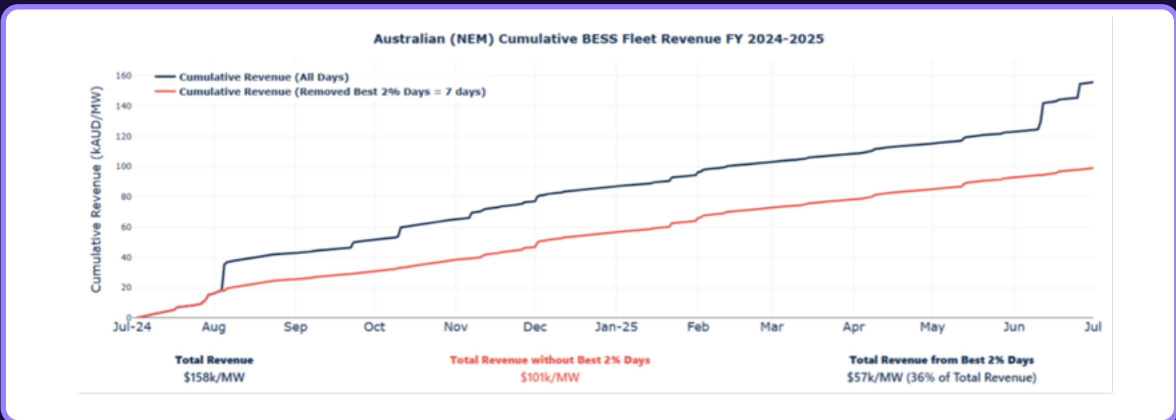
Rapid, weather-driven fluctuations: Passing cloud bands can shift system-wide supply quickly enough to cause sharp market responses.

Australia leads global volatility: Australia is now widely recognised as having the most volatile electricity market in the world, driven in large part by the scale and variability of solar generation [12].

For virtual power plant operators, retailers, and energy traders in general, price forecasting is now inseparable from solar forecasting. The market is becoming more weather-driven — and therefore more unpredictable without advanced intelligence.

"Prices are likely to become predictably more variable and unpredictably more volatile ... extended and unforeseen periods of low wind and solar output pose significant challenges. These shocks can be difficult to anticipate and manage ..."

2025 National Electricity Market Review (The Nelson Review) [43]



Australian (NEM) Cumulative BESS Fleet Revenue FY 2024-2025. Source: Louis Green [33].

In FY24-25, 36% of all revenue generated by battery energy storage systems occurred within only 7 days (2%) of the year [35]. Solar volatility is increasingly one of the strongest drivers of this price volatility and it is essential to get it correct at the most important moments of the year.

3.

The Expanding Solar Ecosystem and the Forecasting Opportunity

Solar's rise is creating new stakeholders — and new data and forecasting demands.

Stakeholder	Key Objective	Example Solar Intelligence Need
Solar Farm and Battery Operators	Maximise yield and market revenue	Site-specific forecasts and curtailment risk prediction
Virtual Power Plants (VPPs)	Aggregate and coordinate thousands of small systems	Fleet-level generation forecasting and dispatch optimisation
Energy Traders / Gentailers	Manage full portfolio's exposure to solar volatility	Regional generation forecasts linked to price dynamics
Network Operators (DNSPs/TNSPs)	Maintain voltage and thermal stability	Feeder-level visibility, congestion forecasting
Market Operators (AEMO, ERCOT, etc.)	Balance supply and demand in real time	State- and market-wide solar output forecasts

Each group is discovering that solar data is strategic infrastructure. Forecast accuracy directly affects profit, reliability, and the pace of decarbonisation.

This section describes the motivations of these stakeholders and quantifies the opportunity for more accurate solar energy forecasts. All values, unless otherwise indicated, are in Australian dollars (AU$).

3.1 Solar Farm and Battery Operators

An operator of a utility-scale solar farm faces a constant challenge: maximising profitability in an increasingly dynamic energy market. While part of the plant's revenue may be guaranteed through contracted revenue and environmental certificates, a substantial proportion of its generation — often 30% or more, and in some cases the full output — is sold on a merchant basis. This means the operator must actively bid the plant's output into the wholesale electricity market every five minutes, every day of the year[3].

In Australia, the operator can rely on forecasts supplied by the market operator, but the most successful operators develop their own in-house forecasting capabilities or use third-party services. These forecasts underpin every operational and trading decision the plant makes.

