Embracing the benefits of hybrid PV systems

for Europe's energy transition

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Foreword

Europe stands at a pivotal moment in its energy transition. As it becomes increasingly clear that our decarbonisation goals will be instrumental to guarantee energy security in the EU, the Clean Industrial Deal and associated initiatives, such as the EU Grid Package, the Affordable Energy Action Plan, and the Flexibility Strategy, mark significant steps toward a more resilient and sustainable energy system.

Contrary to popular belief, most of the technologies we need to achieve those objectives are readily available today. Using them in innovative ways is the next step to maximise their impact and value.

Hybrid solar systems —combining solar photovoltaic (PV) with battery energy storage or wind power— present a clear opportunity to do just that. By integrating complementary technologies within a single facility and grid access point, they maximise renewable energy generation, mitigate intermittency issues, and bolster grid stability. The capacity to store surplus solar energy and deploy it during peak demand periods, or to complement solar with wind generation, extends the availability of renewable electricity and reduces dependency on fossil-fuel-based backup power.

Yet, despite these clear benefits, policy and regulatory frameworks have yet to fully reflect the potential of hybrid solar systems. As is too often the case, innovative applications that do not fit the mould struggle to get the support they need. In a world that is rapidly changing, that needs to change too.

The European Commission and Member States must take decisive action to unlock the potential of hybrid renewable energy projects. This includes integrating hybrid PV into broader energy strategies, ensuring streamlined grid connection processes, accelerating permitting, and adapting support schemes to reflect the added value of hybridisation. The Commission should consider solutions to provide a much-needed framework to ensure hybrid solutions contribute effectively to our energy system. Additionally, addressing regulatory bottlenecks—such as restrictive market participation rules, inadequate support scheme design, and high grid connection fees—will be critical to fostering investment in hybrid renewables.

This report outlines key policy recommendations to advance hybrid solar deployment across Europe. It highlights best practices from leading Member States and offers a roadmap for overcoming existing barriers. By embracing hybrid PV systems, we can enhance Europe's energy security, drive industrial competitiveness, and accelerate the transition to a carbon-neutral future. The time to act is now, and I strongly urge policymakers, industry leaders, and stakeholders to work together in making hybrid solar a cornerstone of our energy strategy."

> *By embracing hybrid PV systems, we can enhance Europe's energy security, drive industrial competitiveness, and accelerate the transition to a carbon-neutral future.*

Bruno Tobback

Member of the European Parliament, S&D

SolarPower Europe Briefing Paper

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Executive Summary

Hybrid solar, combining solar with storage or wind, is key for Europe's energy transition. It supports system flexibility, improves the cost-effectiveness of an asset and makes energy generation more reliable. This is, however, not yet reflected in European or national policy frameworks. The EU plays a crucial role in integrating hybrid renewables in all of its energy policies, ensuring grid access points are used optimally.

Hybrid PV systems can be defined as the combination of technologies in the same facility and sharing a single grid connection access point. The most common combination of hybrid systems today is solar PV with battery energy storage systems (BESS), or with wind turbines. Both project structures offer numerous benefits to the energy system, electricity consumers and developers of renewable projects.

Hybrid solar projects with storage or wind enhances energy security by ensuring a more stable and reliable power supply. Storage allows surplus solar energy to be stored and used when demand is high or sunlight is low. Adding wind power complements solar generation, as wind often produces energy when solar output is low, for example at night or during winter. This increases the number of hours per year when renewables fulfil the EU's energy demand, substantially reducing the EU's reliance on fossil-based back-up plants.

Hybrid solar projects have surged in recent years. Since 2015, solar (PV) + batteries (BESS) represented 5% of total BESS additions across Europe. The UK leads in hybrid PV+BESS installations, representing 62% of total PV+BESS capacity, driven by strong policy support, market dynamics, and large-scale projects. Key factors include financial incentives like the Capacity Market and the Contract-for-Difference (CfD) schemes, streamlined permitting, and market reforms for BESS participation. In contrast, EU countries like Sweden (10%), Italy (8%), Germany (6%), Bulgaria (6%), and Denmark (5%) follow at a much lower level, with the rest of the EU-27 and Switzerland making up for only 3%. The market for PV+Wind is equally concentrated with Poland leading (277 MW), thanks to favourable policies and complementary generation patterns – though co-located setups, sharing the same connection point, regulations still need proper implementation. The Netherlands (150 MW), Portugal (78 MW), and Denmark (7% share) have also advanced, with the UK and the rest of Europe lagging behind with just 11 MW of PV+Wind. Overall, PV+Wind hybrid projects have yet to gain traction in Europe, with only 555 MW installed by the end of 2024—less than 1% of the utility-scale solar fleet.

The EU is far from exploiting the full potential of hybrid solar systems. Addressing existing bottlenecks today would significantly accelerate its development. To support this effort, this report outlines the benefits of hybrid PV, market trends, regulatory barriers and best practices from various European regions.

Summary of Policy Recommendations:

1. **The EU and its Member States should recognise hybrid solar systems as key contributors to the EU's energy security, competitiveness and decarbonisation goals, and integrate hybrid solar into grid planning, flexibility strategies, and funding mechanisms.** The EU is lacking a clear vision on energy storage. The European Commission should propose a Flexibility Package — including an Energy Storage Action Plan — to complement the EU Grid Package as announced under the Clean Industrial Deal. EU funding mechanisms should be opened to hybrid PV systems and unlock their benefits. To enable hybridisation, Member States must set ambitious flexibility and storage targets, integrate storage in their NECPs, and ensure flexibility needs assessments translate into concrete actions.

2. **Regulators and grid operators should improve grid connection procedures for hybrid PV.** They should do this by publishing grid hosting capacity maps to improve transparency and facilitate co-located setup at the same connection point, as seen in Denmark and Australia. Hybridisation of existing renewables projects which has not required an increase in injection capacity, should be prioritised in grid queues, where system needs have been clearly demonstrated, allowing better use of connection points. The EU should ensure that grid operators and asset operators can define grid connection capacity (Pmax) in private grid connection agreements to optimise hybrid system integration, following best practices from Spain and Austria. Electrical licensing for hybridisation of existing projects should be streamlined, to reduce administrative burdens, as demonstrated in Portugal. For entirely new hybrid projects, a joint licensing process should be applied. Digitalising grid connection systems can enhance transparency and coordination, simplifying modifications and shared connections. Meanwhile, a clear structure to manage the multiple entities behind the same connection point is needed. Italy, Spain and Poland offer relevant models for co-located situations on the same connection point.

3. **Member States should improve permitting for Hybrid PV by implementing the streamlined procedures in the 2023 Renewable Energy Directive (RED).** Hybridisation of existing projects should benefit from simpler approval processes, standardised one-stop-shop systems, and entirely new hybrid projects the ability to submit joint permitting requests for different assets under one grid connection. Renewable Acceleration Areas (RAAs) should support hybridisation, avoiding separate zones for solar and wind, as seen in Austria. Lessons from Bulgaria, Poland, Spain, and Austria highlight the need for clearer regulations for hybrid projects, faster approvals, and solutions to administrative bottlenecks.

4. **The EU and its Member States should ensure support schemes are adapted to hybrid PV projects.** Hybrid PV systems should have the opportunity to compete on equal terms with stand-alone PV in traditional renewable energy auctions, as is done in the United Kingdom. Member States can also de-risk hybrid projects by introducing CAPEX support for the battery, as seen in Spain, Portugal, and Bulgaria. Traditional injection-based CfDs do not incentivise hybridisation with energy storage, but a pay-as-produced design, with appropriate metering system would address this issue. Additionally, allowing batteries in Hybrid PV systems to participate freely in all electricity markets would optimise their usage and services to the system, but restrictive rules, such as in Germany and Portugal, currently hinder this potential. Finally, capacity market design should incorporate appropriate de-rating factors for hybrids, considering the actual duration of battery storage to ensure fair competition with other market participants.

5. **Grid tariffs need to be adapted to promote the decentralisation of energy systems and better integration of renewable energy sources with battery storage, addressing issues like high connection fees and double charging of storage assets.** Some countries, such as Denmark and the Netherlands, face challenges with high grid connection tariffs and barriers to battery storage deployment, which hinder the development of hybrid systems. A key recommendation is to eliminate double charging for storage, exempting co-located storage systems from such tariffs to create fairer market conditions and support the integration of renewable energy technologies.

6. **Hybrid renewable projects should receive Guarantees of Origin (GOs) for all renewable electricity they generate, whether directly injected into the grid or stored for later use, requiring an updated metering framework.** Current systems fail to track renewable energy flowing through storage, leading to gaps in GO certification. A more accurate method would be to issue GOs at time of generation, using the same metering approach as for pay-as-produced Contracts for Difference (CfDs), ensuring proper certification and supporting grid flexibility and decarbonisation.

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Definitions

Ancillary services: Services that help maintain the stability, reliability, and efficiency of the electricity grid. In the context of hybrid renewable projects, batteries (BESS), solar, and wind farms can provide ancillary services by helping regulate frequency, stabilising voltage, and offering backup power when needed.

Connection agreement: A contract between the relevant system operator and the power-generating facility owner, which includes the relevant site and specific technical requirements for the power-generating facility.

Connection point: AC electrical interface point where the power-generating facility is connected to a transmission or distribution system, as identified in the connection agreement or as agreed between the relevant system operator and the power-generating facility owner or determined by other appropriate means, where an agreement is not required;

De-rating factor: Performance metric reflecting the reduction in the expected capacity or performance of a given energy asset. It accounts for various conditions that can cause the system to perform below its maximum theoretical capacity. The de-rating factor in hybrid systems ensures that energy generation and storage expectations are adjusted to reflect real-world conditions and technical limitations, providing an accurate forecast of the system's performance. In the context of capacity markets, de-rating factors are impacting the remuneration of participating energy assets.

Frequency regulation: The service of balancing supply and demand in real-time to keep the grid frequency stable. Three types of frequency control services are **FCR (Frequency Containment Reserve) aFRR (Automatic Frequency Restoration Reserve)**, and **mFRR (Manual Frequency Restoration Reserve)**. Hybrid solar or wind + storage assets can offer frequency regulation by adjusting their power output dynamically.

Grid hosting capacity: Maximum generation or demand that the grid can accommodate, as determined by the transmission system operator (TSO) or distribution system operator (DSO) when a grid permit is requested. In this context, Action 6 of the Grid Action Plan aims to establish a harmonised definition. For hybrid, this value would apply to the full facility.

Maximum capacity (Pmax): For this analysis and recommendations, we present the definition from RfG NC 2.0 (December 2023)5. Pmax refers to the maximum continuous active power a power-generating module can deliver, accounting for any demand or losses necessary for its operation. This capacity is determined by the connection agreement, an agreement between the relevant system operator and the power-generating facility owner, or by other appropriate means where no formal agreement is required. This definition underpins our analysis and reinforces the need for clear, harmonised regulatory approaches.

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Introduction

The Clean Industrial Deal represents the next step in Europe's transition toward a climate-neutral economy building on the EU's Green Deal agenda and Fit for 55 package. At the heart of this transformation lies the integration of renewable energy, which plays a crucial role in decarbonising industrial sectors by providing clean, cost-effective and reliable electricity.

Scaling up solar, wind and energy storage solutions can help industries reduce dependence on fossil fuels, stabilise energy costs, and enhance resilience against volatile energy markets. Moreover, the deployment of hybrid renewable projects—combining solar, wind, and battery storage—can optimise energy availability, ensuring stable power supply even in high-demand periods.

Alongside grid expansion and modernisation, hybrid renewable can play a significant role in achieving both short- and long-term EU goals by:

- **Driving decarbonisation** through greater integration and penetration of renewable energy into the grid;

- **Enhancing energy security** by ensuring a more stable and reliable power supply; and

- **Improving affordability** by reducing energy costs and optimising electricity grid usage.

Despite the significant benefits of hybrid renewable projects, their full potential remains untapped in the EU due to regulatory bottlenecks that hinder deployment. This report identifies key barriers and outlines a clear path forward to accelerate hybrid integration across Europe.

To unlock this potential, the EU and its Member States must develop clear strategies for storage and flexibility, enhance grid planning with hybrid potential maps, and ensure accessible EU funding and targeted state aid for hybrid projects. Permitting processes should be streamlined and fast-tracked, particularly for hybridising existing plants in congested grid areas, with standardised rules and alignment with grid expansion plans.

Furthermore, grid operators must modernise their systems by digitalising grid connection agreements, implementing fast-track connection processes, and eliminating double charging for storage to create fairer tariffs.

On the economic front, hybrid-friendly auction designs, CAPEX support for storage, and enabling batteries to participate in multiple revenue streams are essential. Additionally, fair de-rating factors in Capacity Markets, should reflect the role of hybrids in energy security, while Guarantees of Origin (GOs) should be issued for stored renewable energy to ensure transparency and market value.

By addressing these challenges, the EU can accelerate the deployment of hybrid renewables, strengthening its energy security, decarbonisation efforts, and grid resilience.

