14.01.2026

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Hybrid Solar for Resilient Power Systems

IFE Energi

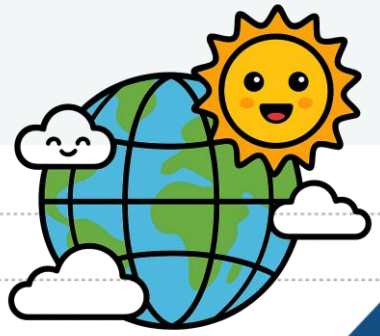
2025

Josefine Selj

Principal Scientist, IFE



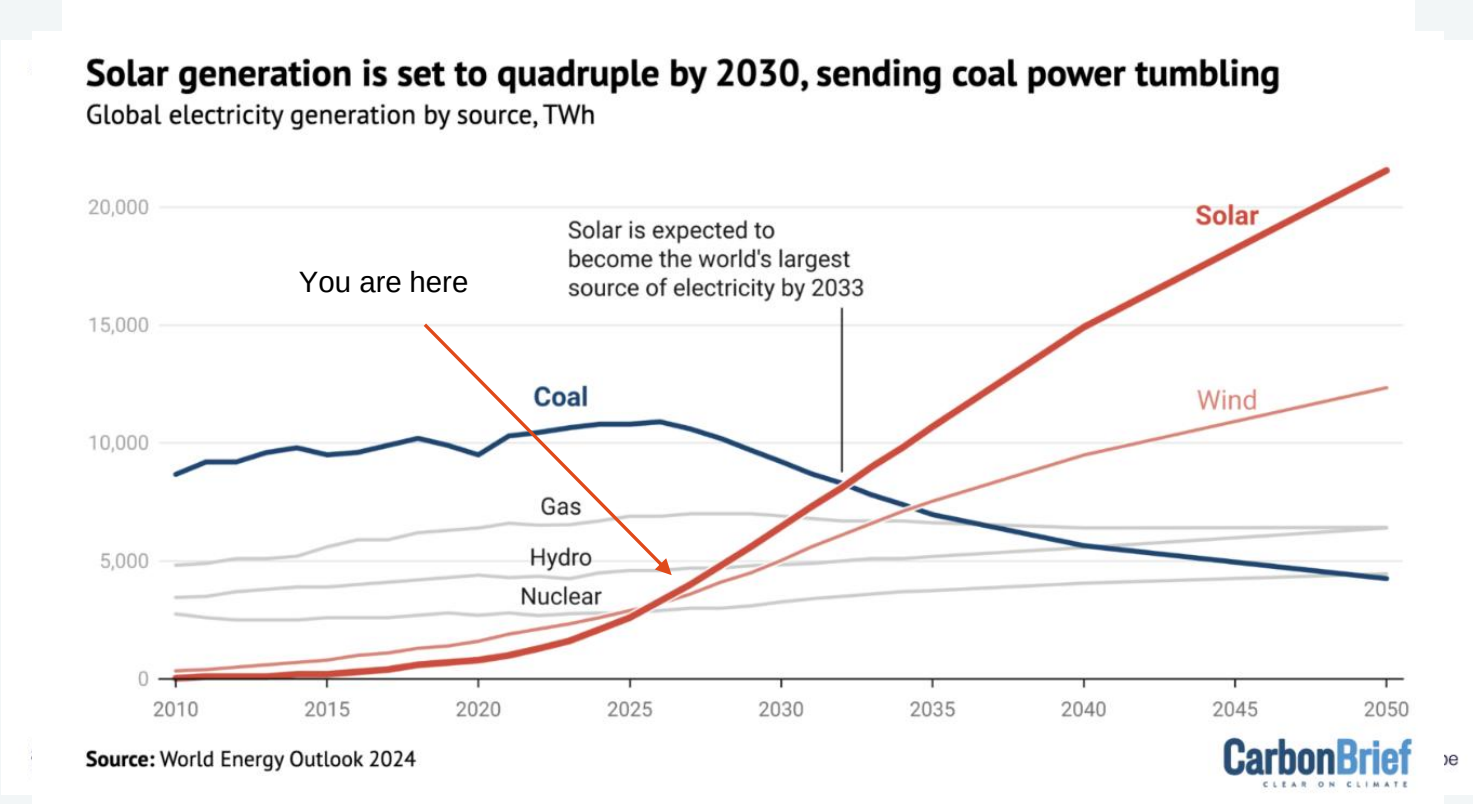
Evolution of **Global Solar Power** installations



Source: *IEA PVPS Trends 2025*

Solar is the cheapest electricity in history

- «Investment in solar PV now surpasses all other generation technologies **combined**»
- Annual installation rates are (**insanely!**) high
- Capacity Additions by 2030:
  - Renewables: ~ 4 600 GW
  - Solar PV: ~ 3 800 GW
- By 2030, ***variable*** renewables will generate almost 30% of global electricity supply, double today's level
- Solar is expected to become the largest source of electricity by 2033