Forecast accuracy is critical. If the operator overestimates generation and fails to deliver the forecasted amount, the plant is exposed to Frequency Performance Payments (FPPs) [13] — penalties imposed to maintain grid stability. For many solar farms, these penalties can represent a meaningful share of their spot-market revenue [14]. One study found that poor forecasting could reduce revenue by around 9% [15]. To avoid such losses, operators often bid conservatively, committing only about 90% of expected generation. This approach minimises risk but also sacrifices significant revenue potential.

Integrating a battery energy storage system (BESS) changes the equation. The battery allows the operator to "firm" the solar output — smoothing short-term variability and covering forecast errors — thereby reducing exposure to penalties.

However, to fully realise these benefits, the operator still depends on high-accuracy forecasts. Battery charge and discharge strategies hinge on understanding not only future prices but also expected solar generation.

Investment confidence in solar and battery storage development is clearly growing: in the Australian government's most recent Capacity Investment Scheme, more than half of the successful bids were for large-scale solar-battery hybrid projects. [33]

[3] In Australia, this interval is every 5 minutes. In other global markets, it may be every 15 minutes (or at some other frequency).

The Solar Forecasting Opportunity

Accurate solar energy forecasting directly affects the profitability and operational performance of utility-scale solar farms. The key revenue drivers affected by solar forecast performance are:

1. **Wholesale market revenue.**
   More accurate forecasts enable less conservative bidding. An accurate forecast can for example reduce missed revenue from 10% to 5% of total market-exposed solar generation.
2. **Reduced forecast-error penalties**
   Under arrangements such as Australia's Frequency Performance Payments (FPP), generators that deviate from their forecasted output incur higher FCAS costs. Improved forecast accuracy reduces these penalties and stabilises net revenue.

   When a solar farm includes co-located battery storage, accurate forecasts unlock additional value:
3. **Energy arbitrage.**
   Forecasts guide when to charge the battery during low or negative price periods and discharge during peak price windows, shaping the revenue profile of the plant.
4. **Provision of grid services.**
   Batteries can respond within seconds to system needs, enabling participation in FCAS and other fast-response ancillary markets. Forecasting the broader impact of solar on grid stability allows the battery state of charge to be held or released strategically to maximise grid-service revenue.
5. **Curtailment management.**
   When periods of likely curtailment are forecast ahead of time, a solar farm can redirect generation to on-site loads or charge co-located storage, reducing wasted energy and improving asset utilisation.

A recent global review of over 100 solar and storage use cases found that each 10% improvement in forecast skill enables an additional US$3.31 per MWh (≈AU$5.11 per MWh) in revenue [16].

In Australia, utility-scale solar PV generated 7.4 TWh in FY2023-24, implying that a 10% forecast improvement translates to AU$38 Million per year.

Globally, utility-scale plants produce ~57% of total solar generation. With solar producing 3,276 TWh in 2025, a 10% forecast improvement therefore unlocks AU$9.5 Billion per year.

By 2030, with global solar generation expected to more than triple, this grows to over AU$30 Billion per year.

3.2 Virtual Power Plant Operators

In a virtual power plant (VPP), thousands of distributed energy assets are operated as if they were a single, intelligent, and responsive power plant. The role of a VPP operator is complex: they must manage the uncertainty of household energy demand, rooftop solar generation, and market prices; coordinate when to charge or discharge a diverse fleet of devices; and ensure that customers remain satisfied — all while maximising portfolio-wide profitability.

Small-scale solar PV systems introduce challenges not typically faced at utility scale. Output is influenced by roof tilt, orientation, multiple panel arrays, local shading, weather patterns, inverter settings, and household consumption behaviour. Determining whether each system is performing as expected is therefore non-trivial. Site inspections are rarely feasible at scale — one VPP operator indicated a single site visit can cost ~AU$2,000 — making data-driven diagnostics essential.

Visibility is also limited. VPP operators often cannot see how much rooftop solar is being consumed behind the meter, curtailed, or exported at any given moment. Operators may deliberately curtail generation during negative price intervals, which complicates performance assessment. Understanding what could have been generated — the true, weather-adjusted solar potential — is critical for evaluating performance, refining algorithms, and improving control strategies.

Finally, VPP operators must integrate diverse data streams and control levers into a single real-time decision framework. Cloud bands passing over dense urban regions can shift aggregate PV output by tens or hundreds of megawatts within minutes, driving sharp price and FCAS responses. Knowing when these events will occur can mean the difference between major gains and significant losses.

Therefore, accurate solar intelligence is fundamental to VPP performance:

- ✓ **Site-level diagnostics** ensure each system is operating at full potential.
- ✓ **Fleet-level forecasts** enable coordinated battery dispatch and demand response.
- ✓ **Regional solar forecasts** increasingly underpin price forecasting, now the core driver of VPP revenue.

