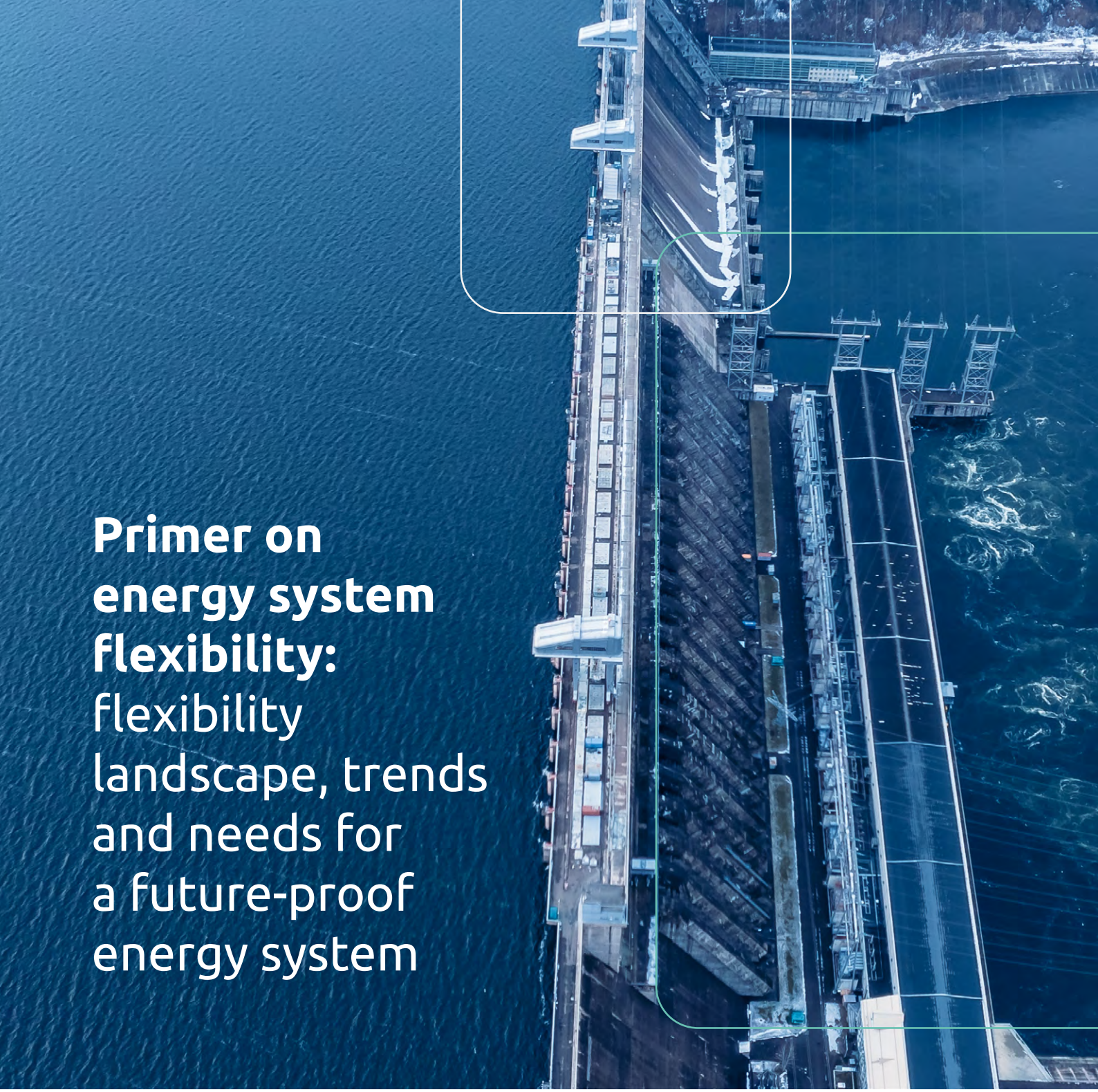

Primer on energy system flexibility: flexibility landscape, trends and needs for a future-proof energy system

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2024

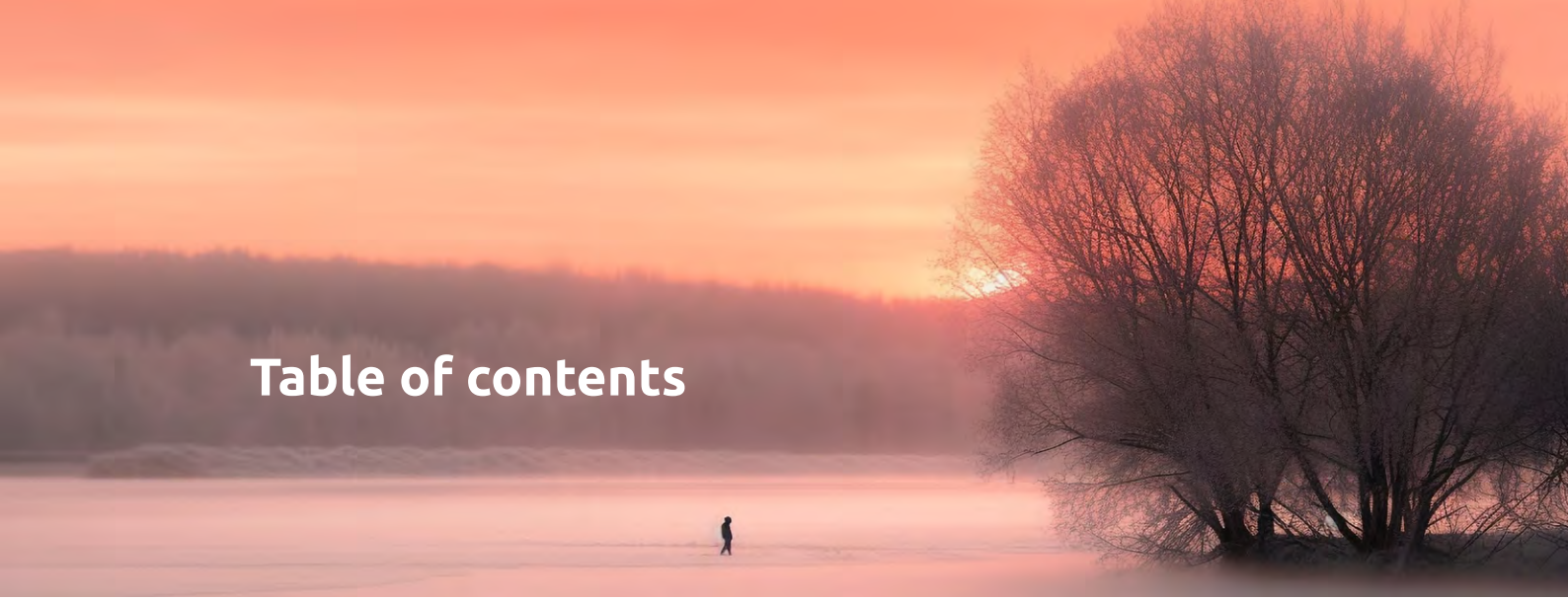
MAGNUS energy

Flexibility is the key component of the energy transition and renewable integration. It will be required in multiple timeframes and from a diversity of sources, including demand and renewables.

