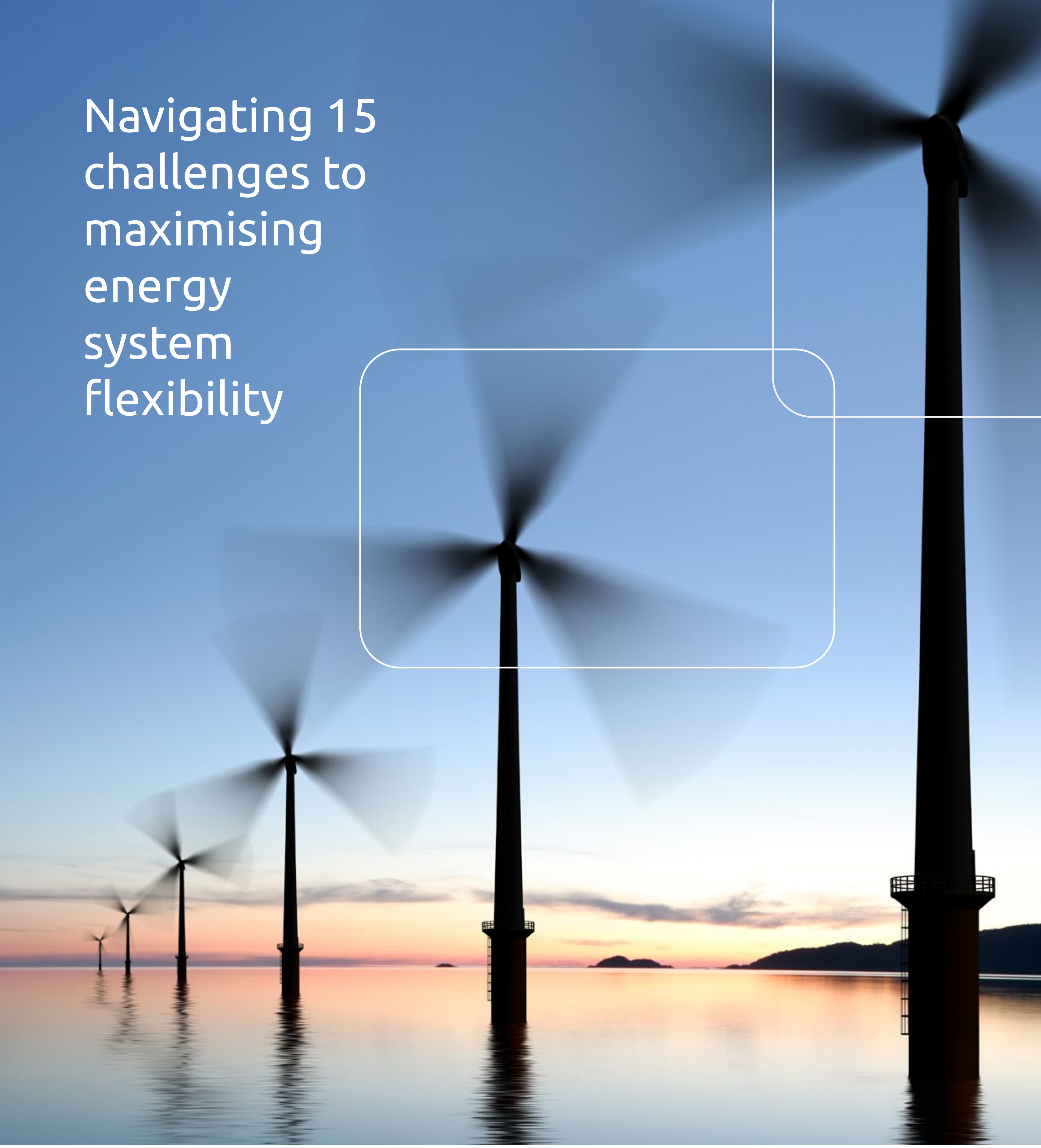
Navigating 15 challenges to maximising energy system flexibility



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1. Why a clean energy future requires more system flexibility

Europe’s pivot towards a clean energy future is driving a transformative shift in the energy sector marked by the rise of distributed energy resources (DERs) and a changing flexibility landscape. In this evolving landscape, energy storage solutions, active demand side management, and advances in IT are gradually replacing conventional large-scale sources of flexibility. These developments spur innovations (like smart grid solutions) and profoundly alter market dynamics.

The ability to adapt to real-time energy supply and demand variations and increasingly frequent congestion situations stand as cornerstones of Europe’s stable energy system, set to be dominated by a significant share of variable renewable energy sources (RES).

Yet, the road to unlocking the full potential of flexibility faces multiple technical, regulatory, and operational hurdles. Transmission system operators (TSOs), distribution system operators (DSOs), market participants, and investors are each grappling with the impacts of these challenges to different extents.

How to navigate these challenges?

2. The 15 barriers to maximising flexibility

What are those barriers to maximising the potential of flexibility? We identified 15 critical barriers constraining the effective leveraging of flexibility in Europe. These range from barriers in grid operations, barriers for market parties along with technological challenges.

In this brief, we'll discuss these challenges, plus the solutions needed for energy system stakeholders to overcome them.

Figure 1. 15 barriers to maximising flexibility

Grid operation challenges

Europe's grids are undergoing a massive transformation at multiple levels, but it doesn't come easy. There are many challenges that still need to be addressed before successfully integrating renewables sources and much-needed flexibility into the grid.