The Solar Forecasting Opportunity

Analysts widely view VPPs as a key enabler of the clean energy transition, allowing distributed resources to provide capacity, flexibility, and stability — without new transmission or central generation.

In Australia, momentum is accelerating. The federal Cheaper Home Batteries program has driven a surge in household storage adoption, with over 100,000 batteries installed between July–October 2025 [17]. 2025 is shaping up as a public awareness turning point for VPPs. Amber — the retailer that passes wholesale prices directly to customers — has reported the fastest battery uptake under the scheme, indicating that households are increasingly willing to participate actively in the market.

Market forecasts confirm this trajectory:

- **Grand View Research:** US$5.01B (2024) → US$16.65B (2030), CAGR 22.3% [18].
- **Fortune Business Insights:** US$1.42B (2023) → US$23.98B (2032), CAGR 37.7% [19].

While estimates vary, the direction is unambiguous: VPPs are entering a high-growth phase globally.

Assessing the solar forecasting opportunity requires estimating how many homes with solar and batteries are likely to participate in a VPP. In Australia, at the time of this report, there are **4.16 million rooftop solar PV systems**, with **41.8 GW** of capacity producing **35 TWh** per year [20]. More than **1 in 2 Australians** indicate they intend to install a battery alongside new or existing solar PV – a 50% attachment rate [21]. Today, **10–15%** of battery owners participate in a VPP; however as public awareness and acceptance of VPPs continues to grow, it is reasonable to assume this will rise to at least **20%** over the next few years.

Under these assumptions, Australia's potential VPP fleet would represent roughly **3.5 TWh**[4] of controllable household solar generation per year. Using the same value of improved forecasting demonstrated for utility-scale solar and storage — **≈AU$5.11 per MWh** (see preceding section) — the Australian VPP **solar-forecasting opportunity is approximately AU$18 Million per year.**

Globally, **~43%** of solar generation is distributed rooftop – a total of 1,409 TWh per year. Applying the same assumptions – ~50% battery attachment rate, and 20% of batteries participating in a VPP – yields an estimated global solar forecasting opportunity of AU$720 Million per year.

By 2030, as global solar generation more than triples, this opportunity exceeds **AU$2 Billion per year**.

[4] *35 TWh x 50% of solar PV owners installing batteries x 20% of battery owners joining a VPP*

3.3 Energy Traders

Here, the term energy trader refers to any participant with exposure to wholesale electricity prices. In Australia, this includes the large gentailers, renewable asset operators, and energy retailers managing market-facing portfolios. In Europe and North America, traders may participate even without owning generation or retail customers — trading electricity as a financial commodity [22].

Energy trading is conducted in one of the world's most volatile and information-driven markets.

Traders must anticipate price movements shaped by the interaction of weather, demand, interconnector flows, network constraints, and generator behaviour. Every five minutes[3], they make decisions about whether to buy or sell energy, charge or discharge storage, or rebalance hedge positions — decisions that translate directly into profit or loss. As an example, in FY2025 alone, more than AU$25 Billion of energy value flowed through Australia's wholesale market [23] – and this is a comparatively small market compared to those in other parts of the world.

As solar becomes a larger share of the generation fleet, **solar variability has become a core driver of market price dynamics**. While the daily pattern of solar production is broadly predictable, cloud movements can change output — and therefore market prices — in a matter of minutes. For a trader, knowing when those clouds will arrive is the difference between:

- charging a battery at a low price or at a high price,
- capturing a price spike or missing it,
- avoiding a loss or incurring one.

Accurate, high-resolution regional solar forecasts now play a central role in trading strategy.

These forecasts estimate the total output of all solar systems across large regions, and are integrated into:

- price forecasting models
- bid and dispatch strategies
- storage optimisation
- risk and hedging systems