The flexibility ecosystem is highly complex. Numerous market and regulated actors compete for the scarce resource. Ultimately, flexibility is a service regardless of its origin, technology or network level. And thus, incentives to provide it and to use it are crucial.

Growing regulatory coverage of flexibility on the EU level so far has been outpacing national implementation. As much as more solutions to offer flexibility are emerging, especially the integration of the demand side still has a long way to go.

A flexibility gap is expected all across Europe. And the time factor is often overlooked. It takes time to invest and build new flexible assets, it takes time to ensure the needed infrastructure, it also takes time to implement and put relevant regulation into practice. Making the most of the existing options, including interconnection, are essential for a successful transition.



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1. Why we need more flexibility in our energy system

What do negative day-ahead electricity market prices, the solar 'duck curve', the coal or nuclear phaseout and soaring balancing and congestion costs have in common? They all point to an urgent need for more flexibility in the energy system.

Since 2020, generation from renewable energy sources (RES) in the EU has consistently exceeded generation from fossil fuels paving the way towards the energy transition. But this way is rocky. Balancing the energy system has never been more challenging. As new generation is coming online – at transmission but also distribution network levels – grid congestion events are getting both more frequent and pronounced. There has never been more market price volatility than today. And it is bound to grow further as large residual load deltas are expected in the future in both directions.

If we want achieve Europe's ambitious net-zero goals while keeping the system stable, more flexibility is urgently needed.

The change is happening on all sides - the grid, the markets and regulation. It was the Clean Energy for all Europeans Package adopted in 2019 that formally brought the topic of flexibility to the fore. In particular, the Electricity Directive (EU 2019/944) promotes the integration of new, distributed sources of flexibility. It empowers consumers to provide demand-side flexibility. It also encourages system operators to make use of flexibility rather than costly grid reinforcements. Yet, the path towards national implementations is long and we are still at its start.

A few years later, European ambitions for RES buildout have been ramped up further. The Fit-for-55 Package (2021) sets the target of a 55% reduction of greenhouse gas emissions by 2030, compared to 1990 levels. Together with the REPower EU plan of the European Commission (2022), they are aimed at accelerating the EU's energy independence and transition to green fuels. REPower EU sets even higher targets for the EU's decarbonisation of the energy system – 45% of RES in the EU's mix by 2030. Realising this ambition will hardly be possible without stakeholder cooperation and integration of new sources of flexibility while ensuring a reliable and secure energy system.

Expectations placed on flexibility are high. And so are the stakes.
But first: what is flexibility exactly?

2. Defining flexibility

Everyone in the energy sector is talking about flexibility. Suppliers, asset operators, investors, service providers, systems operators and regulatory authorities. It is often seen as a 'silver bullet' able to solve many of the energy system's woes. And yet, it often seems it remains an ambiguous, slippery term that requires some clarity.

It is then not a coincidence that the draft Network Code on Demand Response submitted by ACER in December 2022 is all about flexibility yet does not mention it by its name. So, what is flexibility in the energy context then?

Fundamentally, *flexibility is a service that consists in the ability of an asset (or a pool of assets) to increase, decrease, or shift in time, energy generation or consumption.* Especially on the generation side, flexible asset operation is not new. But its sources – at all network levels, in and beyond the electricity sector – as well as the overwhelming recognition that we need much more of it are.

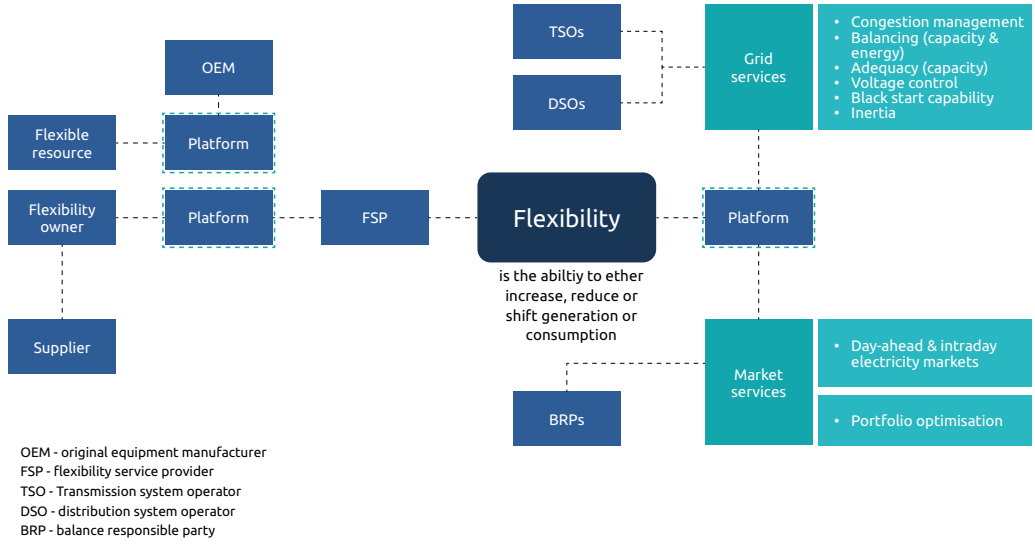


Figure 1. Defining flexibility landscape

Flexibility ***from*** whom?
A tale of many hats or providers of flexibility

Flexible resources or assets include generation (including at consumers' premises) and demand. These also include storage options, which most often refer to short-term storage with fast reaction times. Battery storage is the most commercially viable storage technology so far. Yet, it may also include longer-term storage options, such as thermal storage.

The range of models for ownership and operation of flexible resources varies widely. Generally, the hat of a flexibility service provider (FSP) can be worn by an existing supplier and plant operator exploring new business opportunities. It can also be worn by an independent aggregator pooling flexible assets to deliver one or often several services. An FSP could also be an original equipment

manufacturer (OEM) - of batteries, heat pumps, inverters etc. - using proprietary software to offer automation and optimization. The flexibility ecosystem often involves other actors too, providing IT platforms for dynamic pooling, scheduling, and/or trading as well as software or hardware for asset control. That said, an FSP is commonly not an actor but rather a role multiple actors can potentially assume. A single actor can also potentially wear several hats, such as a supplier also fulfilling the functions of a flexibility aggregator and a balance responsible party (BRP).

The different value streams for flexibility and multiple market actors wearing different hats create tension among them. If a supplier sells energy to its consumer while it is later used for pooling and trading on the market, who should be compensated and how? And who is responsible for potential portfolio imbalances? The growing complexity of the flexibility ecosystem increases the need for coordination and data exchanges among multiple parties, TSOs, DSOs, BRPs, aggregators and suppliers.