1. Lack of structural TSO-DSO coordination

The steady expansion of DERs is already significantly disrupting traditional grid management practices, in particular on the distribution network level. Historically, the grid has been organised through a top-down unidirectional approach, from the TSOs down to the demand centres at the distribution level. Particularly over the last 5 years, DERs such as solar photovoltaics (PV) and home batteries have been moving from small-scale pilots to larger-scale commercial applications both front-of and behind-the-meter. This creates a challenge for DSOs due to bidirectional electricity flows and an increasing risk of distribution grid congestion. At the same time, it creates an opportunity to tap into distributed flexibility for system services. As a result, there's an emerging need for a more collaborative and integrated management approach that synergises the operations of both DSOs and TSOs.

However, there are several obstacles to this cooperation. Data sharing remains a contentious issue, with concerns surrounding proprietary interests, cybersecurity, and legacy systems. Additionally, disparities in technical capabilities and infrastructure readiness between various DSOs and TSOs add to the complexity. This variation in capabilities hinders the information exchange requirements for a high-RES, more decentralised grid ecosystem.

Finally, **the absence of incentive regulation promoting such cooperation and coordinated use of flexibility means that initiatives are based on the goodwill of the parties involved rather than on a well-defined framework.**

2. Lack of observability in the distribution network

The need for DER integration also emphasises the need for enhanced visibility within the distribution network – both for DSO's and TSO's system needs. With very few exceptions, there is a lack of proactive distribution network planning close to real time and, therefore, lack of grid observability. This presents a significant challenge for network operators under the changing conditions. It also precludes potential flexibility providers from offering their services. Instead, **low visibility and a lack of real-time system operational planning at the DSO level limits DER management to a reactive ex post approach.** It increases the likelihood of congestion and/or voltage control issues. This then often leads to RES curtailment, reducing the overall efficiency and effective RES integration as well as underutilisation of local flexibility potential. The lack of a clear view of real-time energy flows can also impact timely decision-making, potentially exacerbating grid stress situations in future high-RES scenarios.

3. Grid congestion and voltage control issues

Variable renewable energy (VRE) can often cause considerable power and/or voltage fluctuations, jeopardising grid stability. Large and simultaneous RES infeed often also produces congestion events, which occur with increasing frequency both in transmission and distribution grid levels. Yet, **VRE are not the only reason for the growing frequency and magnitude of grid challenges. Another important influencing factor is electrification of heat and mobility sectors**, which, if not deployed for flexibility, may significantly aggravate those challenges.

In the upcoming decade, grid congestion is becoming evident even in traditionally congestion-free countries such as France. Others, such as Germany, have been grappling with congestion for years. According to Bundesnetzagentur, the costs of congestion management in the country in 2022 alone reached exorbitant 4.2 billion euro while congestion management measures were used of about 80% of all days of the year! On the distribution grid level, the Netherlands has experienced a quick surge in congestion largely due to a rapid solar PV buildout in the country. As a consequence of rapid local buildout of RES and other DERs, grid connection is also becoming a scarce good which makes projects wait for years for physical connection.

> *Enabling the deployment of flexibility is essential for mitigating grid congestion but also facilitating grid access to new projects.*

Voltage variations necessitate the development and implementation of advanced Supervisory Control and Data Acquisition (SCADA) systems, along with essential network upgrades to ensure grid voltage remains within acceptable limits. Additionally, integrating flexibility from DERs, including demand-side management (DSM) compounds the complexity of these challenges, in particular during the DER scaling phase. Flexibility also has a high potential to help alleviate these challenges by strategically injecting or absorbing power as needed to stabilise voltage levels or adjusting consumer electricity consumption patterns to align with grid needs. To provide this service, flexible resources would need to be remunerated to create an incentive to deliver reactive power. Yet, while there are exceptions that do offer a market for voltage control (e.g. France), it is mostly an unpaid service.

4. Insufficient grid expansion projects

While the EU is ambitiously ramping up its renewable capacity, the pace of grid expansion is not keeping up. This lag has led to a notable curtailment of RES across the EU. This hampers effective RES integration while other sources of flexibility are not sufficiently available to absorb excess renewable generation. The Renewable Energy Market study by the IEA study found that in 2021 Germany curtailed an estimated 3.3% of its total wind and solar power while, in the same year, the share of curtailed wind and solar in Spain and Ireland reached 0.4% and 7.1% respectively[1].

As outlined in the EU's Ten-Year Network Development Plan (TYNDP), tools like demand response (DR) and storage offer cost-effective strategies for deferring investments in new transmission infrastructure. However, it's important to note that **these solutions complement, rather than replace, the need for grid expansion.** Achieving the EU and national renewable targets and guaranteeing a safe system operation necessitates a balanced combination of measures, accelerated grid expansion alongside integrating flexibility solutions.

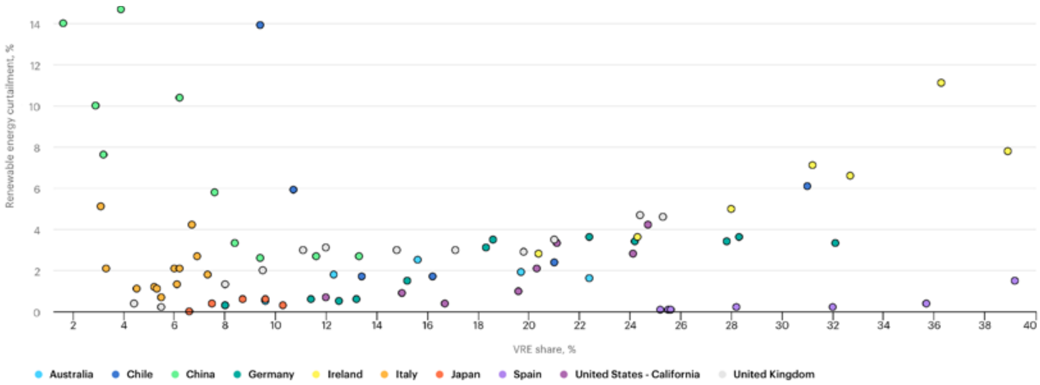

Figure 2: Percentage of curtailments compared to VRE per country. Source: IEA 2021 [2]