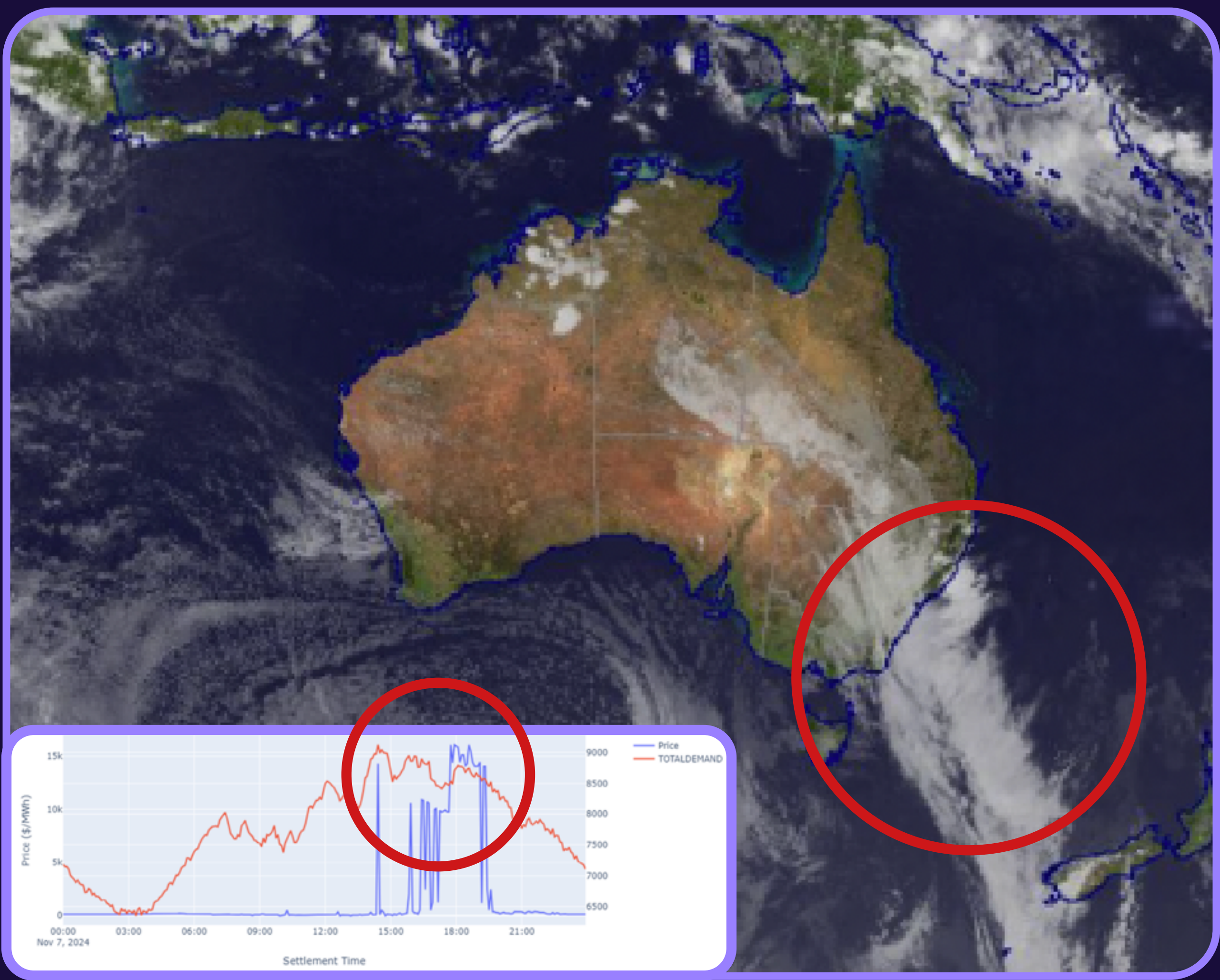
In the National Electricity Market (NEM), where prices can swing from –AU$1,000 to +AU$20,300 per MWh, **forecast accuracy directly translates to trading performance**. Even small improvements in short-term forecasting can materially influence portfolio outcomes — particularly during "event days", where a few hours of price spikes can determine the profit of an entire quarter.

Many individual events in the National Electricity Market illustrate how rooftop solar volatility can drive price volatility, a few examples being:

- **South Australia, 13 Jan 2021:** a thicker-than-forecast cloud band over Adelaide cut PV output by ~420–500 MW in under 30 minutes, triggering a wholesale price increase [41] [42]
- **Victoria, 22 Feb 2024:** smoke from bushfires led to a massive drop of rooftop solar PV generation, leading to a price spike and increased FCAS costs [37]
- **NSW, 29 Feb 2024:** a spike in demand is primarily attributed to an unexpected drop in rooftop solar PV generation, contributing to massive price spikes exceeding AU$14,000/MWh [36]
- **NSW, 7 Nov 2024:** cloud bands passing over population centres in NSW lead to sudden unexpected generation drops, leading to sustained price spikes of over AU$13,000 / MWh
- **NSW, 27 Nov 2025:** Average price in NSW had been $77/MWh the previous month – but on this day, unexpected cloud cover set the price soaring to $20,300 at 11:00am, before crashing to negative $1,000 one hour later – a new volatility record for the Australian energy market [44]"

These events are becoming more and more common, primarily due to increasing levels of rooftop solar and more unpredictable energy patterns.