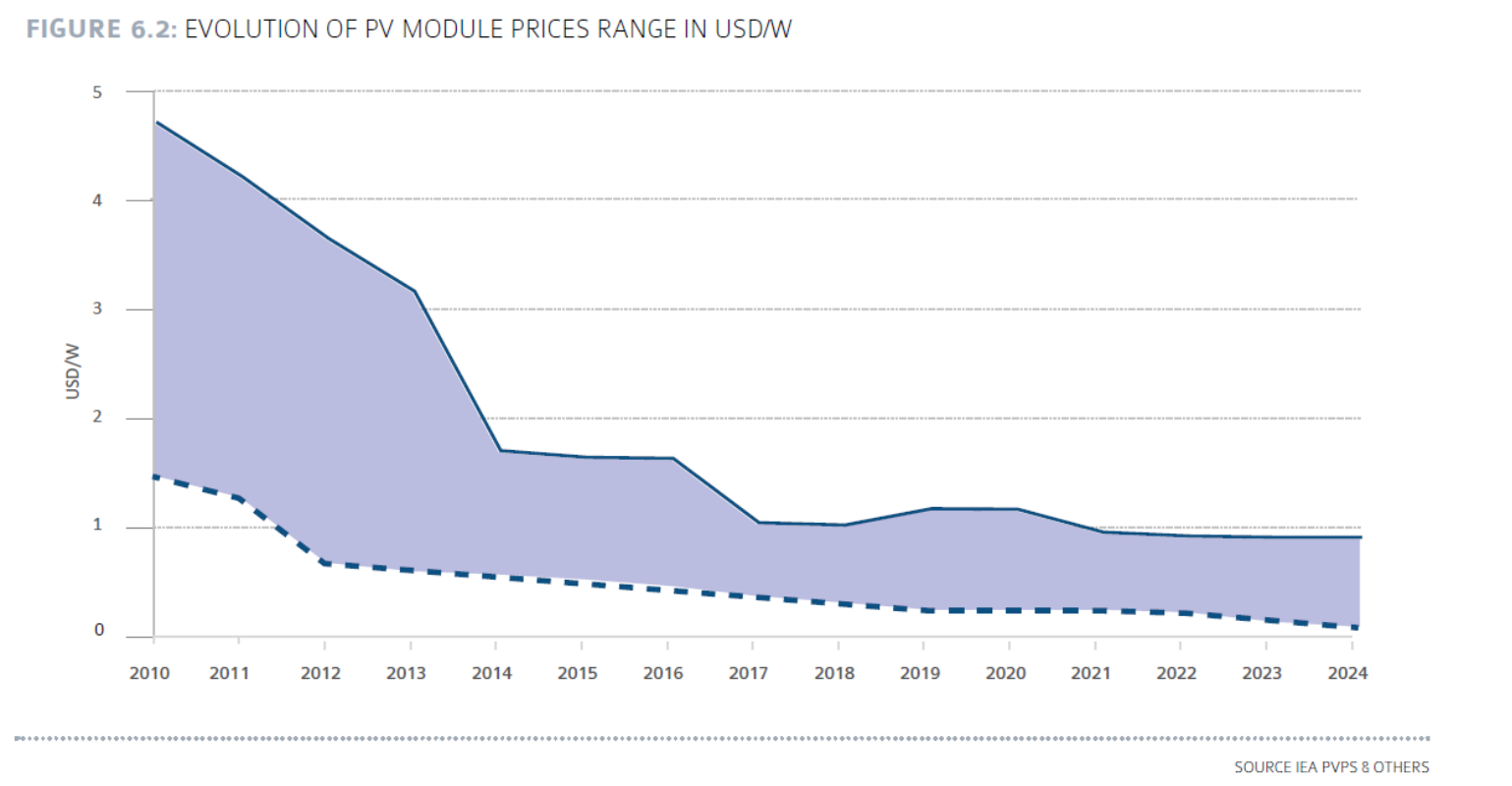
Sources: *IEA Renewables 2025, Solar Power Europe Global Market Outlook 2025, IEA forecast/SPE mid scenario: ~ 3700 – 3 900 GW*

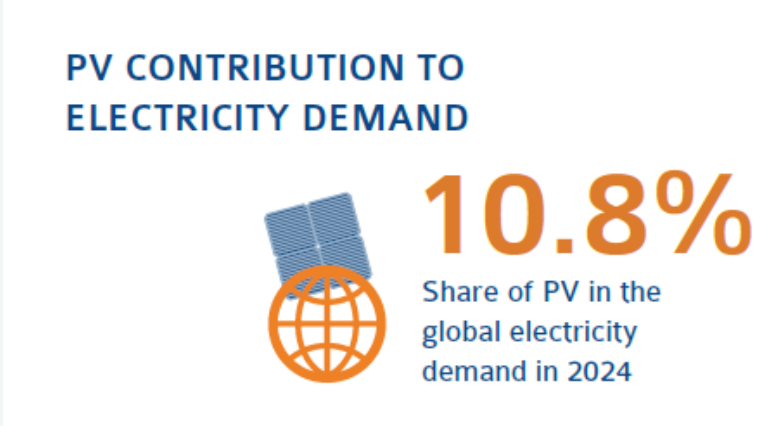
Solar Power Systems Level 1

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Main challenge: Decrease costs by increasing volume, manufacturing throughput & efficiency

Level 1 Goal: Make PV a mainstream energy production technology





The job on Level 1 is done!