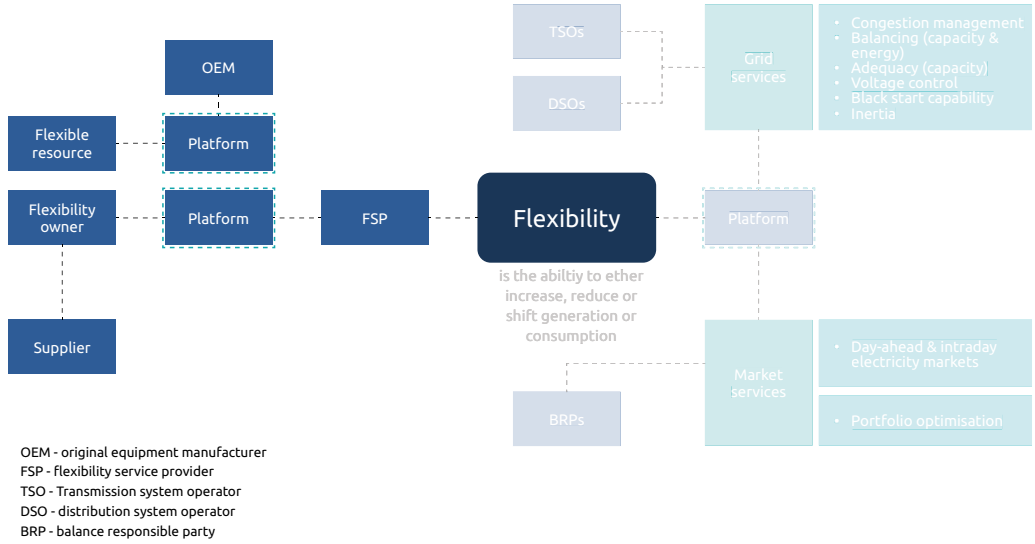


Figure 2. Flexibility from whom?

> *The upcoming Network Code on Demand Response strives to provide more clarity on how such conflicts could be solved. More of this in our upcoming brief.*

Flexibility *for* whom? The paradox of Buridan's donkey or marketplaces for flexibility

On the other, offtaker side, flexibility as a service could play many roles. It could be deployed for a number of system services, such as balancing, congestion management and/or redispatch, system inertia services for transmission system operators (TSOs). Or services for distribution system operators (DSOs) such as voltage control and black start. Beyond that, flexibility is becoming increasingly relevant for system adequacy. Ensuring sufficient flexibility in the future system when the sun doesn't shine, the wind doesn't blow, and most of the thermal generation is phased out.

Beyond the grid services, flexibility could also be used for arbitrage between markets. It can also be used for internal portfolio optimisation of a balance responsible party (BRP) with the aim of minimising (potentially considerable) imbalance costs.

Next to these, more common use cases, additional national markets, in which flexible resources could be used, exist. Just a number of examples, a redispatch market in the Netherlands, a capacity market in Belgium or in France or local DSO markets in Norway and Great Britain.

With such a wide array of use cases for flexibility, which one to choose? Irrespective of their location and portfolio mix, FSPs increasingly recur to value stacking. That is, optimising their assets to participate in several markets in the face of an increasing saturation in the "go-to" markets, such as balancing markets.

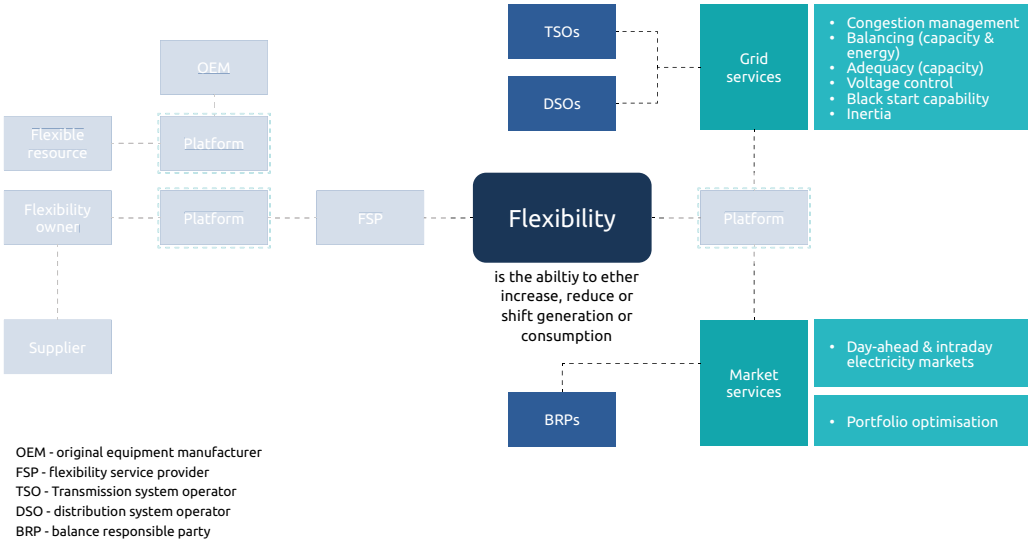


Figure 3. Flexibility for Whom

In Buridan's donkey paradox, a hungry donkey eventually starves as it cannot decide between two haystacks. The tension between multiple use cases of flexibility bears a risk of the flexibility owner eventually "going hungry" if the complexity is high and the framework for coordination between the different stakeholders is not in place. As a result, even in situations when flexibility could technically be available, it is underutilised due to such factors as:

- counterproductive grid tariffs or charges (e.g. double charges for storage or net metering for solar PV),
- aggregator restrictions due to the clauses in consumers' supplier contracts,
- lack of alignment between TSOs and DSOs when distribution-level resources could be used for TSO-level grid services,
- lack of incentives for system operators to make active use of flexibility (e.g. due to CAPEX-based regulation),
- nominal rather than actual market access, i.e. even if flexibility is allowed access to all markets by the regulation, national implementations and the factors mentioned above prevent effective market entry.

3. How much flexibility is needed? Tomorrow's system acrobat

Be it for internal portfolio balancing, addressing frequent congestion events or system imbalances, there is an overall industry consensus about the need for flexibility. Higher shares of variable renewables going online are not the only reason for this development. It is further increased due to the phaseout of flexible thermal generation and growing electrification of heat and mobility sectors.

> *Globally, 4-fold increase in flexibility will be needed to achieve net zero by 2050*

The International Energy Agency (IEA) has developed a global roadmap for 'Net Zero by 2050', showing a strong need for system flexibility from a broad range of sources. Given the phase-out of fossil-fuel generation, this flexibility should be replaced and expanded by renewable generation, such as hydro power, combined with large shares of demand response and battery storage. Given that, in the roadmap, electrification is expected to increase 2.5-fold while system flexibility will have to increase by the factor of 4.

