WINDNODE

SUMMARY REPORT

# FLEXIBILITY, MARKETS AND REGULATION: INSIGHTS FROM THE WINDNODE REALITY LAB

## About WindNODE

WindNODE is part of the funding programme Smart Energy Showcase – Digital Agenda for the Energy Transition (SINTEG) of the German Federal Ministry for Economic Affairs and Energy (BMWi). It encompasses six eastern German states including Berlin and enjoys the patronage of their heads of government. WindNODE brought together more than 70 partners over four years, from 2017 to 2020, to work on transferable model solutions for the intelligent energy system of the future. WindNODE shows how a network of flexible energy users can adjust their electricity consumption to the fluctuating supply of wind and solar power plants. The aim is to integrate large amounts of renewable electricity into the energy system while keeping the power grid stable.

For more information visit:
**www.windnode.de**

## About SINTEG

The funding programme Smart Energy Showcase – Digital Agenda for the Energy Transition (SINTEG) was set up by the German Federal Ministry for Economic Affairs and Energy to show possible futures for the energy supply. The idea behind SINTEG is to develop and demonstrate transferable model solutions that can enable a safe, economical and environmentally friendly energy supply that includes a substantial amount of electricity produced from intermittent renewable sources. The programme converts interesting solutions from the model regions into templates that can be broadly implementation throughout Germany and beyond. There are five showcase regions, in which partners from the energy industry as well as the information and communication sector work together. Since 2017, more than 300 companies, research institutions, municipalities, districts and federal states have joined forces to work on the implementation of a future vision for the energy transition.

For more information visit:
**www.sinteg.de**

The Project Management Jülich | Forschungszentrum Jülich GmbH (PtJ) is in charge of the SINTEG showcases during the implementation of the funding project.

For more information visit:
**www.ptj.de/projektfoerderung/sinteg**

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# Executive Summary

## WindNODE started as a pluralistic consortium to develop ideas and blueprints for an Energy System 2.0.

To make the most of these results, it comprised two coordination committees of relevant experts: these committees focused on energy flexibility and each one developed an independent product. The first committee, Identifying Flexibility!, produced a Best Practices Manual to review individual ways to identify and make use of energy flexibility options. The second committee, Flexibility, Market and Regulation, produced the publication you are holding in your hands. This report focuses primarily on the experiences of grid operators and market participants in the activation of new flexibility options for a range of purposes. In addition, it analyses the relevant legal framework and determines the technical flexibility potential in the WindNODE region.

There is already efficient synchronisation of generation and consumption via the forward, day-ahead and intraday markets. Flexibility providers are able to benefit from particularly high or negative electricity prices – although extreme prices have tended to decline in recent years. The prices for offering balancing power have also fallen. As the analyses in this report show, the low valuation of flexibility is a result of adjustments in the market design, with another possible reason being the current glut of flexibility potential. The availability of flexibility linked to generation will also decline in the coming years due to the double phaseout of nuclear and coal-based power generation.

Flexibility options are needed for the management of grid congestion, and local flexibility potential can be very limited. Power plants are currently required by law to participate in congestion management and operators are reimbursed for the costs this incurs. Close cooperation between transmission system operators (TSOs), distribution system operators (DSOs) and various flexibility providers has made it possible to develop and test in practice a technical solution with market characteristics in the form of a flexibility platform within WindNODE. This determined that the procedures elaborated for the purpose of coordinated requests can easily be integrated into the existing processes deployed by transmission and distribution system operators to manage grid congestion. This makes it possible to develop additional flexibility options open to different technologies and boost synergies between the operators, resulting in increased system security. The design of the processes also fits the operational and technical requirements of the providers and the concept can easily be expanded to include additional product variants. The implemented application programming interfaces (APIs) are particularly suitable for the convenient automation of processes.

From an economic point of view, the consideration of further flexibility options in the process of grid congestion management is particularly interesting if it means that expensive flexibility options can be replaced by cheaper ones or that more renewable electricity can be used. However, the current grid situation is considered to be at high risk of inc-dec gaming,[1] and it appears unlikely that market mechanisms for grid congestion management will be introduced in the immediate future.[2] The German Grid Expansion Acceleration Act (NABEG) 2.0 has added great flexibility potential to the regulated redispatch on a cost basis. The market perspective will, however, remain relevant in the medium to long term if solutions, such as a hybrid model, are implemented to prevent gaming.