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Defining Hybrid PV

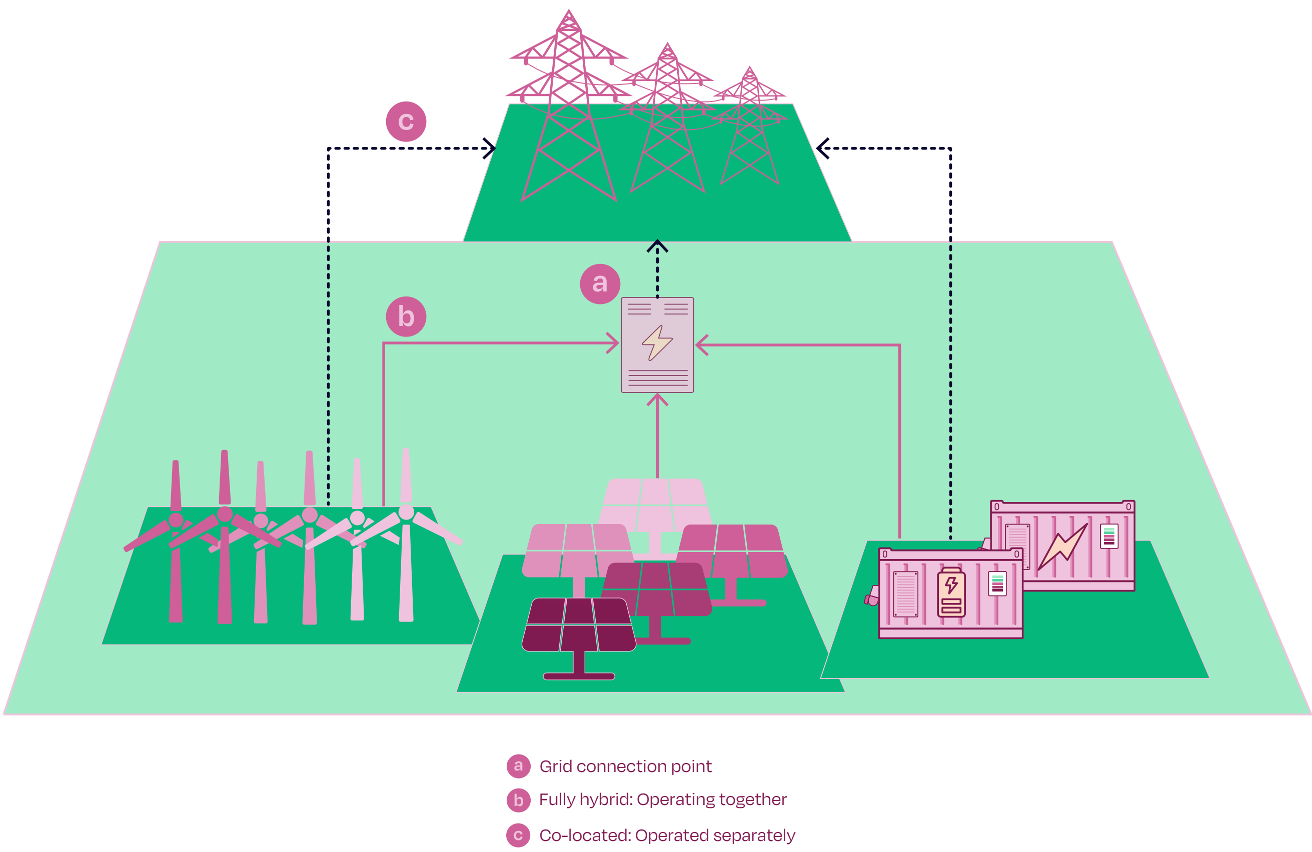
An asset can be classified as hybrid if it consists of two or more energy generating or storing technologies, which (1) share a single grid connection point and (2) are operated in an integrated way.

Hybrid PV systems are characterised by the combination of technologies in the same facility and sharing a single grid connection access point. Two different structures can be observed:

- **Co-located:** The assets are operated independently, but share the grid connection point.
- **Fully hybrids:** The assets are operated jointly by the same entity, leading to an optimised usage of the grid connection point.

Figure 1

Fully hybrid vs co-located projects



Source: AFRY, SolarPower Europe

Box 1: Hybrid projects - Agri-Solarpark Löffingen, Baden-Württemberg (Next2Sun, Germany)

Project Type	Hybrid PV + BESS Project
Project Description	The Agri-Solarpark Löffingen was developed by Next2Sun together by the Löffingen organic farmer on an area of around 11 hectares. Commissioned in 2024, this vertical/ bi-facial PV plant has a nominal output of 4.6 megawatts enough to power demand of 1,500 households per year. The system is supplemented by a 0.5 MW Battery Energy Storage System, which enables part of the electricity generated to be made available in line with demand.
Solar PV Capacity	4.3 MW
BESS Capacity	0.5 MW
Grid connection capacity	3.5 MW

© Next2Sun AG

Box 2: Hybrid projects - Skåramåla Hybrid Renewable Park

(European Energy, Sweden)

Project Type	Hybrid Solar + Wind Project
Project Description	European Energy's PV+Wind hybrid project in Skåramåla in southern Sweden is combining a solar park (39.3 MWp) and 8 Siemens Gamesa 6 MW turbines co-located, and grid connected with a shared point of connection. Six of these turbines also share the power plant controller with the PV park. Within the hybrid plant, there are multiple reference points (measurement points for individual components), but ultimately, all electricity flows through a single point of connection to the grid.
Solar PV Capacity	39.3 MW
Wind Capacity	48 MW
Grid connection capacity	49.6 MW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Benefits of Hybrid PV Projects

Hybrid projects bring numerous benefits to end-users as they offer cleaner, cheaper and more reliable electricity. This chapter delves into the benefits of hybrid projects in different configurations.

The benefits that hybrid projects bring to the system can be distributed in five categories:

i. **Resources utilisation.** By combining different generation technologies, a more efficient usage of the existing resources can be achieved.

ii. **Efficient storage usage.** Allowing hybrids to withdraw electricity from the grid enables an optimised operation of the system.

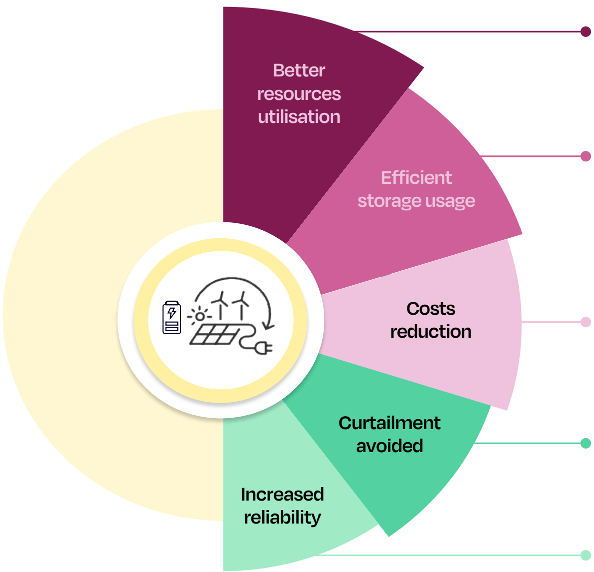
iii. **Costs reduction.** Hybrid projects realise cost synergies by maximising existing infrastructure usage and reducing the financing costs for renewables.

iv. **Curtailment avoided.** By hybridising renewables with storage, the surplus renewable output can be stored and be injected later into the grid during hours of peak demand.

v. **Increased reliability.** Combining different generation technologies and/or storage increases the reliability of the energy output.

Figure 2

Benefits of hybrid projects



Better resources utilisation. By combining different generation technologies, a more efficient usage of the existing resources can be achieved.

Efficient storage usage. Allowing hybrids to withdraw electricity from the grid enables an optimised operation of the system.

Costs reduction. Hybrid projects realise cost synergies by maximising existing infrastructure usage and reducing the financing costs for renewables.

Curtailment avoided. By hybridising renewables with storage, the surplus renewable output can be stored and be injected later into the grid during hours of peak demand.

Increased reliability. Combining different generation technologies and/or storage increases the reliability of the energy output.

Source: AFRY's analysis

Case study projects main parameters

The charts used in this chapter to illustrate the benefits of hybrid projects, correspond to different configurations of hybrid projects. Their main characteristics are listed in Table 1 below:

Table 1

Case study projects main parameters

Project type	Features	Project name
Solar PV Standalone	• Grid connection capacity: 20 MW • Solar PV capacity: 25 MW	Solar PV Standalone
Solar PV + BESS (with grid charging)	• Grid connection capacity: 20 MW • Solar PV capacity: 25 MW • Storage capacity: 15 MW • Storage duration: 2h • Storage efficiency: 85%	Hybrid w/grid withdrawal
Solar PV + BESS (without grid charging)	• Grid connection capacity: 20 MW • Solar PV capacity: 25 MW • Storage capacity: 15 MW • Storage duration: 2h • Storage efficiency: 85%	Hybrid wO/grid withdrawal
Solar PV + Onshore wind	• Grid connection capacity: 20 MW • Solar PV capacity: 25 MW • Onshore wind cap: 15 MW	Hybrid RES

Source: AFRY's analysis

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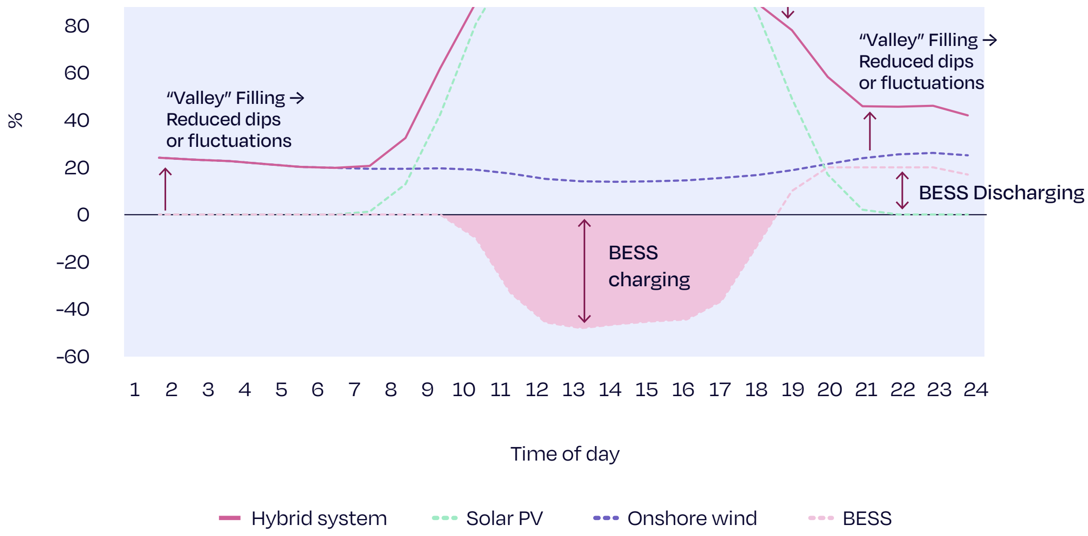
Better resources utilisation

Through hybridisation, resource-related synergies between generation technologies can be achieved. For instance, by combining different generation sources, the grid infrastructure usage (i.e. grid connection point capacity) and the land occupied are optimised.

Combining different generation technologies takes advantage of their complementary profiles. Onshore wind and BESS, which have a more baseload-like dispatch, can be paired with solar PV to enhance output and optimise grid connection point usage during that period. Surplus electricity can be stored with the BESS, and dispatched later.

Figure 3

Illustrative grid connection point usage optimisation (%)



Source: AFRY and SolarPower Europe's analysis

Illustrative land optimisation

Efficient storage usage

Allowing hybrids to withdraw electricity from the grid enhances the project performance, as well as enabling an optimised use of the system resources, since the hybrid project will be alleviating the system in periods of generation scarcity and high electric demand.