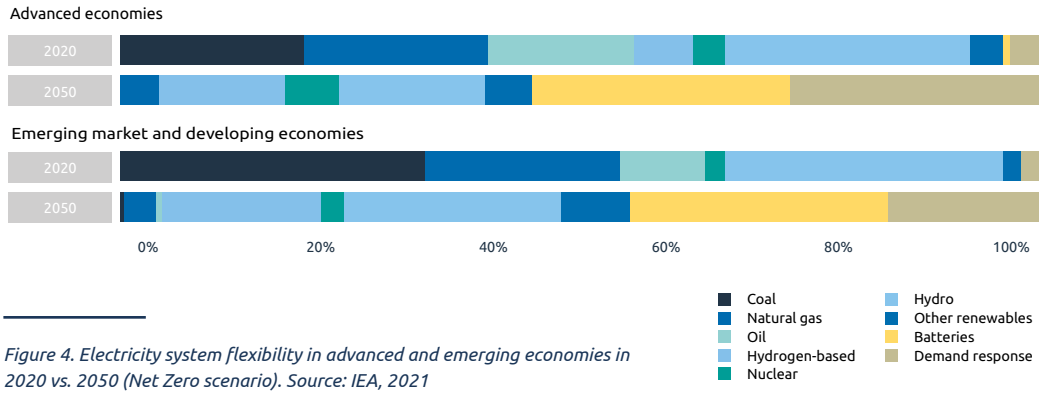


Figure 4. Electricity system flexibility in advanced and emerging economies in 2020 vs. 2050 (Net Zero scenario). Source: IEA, 2021

Europe's system stability but also generation adequacy depends on it

As the generation mix in Europe is rapidly changing towards significant shares of variable RES, whose generation has been outstripping the one from fossil fuels on multiple occasions, flexibility and resource adequacy become more tightly interconnected.

As part of its European Resource Adequacy Assessment (ERAA), ENTSO-E is working on methodologies to assess system flexibility needs as well as its economic viability and trade-offs for the energy system. Beyond the flexible resources mentioned above, it highlights the importance of **interconnector capacity as a source of flexibility** in its own right. The need for flexibility is dependent on reliability standards (how many hours a year would you accept power cuts), the (remaining) availability of flexible generation capacity, and infrastructure.

Looking at the individual European countries, in its recent study, the Belgian TSO, Elia identifies a flexibility gap of 3GW from 2029 in Belgium, which arguably cannot be covered by an energy-only market alone and might require additional capacity remuneration. In Germany, the largest EU market, nuclear generation has been recently phased out after the peak of the energy crisis whereas the remaining 43GW of coal-based generation is expected to be phased out by 2030. As a result, the four German TSOs estimate that the flexibility gap in the country will reach more than 16GW by 2030.

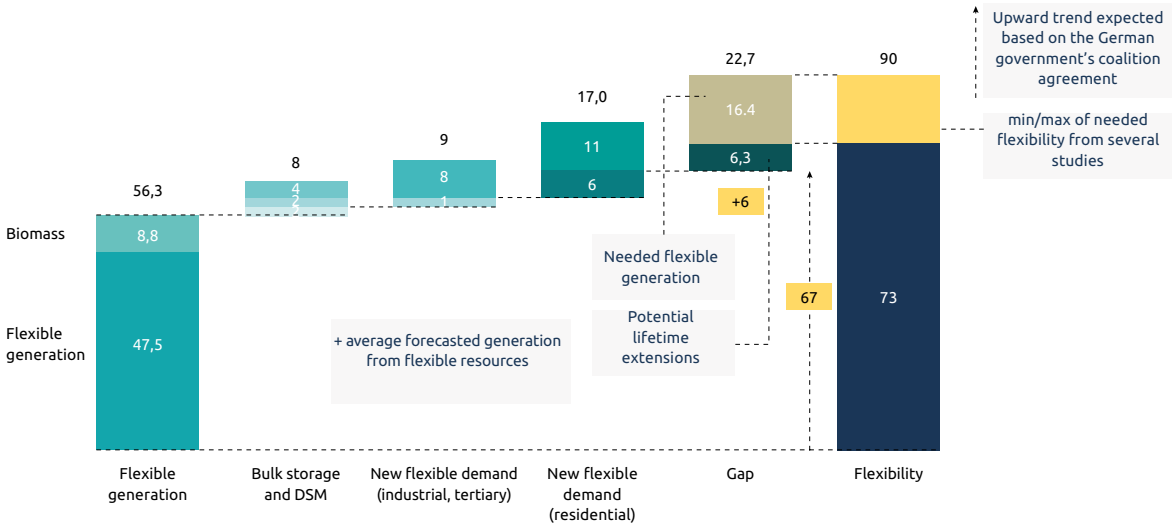


Figure 5. Will enough investment be achieved to close the flexibility gap in Germany in 2030? (Units in GW)
Source: 50Herz, Amprion, TenneT and TransnetBW 2022

> *Belgium alone will need about 3GW of extra flexibility by from 2029 onwards. This is equal to 3 large nuclear power plants.*

It's not just about short-term flexibility. It will be required in multiple timeframes

In its 2023 study, the Joint Research Institute (JRC) estimated flexibility requirements for 2030 and 2050 when wind power is expected to become the largest source of electricity generation. Consequently, the highest flexibility requirements by 2030-2050 are expected in particular in the countries with the largest shares of wind to total demand.

Flexibility has an extra dimension not yet mentioned above – **duration**. That is, flexibility requirements differ depending on the use case from a few minutes (e.g. for balancing) to several hours (for congestion management) to days and weeks (to cover residual load) or even months. JRC's analysis shows the daily flexibility volume needs in the EU to reach 290 TWh/y in 2030 and whopping 900TWh/y by 2050. The volumes of weekly and monthly flexibility are slightly lower, at 180-280TWh/y by 2030 and 500-780TWh/y by 2050.

Among the Member States, flexibility requirements appear to vary between 4% and over 17% of the total demand (FR share in the figure below) between now and 2030 and between 10% and 13% in 2030-2050. The largest amounts of daily flexibility in 2030 will be required in Germany and the largest growth rate between 2021 and 2030 is expected in Italy.

Interestingly, there is a positive correlation in all three timescales between the share of required flexibility in total demand volumes and the share of wind generation. In contrast, a significant correlation between the share of required flexibility to demand and the shares of solar generation was observed only for daily but not for weekly or monthly flexibility.