5. Dwindling system inertia in a VRE-dominated energy system

The expanding share of inverter-based renewables introduces critical challenges concerning system inertia. **Traditional synchronous generators, which have so far been contributing significantly to delivering system inertia, are being progressively phased out.** This makes the maintenance of grid stability increasingly complex. The shift raises concerns about the grid's resilience to rapid large-scale frequency deviations. It requires the European grid to innovate and adapt, for example, by using synthetic inertia delivered by RES inverters.

The feasibility of synthetic inertia has been demonstrated by projects such as OSMOSE (Optimal System Mix of Flexibility Solutions for European Electricity) in Italy[3] or ABS4TSO in Austria[4]. However, the integration of new technologies into established operational frameworks is not straightforward. It requires meticulous synchronisation and real-time response capabilities, particularly when harmonising practices across different national grids within the EU.

Market-party challenges

Next to the operational challenges, is the fact that flexibility is part of the energy market. There are many challenges to offering flexibility as a service in a way that both rewards the provider and maximises social welfare.

6. Barriers to providing ancillary services

There are several key barriers to the integration and utilisation of flexible assets for ancillary services[5] (all services required to enable TSOs and DSOs to maintain the integrity and stability of the grid). These include:

- European countries allowing the direct participation of balancing service providers in ancillary services, but, for instance, making them subject to the permission of the balance responsible party or – for aggregators - consumers' supplier.

- TSOs' requirement of symmetrical bids in some balancing markets.
- TSOs requirements to repeat the prequalification process for already prequalified assets, for instance in case of minor changes in pool composition.
- Market requirements to provide 100% guarantee of their availability or operating within very narrow dead bands.
- Too large minimum bid sizes for DER to participate (1 MW or more) or placing restrictive requirements on their aggregation.
- **In contrast to balancing, other ancillary services such as congestion management or voltage control are mostly non-remunerated thus removing the incentive to provide them in the first place.**

As long as these barriers persist, the flexibility potential of distribution grid connected assets will remain underutilised and limit the rate at which Europe can achieve its decarbonisation targets.

7. Regulatory uncertainty

Europe's ambition to decarbonise its energy system and ramp up renewable penetration has inadvertently introduced **heightened price volatility into its electricity markets.** The share of renewables in Europe's energy mix has increased from 12.5% in 2010 to 21.8% in 2021[6]. However, in order to reach the ambitious goal of 42.5% of RES by 2030 as per the 'Fit for 55 Package', more efforts are required to encourage massive further investment as well as in flexible technologies able to account for its fluctuations.

Concurrently, the regulatory landscape for energy flexibility in Europe remains in flux. **As policymakers grapple with the intricacies of implementing EU regulations into the national legislation, stakeholders face mounting uncertainties. This process often takes several years**. Ambiguous or frequently shifting regulatory stances – in particular as a result of the energy crisis of 2022-2023 - have already been significantly deterring investments in flexible solutions. Coupled with protracted stagflation and supply chain issues, this mixture of market dynamics and regulatory ambiguity represents a complex hurdle that European energy professionals must navigate.

8. Lack of locational signals for flexibility

Currently, the European Union's regulatory framework highlights the importance of flexibility in the energy system. However, the effectiveness of financial incentives for flexibility where it is needed the most shows considerable variance across EU member states. It is often in question whether the financial incentives are sufficient to motivate the necessary investments in DERs or their participation in system service provision. Additionally, there is scepticism about how well these incentives are designed locally to achieve specific objectives, such as prosumer participation in the market and grid support.

Incentivising flexibility further requires a paradigm shift in tariff designs and market mechanisms, incorporating more granular time and locational price signals. The latter has so far been hard to implement given Europe's zonal market model. Yet even then, some measures to help investors improve siting decisions and encourage grid-friendly behaviour could be taken. Consider, for instance, dynamic tariffs reflecting real-time network conditions and more favourable conditions in locations prone to congestion. For instance, through location-specific auctions.

9. Remuneration of flexible capacity

Ever since the topic of flexibility landed on the European agenda, it has mostly been seen in terms of the energy component. For instance, as the energy that needs to be delivered (or consumed) at a rather short notice. Beyond flexibility in the shortest timeframe (from a few seconds to an hour), it will also be needed for longer time periods. For instance, the delivery of a congestion management service would require an activation of several hours in a row. Meanwhile,

the line between system flexibility and adequacy, that is, securing enough supply to cover the demand, is becoming blurrier as we are moving towards a high-RES system. This was also evident from the latest Flexibility and Adequacy Report by the Belgian TSO, Elia[7].

For over a decade, it has been debated in Europe whether energy-only markets are or will be sufficient for delivering a stable and adequate system. One that captures the value of flexibility and generates sufficient investment. Ideally, the robust price signals and volatility in short-term markets should deliver sufficient incentives and enable market actors to cover their fixed costs. On one hand, the effectiveness of these signals can be lessened by existing price caps. On the other hand, severe price volatility, like the one observed during the energy crisis of 2022, can produce the opposite effect making any potential investment in flexibility too risky.