A band of clouds passing over New South Wales on 7 November 2024 contributed to major, sustained wholesale energy market price spikes.



The Solar Forecasting Opportunity

The Australian wholesale electricity market is fundamentally event-driven. Prices remain moderate or negative for much of the day, and then swing sharply during short intervals when demand, weather, renewable variability, and network constraints interact. As documented repeatedly in AEMO's Quarterly Energy Dynamics reports, a small number of high-price intervals often account for the majority of generator and retailer profitability in a quarter.

To provide one example, in a recent analysis it was demonstrated that battery energy storage systems obtained 36% of their annual revenue in only 7 days, i.e. 2%, of the year. In Australia, this would imply that about one third of total trading value is exchanged during price spikes, i.e. on the order of AU$8 Billion.

While solar is not the only driver of price spikes, its influence is increasing rapidly as both utility-scale and rooftop solar expand. Weather-driven fluctuations in solar output now contribute meaningfully to the timing and magnitude of high-price events.

If better solar forecasting improves a trader's ability to predict even 10% of these high-value intervals, the annual value at stake in Australia is plausibly in the **hundreds of millions of dollars**.

International evidence reinforces this conclusion. In the Belgian market, traders have reported €1–2 million losses from a single price-spike event when renewable output was forecasted incorrectly. Similarly, a study of the German intraday market showed that perfect intraday forecasts of variable renewable generation could increase trading profits by an order of magnitude — from €200,000 to €2 million for hourly products [24].

While no single number universally quantifies the value of solar forecasting for energy traders, the underlying relationship is clear: as solar penetration rises, the financial returns to forecasting accuracy rise alongside it. For consistency with the solar farm and VPP cases, we therefore assume a value of ≈ AU$5.11 per MWh of solar generation associated with improved forecast skill.

Applying this value to global solar generation implies a total addressable market for energy traders of AU$16.7 Billion today, growing to AU$50 Billion by 2030.

3.4 Summary of the Solar Forecasting Opportunity

The preceding sections have quantified the global opportunity for accurate solar energy forecasts as follows (all values in AU$, per year):

	2025	2030
Solar Farm and Battery Operators	$9.5 Billion	> $30 Billion
Virtual Power Plants	$0.7 Billion	> $2 Billion
Energy Traders	$16.7 Billion	> $50 Billion

The above does not include several additional important market segments, including network operators and energy market operators, for whom the value of improved solar forecasts is also immense. For example, in the UK it was recently confirmed that more accurate solar forecasts were helping the National Energy System Operator avoid an estimated £30 Million (AU$60 Million) in imbalance costs per year [25].

This suggests broadly a global solar forecasting opportunity by 2030 on the order of AU$80 Billion per year or more, growing quickly in line with accelerating global solar energy growth.

4.

The Data and Technology Revolution Enabling the Solar Transition

A wave of new technologies now underpins the smarter integration of solar energy into our electricity networks. Driven by advances in hardware, AI, and communications, they are turning solar from a variable and opaque resource into one that can be measured, predicted and managed — a prerequisite for ongoing significant solar energy integration. **Five technology pillars are driving this shift.**

4.1 Overhead Imagery & Computer Vision

Capturing images of the ground from above has long been possible, but today's aerial imaging programs have leapt ahead. Large-format digital cameras and streamlined photogrammetry now produce true-ortho mosaics — precisely aligned, high-resolution images with minimal distortion. Commercial providers routinely deliver refreshed coverage, often reaching 7.5 cm per pixel, across broad geographies with expanding footprints. Urban areas may be rescanned monthly, while regional areas may be updated quarterly.