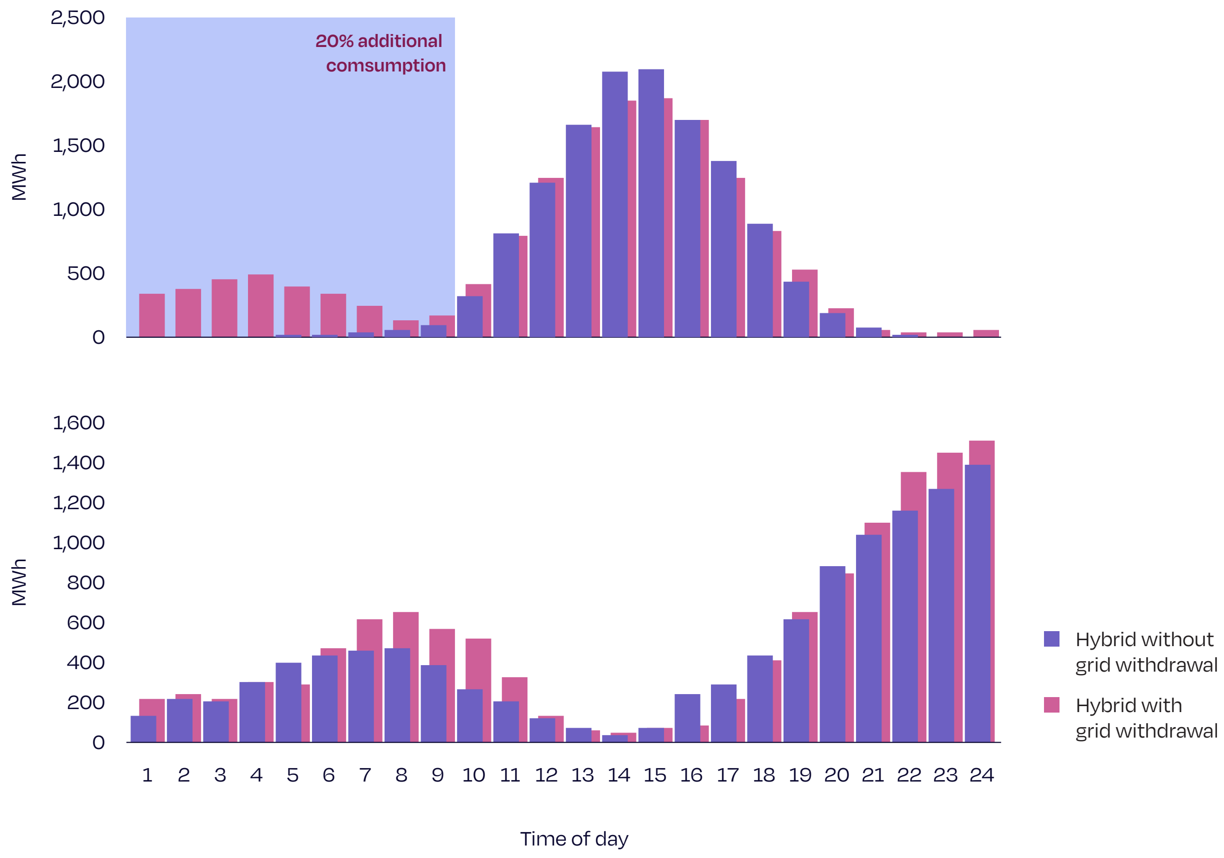
A less constrained operation of hybrid projects, by permitting them to charge from the grid, enables an enhanced usage of the storage flexibility, benefiting both the project's performance and the overall system. The chart below illustrates the improvement in the hybrid operation when grid withdrawal is allowed:

- While charging, top chart in Figure 4, the Hybrid w/grid withdrawal project will also be withdrawing electricity during the night. This will result in an additional 20% consumption from the grid, in a period where electricity prices are lower, allowing the project to capture wider price spreads, thus increasing its revenues.

- The energy volume injected into the system, bottom chart, will be increased when allowing grid withdrawal, benefiting the system by enhancing the benefits that storage brings, such as peak shaving and renewable integration.

Figure 4

Storage charging (top)/discharging (bottom) enhancement (MWh)



Source: AFRY's analysis

Costs reductions

Hybrid systems offer a wide range of cost-saving benefits, including reduced expenses for grid connections, land use, project development (such as feasibility studies), and operations and maintenance (O&M). Hybrid projects can also reduce the project financing costs.

- **LCOE reduction:**

  The Levelised Cost of Electricity (LCOE) of a renewable generator is reduced under a hybrid project as a result of the savings in (among others) the investment costs and operational expenditures associated with the connection of the project (as per the abovementioned example, industry value can be around €50/kW).

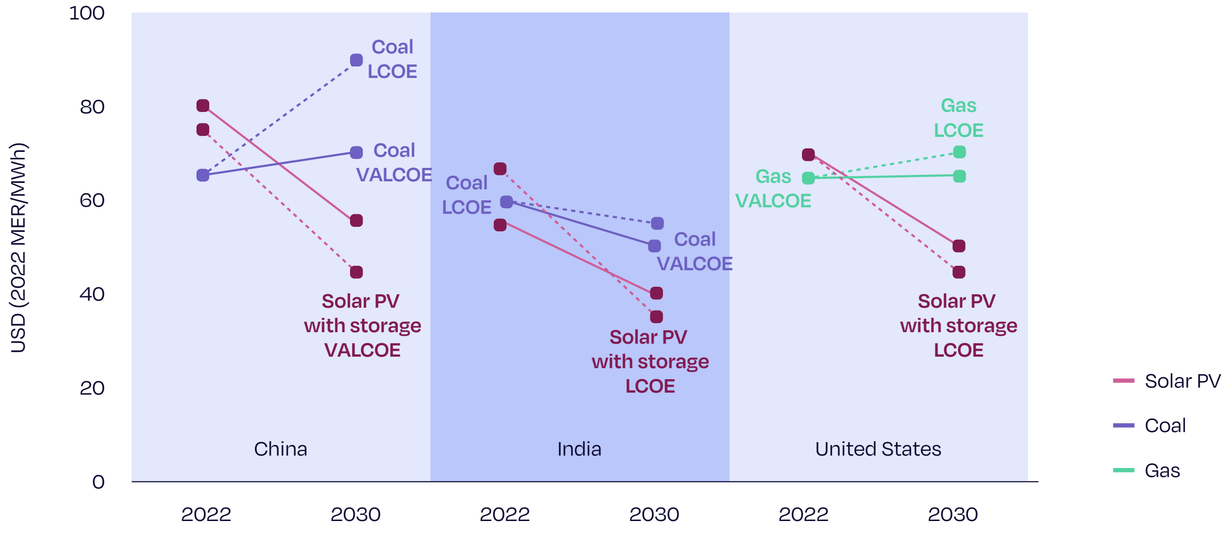
  Furthermore, the risk perception of a hybrid project can be decreased, seen both from the debt and the equity perspective, as the project outcomes are more predictable and/or can be further guaranteed in a PPA (i.e., less merchant risk).

  According to AFRY's estimates, the reduction of the LCOE in hybrid projects compared to standalone commissioning of individual components can be approximately 10%.

  When comparing solar PV and storage hybrid systems to gas plants, the International Energy Agency (IEA) provides detailed modelling on how the LCOE for solar plus storage compares to that of coal in China and India, as well as gas in the US. The analysis shows that solar plus storage is significantly more cost-effective in these markets, often by more than 20%.

Figure 6

LCOE and value-adjusted LCOE for solar PV plus battery storage, coal and natural gas in selected regions, 2022-2030



Source: IEA

- **Savings on network strengthening:**

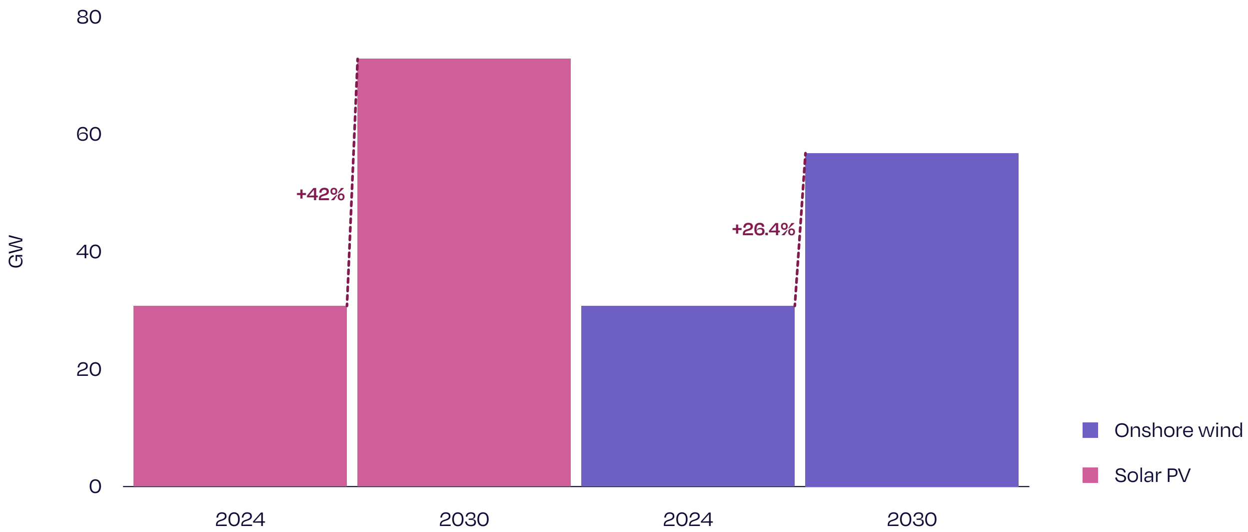
  Using the Spanish National Energy and Climate Plan (NECP) for solar and wind as an illustration (see below), a back-of-the-envelope assessment of the cost of expanding the network to integrate those amounts of renewables has been conducted. Assuming a typical industry figure on connection costs of €50/kW, the additional investments in networks needed to integrate 42GW of solar PV and 26GW of onshore wind will be approximately €3.4bn.

  AFRY also conducted a contrafactual academic scenario, performing the same cost assessment which assumes a degree of hybridisation: 0.2MW of solar per every MW of wind. Please note this hypothesis is based on the Spanish market, where solar is widely available and the scarce resource to be optimised is wind.

  By implementing such hybridisations, the system would provide connections to 26GW of onshore wind, but instead of 42GW of new solar connections, the required capacity will be around 37GW. This reduction of approximately 5GW in network reinforcements translate into savings of €250m: approximately7.5% of the total investment needs.

Figure 5

Spanish NECP solar PV and onshore wind targets (GW)



Source: AFRY's analysis

Curtailment avoided

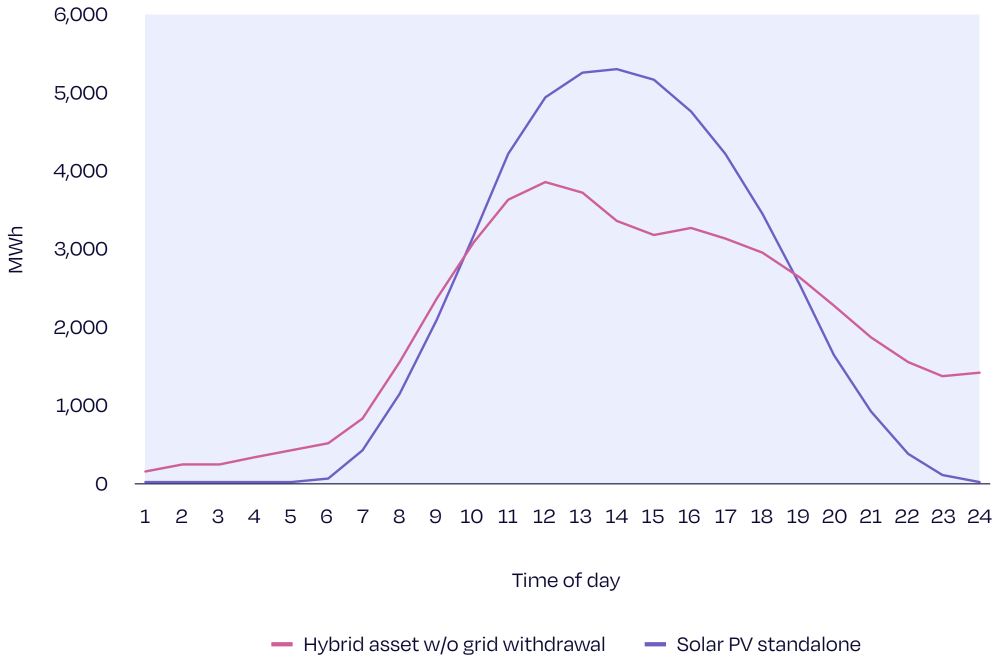
Renewable curtailment occurs when there is a surplus of renewable energy generation that the system cannot integrate. This can be caused by either excess generation compared to electricity demand or by network-related technical constraints.

One way of reducing renewable curtailment is the hybridisation of renewable units with storage, as storage adds flexibility to the system. The surplus renewable energy can be stored during hours of high resource availability and low demand and discharged later, during hours of increased system tightness.

As shown in the chart, the enhanced flexibility of hybrid assets allows for the integration of the surplus renewable generation. By doing so, hybridisation reduces renewable curtailment and increases renewable energy penetration into the electric sector, thereby lowering system costs and wholesale electricity prices.

Figure 7

Increase in solar PV integration by hybridisation (MWh)



Source: AFRY's analysis

Furthermore, when allowing the storage unit to withdraw energy from the grid, the system-wide curtailment decreases, leading to lower system costs while increasing renewable energy penetration. This is closely linked to the benefits shown in the previous sections, as both show that enabling less constrained operation of the hybrid assets benefits not only the individual projects but also the broader energy system.