In such a setting, **flexibility providers might be searching for remuneration for reserving their capacity – to either provide flexibility or support the system in times of scarcity – as a de-risking measure for their investment.** In some countries, such as France or Italy, capacity mechanisms have been used for a while. In others, however, implementation of such mechanisms, or capacity payments for system services, was and is less acceptable. In addition, in its latest report on security of supply 2023, ACER found that capacity mechanisms are still largely tailored to and used for conventional generation capacity making DERs much less able to participate[8].

As we are progressing towards a highly variable system with low shares of conventional flexibility, both the review of the age-old approaches and new solutions will be needed to produce a flexible and technologically diversified system.

10. Participation of the demand side

The EU's demand-response market is still in the early development phase. While the high potential and need for demand response has been recognised both in the EU regulatory framework and by the energy sector's stakeholders, major barriers still need to be addressed. Primarily, there include **a lagging transposition of EU regulation into national legislation, ineffective market access along with a lack of awareness (or interest) on the consumers' side.**

> *Currently, the Network Code on Demand Response (NC DR) is being drafted. This will prove instrumental in standardising and encouraging some of the use cases for demand response across the EU.*

Figure 3.

While there are, theoretically, multiple steps consumers, industrial, commercial or residential, might take to provide demand response, most of these are still at a rather rudimentary stage: Solutions such as dynamic energy tariffs are not novel, but their widespread adoption has been slow and widely differs across EU countries. This is partly due to **a lack of digitalisation (esp. smart meters) in some countries and of attractive offerings from suppliers able to sustain consumers' motivation over prolonged periods of time.** Aggregator's offerings have made a leap over the last few years, but there are still major barriers such as non-harmonised compensation schemes for consumers' suppliers.

As to peer-to-peer transactions and energy-community-driven schemes, the principles governing them have advanced since the adoption of the Clean Energy Package. However, their implementation and operation are highly heterogenous across Member States, intricate and still in their embryonic stages. Furthermore, there's a significant challenge in accessing the necessary data for these initiatives due to the requirements of the General Data Protection Regulation (GDPR). For instance, it is unclear whether energy consumption data falls under personal data in the sense of the GDPR.

Local flexibility markets for DSO-level congestion management have so far been implemented only in the UK, Norway, Sweden and the Netherlands. In other countries, these remain non-existent both due to lack of regulatory clarity or of DSO-level data – or both. On the flipside, the introduction of DSO-only flexibility markets could potentially add layers of complexity to an already intricate energy system whereas liquidity is likely to be low, raising market power concerns. Approaches to using flexibility locally to solve grid constraints are necessary. Yet, so far, other issues such as improved DSO grid observability, incentives for service provision, adequate remuneration and TSO-DSO cooperation would need to be solved first.

11. Non-harmonised aggregation rules

The EU's Clean Energy Package recognises the pivotal role of aggregators in enabling the use of flexibility in the energy markets. Aggregators, by pooling multiple DERs, have the potential to tap into smallest-scale flexibility on both supply and demand sides and provide multiple ancillary services as well as portfolio optimisation. Yet, this potential often remains under-realised due to the gaps and grey areas in national regulatory frameworks governing their operations. **Divergent and restrictive rules surrounding contractual relationships and responsibilities for imbalances form barriers to the activities of aggregators in the market.**

For a truly integrated energy market that capitalises on the inherent benefits of aggregation, there's a pressing need for a standardised, EU-wide framework, which can lay the groundwork for robust cross-border flexibility trading and drive more uniform market participation. **Similar to increasing regulatory clarity with regard to demand response in Europe, the NC DR will be crucial for specifying the rules, roles and responsibilities with regard to independent aggregation.**

Technological challenges

Next to the operational and market challenges is the technological reality of flexibility. Although there are many non-fossil sources of flexibility, their large-scale adoption faces many challenges.

12. Phaseout of conventional generation and a lack of low-carbon peaking plants

As a consequence of the EU's ambitious decarbonisation goals, further spurned by the gas crisis of 2022 and the war in Ukraine, the rapid phaseout of conventional generation is impacting the availability of peaking plants during hours of scarcity. **There's a pressing need to pivot from fossil-fuel based peaking plants to cleaner, low-carbon alternatives in time.**

Traditionally, peaking plants (often powered by natural gas or even oil) have been critical in addressing demand spikes and ensuring grid stability during peak load intervals. However, the integration of more intermittent renewable resources into the energy mix demands a re-evaluation of our peaking infrastructure. The primary challenge of this is identifying and developing clean alternatives that can match the rapid-response capabilities inherent to traditional peaking plants. This is essential, given the intrinsic link between flexibility and system adequacy. At the same time, as such technologies' capacity factors are going further down, peaking technologies are facing an additional profitability challenge.

13. Insufficient energy storage

The lack of advanced storage solutions in Europe is a particularly acute constraint in an increasingly renewable energy system. The inherent variability of RES necessitates robust storage capabilities to ensure supply-demand equilibrium at all times and at a short notice. Beyond that, more frequent extreme weather events and global warming increase the need for a "buffer" technology. Without this, grid operators face the daunting challenge of managing sharp peaks and troughs of the residual load. This potentially leads to issues such as increased curtailment of renewables, and an increased risks to system security and reliability.

The 2019 recast Electricity Directive outlines stringent ownership conditions for TSOs concerning energy storage. It underscores the EU's preference for market-driven storage solutions over TSO or DSO-controlled assets. Creating sufficient incentives for storage operators in terms of market access, grid tariffs and a stable regulation are just some of the many challenges that remain to be solved.