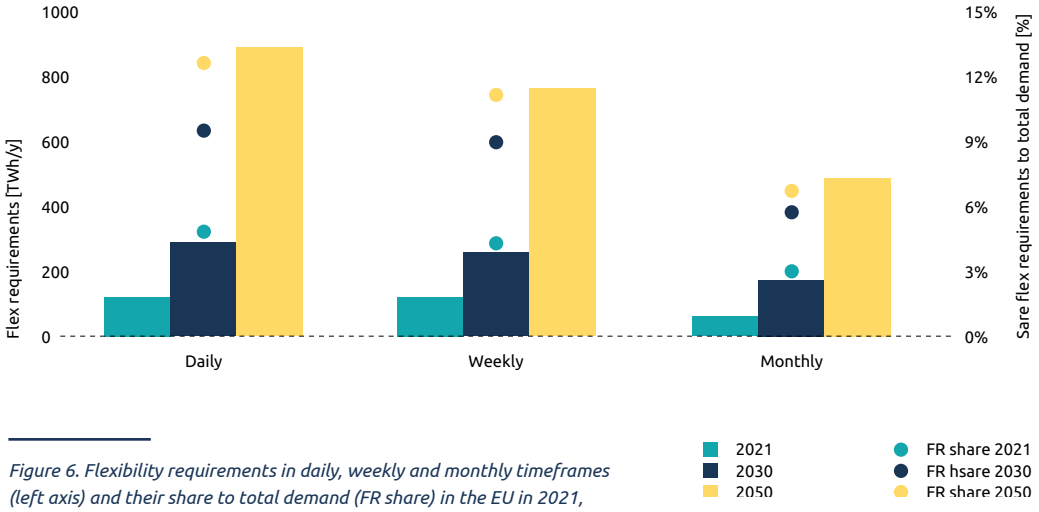


Figure 6. Flexibility requirements in daily, weekly and monthly timeframes (left axis) and their share to total demand (FR share) in the EU in 2021, 2030 and 2050. Source: JRC 2023.

Tomorrow's system acrobat

Overall, over the last 5 to 10 years, 'flexibility' has often been seen as a system acrobat able to make a split between all the different needs of the future system. However, as much as it is evident from all the recent studies that the system requires more flexibility in the short and long terms, three important observations must be made:

1. **A broad spectrum of technologies** will be required to provide flexibility, yet not all of them are able to deliver the same services due to technical constraints. In addition, only very few technologies (e.g. pumped hydro storage or electrolysers) can provide long-duration flexibility, making the coverage of this need extremely difficult.

2. **Flexibility alone might likely not be sufficient** to address all the growing system needs. It is crucial to complement them with network expansion and an increased system and market interconnection.

3. **The time factor is often overlooked.** It takes time to invest and build new flexible assets. It takes time to ensure the needed infrastructure is there. It also takes time to implement and put relevant regulation into practice. Making the most of the existing options, including interconnection, are essential for a successful transition.

Top 5 flex-trends

The bigger role of flexibility can already be observed in today's energy system:

1. **'Triple D' or decentralisation, decarbonisation, and digitalisation.** The availability of distributed energy resources (DERs) has been growing over the last 50 to 10 years. Access to DERs, such as small home batteries, small-scale RES, heat pumps, and electrical vehicles (EVs) is meant to democratise energy generation as well as the use of flexibility at all network levels. All this should become possible thanks to the advances in IT to improve asset controllability and information exchanges.

2. **Electrification.** Linked to the one above, it implies growing shares of mobility and heating & cooling sectors powered by electricity. As a result, rapid electrification is expected to become a major factor in growing flexibility needs.At the same time, it promises potential to use this trend as part of the solution. Business cases involving aggregation of heat pumps or EVs are emerging.

3. **The new normal.** The energy crisis revealed the vulnerabilities in the European energy system and further highlighted the need for more system flexibility, accelerating regulation, RES & battery investments along with permitting processes.

4. **Negative prices.** Growing frequency of negative prices in the short-term electricity markets spreading over a larger geographical area is a symptom of a growing flexibility gap, in particular downward flexibility. According to ACER, the number of hours with negative prices in the EU ranged between about 400 and 1200 hours in 2020-2022.

5. **Interoperability.** As flexibility is needed for an increasing number of use cases, digital solutions for its commercial & IT aggregation, local flexibility platforms, and large market platforms (e.g. balancing energy platforms, PICASSO and MARI) start proliferating increasing the need for smart interoperable solutions.

4. How much flexibility is out there? Searching for the yeti.

At an event a couple of years ago, an expert quipped, "aggregators are like yetis, everyone is talking about them, but no one has seen them". In the meantime, aggregators have turned into well-established market actors. Is flexibility following a similar path? It could well be.

What is evident from the recent data is that growing regulatory coverage of flexibility on the EU level so far has been outpacing implementation. The adoption of new business models associated with the provision of flexibility beyond conventional generation hinges on several important factors:

- whether the ambitious EU regulation has indeed been **implemented nationally,**
- whether the **investment** into large-scale or distributed flexibility is attractive,
- whether the **enabling infrastructure** for the provision of flexibility is available (smart meters, controllers, industrial optimisation software),
- whether available **consumer tariffs** incentivise demand-side flexibility or other **incentive mechanisms are available**.

The flexibility ecosystem is highly complex where numerous market and regulated actors compete for the scarce resource. Ultimately, flexibility is a service regardless of its origin, technology or network level. And thus, **incentives to provide it and to use it are crucial.**

Multiple providers on the generation side. The technological mix is evolving.

In terms of generation technologies, the Joint Research Center (JRC) of the European Commission expects battery storage, electrolysers and pumped hydro storage to play a significant role in covering future flexibility needs. A tangible share would still need to be provided by conventional fossil-fuel-based technologies, combined cycle gas turbine plants (CCGTs) and – to a lesser extent – by coal generation.

Beyond that, similar to ENTSO-E's conclusions, JRC highlights **interconnectors** as a major source of – particularly longer-term – flexibility (between 15% and 33%). The contribution of batteries and EVs is expected to be greater between 2030 and 2050 as the adoption rate increases. Biomass and biogas are expected to replace coal and gas in the longer term with CCGTs predominantly used to cover longer-term seasonal flexibility requirements in 2030-2050. These estimations still leave about 20% of the total flexibility needs to be covered by "other" sources. But which ones? Here is where demand-side flexibility comes into play.

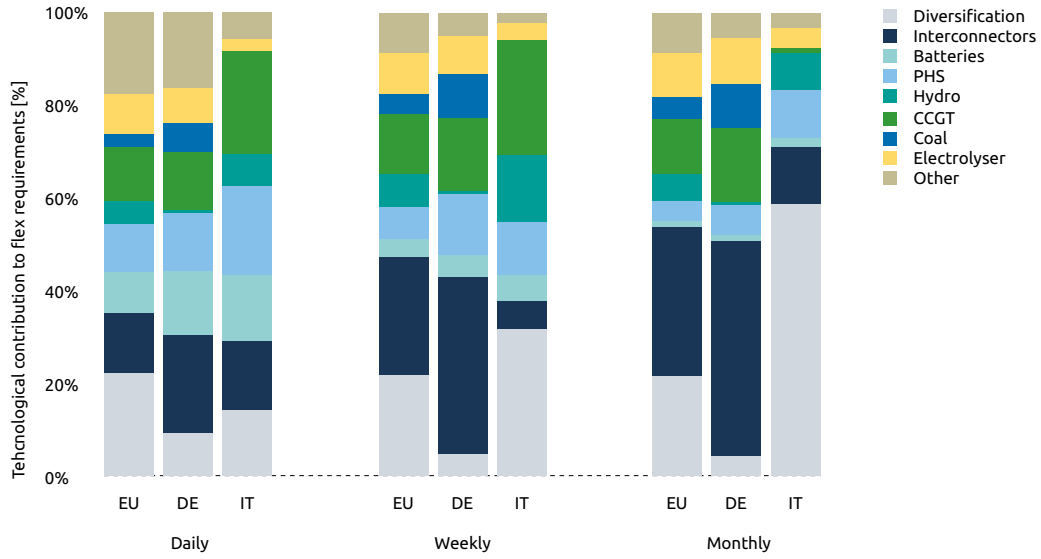


Figure 7. Technological contribution to flexibility requirements in the EU, Germany and Italy, 2030. Source: JRC 2023.