To conclude, hybridisation with storage is crucial to increase the renewable penetration, especially in energy systems where renewable deployment surpasses demand growth and storage installation, helping to meet the global decarbonisation targets.

Increased reliability

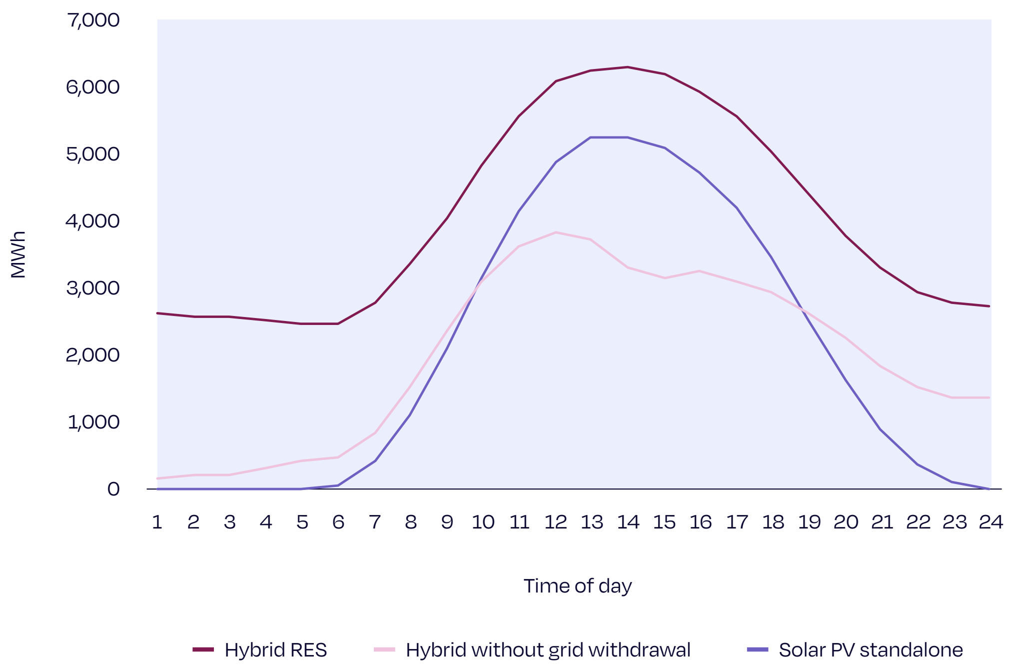
With hybridisation, a more baseload-like generation profile can be achieved. Depending on the technologies involved, hybridisation falls into two main categories:

- Hybridisation of renewables (e.g. onshore wind and solar PV): a more baseload-like generation is achieved, due to the complementary availability of both technologies.
- Hybridisation of renewables with storage: the variability of renewables, due to short-term variations in weather patterns, is mitigated through the storage flexibility.

While standalone renewable generation is constrained by resource availability, hybridised renewable systems (either with other renewables or storage) can achieve a stronger production profile. This enhanced reliability positions hybrid systems as an attractive option for Power Purchase Agreements (PPAs) and other revenue streams that require a consistent baseload profile.

Figure 8

Hourly flow to grid (MWh)

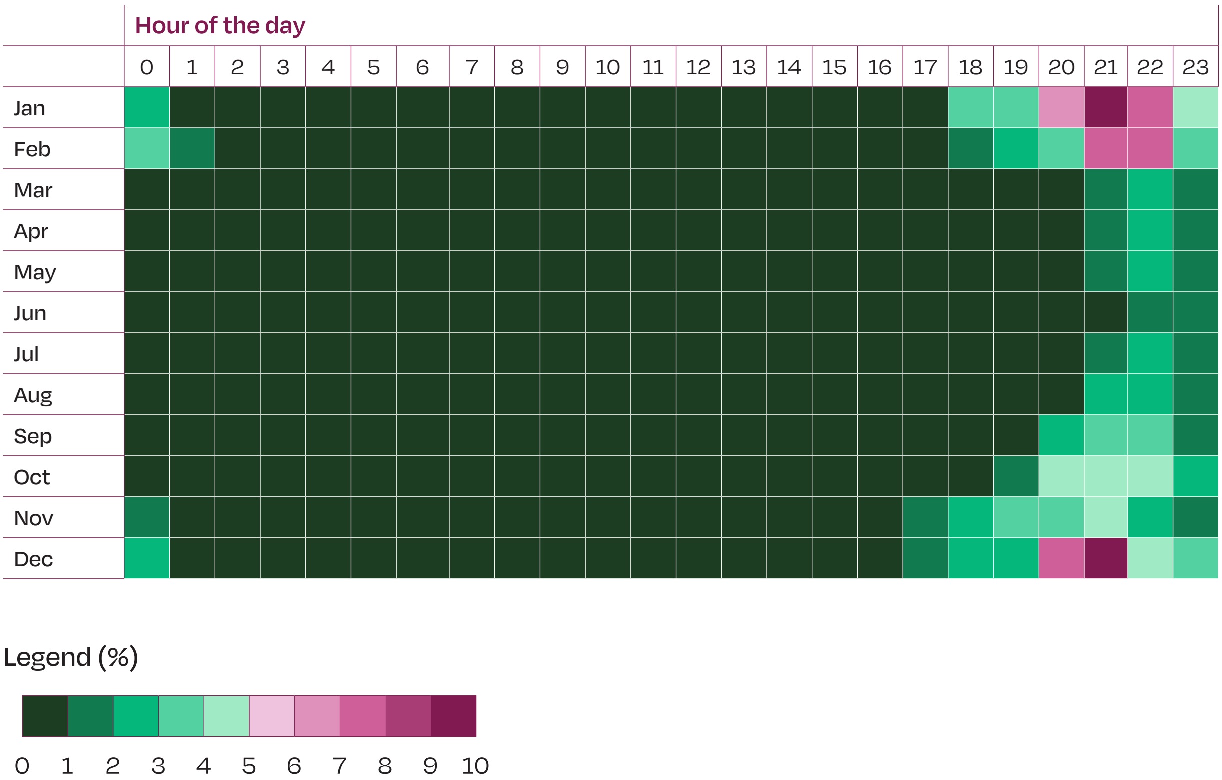


Source: AFRY's analysis

In addition, hybrids can contribute to security of supply due to their increased electricity generation stability with respect to standalone renewable sources. Critical hours tend to occur after the sunset during winter months, when demand peaks but solar PV generation is less available(i.e. there is no solar PV generation after the sunset). Therefore, by combining solar PV with onshore wind and/or storage, hybrid projects enhance security of supply by ensuring electricity generation even after sunset.

Figure 9

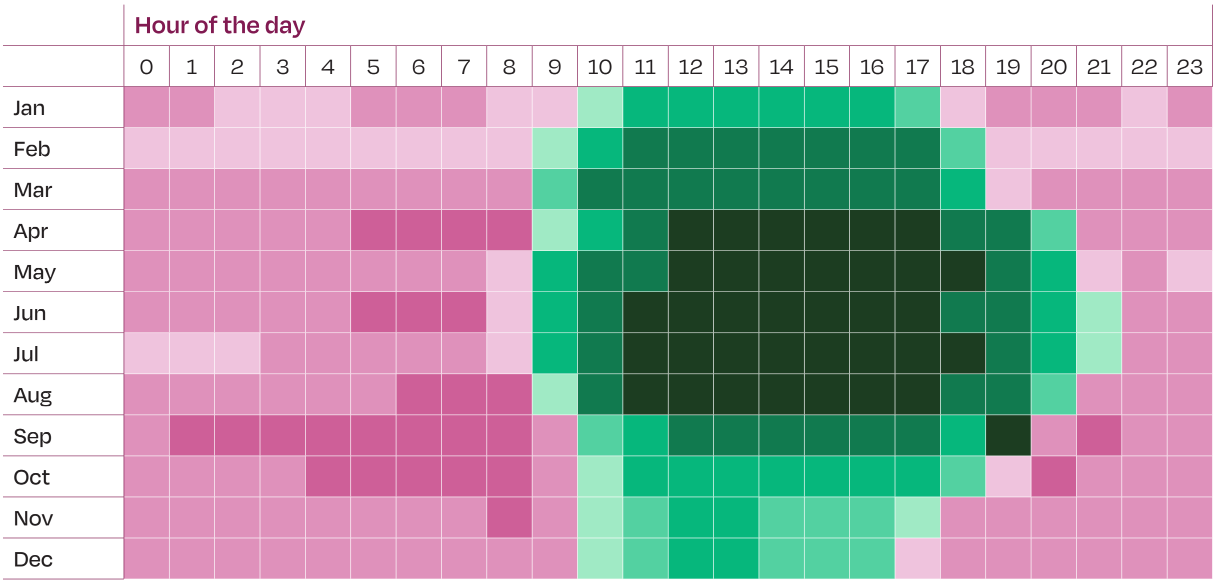
Illustrative distribution of critical hours over a year versus generation profiles of hybrid systems



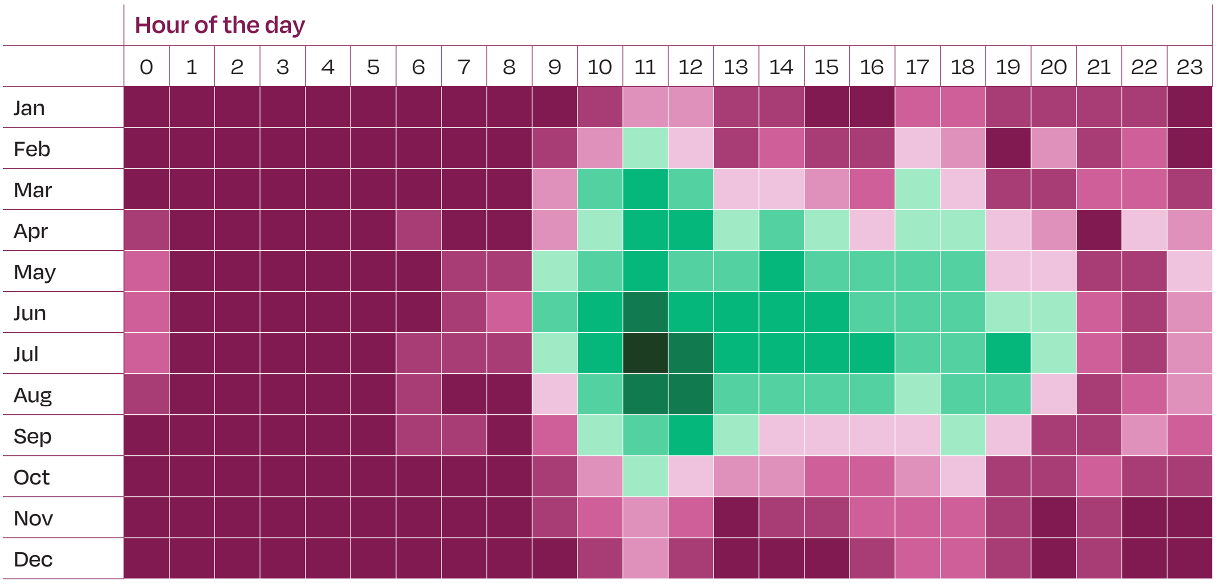
Source: AFRY's analysis

Figure 10

Generation profile of the Hybrid RES (above) and Hybrid wO/grid withdrawal (bottom)

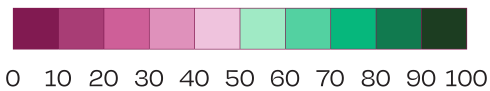


Hybrid RES generation profile



Hybrid wO/grid withdrawal generation profile

Legend (%)



Source: AFRY's analysis

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Hybrid PV European Market

The expansion of renewables, especially for solar PV, has been outstanding over the past decade in Europe.[1] Solar PV alone has grown to 370 GW of installed capacity at the end of 2024, from just 88 GW at the end of 2015 (+320%).

Along with the enormous increase in capacity, solar PV provided 11% of EU electricity last year (304 TWh), overtaking coal (269 TWh) for the first time ever.[2] Combined with wind, solar PV provided almost 30% of total EU electricity consumption, marking an all-time high.

Out of the solar PV fleet in Europe, more than a third is installed at the utility-scale level (124 GW), with Spain (36 GW) and Germany (30 GW) accounting for more than 50% of the ground-mounted PV fleet. However, the bulk of this large-scale PV capacity has been built as standalone installations, without co-located wind or battery storage systems.

Renewable + Storage Hybrids

Grid-scale Battery Energy Storage Systems (BESS[3]) has experienced a rapid growth, driven by technological improvements, a sharp decrease in prices, and policy support in some European markets. As a consequence, storage significantly contributed to mitigating the energy crisis starting in 2021. Additionally, the prevalence of renewable curtailment and decreasing capture prices urges project developers towards pairing generation with BESS. Despite the slow uptake, relative to standalone generation or storage, positive growth signs suggest that hybrids are set to become the industry standard for renewable energy deployment.