The balancing markets have historically been the primary market for battery storage. However, recent price changes and growing market saturation present new challenges for battery operators. To stay profitable, they must now employ strategies like value stacking, which involve leveraging multiple revenue streams and optimising battery use across various energy markets.

Despite these challenges, it is also important to acknowledge that storage investments – both behind- and front-of-the-meter – have increased significantly in the past 3-5 years and are forecasted to increase dramatically until 2030 [Figure 4].

Finally, **the required solutions span more than short-term fast-reacting battery storage. They also include an urgent need for longer-term storage technologies able to absorb weekly, monthly or seasonal changes. Technologies that are much less mature than battery storage.** The maturation of economically viable technologies, notably hydrogen-based solutions and thermal storage, remains the pivotal challenge.

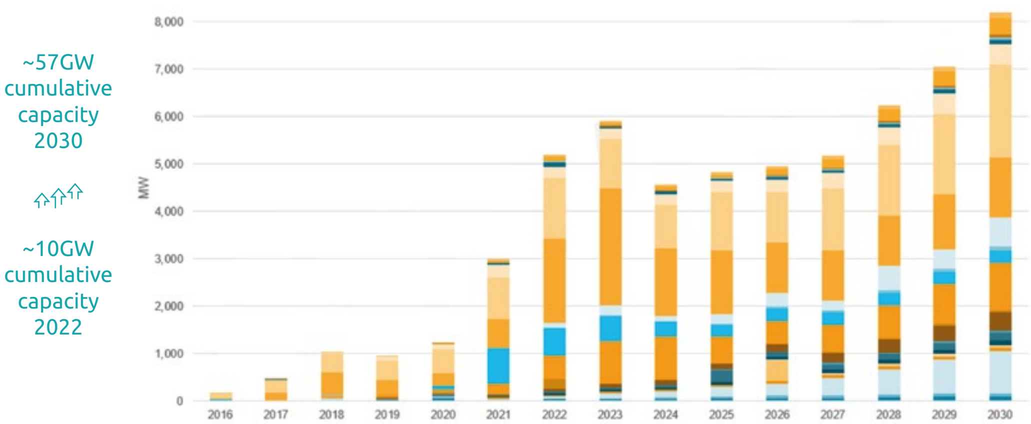

Figure 4. Yearly battery power capacity forecasts[9]. Source: EASE & Delta-EE 202.

14. Supply chain issues

Europe's reliance on external sources for essential components and technologies related to energy flexibility exposes it to uncertainties in geopolitics, trade regulations, and disruptions in global supply chains. This affects their acquisition and continuous supply. Ensuring a sustainable and dependable supply of specific raw materials such as lithium, cobalt, and rare earth elements, which are integral to the availability of, for instance, energy storage solutions, is a critical challenge. Battery storage is particularly impacted by supply chain bottlenecks, as there is an escalating demand for these technologies driven by the imperatives of electrification and decarbonisation. These bottlenecks subsequently affect the ability to modulate energy supply effectively, to meet the separate, but often concurrent, demand peaks in heating and mobility sectors.

15. Expected massive electrification

The anticipated widespread electrification in Europe signals a transformative shift in the energy landscape. In the future, everything but hardest to abate sectors will likely be electrified. The TYNDP sees **electricity demand across Europe increasing by almost 20% by 2030 driven by the uptake of EVs (see Figure 3) and heat pumps - despite a significant increase in various energy efficiency measures**[10]. These shares are even higher for some EU countries. This significant

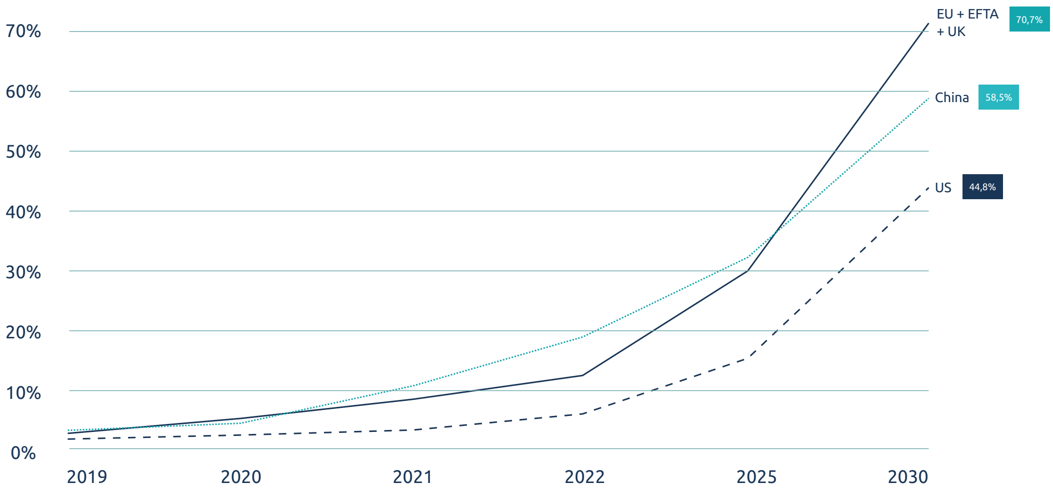

Figure 5. Forecasted battery electric car sales (%)[11] *Source: ACEA and S&P Global 2022.*

increase in loads (and generation), particularly due the proliferation of electric vehicles, will have sweeping ramifications for the grid and the need for flexibility all the way down to the lowest levels. Electrification will necessitate additional infrastructure and markets capable of accommodating large increases in demand and turn these new resources into future sources of flexibility.