Batteries leading the way among new flexible technologies.

So far, battery storage has been the most attractive technology both in terms of investments and business model maturity among new flexible technologies. Annual installed battery storage capacity, including front-of-the-meter utility-scale storage, in the EU (+GB) is expected to grow almost 12-fold between 2018 and 2030, according to EASE. In several countries, e.g. in Germany and Belgium, batteries are already providing a large share of balancing services (especially frequency containment reserve).

In 2023, behind- and front-of-the-meter installations together exceeded the 6GW mark (58% FoM). By 2030, the largest shares of battery storage will arguably be concentrated in Germany (mostly BTM), the UK, Italy (mostly FOM) and Spain.

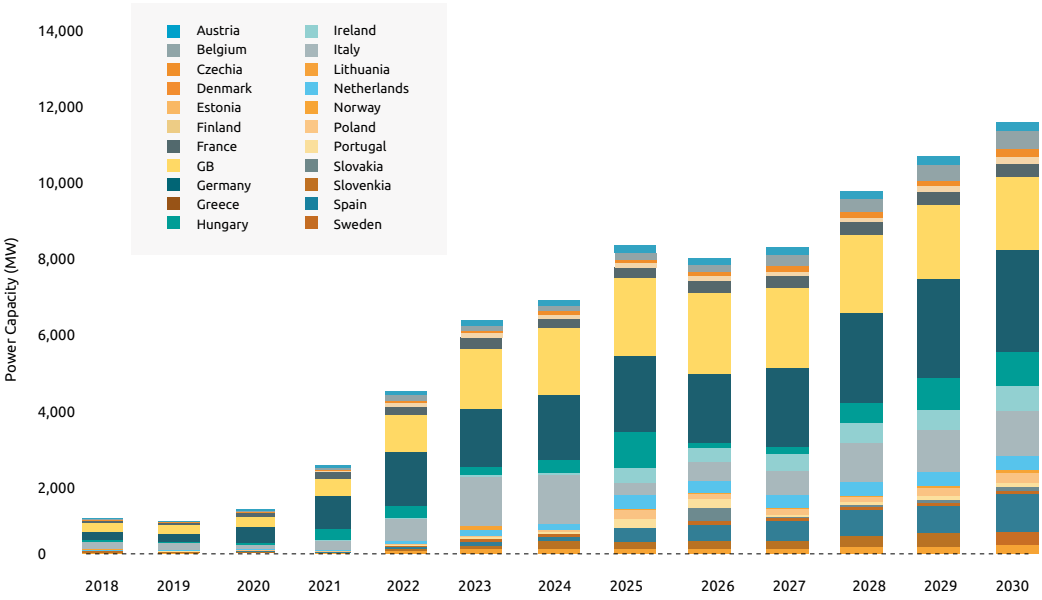


Figure 8. Evolution of the installed battery capacity in the EU countries between 2018 and 2030 (Source: EASE, EMMES 7.0, Q1-2023)

Leaving a big role for the demand-side

When it comes to flexibility on the demand side, the minimum requirements are the availability of high-resolution (at least 15 minutes) smart meters and dynamic consumer tariffs. That is, tariffs varying based on the time of use and/or additional factors such as system stress.

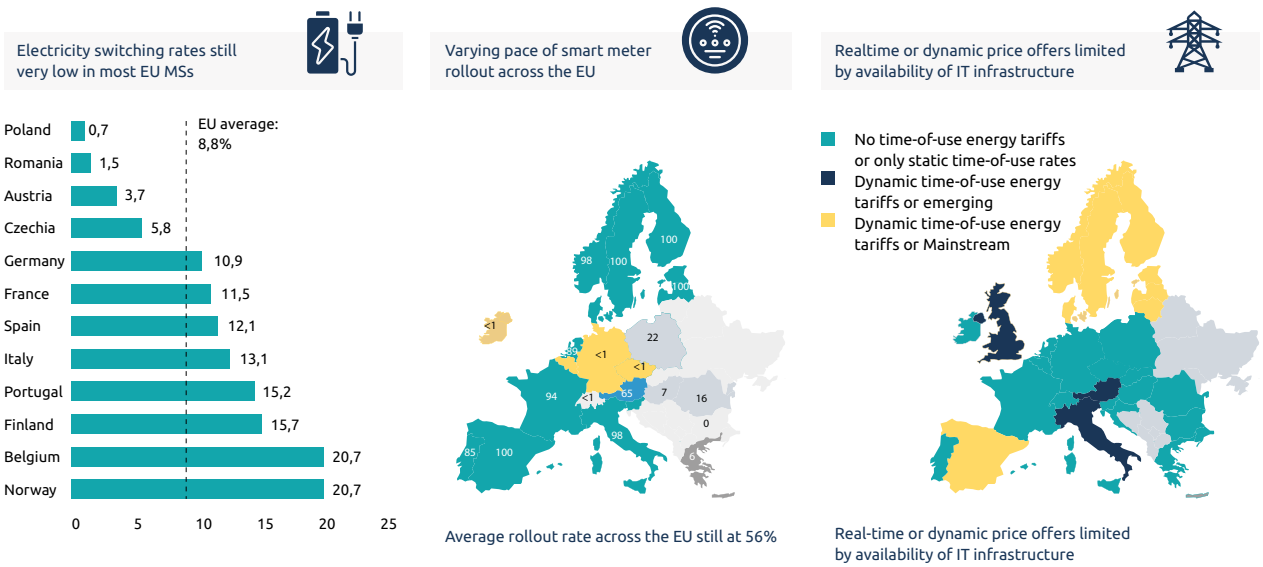


Figure 9. Limitations in terms of supplier switching rates, availability of smart meters and time-of-use tariffs.
Sources: ACER MMR, Volume Retail Markets, Nov. 2021, Eurelectric 2023, Regulatory Assistance Project (RAP), 2022

Now, smart-meter rollout is still lagging in a large part of Central and Central Eastern Europe, making it de facto impossible for consumers to monitor their consumption or offer flexibility. According to the latest data, the Nordic, Baltic regions and Spain are already mainly offering dynamic consumer tariffs while in the rest of the EU barely any time-of-use offerings are available.