Automation and digitalisation within WindNODE have already led to new options for flexibility across a range of requirements. For instance, Siemens' industrial site was able to benefit from new marketing options through the implementation of a suitable metering system and the detailed evaluation of individual processes. The BMW Group redeployed used and new vehicle batteries to build a second-life power storage farm which is active on the electricity market and can be used in the future to synchronise generation with consumption through the factory infrastructure. Algorithms developed by the GASAG Group for the intelligent and forecast-based steering of energy systems benefited from a new power-to-heat/power-to-cold storage system which significantly expanded the optimisation options. Work by the Borderstep Institute showed that buildings and neighbourhoods can function in a way that benefits the grid and the market while maintaining

*1 Inc-dec gaming refers to strategic bidding within a market-based approach to grid congestion management, where market participants create or reinforce congestion in order to then be able to eliminate it with their own resources, leading to profits.*

*2 Cf. studies by Neon and Consentec commissioned by the BMWi: 'Kosten- oder Marktbasiert? Zukünftige Redispatch-Beschaffung in Deutschland' (2019) and 'Zusammenspiel von Markt und Netz im Stromsystem' (2018).*

a high level of comfort for the residents. To make the most of this potential, however, it is important that the valuation of flexibility increases, so that the identified business models can be implemented by a large number of providers.

German regulations are not yet very supportive for the provision of flexibility. One reason is that German energy law consists of a mesh of regulations that have grown over time as opposed to being drawn up all at once in a coherent vision. Much of it was originally written at a time when electricity generation could always be adapted to consumption. The current fixed and inflexible system of fees and levies should be revised to leverage the flexibility potential of storage systems, flexible consumers and the various power-to-X technologies. The aim should be to promote demand behaviour that is beneficial to the grid and the system in periods of electricity surpluses and low prices. Incentives to provide flexibility should in principle be designed without prejudice to the type of technology deployed, and should also contain green criteria so that real environmental action is encouraged in a competitive setting. The formulation of Section 14a of the German Energy Industry Act (EnWG) and the introduction of carbon pricing in the mobility and heating sectors are important steps to enabling business models that can provide more flexibility. Sector coupling plays an especially important role because only renewable electricity can efficiently supply the mobility and heating sectors with low-carbon energy while also enabling seasonal storage, if necessary.

# Foreword

## Deploying flexibility as a step on the way to 100% renewable power

WindNODE is one of five showcases for intelligent energy within the BMWi's SINTEG programme. Its aim is to consider the question: 'Which technologies and innovations are necessary to operate an energy system based on renewable energy safely and efficiently?' and to provide blueprints to answer it. The question is crucial because the reduction in conventional electricity generation through the simultaneous phase-outs of nuclear and coal-generated power may, in times of low wind and solar power generation, lead to a large difference between supply (generation) and demand (load). In order to close this potential supply gap, fundamental economic considerations about the use of flexible systems are necessary. Furthermore, the core concept of the energy transition – limiting average global warming to 1.5 °C – requires that the environmental impact of the flexibility used is also taken into account. Countering the problem of the 'dark doldrums'[3] will require measures like the seasonal storage of green electricity in the form of gas. However, this report focuses on new use cases for using and marketing power that can compensate for short-term fluctuations in generation and demand.

To efficiently promote the further expansion of renewable energy sources, consumers must be enabled to use the available electricity at the right time in the right place. Grid expansion and upgrading have a major role to play in this context – but there are other useful measures as well. So-called flexibility options are becoming more and more important, for instance. In this report, flexibility is understood to refer to active reactions by various elements to external signals caused by the variability of electricity generation and consumption. These reactions respond to short-term deviations to restore the balance between generation and consumption. They can also help relieve critically stressed grid resources and enable the smooth transport of electricity. In the long term, the availability of such flexibility is also a necessary precondition to achieving climate action goals, because the lower variable costs of renewable electricity mean that integrating it into the grid helps push fossil power plants out of the market. Once there is little to no conventional power plant capacity remaining in the energy system, the only way to guarantee security of supply will be with abundant flexibility.

In the period preceding the SINTEG programme, the industry was increasingly discussing approaches to grid congestion management, which built on a market-based deployment of flexibility.[4] This discussion rested in large part on the observation that expected medium-term delays in the expansion of the grid meant that the cost of promoting renewably generated electricity would be paralleled by similarly growing costs linked to curtailment. In 2016, for example, based on the cost structure at the time, the Federal Network Agency (BNetzA) forecast that the total cost of congestion management (redispatch, feed-in management and maintenance of the grid reserve power plants) would be €4 billion in 2023.[5] Between 2018 and 2019, the cost of grid congestion management dropped from €1.4 billion to €1.2 billion in Germany as a whole and from €153[6] to €85 million[7] in the 50Hertz control area. In the same period, the cost of feed-in management rose from €635 to €710 million in Germany and from €71 to €91 million in the 50Hertz control area.[8]

Against the background of this national trend and the beginning of the preparatory work on the European level for the EU Clean Energy Package, in which a market-based redispatch was clearly considered and recognised as desirable, the corresponding concepts moved to centre stage in the SINTEG showcase.[9] Consequently, four of the five showcase projects featured various flexibility platform designs conceived and piloted as market-based mechanisms for grid congestion management.