This will further strain the demand for and associated supply chain issues of batteries, which are expected to grow exponentially proportional to the growth of the EV market.

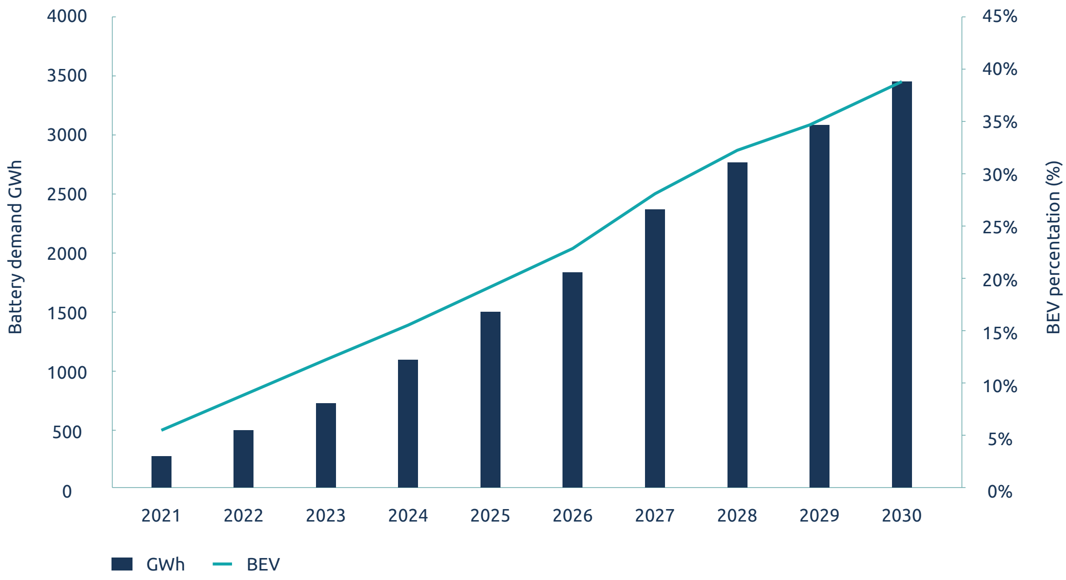

Figure 6. Forecasted battery demand (GWh) vs BEV penetration (%)[11]. Source: ACEA 2022.

3. Our 6 Solutions

However knotty the barriers are, there are multiple solutions to maximising the availability and use of flexibility - especially when addressed in a coordinated fashion. Which routes to tapping into more flexibility are there?

Figure 7. Six solutions

1. Market & grid integration with product harmonisation

One of the bedrock strategies for enhancing flexibility lies in capitalising on market and grid integration, complemented by product harmonisation.

Generally, EU market and grid integration has been a double-edged sword. It is no secret that, apart from large welfare benefits, it does augment national interdependencies. This implies that at times vulnerabilities in one area may cause chain reactions in other areas. European market coupling, however, has proven extremely valuable in abating these challenges even in the extraordinary conditions such as those of the energy crisis of 2022.

As energy experts recognise, **closer coupling of regional markets and grids can mitigate local flexibility constraints and ensure a more efficient allocation of resources.** For instance, the MARI & PICASSO balancing platforms achieve a significant increase in overall social welfare, in particular for smaller market areas, as quantified in Figure 8. The aggregate welfare improvement for Q3 and Q4 of 2022 was €375 million, not accounting for additional demand fulfilment, and up to €670 million is additional demand satisfaction is included[12]. Additionally, avoiding uncoordinated purely national implementations minimises fragmentation which tends to create undue barriers to market participation. This enhances the seamlessness of cross-border transactions, increases market size for flexibility providers, and optimises the overall EU energy market efficiency.

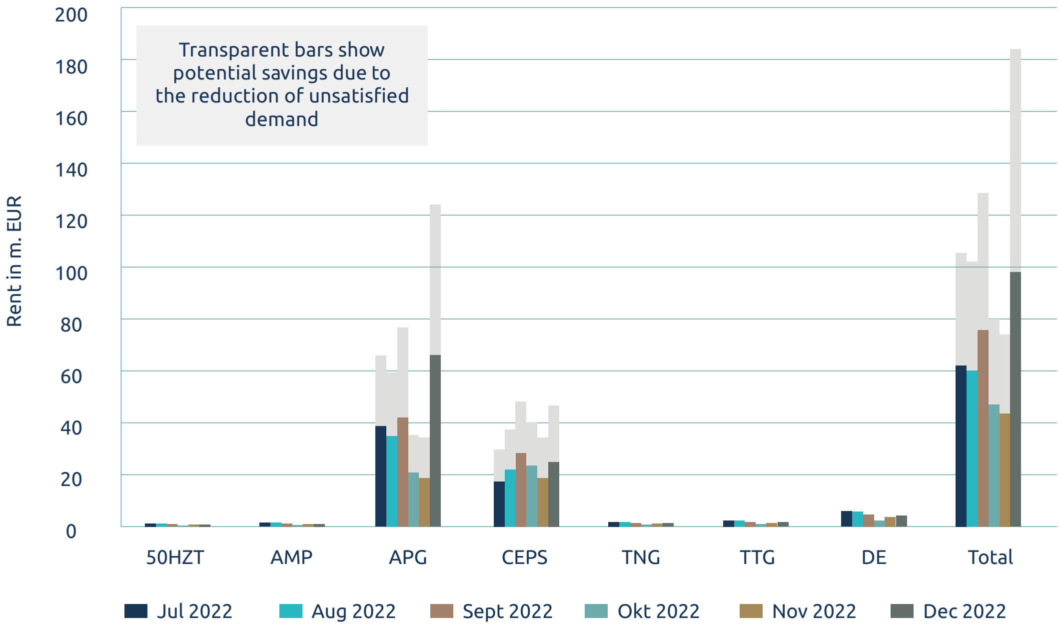

Figure 8. Social welfare gains of PICASSO per month since start of operation as compared to against a baseline scenario without cross-border exchanges [12]. Source: MESC 2023.