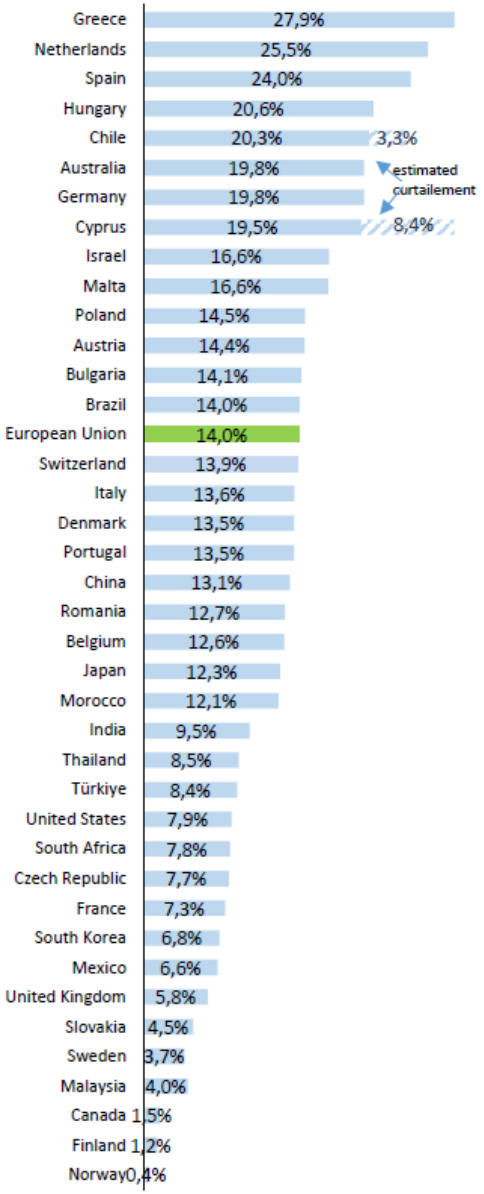
Solar Power Systems Level 2 –

solve the new challenges for secure energy supply in high penetration markets

Sources: *IEA PVPS*

High penetration power markets

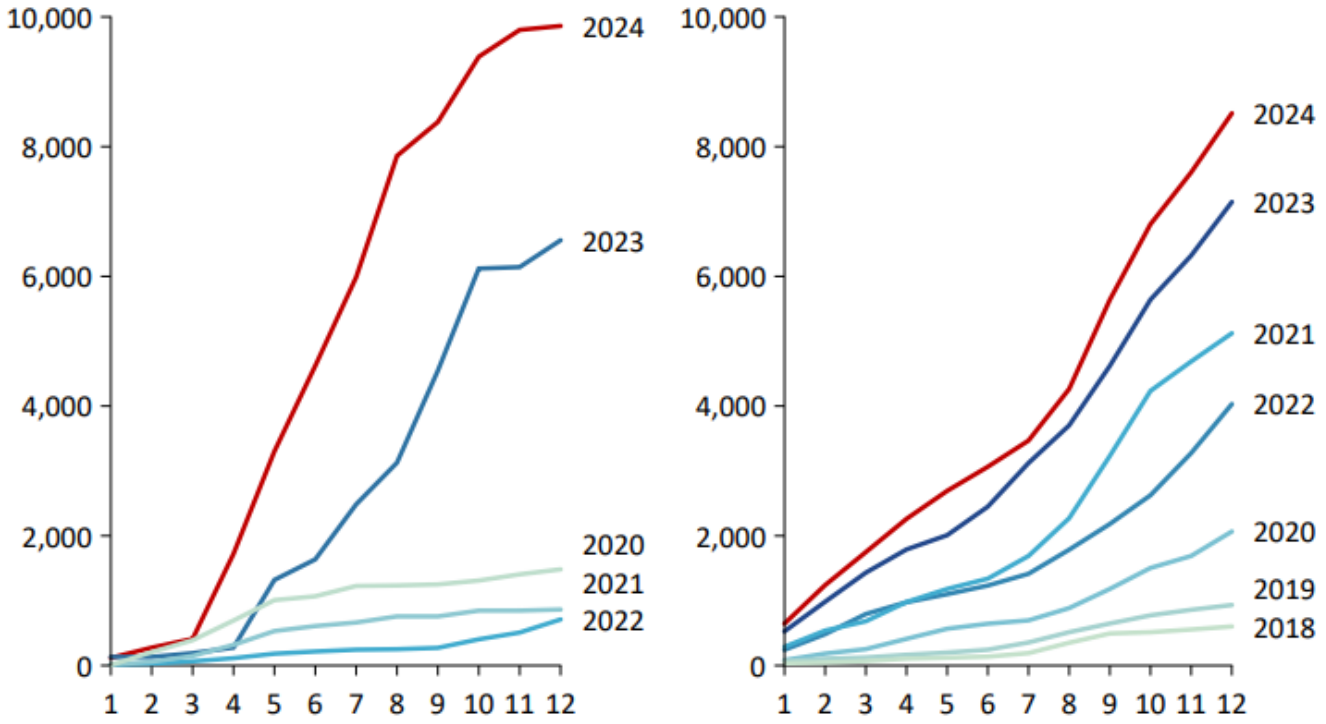
FIGURE 8: THEORETICAL PV PENETRATION 2024



Source : IEA PVPS

Number of hours with negative prices in Europe (left) and Australia (right)*

Number of hours



*Across all power markets in Europe and Australia, respectively. Since the number of power markets across the two regions are different, the two charts are not directly comparable

Source: Rystad Energy Renewables & Power Solution

Sources: *IEA PVPS Snapshot 2025, Solar Power Europe EU Solar Market Outlook 2025-2030, Rystad Energy Renewables & Power Solution*