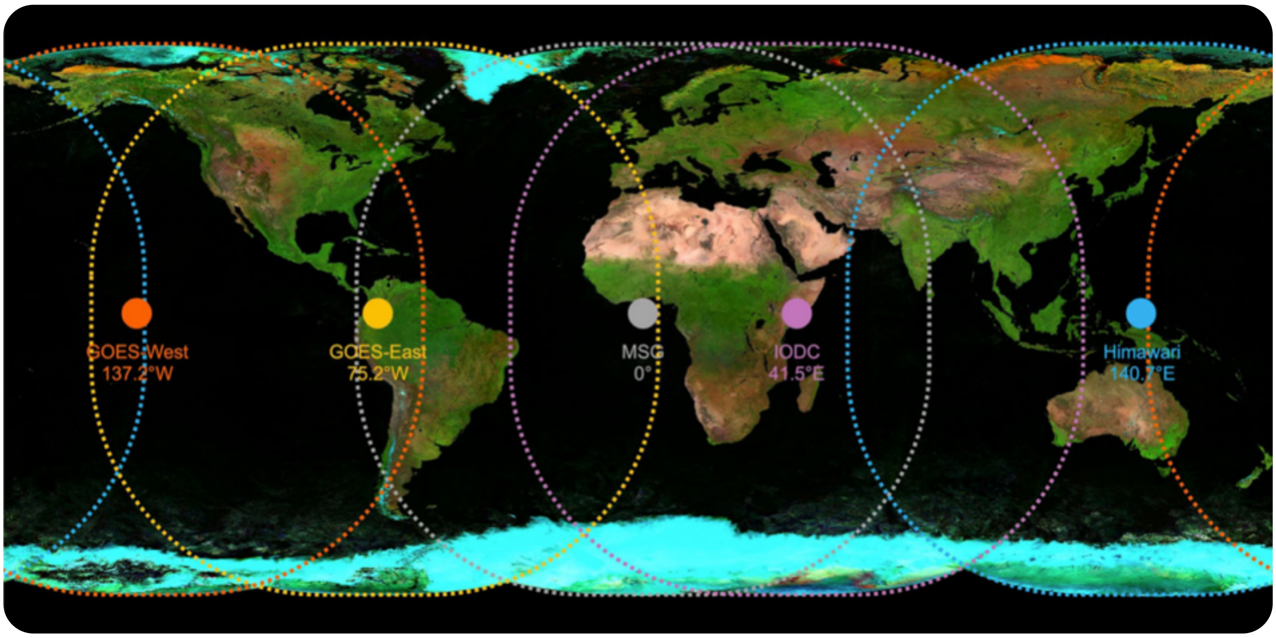
These advances mean that **vast regions can now be scanned for the presence of solar PV panels**. While official databases (such as the DER and CER registers in Australia [26] [27]) exist, they are often incomplete or outdated due to manual data entry, which is inevitably error-prone. Overhead imagery, by contrast, provides an accurate, current, and spatially precise view of installed solar capacity. New AI-based computer vision techniques can now detect solar panels automatically — even distinguishing between different panel types and applications (e.g. electricity generation vs. water heating).

Several commercial imagery providers already offer solar identification as part of their analytics platforms. Even when they don't, these datasets can readily be processed using AI-based detection models.

We can now find and quantify solar generation capacity with a level of accuracy that was previously impossible.

Example: *Overhead imagery and automated identification of solar panels (blue)*

In a pilot project with a European utility, Solstice AI used overhead imagery to identify solar PV installations across a region of interest. The analysis revealed **six times more installed capacity** than local government records indicated — a striking difference with major implications for solar planning and energy management strategies [40].



Global coverage by five geostationary satellites. Image adapted from [28].

4.2 Satellite Observation

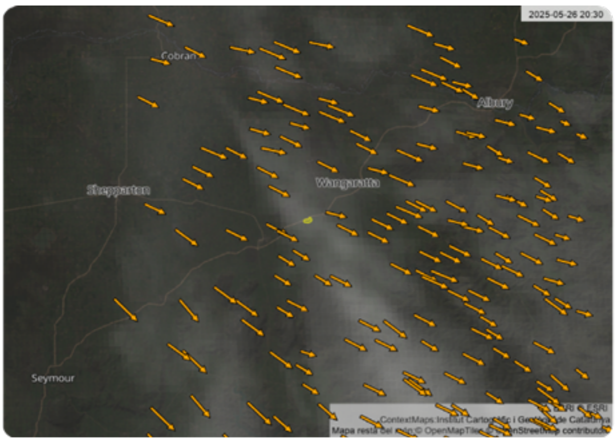
Satellite imagery has become one of the most powerful sources of information for understanding solar generation at scale — and its value is increasing rapidly. The latest generation of geostationary weather satellites now provides imagery at 1–2 km spatial resolution, refreshed every 5 to 10 minutes. This represents a major improvement over earlier systems and, crucially, offers update rates far faster than numerical weather prediction models, which typically refresh every 1–6 hours.

For short-term solar forecasting — where cloud motion over tens of kilometres can change output dramatically — this high-frequency visibility is transformative.