Over the last decade, annual grid-scale BESS installations went from less than 100 MWh in 2015, to more than 8.3 GWh in 2024 (see Figure 11). This acceleration was particularly pronounced after 2020, when installations reached 246% to almost 2 GWh built in 2021. In the following years, the annual market grew consistently by 63% year-to-year , exceeding 8 GWh by the end of 2024.

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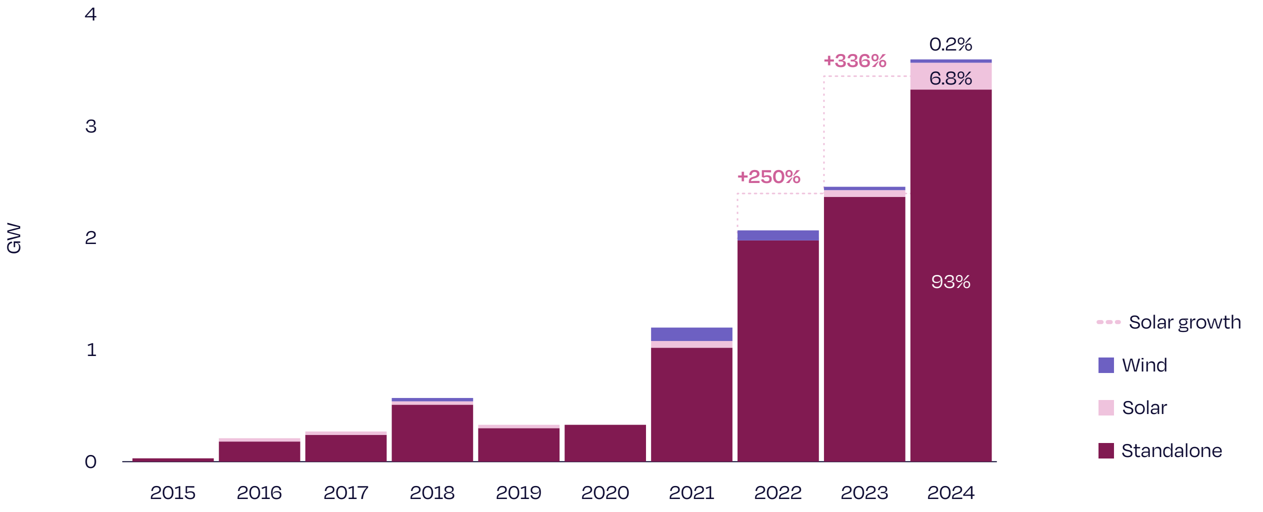
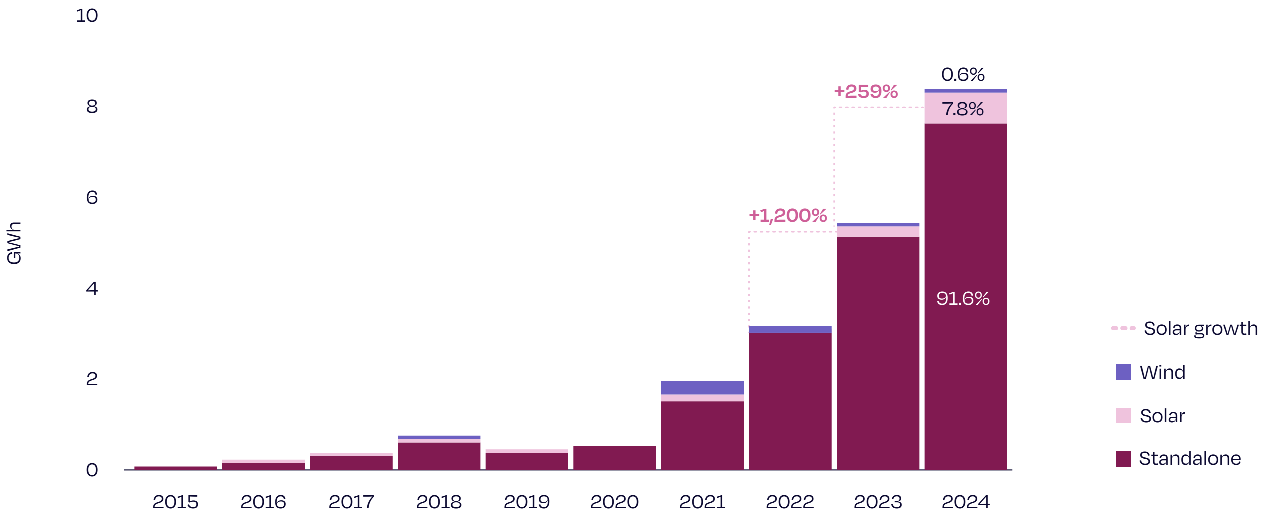
1 All the figures included in this chapter refer to the EU-27, the United Kingdom and Switzerland
2 Ember (2025): European Electricity Review 2025
3 Projects larger than 1 MW are considered utility-scale BESS

Figure 11

Standalone and Hybrid BESS annual installations in Europe





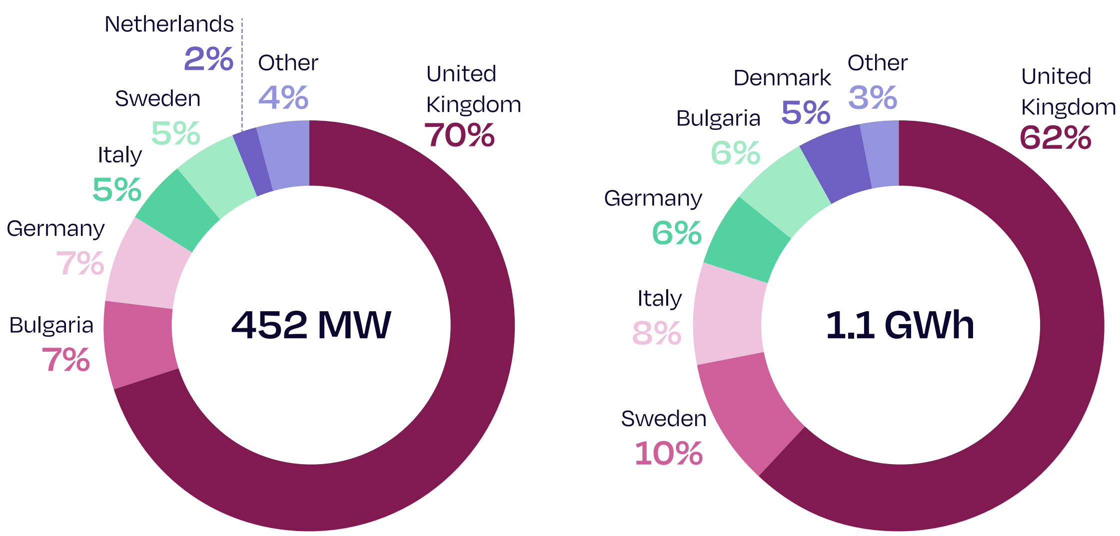
Source: Rystad Energy Powercube

Out of this remarkable decade-long expansion, standalone BESS has consistently added more than 90% of the annual installations, except for 2021. That year, three major wind projects in the UK incorporated BESS, contributing to a total of 263 GWh, while solar and BESS connected 121 MWh. This allowed hybrid solar/wind configurations to reach 20% of the annual installations. Altogether, since 2015, 21 GWh of grid-scale BESS have been grid-connected, with standalone projects representing 93% of this capacity, while PV+BESS constitutes 5% of total additions (over 1 GWh). Wind and battery storage projects have added slightly less than 500 MWh. This difference between solar and wind hybrid projects with storage is mainly due to two factors: the 50% drop in battery prices since 2021, and the necessity of maximising the utilisation of the solar asset and improving of the overall economics of the project.

All additions considered, the total BESS fleet reached 11 GW/22 GWh at the end of last year (see Figure 12), with an average discharge duration of 2 hours. However, and despite the exponential growth of BESS in recent years, the installed power is still insufficient to deal with the inherent intermittency of renewables, especially large-scale solar PV. At the end of last year, the ratio of grid-scale storage to solar PV stood at less than 10%, with less than 1% of PV systems coupled with BESS.

Figure 12

Geographical breakdown of cumulative installations at the end of 2024



Source: Rystad Energy Powercube

In Europe, the leading country for grid-scale BESS deployment is the United Kingdom, followed by Italy and Germany. The UK also leads in hybrid PV+BESS installations, with 62% of the total capacity built deployed nationwide. This leadership is , thanks to a combination of policy support, favourable market dynamics and the development of the largest hybrid parks in Europe. The UK government has provided long-term financial incentives to hybrid projects with a well-designed Capacity Market and inclusive CfD design. Additionally, streamlined permitting for hybridisation and market reforms enabling BESS participation in grid services have positioned made the UK as Europe's most attractive hybrid markets in Europe.

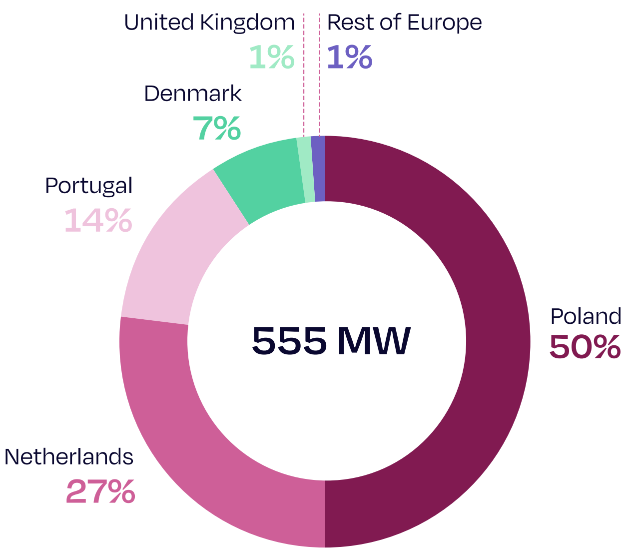
Beyond the UK, other major hybrid PV+BESS markets include Sweden (10%), Italy (8%), Germany (6%), Bulgaria (6%), together with Denmark (5%). Remaining EU-27 countries and Switzerland together account for just 3% of the existing fleet. Despite positive developments in several EU countries, the existing hybrid solar and storage fleet is highly concentrated in the UK.

Solar + Wind Hybrids

The other hybrid combination is pairing solar PV and wind generation. It has not yet taken off in Europe. At the end of 2024, solar + wind installed capacity only accounted for 555 MW (see Figure 13), representing less than 1% of Europe's utility-scale solar fleet.

Figure 13

Geographical breakdown of Hybrid Solar + Wind installations at the end of 2024



Source: Rystad Energy Powercube

Poland alone, accounts for half of the total installed capacity (277 MW), having successfully deployed solar and wind energy together due to a combination of supportive policy changes, economic conditions and stronger complementary of generation patterns. However, the new regulations around co-located set-up, sharing the same connection point, which were adopted in 2023, still require effective implementation for the country to fully unlock the potential of combined solar and wind projects.

The Netherlands, Europe's second-largest solar+wind hybrid market (with almost 150 MW installed) has also supported multiple solar and wind projects over the last few years. This is due to the country's land constraints and the need to maximise utilisation of earmarked locations, supportive incentives such as SDE++ grants, and the innovative approach to co-located set-up, sharing the same connection point.

Portugal (78 MW) has also supported the early adoption of hybrid renewable plants with governmental support and auctions, smart investments in the grid infrastructure and co-located systems possibilities to share grid connection points, reducing costs and permitting delays.

Lastly, Denmark has deployed 7% of Europe's total hybrid renewable capacity, leveraging its status as a global wind energy leaders. Favourable national policies streamlined co-located systems, with same connection point, permit, and supportive incentives have accelerated hybridisation in the country.

In contrast, the UK and the rest of Europe have deployed only 11 MW of hybrid solar and wind projects. This shows the urgent need for improved market and policy frameworks to fully unlock the potential of these technologies working in tandem. In the next section, we will explore the strategies needed to achieve these goals.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05

Regulatory Framework Assessment

1. EU & Member States should embrace hybrid solar projects in their grids and flexibility plans, and support mechanisms

a. The EU and its Member States should develop a clear strategy and monitoring framework for deploying storage, including alongside PV. While the EU has planned to include a Grids Package scheduled for 2026, dedicated action on storage is still missing. **To effectively address flexibility requirements, the European Commission should propose a Flexibility Package, including a dedicated Energy Storage Action Plan,** alongside the Grids Package and as part of the Commission's plan to boost flexibility, announced in the Action Plan for Affordable Energy.

b. **The EU should support hybrid projects as part of their budget, such as via the Innovation and Modernisation Funds and the Clean Industrial Deal State Aid Framework.** Today, the underlying methodologies sometimes limit this option. For example, the methodology to calculate greenhouse gas (GHG) emissions for the Innovation Fund heavily supports CCS rather than innovative hybrid projects.