2. Accelerated implementation of flexibility-related EU regulation

Addressing flexibility challenges requires a comprehensive and consistent regulatory framework – on the EU as well as national levels. The primary goals of this framework should be on reducing entry barriers and ensuring that new market players (especially smaller participants), have a "level starting point". For instance, that they are given sufficient support to be able to compete on par with more established technologies and players until they reach maturity.

Based on ACER's latest analysis of barriers to entry, regulation remains the biggest barrier. Thus, the transposition of EU directives into national legislation is urgently needed[7]. The Network Code on Demand Response, which besides demand includes supply-side flexibility and storage, is supposed to provide more structure and clarity on the roles, responsibilities and guiding principles for flexibility provision, which will need to be directly applied nationally. Its adoption is expected in 2025.

3. Liquid intraday & balancing markets

By ensuring robust intraday and balancing markets, flexibility service providers can respond to deviations from forecasts or system imbalances. Liquid intraday and balancing markets enable more flexible and grid-friendly generation and consumption behaviours. Just over the last decade, the volume of energy traded in the intraday timeframe has witnessed a major increase across power exchanges. **On EPEX Spot alone the intraday trading volume has risen more than twofold over just 6 years,** as shown in Figure 9.

> *More flexibility can be provided if liquid intraday markets are available and providers can support the system in reaction to (close-to-)real-time data.*

In addition, it is still part of an ongoing debate on the extent to which market actors should be supporting TSOs. By balancing not only their own portfolios but also the system – in reaction to real-time imbalance signals. This so-called "passive balancing" approach might make good use of flexibility and potentially reduce the need for dedicated balancing resources. It is already in use in e.g., the Netherlands and Belgium. In many other countries, the acceptance remains low due to concerns around a high information asymmetry and the risk of market actors overcorrecting and thus worsening the original situation. While the best approach may differ from TSO to TSO, **timely access to information remains one of the crucial factors influencing availability of flexibility.**

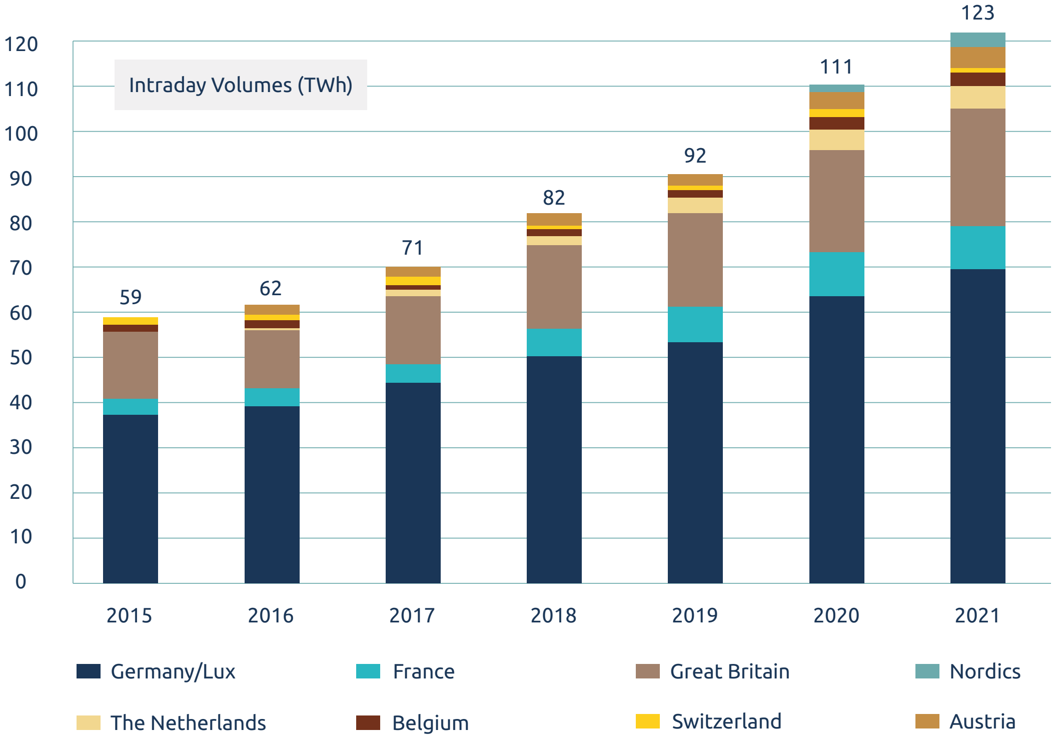

Figure 9:. ID electricity market trading volumes on EPEX Spot 2015-2021 (TWh). Source: EPEX Spot 2022[13]

4. TSO-DSO cooperation

Harmonising or synergising the operational dynamics between TSOs and DSOs is of paramount importance as more DERs are coming online. Enhanced collaboration between these entities would allow a holistic system view, ensuring active system planning on all levels. It should also make it possible for flexibility resources at the distribution level to be integrated into the broader transmission and market services. This implies advanced information exchanges in different timeframes, coordinated use of flexibility for both TSO and DSO services, as well as ensuring that TSO's deployment of distributed flexibility does not cause operational issues in the DSO grid.
Interoperability of IT solutions enabling multi-actor coordination is essential is making sure that the value of flexibility is maximised.