This report opens a range of perspectives on the topic of flexibility. It starts with a systemic view of the different uses of flexibility within the electricity system and of the value it has had in existing markets in recent years. It then quantifies the costs for redispatch, grid reserve and feed-in management for this period and explains the main features of the planned changes to the redispatch system. Next, the report analyses the technical potential that currently exists in the WindNODE area. While there were no systematic studies of flexibility

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[3] *Longer periods without considerable hours of wind or sunshine.*

[4] *These discussions were reflected, with some delay, in relevant expert reports and position papers. Representative examples include Ecofys and Fraunhofer IWES (2017) and BNetzA (2017).*

[5] *Cf. Zypries (2016).*

[6] *Cf. 50Hertz (2019).*

[7] *Cf. 50Hertz (2020).*

[8] *Cf. BNetzA (2020).*

[9] *Cf. European Commission (2017).*

options in the project region at the beginning of the project, there was an obvious need to catalogue any possibility to boost the use of renewable energy sources, as this would make it possible to identify all types of additional contributions to the success of the energy transition.

The main focus of the report, however, is on the efforts that the different participants in WindNODE have made to deploy flexibility efficiently in the system and exploit it economically. The report presents practical experience with the WindNODE flexibility platform from the perspective of the grid operators and providers. For instance, the lowering to 100 kW of the threshold at which participation in the redispatch becomes mandatory following the amendment to NABEG adds considerable new potential to the regulated redispatch. Moreover, from October 2021 generating plants with a capacity below 100 kW, which cannot be steered by the grid operators, and loads of different sizes will represent the unregulated flexibility potential of congestion management.

The report goes on to present the findings of providers on the addition of new flexibility options to the existing regulatory regime. It considers the use of flexibility in low-voltage applications from the perspective of a distribution system operator. Furthermore, it classifies the current regulatory framework and discusses possible evolutionary adjustments against the background of the practical experiences detailed by the project partners. Finally, it provides an outlook on the future use of flexibility in Germany. For readers in a hurry, there is a summary of the main takeaways at the end of each section.

The authors of this summary report compiled essential findings from WindNODE in addition to subproject descriptions mandated by funding decisions. From our point of view, it is clear that dealing with the topic of flexibility from an environmental and economic perspective is absolutely imperative given the challenges of lowering the emissions our society produces. We are well aware that this perspective conflicts with the sober business perspective on the subject, which is prevalent today. So far, companies have lacked extensive incentives for using a range of technologies to bring flexibility to market in a way that stabilises or relieves the system. One of the major challenges in the coming years will therefore be to adapt the background circumstances in a way that reconciles the market and grid-related perspectives.

We have one more remark about current events. In 2019, the young generation decisively attracted public attention to the climate crisis through the Fridays for Future movement. During the genesis of this report, the coronavirus pandemic was causing another societal crisis. Anyone who thinks that the COVID-19 pandemic is pushing the debate about carbon emissions and important decisions related to the energy transition to the margins has failed to understand that bold energy and climate strategies in Germany also represent solid industrial policy. The industries and technologies that will enable us to achieve our Paris goals in the long term will also create and secure new jobs while strengthening Germany as a location for innovation. Jumpstarting the energy transition will not be another burden for an economy that has already been laid low by COVID-19: more than ever, it will be a ray of hope for our economic and environmental future.

We hope to win you over – as innovators in the identification and utilisation of flexibility options and as participants in the regulatory debate in favour of their successful system integration.

Of course, first of all, we hope you enjoy reading this report.

Berlin, autumn 2020,
The authors

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# Flexibility in the electricity system

Ensuring a cost-efficient and comprehensive power supply requires systems that can flexibly adapt their electricity production or use. Such systems can maintain the balance between generation and consumption during short-term variations, while also helping relieve any critically stressed grid resources and thus facilitating the transport of electricity.

In the long term, such flexibility is also necessary to achieve climate action goals. Decarbonising energy systems requires boosting renewable energy, especially wind and solar facilities – but, as their power production depends on external circumstances, these energy resources ask more flexibility of the electricity system.[10] Flexibility options thus address the three energy policy goals of ensuring that the energy supply is secure, environmentally friendly and affordable, and are therefore a crucial component of the energy system of the future.

This chapter covers the basic topics linked to flexibility. Section 1.1 provides a definition of the concept, while sections 1.2 to 1.4 describe its fields of application – the electricity market, ancillary services and grid congestion management – in more detail.

[10] *Cf. IEA (2014).*

## 1.1 Defining flexibility

Properly determining the need for flexibility in an electricity system requires a robust definition of the concept first. The following definition of flexibility was agreed upon through a discussion process within WindNODE and forms the basis of our consolidation of results.

The term ‘flexibility’ is understood to designate the capacity of various elements in an energy system to actively react to external signals caused by the variability of electricity generation and consumption. These reactions are labelled as flexibility options. The demand for flexibility in an energy system can originate in wholesale markets (day ahead or intraday) or in the need to eliminate grid congestion. Flexibility options can also be requested on the electricity balancing markets or needed to provide additional ancillary services.