Limited flexibility from residential consumers

Over the last 5 to 10 years, consumer adoption of flexible technologies has been increasingly commonplace. Such as home battery storage coupled with solar panels (PVs), heat pumps, or EVs. This development is driven largely by generous government subsidies and – in some countries – attractive aggregator offerings allowing consumers to generate energy savings. And yet, if we take a closer look at the adoption levels, in the global picture, these remain rudimental:

- Small-scale residential PV is installed in about 16% of all European households – most of them in Germany,
- Only half of these are on average coupled with home batteries, 8% with large divergences between EU countries,
- 6,7% of all households are equipped with heat pumps as of 2020, most of which are installed in the Nordics and Germany,
- While only 0,6% of all cars by 2020 were EVs (hybrid cars not included), the bulk of these are again in the Nordics.

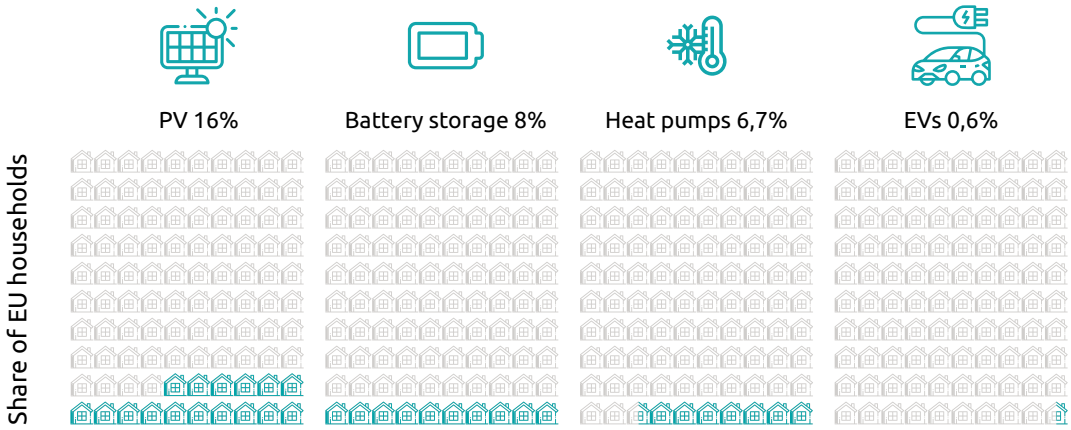


Figure 10. Adoption of flexible technologies among households is still in its infancy (based on data from 2021).

Limited flexibility from the industrial and tertiary sectors

It is important to keep in mind that households roughly constitute about one third of all consumption whereas the industry and commercial customers cover the rest. Often, industrial premises already include facilities capable of providing flexibility for system needs or could be used to save energy costs. The level of flexibilisation is, however, still low as it requires a high degree of digitalisation & automation, process optimisation as well as extra personnel with the right expertise available beyond the usual working hours.

Beyond this, other issues make provision of flexibility services from the demand side challenging, such as:

1. **scalability**, i.e. going from small-scale pilots into large-scale implementation and system integration,
2. **sustaining a long-term incentive** to participate in flexibility schemes (electricity still an ambiguous concept, lack of plug-and-forget solutions),
3. **insufficient collaboration** among TSOs, DSOs, suppliers, and aggregators.

More on these and other challenges in energy system flexibility in our next report.

Top 5 enablers of demand-side flexibility:

1. smart meters coupled with dynamic tariffs for long-term consumer engagement,
2. digital solutions for optimization, controllability and automation of industrial flexibility,
3. market signals reaching flexibility owners coupled with grid tariffs reduction to increase attractiveness,
4. regulatory clarity and stability to improve investment climate,
5. stakeholder coordination to ensure flexibility is being used whenever it's needed the most.

Flexibility potential is high but there is still a long way to go

Overall, the attractiveness of investment into flexibility options largely depends on the current and future price levels in the relevant markets, regulatory facilitation, ease of entry as well as other incentive schemes available.

Electricity sector stakeholders across the board recognize the crucial role of flexibility providers on the demand side in the future. The European association for smart energy, smartEN, found in 2022 that, in 2030, harvesting demand-side flexibility (DSF) would bear large benefits for RES. It would reduce their curtailment by 61%, for decarbonization, saving about 8% of greenhouse gas emissions per capita, and saving about €4.6 billion or 5% of electricity generation costs. DSF could reduce balancing energy costs by 43% to 66% whereas consumer costs could achieve a reduction of up to 64% across Europe. The Belgian TSO, Elia, expects the highest potential from industrial flexibility, especially due to electrification of industrial processes, and estimated the cost savings of over 200€ Mio by 2034 in Belgium alone.

And yet, barriers to the integration of new source of flexibility remain. Strict prequalification requirements in the balancing markets, so far, the largest revenue stream for flexibility, have been a major stumbling block. In particular for the new entrants and small-scale participants. ACER survey on major barriers to entry 2021 found that **national** regulatory frameworks are still lagging behind and constitute the largest barrier. It is followed by insufficient cross-zonal capacities. To add to the complexity, these conditions are highly country-specific, making business case expansion across borders highly challenging.

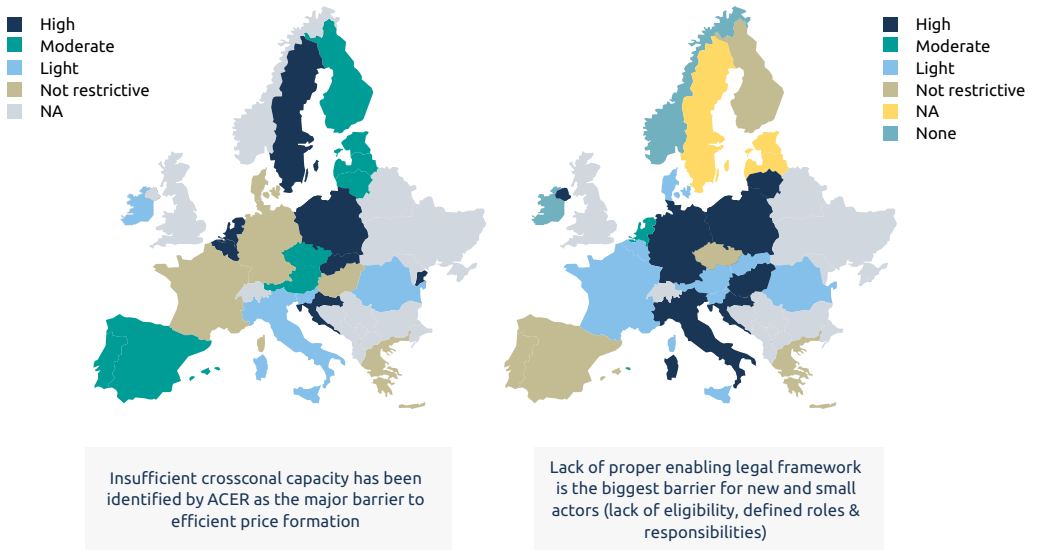


Figure 11. An enabling national legal framework and a lack of cross zonal capacity are seen by the EU regulators as the main barriers. Source: ACER's Market Monitoring Report 2021, Wholesale Electricity Markets

There is still a long way to go to solve the multiple issues mentioned above. The Network Code on Demand Response submitted by ACER at the end of 2022 includes provisions as to the overarching principles for aggregation, congestion management, balancing and DSO services. Yet, adoption is expected in 2025 and national implementation would take even longer leaving the market to pick up the slack in the meantime.