> *Stay tuned for our upcoming brief on interoperability in the context of energy system flexibility*

5. Digitalisation and flexibility platforms

Digitalisation and the emergence of flexibility platforms are a key solution to the challenges introduced by DERs. The digitalisation of distributed assets has enabled their connectivity and control by market players and/or system operators. It also enhanced the availability of flexibility for markets and grid services. Digital solutions need to provide much needed automation and optimisation of DER's operation in such a way they can provide flexibility for the grid while observing the industrial process requirements or comfort levels.

Interoperable flexibility platforms serve as crucial intermediaries, communicating between (aggregated) assets to the marketplaces, facilitating trade, information exchanges, and settlement of energy or system services between TSOs / DSOs and DERs. Including a filter function allows for targeting local flexibilities, primarily aimed at resolving distribution network constraints. Additionally, this approach can be extended to address broader issues like national or cross-border electricity system balancing and congestion management.

This innovation is set against the backdrop of a rapidly digitising grid, transitioning towards a 'smart' system. A system that optimises physical grid utilisation and fosters pan-European coordination between system operators. These technological advancements are unlocking the potential of distributed flexibility, allowing various generation sources, dispatchable loads, electric vehicles, and energy storage to be more responsive to the needs and constraints of the power grid.

6. Engagement of the demand side

The key challenge to demand response is engagement. To participate, households, industry and the tertiary sector require a high degree of digitalisation, smart meters and a sufficient sustained interest. **By enabling tools like dynamic pricing, tailored grid tariffs, and providing consumers access to timely energy data, consumers can be transformed from passive participants to active contributors of flexibility through implicit demand response.**

To increase the range of flexibility options in the energy system, it's crucial to ensure that consumers are well-informed and that incentives are structured to align their energy use with the system's needs. This can be achieved by making aggregation offers more appealing, which in turn supports direct market participation through explicit demand response. These two approaches – informing consumers and enabling aggregation offers – should be used together, not separately. On another note, it's important to re-evaluate the incentive regulation for system operators. This is to ensure that the regulatory framework does not overly favour capital expenditure (CAPEX) incentives. Instead, it should ideally encourage operators to utilise flexibility solutions rather than defaulting to grid reinforcement or other capital-intensive measures.

5. Path forward

For Europe's future energy system dominated by variable RES, flexibility will not just be of benefit, but of fundamental necessity. Traditional energy infrastructure is being challenged to accommodate variable generation without compromising grid reliability. This volatility mandates a responsive system capable of adapting to real-time energy demand and supply fluctuations, both efficiently covering residual load and handling sudden oversupply of energy.

Achieving this will require a multifaceted approach: enhanced TSO-DSO coordination streamline grid management in the view of growing volumes of distributed assets, advanced observability within the distribution network to pre-emptively mitigate congestion and voltage issues, establishing market mechanisms that incentivise flexibility solutions as well as speeding up investment in flexible technologies.

Moreover, it is crucial for regulatory reforms to be well-aligned with the advancements in our technical capabilities, ensuring that the regulation facilitates rather practical implementation "on the ground". The path forward requires a coordinated effort among policymakers, industry stakeholders, and technology innovators, aligning on a vision that prioritises adaptability and resilience in Europe's future energy system for the benefit of society.

References

1. J. Michael, I. Staffell Short-term integration costs of variable renewable energy: Wind curtailment and balancing in Britain and Germany, Renewable and Sustainable Energy Reviews, Volume 86, 2018, Pages 45-65, https://doi.org/10.1016/j.rser.2018.01.009.

2. IEA, VRE shares in generation and technical curtailment for selected countries, https://www.iea.org/reports/renewable-energy-market-update-june-2023/will-more-wind-and-solar-pv-capacity-lead-to-more-generation-curtailment

3. OSMOSE Project Overview: https://www.osmose-h2020.eu/project-overview/#key-figures

4. Energy Innovation Austria: https://www.energy-innovation-austria.at/article/abs4tso/

5. smartEn, 2022: The smartEn Map, ancillary services 2022 - https://smarten.eu/wp-content/uploads/2022/12/the_smarten_map_2022_DIGITAL-2.pdf

6. EU Directive 2018/2001: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en

7. ELIA Adequacy and Flexibility Study for Belgium 2024 – 2034: 20 https://issuu.com/eliagroup/docs/adequacy_flexibility_study_for_belgium_2024-203?fr=sOTBhNDYxOTUwMTY

8. EU (2023) EU electricity Supply: https://acer.europa.eu/Publications/Security_of_EU_electricity_supply_2023.pdf

9. EASE (2022) https://ease-storage.eu/publication/emmes-6-0-june-2022/

10. ENTSO-E (2021) REVIEW OF FLEXIBILITY PLATFORMS: A report prepared by Frontier Economics: https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/SOC%20Reports/210957_entso-e_report_neutral_design_flexibility_platforms_04.pdf

11. ACEA (2022) Electrification Trends Worldwide: https://www.acea.auto/news/electrification-trends-worldwide/

12. Update on Balancing Platforms March 9th Web Conference: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Network%20codes%20documents/MESC/2023%20MESC%20documents/230309_MESC_TOP_5.1_Update_on_balancing_platforms.pdf

13. EPEX Spot 2022: https://www.epexspot.com/sites/default/files/2022-07/22-07-12_TradingBrochure.pdf










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