Bad practice: Innovation Fund

The bias toward Carbon Capture and Storage (CCS) stems from the fund's methodology for calculating GHG emission reductions, which compares a project's emissions to those that would occur in its absence. This approach heavily influences two of the five evaluation criteria, impacting each technology's chances of success. As the electricity grid is already decarbonising, hybrid generation—whether new or retrofitted—has less potential for emission reductions than CCS in energy-intensive industries, but only in the short-term. Comparing these two pathways creates unfair competition and overlooks their distinct roles in decarbonisation.

Good practice: Recovery and Resilience Plan

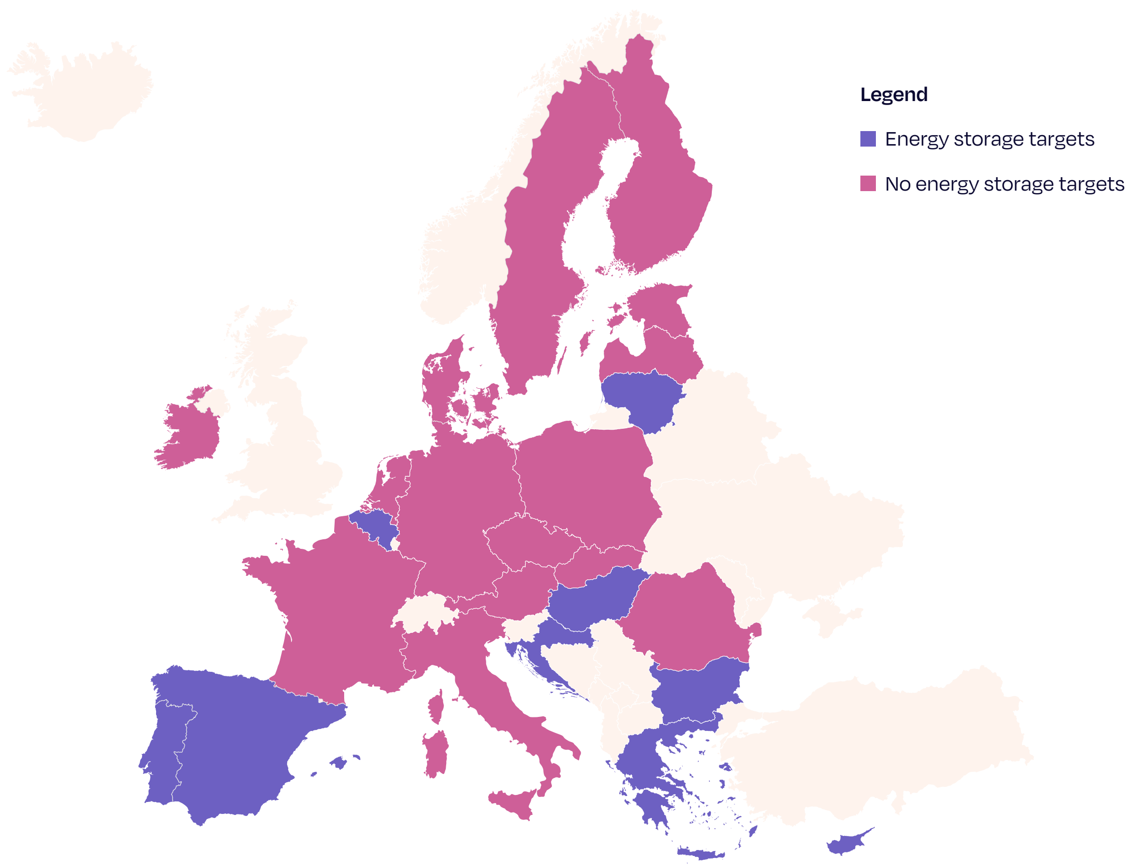
Funds from Bulgaria's National Recovery and Resilience Plan (NRRP) have been used to contribute to the decarbonisation of its energy system by means of auctions for co-located PV with storage. In total, 270 million euros have been made available for a single round.

c. **Member States are urged to promptly assess their flexibility needs, while the European Commission should set ambitious flexibility and renewable energy targets for 2040.** National Regulatory Authorities (NRAs) must also incentivise TSOs and DSOs to integrate flexibility resources, such as batteries and demand-side response, into their planning processes. Flexibility needs assessments must lead to concrete measures and actions to be implemented in EU Member States, including the facilitation of renewable hybridisation. Although EU Member States are required by the Electricity Market Design to conduct flexibility needs assessments, it remains unclear how they will concretely act on their findings and whether facilitating hybridisation will be considered a key measure.

d. **At the national level, the situation is similar:** Only nine Member States have included storage targets in their 2024 National Energy and Climate Plans (NECPs) to date. These targets are a crucial first step in identifying system needs for greenfield projects and the hybridisation of existing PV plants.

Figure 14

EU map of storage targets in NECPs (2024)



Source: SolarPower Europe analysis

2. Regulators and grid operators should improve grid connection procedures for hybrid PV

Implement grid hosting maps

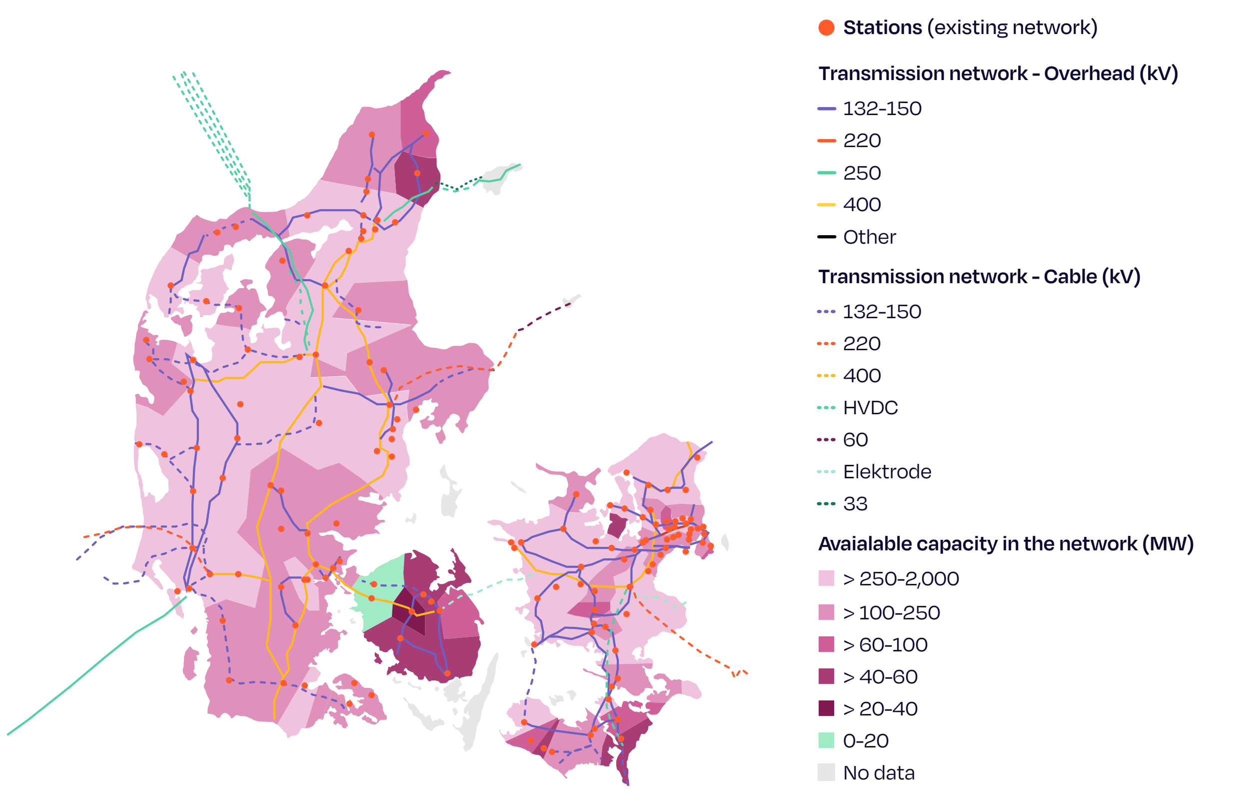
Grid operators or regulators should implement grid hosting maps, displaying existing projects on the grid to facilitate co-location at the same connection point. Developers not only need clear visibility of grid availability and site (land) control from the outset but also access to information on existing grid connections. Knowing where grid connections are already available would allow them to approach site owners for shared connections.

Good practice: Denmark's Grid Capacity Hosting Map

In Denmark, both TSO and DSO grid capacity hosting maps can be found on the same website with detailed information on the current situation and the planned reinforcement. The platform also uses colour coding to display regional levels of wind, solar, and thermal generation.

Figure 15

Denmark grid capacity hosting map



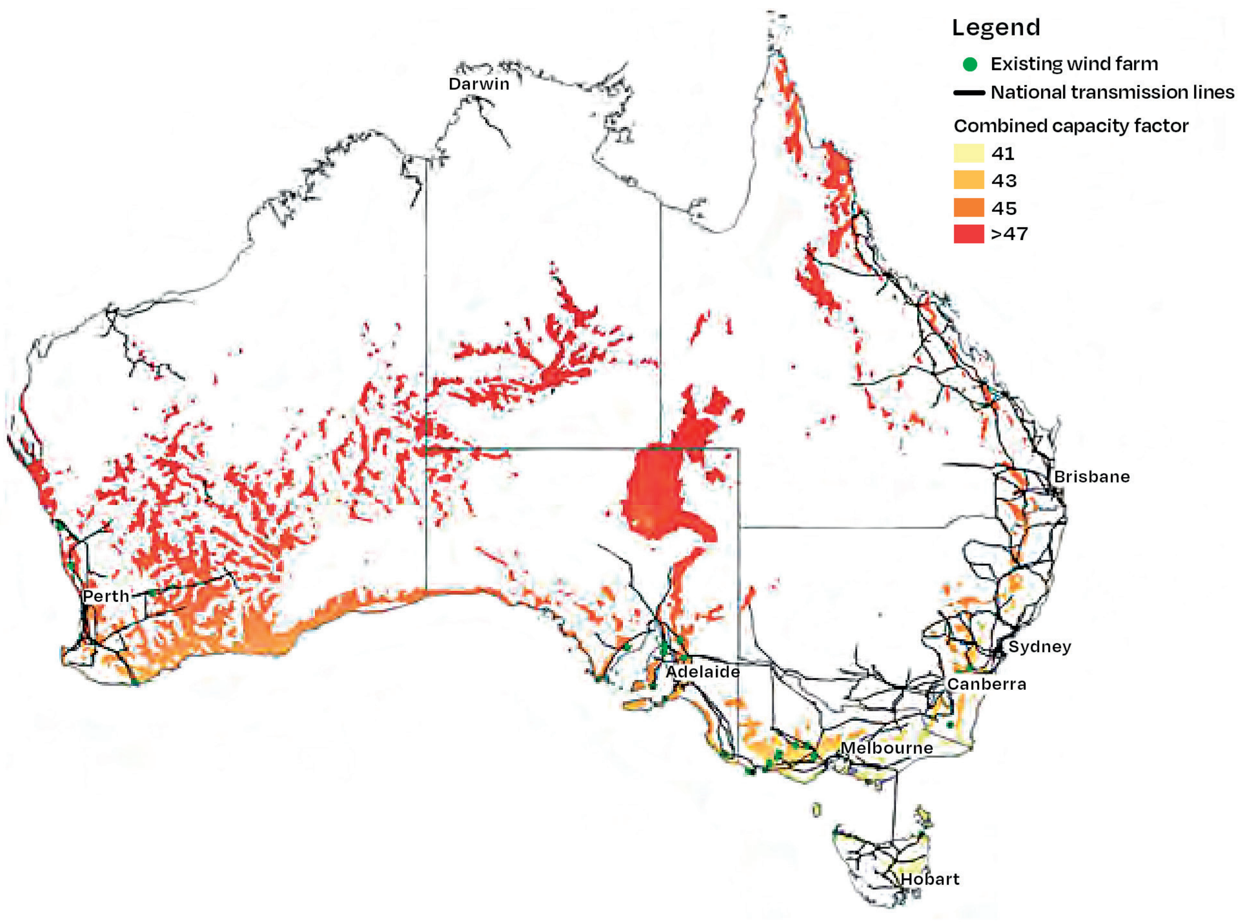
Source: Green Power Denmark, Energinet

Good practice: Australia's Hybrid Systems Potential Map

ARENA, the Australian Renewable Energy Agency, has developed a map showcasing the great potential for hybridisation across its various regions. The map also displays existing wind farms to encourage retrofitting with solar PV. Coupled with data on grid capacities and system integration metrics, such a high-level vision is a good example of how we can improve transparency and get the tools for efficient planning of renewable integration with hybridisation.

Figure 16

Australian map of renewable hybridisation potential



Source: ARENA (Australian Renewable Energy National Agency)

Prioritisation of hybridisation of existing projects in grid queues

Grid prioritisation should be granted within the connection queue for the hybridisation of existing projects that do not require an increase in injection capacity and which support better use of the connection point. However, any prioritisation should be limited to cases where system needs have been clearly demonstrated. The absence of a fast-track connection process for retrofitted projects that improve grid stability and flexibility remains a major gap.