Providing a technical quantification of a flexibility option within an energy system requires that at least the following parameters be determined:

- Positive/negative value range of the change in production/consumption
- Duration of the change in production/consumption
- Lead time until the change in production/consumption

The supply and demand jointly determine the level of the technical flexibility potential in an energy system. The economic flexibility potential must also – depending on the regulatory framework – consider the costs and benefits achieved by the flexibility provided.

Based on this definition, the following fields of application for flexibility in an electricity system can be derived: i) the balancing of short-term changes in the residual load on the wholesale markets, ii) the provision of ancillary services and iii) the elimination of grid congestion. The processes and measures in these domains, some of which run in parallel, are visualised in Figure 1 and explained in more detail in the following sections.

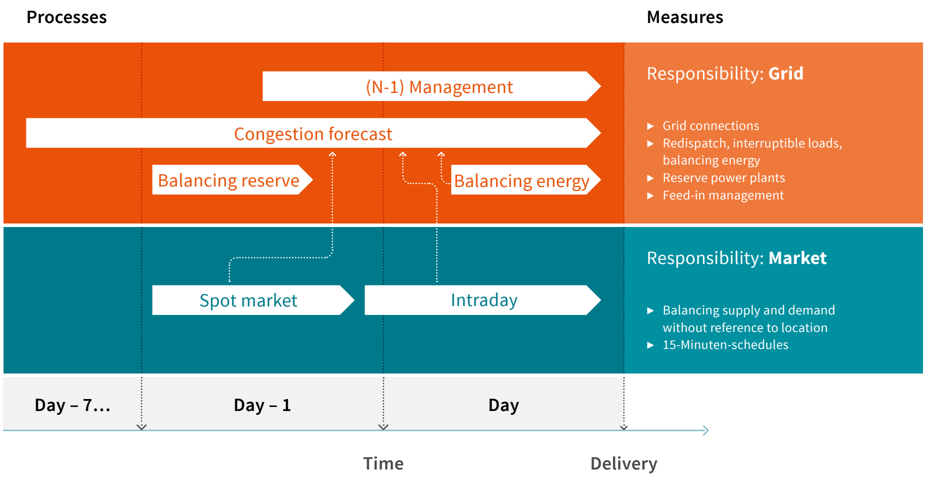


**Figure 1:** Overview of processes and measures for market and grid-related flexibility options.[11]

## 1.2 Flexibility in the electricity market

The primary goal of electricity markets is to balance overall generation and consumption in the system at all times while ensuring the stability of the system. For this purpose, aggregate demand in a given time range is covered by aggregate supply in the most cost-effective manner. For anyone to participate in the market, regardless of the type of provision or manner in which the product is brought to market, they must be assigned to a balancing group. Each balancing group must be equalised – with the total amount of electricity generated and purchased in the balancing group matching the total amount consumed or sold – within every 15-minute period. Each balancing responsible party must submit a schedule for every quarter-hour billing interval to the responsible transmission system operator (TSO) in advance. This schedule

[11] *Our own representation.*

must contain information about the quantities generated and consumed as well as those that are purchased and sold.

Electricity can be traded in a range of different ways. This includes bilateral contracts between individual actors, known as over-the-counter transactions, as well as trading on a power exchange. Long-term trading takes place on the futures market, while short-term trading is carried out on the spot market.[12] The higher time granularity of its price structures means that the latter is taken as the index for the flexibility needs in the electricity system. In the German market area, short-term trading is first carried out in a **day-ahead auction**. The main trading venue is the EPEX SPOT power exchange. Here, bids can be made for any given hour, and must be submitted no later than noon on the day before the physical delivery.[13] The annual trading volume on the exchange has been around 250 TWh in the last few years (see Figure 2). Once their bids have been accepted, electricity providers plan their respective power plant activation and pass this on to the responsible TSO in the form of schedules by 14:30.[14] Forecast deviations from the day-ahead result can be offset later on the **intraday market**.[15]

The intraday market is divided into an auction section and continuous trading. Next to the day-ahead auction, the **intraday auction** enables products to be traded every 15 minutes, with bids submitted by 15:00 the day before. This makes it possible to map the quarter-hour schedules on the market side in the context of balancing group management. The time lapse between each of the two auctions and the respective delivery time is 9-36 hours, depending on the auction and the product traded. During this time, market participants receive updated forecasts of the load and the feed-in from renewable energy sources, and power plant outages can occur. The resulting deviations can be balanced out by **continuous intraday trading**.

In contrast to the auctions, continuous intraday bids are accepted on the order book principle. This means that there is no uniform price for a given hour, half hour or quarter hour, but rather a separate price for each successful trade. The gate closure is 30 minutes before delivery time. In addition, market participants have the option to contract bids from the same control area up to five minutes before delivery. The steady growth of the cumulative trading volume shows that the liquidity in intraday auctions and continuous intraday trading has increased in recent years (see Figure 2).