High penetration power grids - “No transition without transmission”

- **Insufficient and old grid infrastructure:**
  - Significant increase in investments needed
    - Modernization of **distribution networks**
    - Doubling of cross-border **transmission capacity**
- **Grid connection queues. 1000 - 1700 GW** of RES capacity awaiting grid connection approval just in in *Europe*.
- **Insufficient flexibility** to facilitate integration of variable renewables.
- **Insufficient grid stability services** from the “new” dominating power sources (black-start & intertia)

Grid stability feature	Hydropower and fossil assets – Traditional Synchronous Generator	Grid-Forming Inverter – Mostly via batteries
Frequency regulation	**Yes.** Ramping up/down generation	**Yes.** Ramping up/down injection, also fast regulation
Voltage control	**Yes.** Inherent	**Yes.** Inherent by actively controlling reactive power
Inertia	**Yes.** Rotating turbines naturally create and respond to stabilise voltage and frequency	**Yes.** Specifically designed control algorithms to provide the behaviour of an inertial voltage source at the inverter’s output
Black start capability	**Depends, often yes.**	**Yes.** Limited by energy availability.

Historic European grid investments vs. projected required level

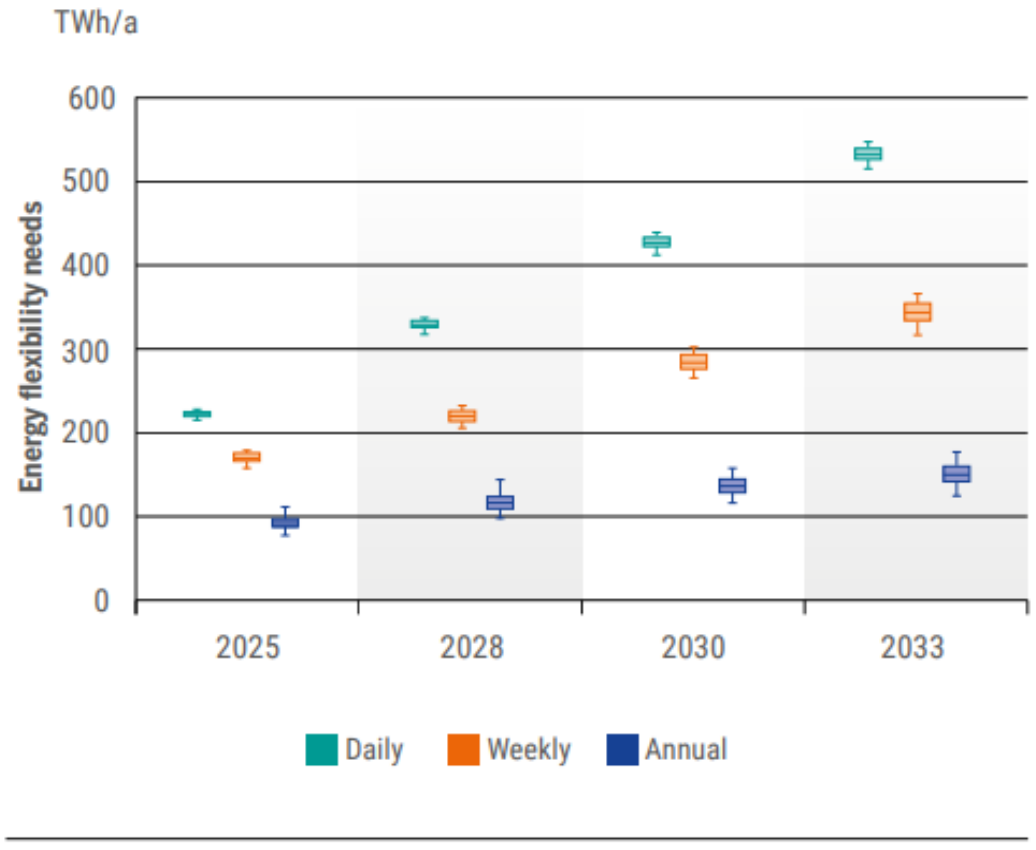


Figure 7: Evolution of annual European flexibility energy needs from 2025 to 2033

Sources: *IEA grid report 2023, Aurora Energy Research and its 2026 European Renewables Market Overview Report (RESMOR), E3G report, EU Grid Action Plan, ENTSO-E Report 2024 System Flexibility Needs for the Energy Transition*

New requirements for secure energy supply

– Energy security is no longer just about profitability, supply and supply chains:



Reliable supply chains



Resilience



Flexibility

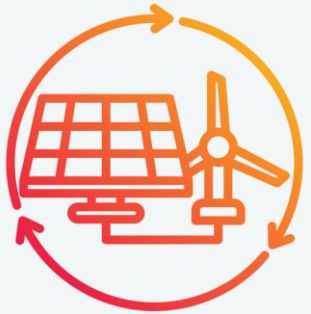


Cybersecurity

Source Icons: IEA Renewables 2025, uniconlabs

Solar Power Systems Level 2 – Hybridization & storage

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- A hybrid power plant is any combination of production and/or storage technologies behind the same conection point (if it is not behind the same connection point, it is often called «co-located»)
- Improves the market conditions and profitability for all VRE power plants by increasing flexibility, and better exploitation of land and grid/infrastructure
- Improves the economy and feasibility in high-penetration markets on *individual plant level*