Grid connection issues are increasing across the EU, making efficient grid use essential. Ground-mounted PV projects can take up to eight years to connect, with an average wait time of four years. To address this, regulators must implement effective queue management systems with clear entry criteria and milestones to prevent speculative projects from blocking the capacity needed for ready-to-build installations. Deadlines and timelines should only apply to milestones under the developers' responsibility. Such queue management systems, adapted to each Member State's reality, should encourage project progress. Most importantly, it would free grid capacity to developers who intend to develop the project

Good Practice: Acceleration of grid connection approach in the UK

The framework in the United Kingdom is currently going through significant reforms. Although complex, these should accelerate "ready" projects. It is moving from a "first come, first served" to a "first ready, first connect" queue.

Good Practice: Optimisation of grid connection approach in the Netherlands

DSOs are also exploring innovative approaches to managing renewable energy, particularly in congestion management. One such approach is co-located systems, which functions similarly to hybridisation by integrating multiple generating assets—such as a solar PV park and an onshore wind farm—under a single grid connection. Like fully hybrid projects, co-located systems optimises grid usage by combining sources with complementary generation profiles. While this setup involves an undersized grid connection that may lead to curtailment, the cost savings on grid infrastructure often outweigh the losses. The concept is gaining significant traction in the Netherlands, especially when combined with battery storage, as it helps mitigate both curtailment and, in some cases, revenue cannibalisation.

Grid connection capacity and requirements

The definition of maximum capacity (Pmax) during the connection agreement process remains unclear in most countries, particularly for system operators and regulators when multiple technologies are integrated at a single connection point. It is uncertain whether Pmax should be defined as the sum of installed capacities of each technology or as the aggregated operational capacity based on real-time grid conditions.

Rather than simply adding the installed capacities of different technologies, Pmax should be determined through an agreement between the system operator and the hybrid power plant owner. This approach allows for greater flexibility while ensuring grid compatibility. Over-export risks can be effectively managed through control systems and relays, meaning that over-installing capacity on-site (e.g., 50 MW PV + 50 MW BESS on a 50 MW connection) should not be a barrier.

The European Commission and ACER should take the lead in developing best practices for Pmax calculation in hybrid systems, ensuring a fair and balanced approach that considers all relevant factors.

In this context, the EU must ensure that the Network Code Requirements for Generators (NC RfG) support a flexible approach to defining connection capacity for hybrid PV power plants. While the latest version, published by ACER in December 2023, follows this approach, its implementation across different countries is not yet clear. Maintaining flexibility, as already adopted by some TSOs (e.g., REE in Spain), would better support the integration of hybrid systems while ensuring grid stability and optimising infrastructure utilisation.

Additionally, a task force under ACER's oversight should be established to support the ENTSO-E Implementation Guidance Document (IGD) on hybrid connections and promote best practices for network code implementation across Member States.

Good Practice: Maximum capacity definition in Spain

To clarify the difference between grid access capacity and maximum capacity, the Spanish TSO has published a FAQ[5] (Reference link section 8.3). According to this resource, in the context of a hybrid installation:

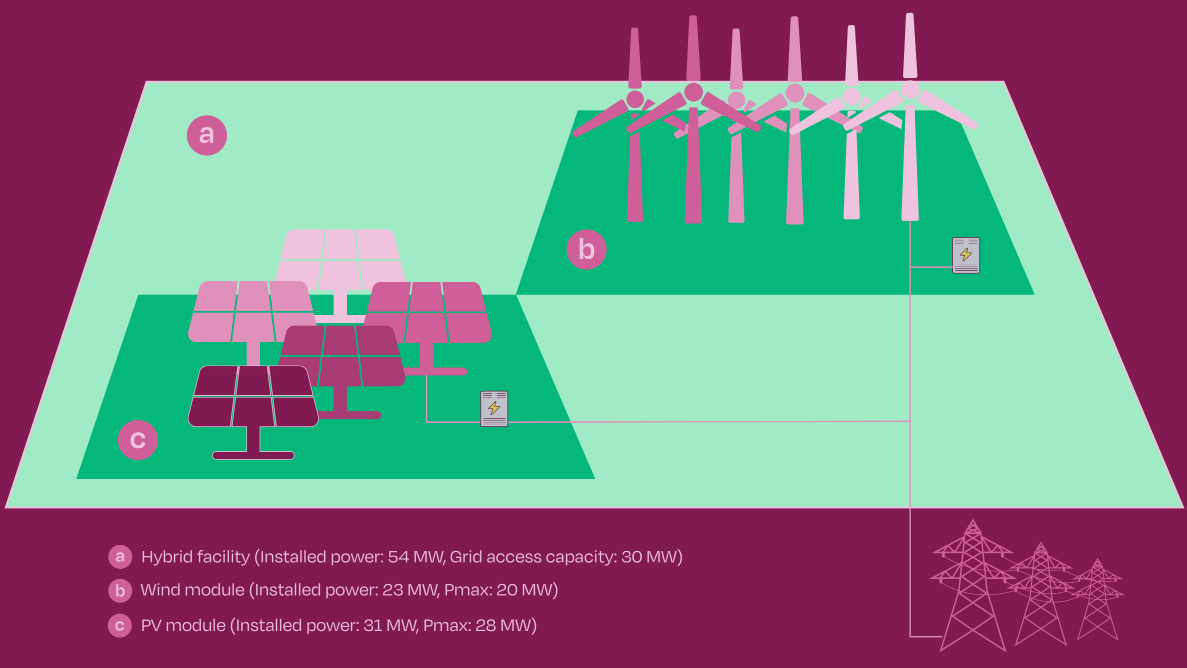
- Installed power refers to each technology installed capacity
- Access capacity refers to the maximum active power that the whole installation is allowed to inject into the grid.
- Maximum capacity represents the highest active power that an individual generation module within the installation can produce while complying with the required reactive power capability, as defined in Regulation (EU) 2016/631.

Therefore, in a hybrid installation, power definitions involve:

- An installed power value and an access capacity value at the overall installation level.
- An installed power value and a maximum capacity value for each generation module within the installation.
- The total installed power of the installation corresponds to the sum of the installed power of all its individual generation modules. The Spanish TSO also provides an illustrative example to further explain this distinction.

Figure 17

Example of a Hybrid Installation Illustrating Power, Definitions by the Spanish TSO[6]



5 Red Eléctrica FAQs for grid connections
6 Red Eléctrica FAQs for grid connections

Country	Description of current situation
Austria	**Good Practice**: The current national code states that the "maximum capacity" is equivalent to the "contractually agreed power capacity," meaning that Pmax is defined during the connection agreement process. This approach provides flexibility and allows the developer to showcase and give clarity to the system operator on how the hybrid project can support the grid.[7]
France	**Bad Practice:** In France regarding grid connections: eligibility is based on the total installed capacity (Pinstalled) rather than the maximum injection power (Pmax). 1. DSO Connection Eligibility: • The total installed power (sum of PV and BESS inverters) must be below 17 MW, regardless of the actual injection limit. • Even if a plant intends to inject no more than 17 MW, it won't qualify for a DSO connection if its Pinstalled exceeds this threshold. 2. TSO Connection Eligibility: • 63 kV or 90 kV connections: Pinstalled must be under 100 MW (or 50 MW for T-insertion). • 225 kV connections: Pinstalled must be below 250 MW (or 120 MW for T-insertion). **Example:** A hybrid plant with 10 MW PV + 10 MW BESS (Pinstalled = 20 MW) cannot connect to the DSO, even if it limits its injection to 17 MW. To qualify, the Pinstalled must be reduced to 17 MW or less. This means project developers must carefully size their inverters to comply with connection criteria, as regulatory limits are based on potential installed capacity, not actual injection power.
Finland	**To improve:** Fingrid, the Finnish TSO, defines Pmax as the highest continuous active power output a facility can sustain at the connection point. This capacity is specified in the connection agreement or determined by the network operator and the facility owner. However, it also says that the capacity may not be limited by means of software to a lower level than the nominal rated capacity of the power generating facility owner's electricity generation installations. While this definition provides clarity, it may not fully accommodate modern inverter-based technologies, which rely on software for dynamic power management. A more flexible approach could better align with current industry practices.

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7 Definition of maximum capacity in Austria

The lack of clarity regarding the definition of Pmax may lead national regulations to impose a limit on this value. However, **there should be no fixed limit on the over-installation ratio for hybrid systems, as they optimise grid use by balancing their load profiles.** If a limit is needed, it should be agreed with the hybrid owner in the connection agreement to maximise renewable and storage use while ensuring grid stability.

Country	Description of current situation
Ireland	**To improve:** There is a rule mandating that the capacity of the asset on a site cannot be more than 120% of the maximum permitted export capacity for that site.
Spain	**Good practice:** Spanish regulations on hybridising existing power plants require that at least 40% of the granted access capacity remains dedicated to the original technology. Additionally, the total access capacity cannot increase by more than 5% from the original permit. This means that while full replacement of the original technology is not allowed, there is no upper limit on the capacity of the new technology. For example, a 120 MW PV plant with a 100 MW access capacity can hybridise with any additional technology, as long as the total grid export remains within 100 MW and at least 40 MW of PV remains in operation. This regulation ensures that hybridisation does not serve as a loophole for completely replacing the original energy source or for retaining grid access before decommissioning. Instead, it guarantees that a significant portion of the original technology remains in use.

Streamlining the electrical licensing process

Obtaining an electric license for hybrid projects can be complex in some countries, affecting both renewable-to-renewable (RES-to-RES) and renewable-to-storage (RES-to-BESS) projects. **The licensing process for hybridisation, meaning retrofits, should be streamlined when a connection point and grid injection capacity have already been allocated, provided no changes are required. In such cases, retrofitting an existing plant should not necessitate a new injection license.**

Additionally, the lack of clarity and transparency in storage consumption licensing remains a significant challenge, adding to regulatory uncertainty. Clear and well-defined rules for both injection and consumption in storage-integrated systems are essential to ensure regulatory consistency and project feasibility.

For entirely new hybrid projects, a joint licensing process would streamline approvals, reduce administrative burdens, and facilitate more efficient market entry.

Electrical licensing approach in Portugal

Good Practice: Portugal has streamlined the electrical licensing process for the hybridisation of RES-to-RES and RES-to-BESS connections. When retrofitting an existing plant, a new injection license is not required.

To improve: However, grid operator validation is still necessary for the BESS's consumption capacity. One of the main bottlenecks, therefore, is the lack of a unified permitting process for consumption and generation to allow storage to charge from the grid, as they remain separate. The absence of clarity and transparency in consumption permits continues to be a challenge, especially with rising demand from data centers and other high-consumption projects.

Digitalisation of the connection agreements

In line with the reform of the electricity market design, system operators should implement a digital grid connection system with monitoring capabilities. Digitalising connection agreements through a national platform would enable seamless updates, allowing developers to easily request modifications to their connection agreements and streamlining communication among multiple entities sharing a connection point.

Grid operators should adopt clear guidance for managing several entities behind one connection point. There should be one managing entity, who communicates with the grid operator and coordinates the other parties. Retroactively modifying grid connection agreements for existing power plants is complex, time-consuming, and costly. When multiple legal entities are involved in a single hybrid power plant, system operators often face challenges in identifying the main point of contact. The Polish case provides a useful example of how to designate a primary installation for system operator interactions.

Good Practice: Hybrid system with multiple entities approach in Poland

Multiple RES installations can connect to the same connection point, either by adding new installations to an existing connection or by multiple installations sharing a new connection. There are no restrictions on the type, number, or ownership of the RES installations.

Adding a new installation to an existing connection point requires an amendment to the grid connection at TSO or DSO level. In case of multiple owners, they must establish an agreement covering key aspects such as:

- Designating one installation as the primary installation responsible for grid-related agreements.
- Ensuring all parties install equipment to prevent exceeding the connection capacity.
- Each installation must have a separate meter to ensure accurate measurement and compliance.

The primary installation is the party responsible for all grid-related documentation, including connection conditions, the grid connection agreement, and transmission or distribution agreements.

Country	Description of current situation
France	**To improve:** Modification of connection agreements is free of charge, but implementation takes time.
Italy	**To improve:** Lesson learned: Digitalisation progress is becoming evident. However, retroactively modifying a connection agreement remains time-consuming and not always feasible. **Good Practice**: Regarding multiple entities, in Italy this is a typical scenario for high-voltage (HV) connections, where the same connection point is often shared between multiple users, such as the owners of different plants. This is facilitated through the construction of a shared electrical substation connected to the assigned connection point. To effectively manage this arrangement, users are required to sign a Sharing Agreement, which designates a common interface or single point of contact for all interactions with the TSOs.
Spain	**Good Practice**: In co-located installations with the same connection point, a representative for all generators must be appointed to manage common grid-related issues with the TSO. This includes various responsibilities, such as covering the costs of shared non-contestable works during the development phase and managing communications for operations and maintenance during the operational phase. **To improve**: In fully hybrid facilities, multiple entities are not typically allowed. The scope of the representative's responsibilities may differ depending on the specific circumstances.