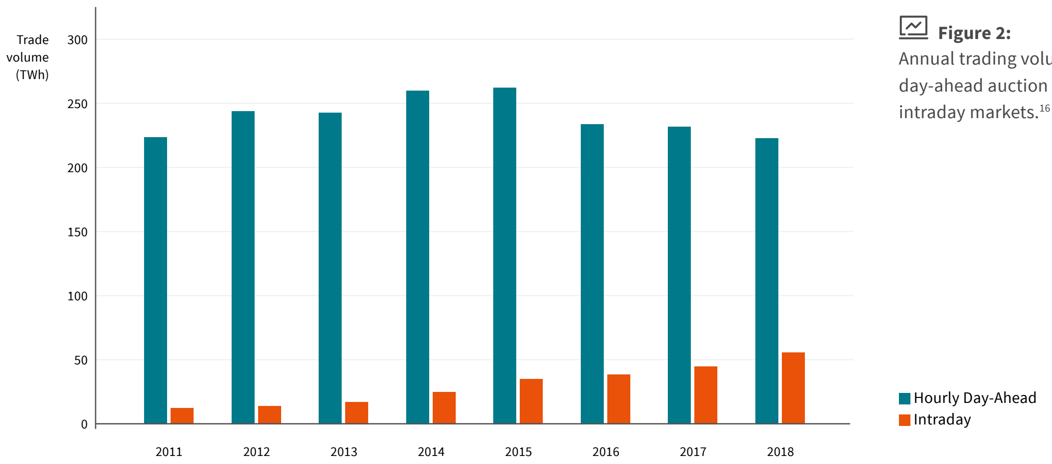


**Figure 2:**
Annual trading volume of the hourly day-ahead auction and the three intraday markets.[16]

This market structure means that there is a need for flexibility in both phases of short-term trading, on the supply as well as the demand side. When supply and demand are brought together on the hourly day-ahead market, flexibility options make up for the difference between the non-shiftable portion of the consumption on the one hand and the supply from intermittent renewable energy sources and must-run power plants on the other. If the market prices are high, this reflects a shortage of supply, while low – or even negative – prices indicate a surplus: either situation stimulates the provision of flexibility. The number of hours in which market prices were high declined between 2011 and 2015, and grew again after 2016. The number of hours with negative prices has increased over the entire period (see Figure 3). The lead time of several hours means that numerous power plants, power storage systems and shiftable loads can potentially offer flexibility on the day-ahead market. The prerequisite is simply that a change in generation or consumption lasting only a few hours make

[12] Cf. EEX (2019).
[13] Cf. EPEX (2019a).
[14] Cf. BNetzA (2011).
[15] Cf. EPEX (2019a).
[16] Our own representation based on data from EPEX (2019b).

economic sense despite the transfer costs or the expenses incurred in shifting demand.

In the intraday auction, deviations from the hourly mean are compensated by the quarter-hour products. These can be systematic, as with loads and electricity generation from solar facilities, or occur stochastically, as with wind power. This results in price deviations from the hourly averages (see Figure 4), from which flexible systems can benefit if they generate more (or consume less) in more expensive 15-minute periods and/or generate less (or consume more) in cheaper ones.

On the continuous intraday market, the forecast deviations in a schedule are balanced against the day-ahead forecast. This is done by the portfolio manager so as to respect the contractual obligation to comply with the schedules at all times – the so-called Bilanzkreistreue, or balancing group fidelity. Another incentive is the payment of imbalance prices for a given deficit in the balancing group.[17] The shorter duration between the acceptance of a bid and the delivery increases the technical requirements the corresponding flexibility option must fulfil. Restrictions in production planning can also mean that participation in the intraday market cannot be mapped for some flexibility options, in particular flexible consumers. In addition, continuous trading involves greater effort for market participants than an auction. All these features mean that the supply of flexibility drops with shorter lead times. Intraday prices therefore fluctuate more strongly than those on the day-ahead market. Between 2011 and 2018, there were around five times more hours on the intraday market than on the day-ahead market in which at least some transactions were made at a negative price or a price greater than €70/MWh (see Figure 3).