Even more importantly, today's satellites capture multiple spectral bands of data, including visible, infrared, and near-infrared wavelengths. These channels allow us to infer cloud height, thickness, temperature, and moisture content — key determinants of how much sunlight will reach solar panels on the ground. Yet much of this information remains under-utilised. Historically, forecasting systems have drawn only partially on the richness of satellite data, often simplifying it into broad cloud-cover classifications.

This is now changing. A vibrant wave of research and new satellite missions — including next-generation Himawari (Asia-Pacific), GOES (Americas), MTG (EU & Africa), and high-resolution commercial constellations — is expanding both the quality and frequency of Earth observation. Combined with modern AI techniques (see Section 4.3), we can now extract far more structure and predictive insight from these multi-spectral datasets.

The result is the ability to model cloud dynamics with greater precision — delivering more accurate, more localised, and more responsive solar forecasts across entire regions.



Example of how cloud movement can be detected using advanced computational techniques. ***Source:*** *Solstice AI.*

4.3 Artificial Intelligence

Artificial intelligence has advanced rapidly in just the past few years. Modern deep learning models can now process extremely large datasets, recognise subtle spatial and temporal patterns, and learn which parts of a sequence carry the most predictive value. This capability is particularly important for interpreting satellite imagery, where cloud systems evolve continuously across space and time.

Forecasting solar generation from satellite data is fundamentally an AI challenge known as motion prediction — the task of predicting future frames in a sequence. This field has been pushed forward significantly by research in other domains, such as autonomous vehicles, where AI systems must anticipate how the scene ahead will change moment-by-moment. The same techniques can now be applied to satellite imagery: **AI models can learn to forecast how clouds will move, form, dissipate, or thicken in the near future.**

Critically, these models can learn local behaviour — how clouds and irradiance patterns evolve in the specific region being forecast. Weather is shaped by unique geographic influences: coastlines, mountain ranges, sea breezes, inland heating, humidity corridors, and river valleys can all produce distinct cloud patterns that recur daily or seasonally. **By training on data from the region of interest, AI systems learn these local signatures directly, rather than relying on generalised assumptions.**

The result is forecasting that is more accurate, more adaptive, and more regionally informed — particularly over the short-term operational window (minutes to hours ahead) where most of the economic and reliability value sits for solar farms, VPP operators, and energy traders.

4.4 Real-time Data at Scale

The shift to distributed energy has created vast new streams of real-time data. Modern inverters report voltage, current, and power output at high frequency. Smart meters provide export and consumption profiles. Sky-facing cameras monitor cloud cover at rooftop or substation scale. Weather stations, irradiance sensors, and network telemetry feed continuous measurements into control systems.

However, this data is highly fragmented — spread across thousands of devices, brands, and communication protocols. Historically, limited interoperability made it difficult to use these signals effectively for forecasting or optimisation.

That is now changing. Standardised telemetry APIs, improved inverter connectivity, and scalable cloud infrastructure make it possible to aggregate and analyse these data streams in real time.

With access to true generation ground truth — not just theoretical output — forecasting models can continuously learn and recalibrate, improving performance over time and adapting to seasonal and operational changes.

This real-time data layer closes the loop between observation and prediction — enabling a continuously improving, self-correcting forecasting ecosystem.

Individual data sources can be used to infer solar generation across broad regions – together with, or without, satellite imagery. ***Source:*** *Solstice AI.*

4.5 Novel Forecasting Approaches

The technologies outlined above enable a new class of forecasting methods that do not rely on a single data source or model philosophy, but instead combine the strengths of each:

- Overhead imagery provides accurate, spatially resolved estimates of installed solar capacity.
- Satellite data offers continuous visibility into cloud dynamics across wide geographic areas.
- AI models learn region-specific patterns of cloud formation and movement.
- Ground-based data streams supply real-time calibration signals and performance feedback.

Forecasting approaches that integrate these data layers can achieve significant accuracy improvements, particularly in the critical operational window of 5 minutes to 6 hours ahead, where most economic and system value lies. They also provide resilience to data dropouts: satellites periodically undergo maintenance, and ground-based sensors may lose connectivity.

Forecasting systems that draw from multiple, complementary sources maintain stable performance even when individual feeds are temporarily unavailable.

These new hybrid forecasting architectures enable more confident market bidding, reduced curtailment, smoother battery dispatch, and more stable grid operation. They are transforming solar from a variable resource into a predictable and manageable component of the energy system — a foundational requirement for reaching ultra-high renewable penetration.

5.

Australia as a Living Laboratory

Australia is one of the world's most advanced testbeds for high-penetration solar and distributed energy. With the highest per-capita uptake of rooftop PV globally [29], solar has become not just a component of the electricity system, but a defining feature of how the system behaves day-to-day. Entire suburbs now routinely export more energy than they consume, and in some regions, rooftop PV alone can meet over 100% of local demand at certain times of the day.