3. Member States should improve permitting procedures for hybrid PV

In some EU countries, complex permitting processes have slowed the development of renewable energy projects. To address this challenge, the Renewable Energy Directive (RED), amended in 2023, introduces measures to streamline permitting. However, these measures have yet to be implemented, and new challenges are emerging, particularly for innovative projects such as hybrid systems.

Permitting process in Bulgaria

Good Practice: If sufficient space is available on-site and no increase in grid capacity is required, the process is relatively straightforward. The developer signs an annexe to the grid-connection contract, and the BESS is added to the PV plant's generation license (behind-the-meter). Since the land is already zoned for industrial use, zoning procedures are generally smooth, with potential complications arising mainly from fire safety concerns. However, in most cases, projects progress efficiently.

One hybrid project, combining wind, solar, and storage, is currently being developed in phases, aiming to demonstrate the viability of hybridisation despite challenges posed by an uncooperative regulatory environment. You can read more about it here: https://tenevoproject.bg/en/

To improve: The permitting process for RES-to-RES hybrid projects remains unfamiliar and poorly defined. Local authorities often struggle with zoning procedures, leading to inconsistent requirements and, at times, contradictory practices across the country.

Country	Description of current situation
Poland	**To improve:** Hybridisation regulations in Poland apply exclusively to RES-to-RES installations and not to RES-to-BESS. However, as the definition of an RES installation allows for the inclusion of a battery component without specifying a required ratio between RES and battery capacity, this creates a practical loophole. Consequently, BESS projects with minimal integrated solar PV capacity, such as a 50 MW BESS paired with just 0.1 MW of solar PV, can still qualify as "RES installations." Despite this loophole, the regulation still does not address the broader issue of unclear regulations, which continue to hinder developers from effectively planning hybrid systems with storage.
Spain	**To improve**: Increasing the installed capacity due to hybridisation can trigger unclear additional permitting requirements. For example, in Spain, a 50 MW limit on installed capacity determines whether the national or regional administration manages the permitting process. If hybridisation pushes the total capacity above 50 MW, the responsible administration changes, potentially requiring the permitting process to restart. In practice, this creates a barrier to hybridising projects developed under regional administration.

To improve the permitting process, simpler and more efficient procedures should be introduced, especially for hybrid projects that build on existing infrastructure. Since much of the administrative groundwork is already in place, requiring duplicate permits adds unnecessary delays and complexity. A harmonised regulatory framework is needed, including faster approval processes, clear deadlines, and consistent permitting rules. Key measures should include shorter and more predictable timelines, a standardised one-stop-shop system, and the application of overriding public interest for RES-to-BESS projects. Member States should allow joint permitting requests for different assets under one grid connection point.

Bad Practice: Designated go-to areas in Austria

Hybrid PV and wind projects are only permitted if wind parks are within designated go-to areas. However, many wind parks in Austria fall outside these areas, creating a significant barrier to hybrid project development.

The development of new storage acceleration areas and ongoing renewable acceleration areas should preserve opportunities for hybridisation between different renewable sources or/and with storage solutions. Additionally, their selection should align with future grid developments. Additionally, under the RED regulation, EU countries must designate at least one type of renewable energy technology within "Renewables Acceleration Areas" (RAAs) by February 2026, ensuring faster permit approvals in these zones. However, some countries are discussing the establishment of separate RAAs for solar and wind power plants, which limits the possibility of connecting these technologies to the grid at the same point, as is the case of Austria.

4. Support schemes should be adapted to hybrid PV projects

Hybrid projects should be able to participate to traditional renewable energy auctions

Several Member States have already organised auctions, opened or fully-dedicated to hybrid projects. To provide clarity on the way forward, **new hybrid projects should be eligible to participate in traditional RES auctions.** Allocation Rounds (AR) in the United Kingdom serve as a strong example of auction design, where hybrid projects have participated alongside stand-alone PV under fair competition, leading to significant deployment of both types of projects.

Member States should grant CAPEX support for storage under hybrid projects

For both new and retrofitted Solar + Storage hybrids, **Member States should consider setting up specific hybrid auctions with financial support of a portion of the battery's CAPEX when connected to a renewable asset** with an appropriate metering system, contributing to the de-risking of the entire project.

In 2023 and 2024, CAPEX subsidies for hybridising renewables with batteries were awarded respectively in Spain and Portugal, with a maximum amount equivalent to 40% and 20% of the reimbursable CAPEX. Auctions were successful in attracting +800MW and c.500MW, respectively, in Spain and Portugal, signaling a strong desire towards hybridising with storage in solar-driven markets.

In the Innovation Auction in Germany, eligible plants are either a combination of different renewable sources or renewable energy plants with storage. However, in practice, participation in the innovation scheme has historically been limited to solar + storage projects, with restrictions on battery usage, which we will explore later in this chapter.

Type of support	Country	Description	SPE analysis
Auction with CAPEX grant	Spain	Grant covering 40% of the battery's CAPEX	Good practice
Auction with CAPEX grant	Portugal	Grant covering 20% of the battery's CAPEX	Good Practice
Auction with CAPEX grant	Bulgaria	Grant covering up to 50% of the battery's CAPEX	Good Practice
Innovation Auction	Germany	The design of the auction failed to provide incentives to the participation of Solar + Wind Hybrids.	Bad Practice

CfD design must account for hybrid projects with storage

While implementing the EMD and designing non-distortive two-sided CfDs, Member States should envision the benefits brought by hybrid PV projects to the system. Injection-based Contracts for Difference (CfDs), or 'traditional CfDs,' do not always facilitate the co-location of storage assets alongside PV plants. Where remuneration of solar electricity is based on megawatt-hours (MWh) injected, there is no added value for electricity dispatched during non-sunny hours via the battery.

Member States can solve this issue by ensuring two-sided CfDs are designed as pay-as-produced contracts where the energy is settled at the point and time of generation and not when exported to the grid. Appropriate metering arrangements would enable CfD-settled energy to be directed either to the BESS or the grid, effectively allowing it to buy and sell power on the market and supporting the BESS in executing its intended business model.

Good practice: CfD design in the UK

The approach values the RES asset at the time of generation under the CfD, regardless of when electricity is dispatched to the grid. The battery is then able to participate in its usual markets without impacting its value.

Member States should allow value stacking for assets under support schemes

Auction rules and capacity markets often restrict batteries from charging from the grid. This limits them in participating in electricity markets and providing ancillary services. Germany's "innovation auctions" ban this. In Portugal, batteries can only charge 25% of their energy from the grid.

Batteries attached to a solar plant should be able to value their electricity in multiple markets to maximise their added value to the system, even when the attached renewable plant receives public support. Short-term electricity markets (balancing, ancillary services) are not subsidised, so they should not be accounted for as state aid cumulation.

Country	Description of current situation
Germany	Under the current innovation tender rules, storage can only be charged from the PV system and not from the grid (DC-coupled system). In this setup, both the PV and storage share a common DC bus[8] and typically connect to the same AC inverter to feed power into the grid. Storage can only discharge to the grid but cannot charge from the grid and therefore cannot participate in arbitrage trading in spot markets (since charging from the grid would potentially be fossil electricity, and in order to receive the subsidy, only renewable electricity can be awarded. This scheme is currently being revised by the German regulator.
Portugal	The regulator, DGEG, currently considers implementing limitations in the operations of BESS applying to all storage above 1MW, including co-located with RES. These limitations also apply if co-located under self-consumption schemes. Limitations are that BESS are obliged to provide FCR, which is non-remunerated, but also aFRR, mFRR and congestion management services. Furthermore, the CAPEX subsidy auction forces the projects to consume at least 75% of their energy from the associated renewable producer. This undermines the economics of the projects while preventing storage assets from supporting the system by absorbing a surplus of renewables.

8 A DC bus is a common direct current (DC) connection that links multiple electrical components in a power system, allowing them to share power efficiently before converting it to alternating current (AC) for grid injection or usage

In addition, capacity markets are often unsuitably designed for hybrid projects. Where Member States have designed capacity markets, Hybrid PV systems are not able to participate on equal footing with other participants. This is because most capacity markets do not apply appropriate de-rating factors to hybrids. Methodologies vary across the EU and the storage duration capacity of the battery is not always reflected in the design. Yet, a hybrid de-rating factor would be useful for projects that do not have other support mechanisms. **Capacity Markets should design and make use of adequate de-rating factors for hybrids and consider the duration feature of storage systems within their methodology.**

	Country	Description	SPE analysis
De-rating factor design	EU-wide	There is no de-rating factor methodology for solar + storage hybrids in the EU.	Bad Practice
De-rating factor design	UK	The de-rating factor calculation methodology considers the discharge duration of a storage technology.	Good practice
De-rating factor design	Belgium	The de-rating factor calculation methodology considers the discharge duration of a storage technology.	Good practice

5. Grid costs must offer a level playing field between grid management technologies

The existing grid structures and tariff methodologies were designed for centralised generation. To accommodate decentralised renewables and storage, it is necessary to adapt these systems with grid tariffs that encourage greater flexibility.

For example, some countries have different network connection tariffs between the TSO and DSO levels, which can discourage decentralisation. **Grid connection tariffs should not vary based on voltage levels. They should be designed to promote the decentralisation of systems and better integration of renewable energy sources.**

Country	Description of current situation
Denmark	**Bad Practice:** There are more grid connection tariff incentives to connect directly to the TSO than the DSO. Several utility-scale projects designed for DSO connection have been abandoned due to high connection tariffs.
The Netherlands	**Bad Practice:** Battery storage systems are subject to high grid fees, equivalent to those paid by traditional electricity off-takers. This significantly undermines the financial viability of battery projects, making them unprofitable. As a result, these high costs create a major barrier to battery deployment, slowing down the development of essential energy storage infrastructure.

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The lack of a supportive grid tariff framework is a significant challenge for hybrid systems with energy storage technologies. To optimise grid usage, tariffs should be designed to reduce costs for batteries, which improves grid use efficiency. **A key priority is eliminating double charging for storage, regardless of whether the same or a different PV inverter is used.**

Double charging occurs when energy storage is charged fees both as a consumer, when drawing electricity from the grid, and as a producer, when injecting it back. This places energy storage at a disadvantage compared to fossil fuel generators, creating a financial burden that slows its deployment. The Clean Energy Package of 2019 aimed at preventing double charging for prosumers providing flexibility services, but unclear wording has led to inconsistent implementation across Member States. A 2023 NECPs analysis found that only five countries—Czech Republic, Germany, Portugal, Spain, and Sweden—are taking steps to address the issue, with Czech Republic set to introduce a specific ban in 2025.

As it applies to hydro pump technology, which also functions as a storage technology, BESS should be exempt from "consumption" and "production" charges across Member States.

To improve: Storage grid tariffs in Portugal

In Portugal, there are no injection tariffs, solely consumption tariffs. The key concern for the National Regulatory Authority (NRA) is Behind-the-Meter (BTM) storage in consumers with self-consumption units (UPAC), as it is more challenging to distinguish between energy consumed by the battery and final consumption.

Similar to pumped storage, hybrid PV systems with BESS should also be exempt from consumption tariffs, not just injection tariffs, as it plays a vital role in optimising grid usage and efficiently integrating renewable energy.

6. Guarantees of Origin (GOs) should be issued for all renewable electricity generated by hybrid projects

Hybrid renewable energy projects should qualify for a Guarantee of Origin (GO) for each megawatt-hour (MWh) of renewable electricity they generate—whether it is immediately injected into the grid or first stored and injected later. Achieving this requires an appropriate metering framework to track the flow of renewable energy.

At present, hybrid PV projects do not receive GOs, as the existing GO framework only accounts for electricity directly injected into the grid. The current metering setup does not track renewable electricity that is temporarily stored in batteries or energy drawn from the grid for storage. Neither the EU nor national regulations provide clear guidance on how to certify renewable energy once it has passed through a storage system.

To accurately track renewable energy and issue GOs accordingly, at least two metering points are necessary to monitor the flow of renewable electricity:

- A generation meter which captures the initial renewable energy output from the inverter.
- A storage input/output meter which tracks energy flowing in and out of the battery to account for losses and prevent double counting.

Measuring generation only at the inverter is insufficient because it does not account for storage-related losses, potentially leading to discrepancies in the amount of certified renewable electricity.

A more precise method is to issue GOs at the moment of generation, using the same metering methodology as CfDs. This ensures accurate tracking of renewable energy, even when stored before injection, preventing the dilution of green energy claims.

By refining the GO framework to account for hybrid systems, policymakers can support grid flexibility through hybrid projects providing ancillary services and decarbonisation by ensuring renewable energy used in CfDs and PPAs is properly certified.

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