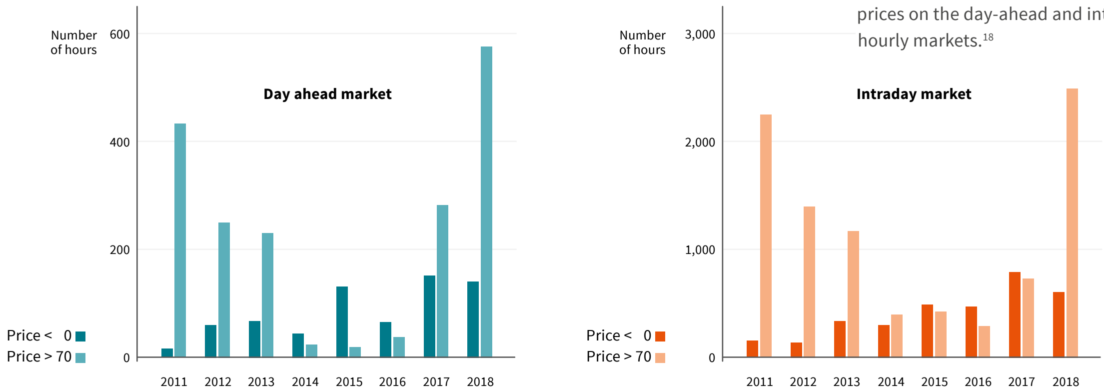


**Figure 3:**
The number of hours with high or negative prices on the day-ahead and intraday hourly markets.[18]

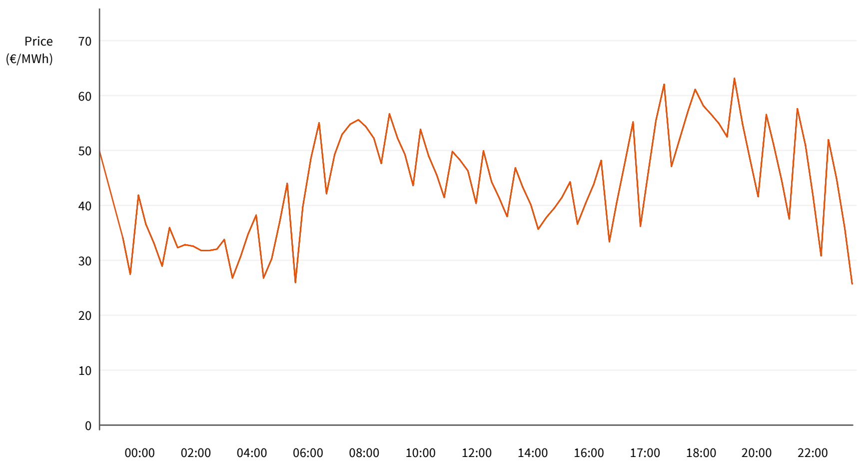


**Figure 4:**
Average fluctuation of prices in the intraday quarter-hour auction in 2018.[19]

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[17] *Cf. BNetzA (2013).*

[18] *Our own representation based on data from EPEX (2019b).*

[19] *Our own representation based on data from EPEX (2019b).*

## 1.3 Flexibility for the provision of ancillary services

The Energy Industry Act (EnWG) of 7 July 2005 (Sections 11 et seq.) obliges grid operators to operate, maintain and optimise, as required, a safe, reliable and efficient energy supply grid without discrimination.[20] The tasks include operational management (see section 1.4), frequency and voltage maintenance, and restoration of supply. To maintain the right voltage, the permissible voltage range must be adhered to during normal operation (e.g., by providing reactive power) and it must be possible to prevent equipment from being overburdened in the event of a malfunction (by limiting short-circuit power). To restore supply, there must be sufficient power plants that can start up independently of other existing power sources (black start capability).

The maintenance of frequency is achieved primarily through the use of **balancing reserves**.[21] There is a distinction between Frequency Containment Reserve (FCR) and Frequency Restoration Reserve with automatic and manual activation (aFRR and mFRR). Their activation times range from 30 seconds to 15 minutes, respectively (see Table 1). FCR is tendered on weekdays for the day after the next. The minimum bid size is 1 MW and the product is remunerated with a capacity price. In contrast to FCR, aFRR and mFRR are tendered separately for positive and negative reserves with a minimum bid size of 5 MW each. The announcement is made daily in six time slices of four hours each. The provision of aFRR and mFRR is remunerated with a capacity price and the request with a working price.

**Table 1:**
Characteristics of balancing power products.[22]

| | FCR | aFRR | mFRR |
|---|---|---|---|
| **Time to activate** | 30 seconds | 5 minutes | 15 minutes |
| **Minimum bid size** | ± 1 MW (posative and negative) | 1 MW [21] (positive or negative) | 1 MW [21] (positive or negative) |
| **Tendering period** | Daily (on weekdays for the day after next) | Daily (for the next day) | Daily (for the next day) |
| **Time division** | 6 time slices lasting 4 hours each | 6 time slices lasting 4 hours each | 6 time slices lasting 4 hours each |
| **Remuneration** | Capacity price (pay-as-clear method) | Capacity price and working price (pay-as-bid method) | Capacity price and working price (pay-as-bid method) |
| **Presence on multiple markets** | This is possible provided that technical requirements can be met even in case of multiple simultaneous deliveries. | | |

The structure of the market for the procurement of balancing reserve products means that these ancillary services represent a crucial way to bring flexibility to the market. The FCR advertised for continental Europe is set at 3,000 MW and is distributed to individual grid operators by percentage based on load. Since 2012, Germany has been participating in an international FCR partnership in which it gradually established joint tendering with Switzerland, the Netherlands, Austria, Belgium and France. In this respect, the increase in the advertised FCR shown in Figure 5 is due to the growing association of grid operators and not increasing demand within Germany.