Here is where it becomes apparent that energy system flexibility is associated with quite a few contentious issues such as:

- Who should own flexible resources, market participants alone or system operators as well?
- To which extent are (local) flexibility markets needed to solve DSO issues?
- To which extent can (and may) variable RES provide flexibility to support system stability and security?
- Should flexibility receive an extra incentive and what should such incentives look like? (Grid tariffs? Flex bonus? Local flex markets? Something else?)
- Should flexibility providers receive capacity payments?
- Should demand-side flexibility be encouraged implicitly through tariffs and energy savings or explicitly through direct market participation?
- How to solve the tension between the use of flexibility for the grid and for the markets and who should ultimately decide what flexibility is used for?
- How to ensure interoperability of the numerous platforms for flexibility aggregation, communication and market participation?

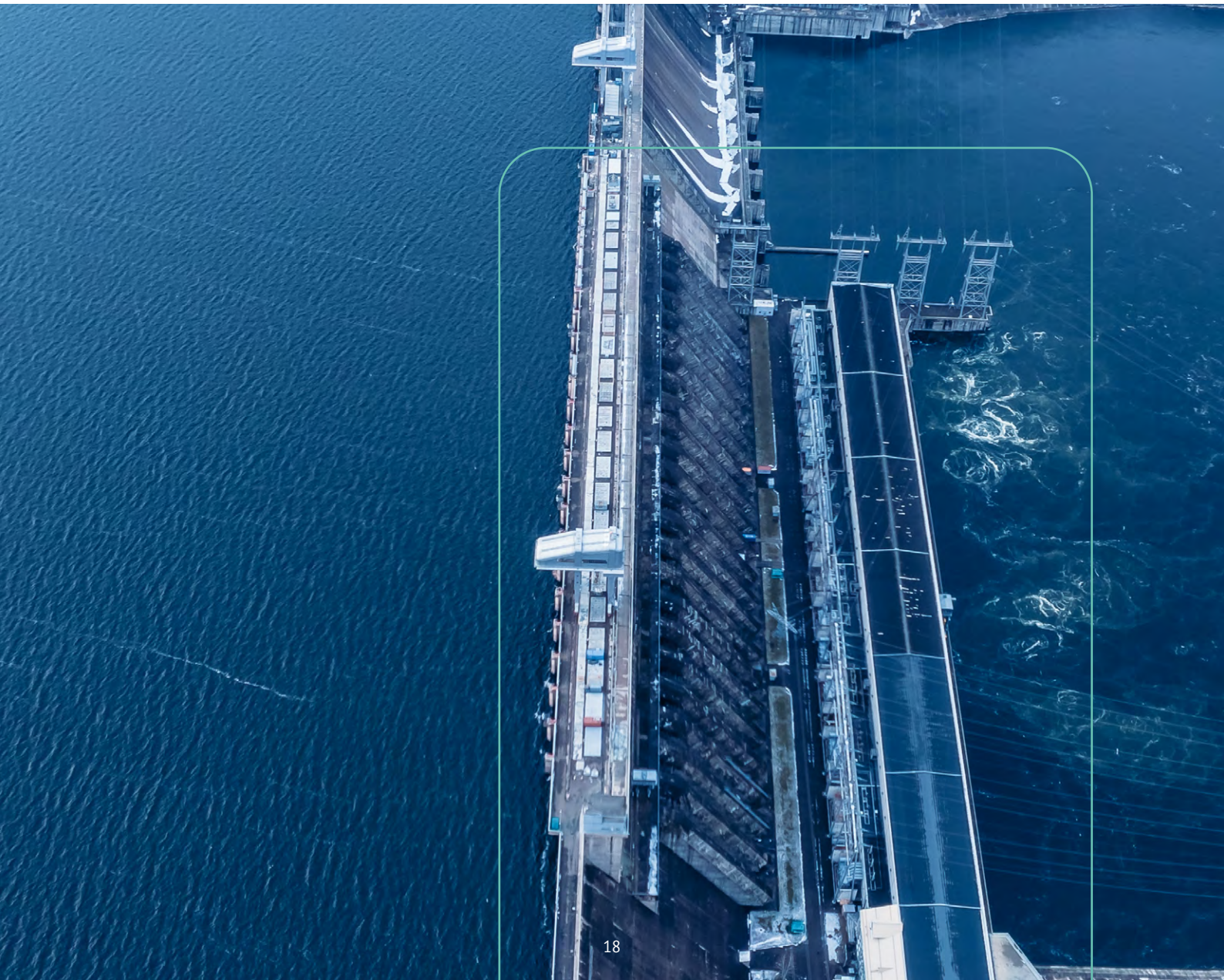
We will address these and many other issues in flexibility in our next report. Stay tuned.

5. Final thoughts

As conventional generation is being phased out and flexible generation from gas in Europe is subject to strong geopolitical influences and the mercy of volatile global LNG markets, using flexibility on all network levels, including distribution networks, is both technically viable and necessary. Often, it is the incentives to invest in it, offer it and use it are missing.
The flexibility on the demand side proves to still be in its infancy – despite a considerable potential for the energy system expected by a broad range of stakeholders.

To bridge the gap between available and urgently needed flexibility, more than a regulatory framework is needed. Successful flexibility integration is unthinkable without digital solutions for asset optimization, automation, and controllability, smart meters, and dynamic tariffs for all consumers. To ensure that flexible assets can be deployed in a grid-friendly manner, a rethinking of grid tariffs is needed. To effectively react to market signals, flexibility owners and operators require timely access to market information.

Finally, it is coordination among stakeholders along the value chain, aggregators, suppliers and BRPs, TSOs and DSOs that is crucial to ensure that flexibility is not a hype but an effective contributor to RES integration and the stability of the energy system.



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Magnus Energy works on a bright future. Helping to build strong energy systems that fully incorporate renewables. Balancing sustainability, security, and affordability. Navigating the challenges of the ever-evolving energy transition.

We employ the best and brightest consultants with in-depth knowledge of energy markets and systems, covering every aspect of the energy transition. Serving as independent guides.

We help make strategic decisions, offering our insights into the energy landscape. Our technical experts conceptualise changes in models, grids and regulations. We manage complex programs, fostering trust and progress in international cooperation. Additionally, we advise individual organisations in navigating the energy transition.

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