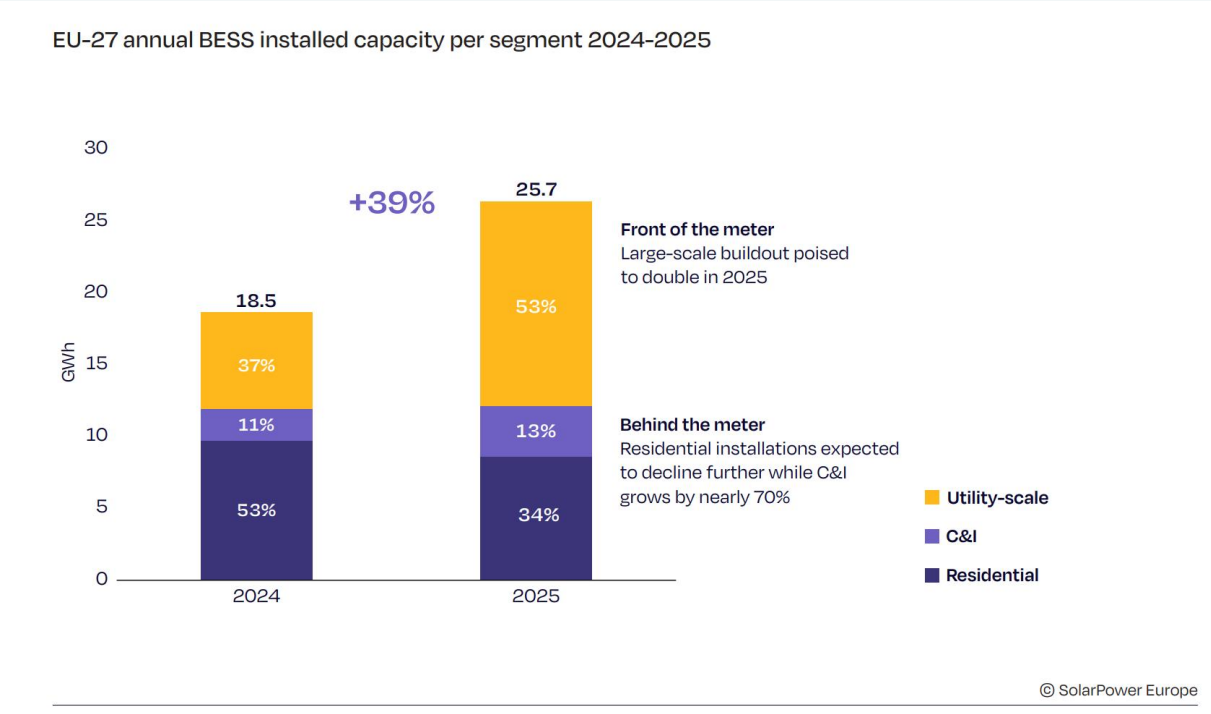
Benefits of hybrid power plants

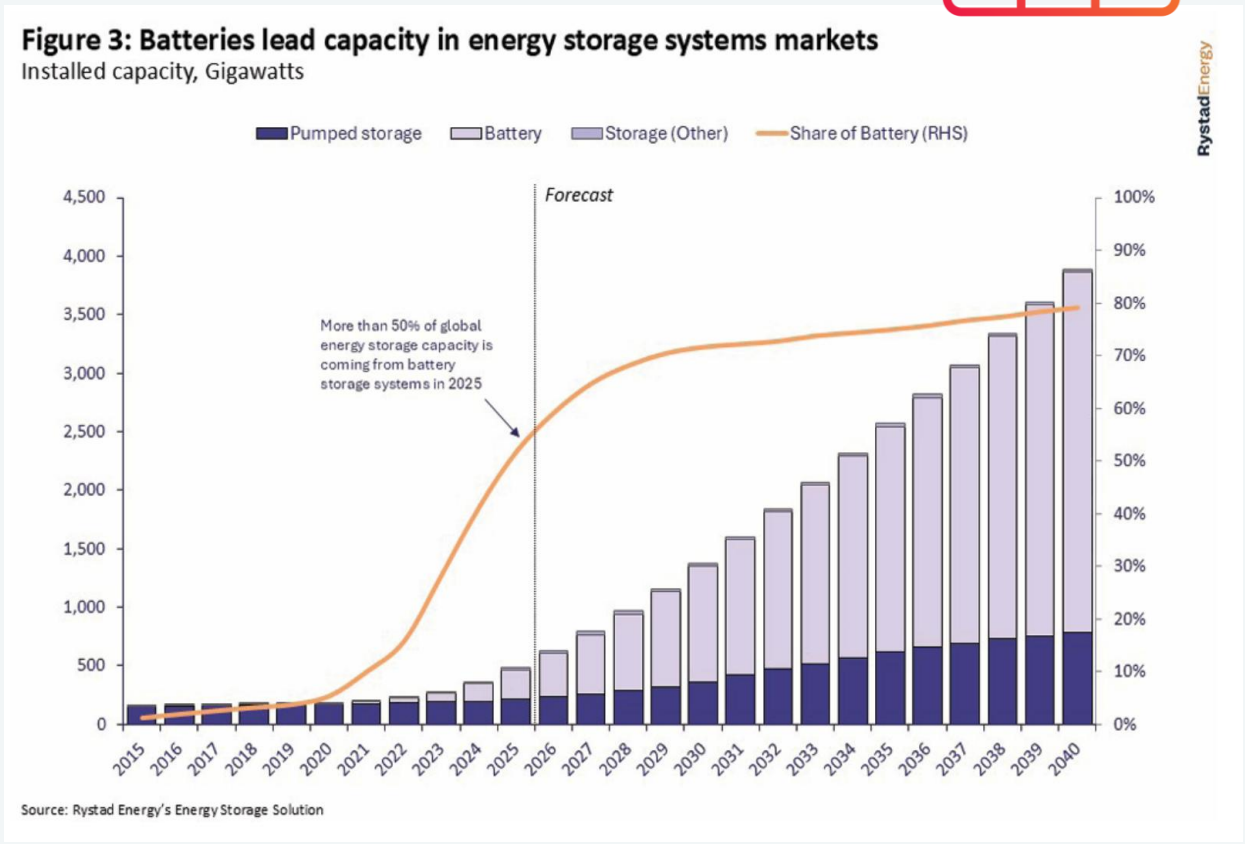
Access to grid	Facilitated grid integration due to smoother and more predictable power production More effective grid utilization by combining complementary production profiles More reliable grid operation by supplying grid services (with BESS)
Profitability	Reduced CAPEX through shared electrical and physical infrastructure Reduced OPEX due to synergistic design and operation Reduced DEVEX in retrofit projects Increased revenue by enabled participation in multiple electricity markets
Access to area	More efficient land use More efficient use of existing grid lines