At the same time, Australia is rapidly evolving new models for coordinating distributed energy. In 2024, Australia was ranked #1 globally in the Virtual Power Plant (VPP) Readiness Index published by Blunomy [30], reflecting its VPP resource availability, flexibility needs, market attractiveness, regulatory environment, and grid readiness. VPP operators, energy retailers, distribution networks, and technology providers are actively experimenting with new approaches to coordinated solar, battery storage, and demand response — at commercial scale.

This environment is not an accident. Australia's grid is:

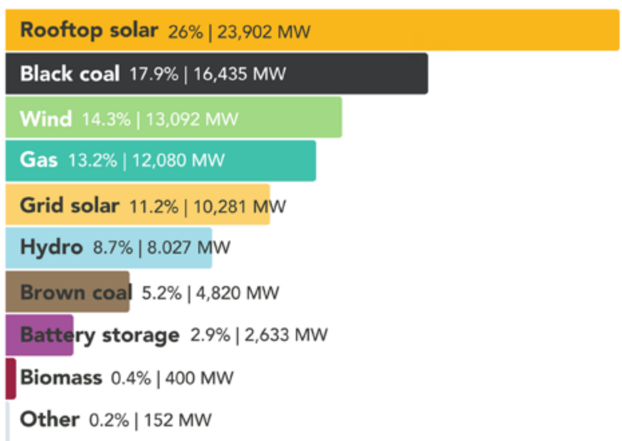
- **Large enough** to demonstrate meaningful operational challenges and solutions
- **Small enough** that new ideas can be deployed and validated quickly
- **Diverse enough** to test performance across climate zones, urban conditions, and network types
- **Open enough** that innovation can meaningfully influence market behaviour

This makes Australia a living laboratory for the future of solar-dominated grids. Innovations developed and validated here — from forecasting algorithms, to inverter control standards, to market participation models — are increasingly being exported to Europe, North America, and the broader Asia-Pacific region, where rooftop PV adoption and renewable penetration are now following similar exponential trajectories.

In short, Australia is solving tomorrow's energy problems today. As global grids move toward higher shares of solar and distributed energy, the insights, technologies, and operating models proven here will define how the next wave of renewable integration unfolds worldwide.

Generation capacity

By fuel type in FY25



Generation capacity by fuel type in Australia's National Electricity Market [23].

6.

Conclusion – Intelligence Enables Growth

Solar will define the future of electricity. Its economics, scalability, and speed of deployment make its continued growth inevitable. The key challenge is no longer how to generate solar energy, but how to integrate it — reliably, profitably, and at scale.

As solar reaches 30–50% of supply in many regions, the energy system becomes more weather-driven. Forecasting, real-time visibility, and coordinated control shift from supporting functions to essential grid capabilities. Every percentage improvement in accuracy reduces curtailment, improves market outcomes, strengthens network resilience, and enables higher renewable penetration.

The technologies to solve this challenge are now emerging: high-resolution satellite imagery, automated solar capacity detection, real-time inverter telemetry, and AI systems capable of learning local cloud formation and movement. Together, they enable solar to become highly predictable, not just variable.

Australia is demonstrating what this future looks like. Other markets will follow — and quickly.

At Solstice AI, our mission is to provide the intelligence layer for a solar-dominated world. By turning distributed data into foresight and coordinated action, we are helping energy systems everywhere unlock the **Great Solar Opportunity**.

About SOLSTICE AI

Solstice AI is an Australian technology company building the intelligence layer for a solar-dominated energy system. Headquartered in Melbourne, Australia, the company combines expertise in artificial intelligence, energy systems, and large-scale software engineering to deliver high-accuracy solar generation forecasts across utility-scale assets, distributed rooftop PV, and for entire regions.

The Solstice AI platform fuses multi-spectral satellite imagery, real-time device telemetry, and advanced machine-learning models that learn region-specific cloud formation and movement. This hybrid approach provides superior short-term forecasting accuracy compared to traditional numerical weather prediction methods — enabling better bidding decisions, improved VPP performance, and more stable grid operation.

Solstice AI works with solar asset owners, virtual power plant operators, and energy traders to help them navigate increasingly weather-driven electricity markets. By turning distributed energy data into foresight and coordinated action, Solstice AI is helping energy systems unlock the full value of the solar transition.

Solstice AI cofounders Peter Ilfrich (CTO) and Julian de Hoog (CEO).

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