The biggest leap came in early 2017 when France joined the group.[24] As expected, competition with power plants abroad and the prequalification of new providers (especially batteries) have led to falling power prices since 2015 (see Figure 6).

Although intermittent renewable energy sources have further expanded in Germany in recent years, it was possible to reduce the tendered capacity for aFRR and mFRR (see Figure 5). The cause of this seeming contradiction is the increased efficiency potential on the part of the portfolio managers and the grid operators. This includes improved weather forecasts,

[20] *"… ein sicheres, zuverlässiges und leistungsfähiges Energieversorgungsnetz diskriminierungsfrei zu betreiben, zu warten und bedarfsgerecht zu optimieren."*

[21] *It is also possible to use disconnectable loads, which are provided by units that can reduce their consumption by a certain amount at the request of a TSO. There is a distinction between loads that can be switched off immediately and those that can merely be shut off quickly, which are provided by 4 and 12 prequalified suppliers, respectively (50Hertz et al., 2019a). Since these products are rarely deployed, they will not be discussed further in the text.*

[22] *Possible from 1 MW, if only one offer is made per product and zone.*

[23] *Our own representation based on 50Hertz et al. (2019b), VDN (2003), VDN (2007) and VDN (2009).*

as well as, in particular, the creation of the International Grid Control Cooperation (IGCC) – which avoids contradictory requests for balancing energy – and the increased use of the intraday market for offsetting within the balancing group.[25] At the same time, the number of providers has risen sharply.[26]

These circumstances together led to increased competition and an abrupt drop in capacity prices. In contrast, working prices rose steeply in the same period (see Figure 6). The reasons for this included the use of new technologies, such as power-to-heat and biogas plants, in the provision of balancing power. These new facilities can offer low service prices, but are forced by the prevalent electricity rates or the risk of lost EEG remuneration to charge high commodity prices.

This trend was initially reversed with the introduction of the mixed price method in October 2018, in which contracts were awarded based on a weighted combination of the capacity price and the working price.[27] At the end of July 2019, however, the Düsseldorf Higher Regional Court annulled this procedure and the Federal Network Agency (BNetzA) ordered a return to the mechanism that had previously applied.[28]

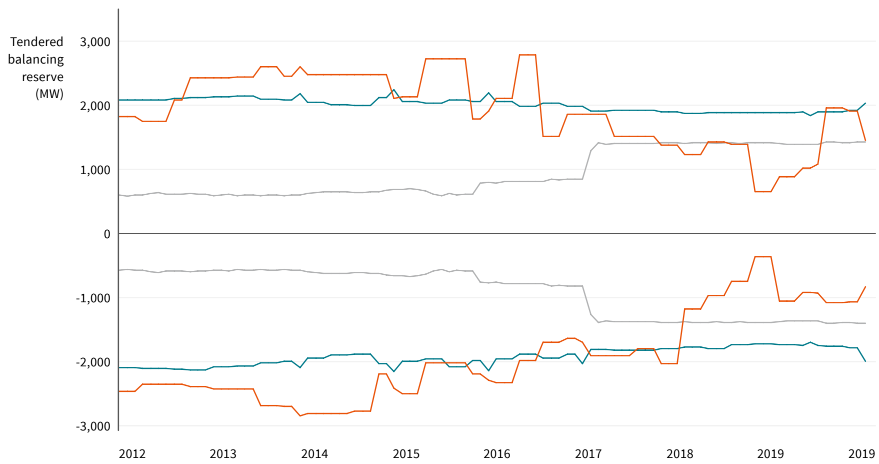
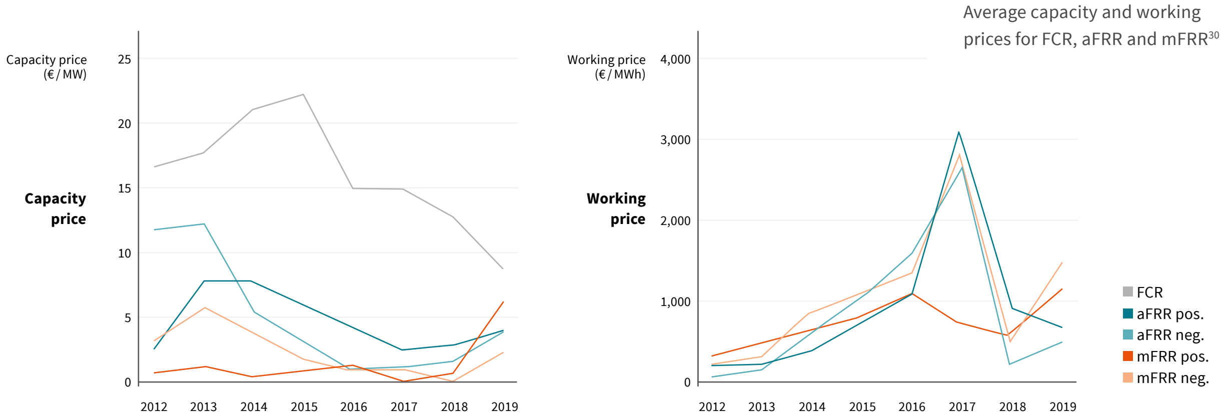