Sources: Embracing the benefits if hybrid PV systems for Europes energy transition. Solar Power Europe 2025

Solar Power Systems Level 2 – Hybridization & storage

- Battery pack prices for stationary storage fell to $70/kWh in 2025, a 45% decrease from 2024





Source: Bloomberg New Energy Finance, PV Magazine, Rystad Energy

Examples: Solar & BESS providing firm power

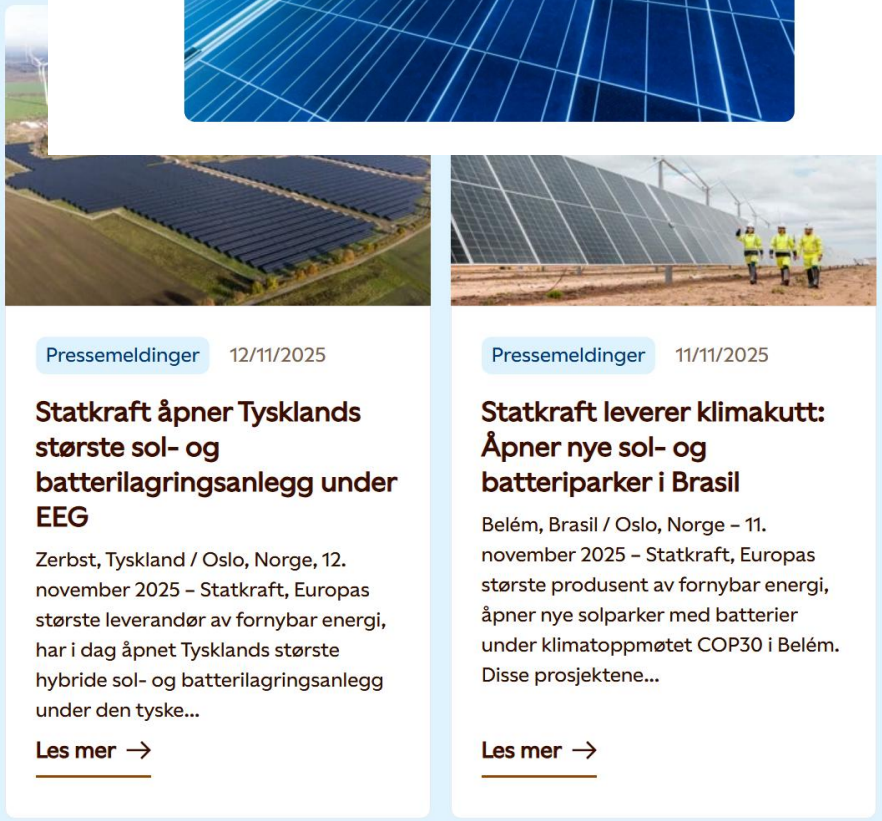
- Solar & BESS for continuous, around-the-clock renewable baseload power
  - Kenhardt - 150 MW of dispatchable power from 5 am to 9.30 pm year-round, in operation from 2023
  - 1.1 GW Obelisk solar and 100 MW/200 MWh battery storage project in Egypt (under construction)



Scatec signs landmark PPA in Egypt for 1.95 GW Solar and 3.9 GWh BESS capacity

January 11, 2026 | Stock exchange notice





Pressemeldinger 12/11/2025

Statkraft åpner Tysklands største sol- og batterilagringsanlegg under EEG

Zerbst, Tyskland / Oslo, Norge, 12. november 2025 – Statkraft, Europas største leverandør av fornybar energi, har i dag åpnet Tysklands største hybride sol- og batterilagringsanlegg under den tyske...

Les mer →

Pressemeldinger 11/11/2025

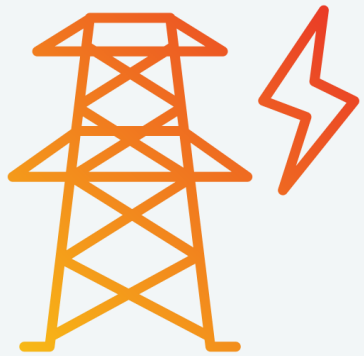
Statkraft leverer klimakutt: Åpner nye sol- og batteriparker i Brasil

Belém, Brasil / Oslo, Norge – 11. november 2025 – Statkraft, Europas største produsent av fornybar energi, åpner nye solparker med batterier under klimatoppmøtet COP30 i Belém. Disse prosjektene...

Les mer →

Solar Power Systems Level 2 – Grid Services

- Advances in battery and power electronics technologies enable renewable technologies to provide cost-effective alternatives for grid-stability services
- Grid-following (GFL) inverters can provide «basic» services like Fast Frequency Reserves – well established in many markets
- Grid-forming (GFM) inverters are designed to function like traditional synchronous generators
- Batteries with grid-forming inverters are already deployed at scale in regions like the UK, Germany, Australia and parts of the U.S., solar PV with (and without BESS) grid-forming functions are not available today.



	Hydropower and fossil assets	PV-only	PV + storage	Standalone batteries
Transmission grid	Technology is commercially available	Technology is not mature	Technology is available	Technology is commercially available
Distribution grid	Technology is available			Technology is available

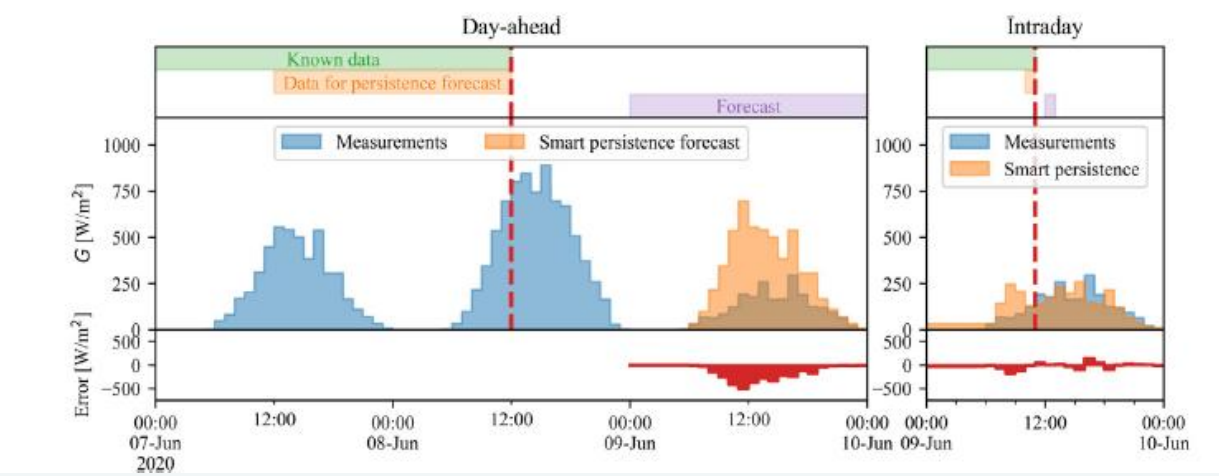
Table 1: Technology-readiness of grid-forming functionalities at different voltage levels and technologies.

Sources: *Solar Power Europe and Battery Storage Europe Platform Grid Stability 2.0*

Solar Power Systems Level 2 – Digitalization

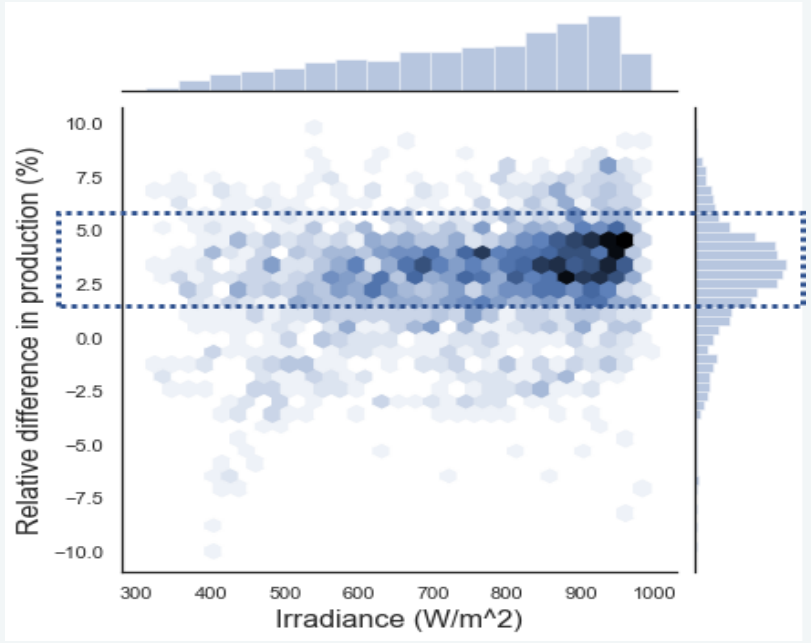
- The renewable-energy dominated energy system is variable, distributed, data-intensive and complex.
- Digital technologies will be key for reliability, flexibility, security & profit – for the individual power plant & for the power system
- A couple of examples:

Forecasting and market operations



"The value of forecasts for PV power plants operating in the past, present and future Scandinavian energy markets", Øyvind Sommer Klyve, Magnus Moe Nygård, Heine Nygard Riise, Jonathan Fagerström and Erik Stensrud Marstein, **Solar Energy 2023**

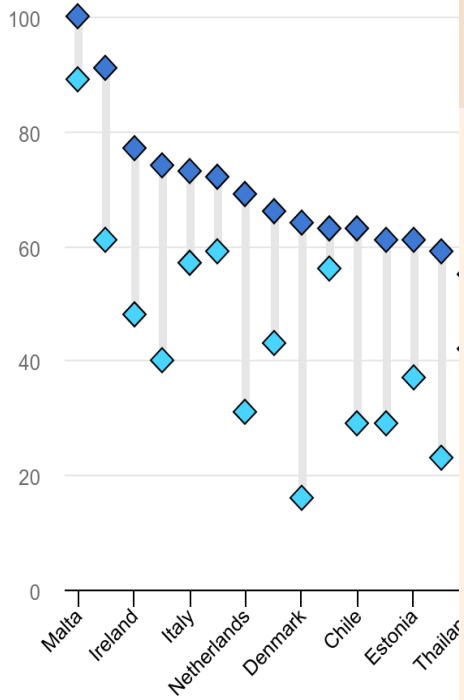
Performance analysis



"Cooling of floating PV and the importance of water temperature", Torunn Kjeldstad, Dag Lindholm, Erik Stensrud Marstein and Josefine Selj,**Solar Energy 2021**

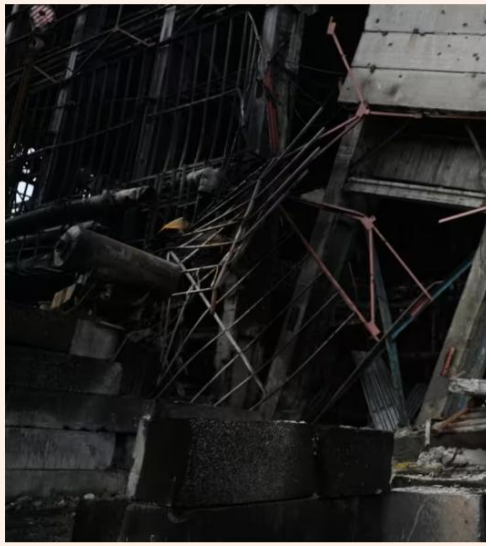
Solar Power Systems Level 2 – Supply chains, distribution & diversification

- Reduced dependence on import of fossile fules
- Distribution & Diversification



Ukraine's wartime batte

Grid-level storage takes off as energy system



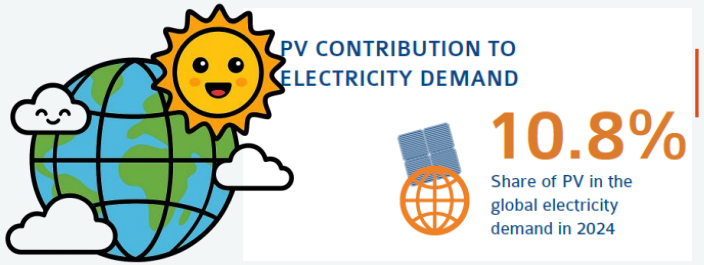
Damage at a power plant run by Ukrainian energy compa
battery storage is surging as Ukraine aims to build greate

A Multi-Layered Market Boom: Utility, Commercial, and Home Fronts

The market's response has been rapid and multi-faceted, developing on three distinct fronts:

1. **Utility-Scale: Rebuilding the Grid's Backbone.** The strategic response is ***large-scale storage***. Following the successful deployment of Eastern Europe's largest battery system (200MW/400MWh), Ukraine has set ambitious national targets. The goal is to deploy **1.5 Gigawatts of storage capacity by the end of 2026**. These grid-scale batteries are essential for stabilizing the fragile network, integrating renewable energy, and replacing lost flexible generation capacity—a cornerstone for long-term reconstruction.
2. **Commercial & Industrial: The Economics of Resilience.** For businesses, the equation blends survival with savvy economics. Prolonged outages threaten operations, while volatile energy prices squeeze margins. Installing storage allows a factory to avoid peak tariffs and keep critical lines running during grid outages. The business case is compelling, with analyses showing **payback periods as short as 2.5-3 years** for well-designed systems. This segment represents a massive opportunity, with an estimated annual potential of **300 MW** —a clear signal that resilience is also a sound investment.
3. **Residential: Power to the People.** The most poignant transformation is in homes. Across the country, Ukrainians are taking power into their own hands—literally. The installation of rooftop solar panels coupled with ***battery storage*** has skyrocketed, with year-on-year growth exceeding 300%. This decentralized wave is building a more resilient, democratic energy system from the bottom up, reducing strain on the central grid and empowering communities.

Solar Power Level 1 – cheap, abundant electricity



The new challenges:


Flexibility

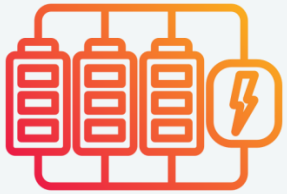

Resilience


Cyber security


Supply chains

Solar Power Level 2 – secure electricity supply in a solar dominated power system


Hybridization


Storage


Grid-services


Digitalization


Distribution &
diversification


Reduced fuel
dependence

Source Icons: uniconlabs

Thank you for the attention!

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