**Figure 5:**
Tendered balancing reserve for FCR, aFRR and mFRR.[29]

**Figure 6:**
Average capacity and working prices for FCR, aFRR and mFRR[30]




[24] Cf. 50Hertz et al. (2019b).
[25] Cf. Ocker and Ehrhardt (2017); Koch and Hirth (2019).
[26] Cf. BNetzA (2018b).
[27] Cf. BNetzA (2018c).
[28] Cf. 50Hertz et. al. (2019c).
[29] Our own representation based on data from 50Hertz et al. (2019d) and 50Hertz et al. (2020).
[30] Our own representation based on data from 50Hertz et al. (2019d) and 50Hertz et al. (2020).

## 1.4 Flexibility for grid congestion management

For operational management and the maintaining of system security, Section 13 EnWG specifies a cascade of measures that can be taken by the TSOs. These measures must be taken in a sequence determined by law. Section 13 (1) and Section 13a (1) EnWG prescribe the use of grid-related measures, especially grid connections, to relieve overburdened facilities first. If grid congestion persists, the TSOs may, in a second step, call on market-related measures – in particular **redispatch** – so that power plant output is reduced in a given location and increased accordingly in another. For this purpose, TSOs have their own power plant reserve capacities, the so-called grid reserve, at their disposal. The amount of this reserve is determined every year via a system analysis. If the analysis finds the redispatch measures to be insufficient, the TSO may, under Section 13 (2) EnWG, request further adjustments to electricity feed-in and consumption quantities. Combined with Section 14 (1) EEG, this also explicitly affects renewable power plants, CHP facilities and coal mine gas (firedamp) plants. The reduction of the grid power fed into the grid by these systems initiated by the grid operator is referred to as **feed-in management**. Measures in accordance with Section 13 (2) EnWG are also used by DSOs for congestions in the distribution grids.

The existing grid topology and the expansion of supply-dependent renewable generation capacity are increasingly causing grid congestions on the transport routes from the wind farms in the north to consumption centres in the south. The increase in the energy needed to resolve grid congestions within the German grid control network is shown in Figure 7. From 2012 to 2019, this grew from 5 to 20 TWh, with a slight downward trend since 2017. So far, the German TSOs have mainly used large power plants and feed-in management to deal with congestion, without calling on much of the potential of small and medium-sized flexible systems. However, the latest amendment to the Grid Expansion Acceleration Act (NABEG) specifies a reorganisation of the redispatch process by 1 October 2021 (see text box on the adjustments to grid congestion management as part of the amendment to NABEG).

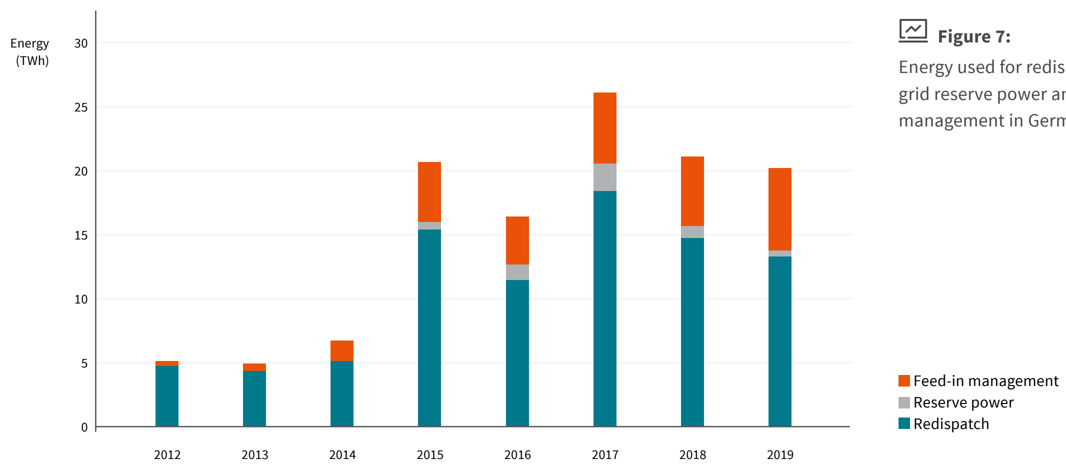



**Figure 7:** Energy used for redispatch, grid reserve power and feed-in management in Germany.[31]

The full costs of redispatch, feed-in management and grid reserve power are transmitted into the grid fees and thus borne by end consumers. Between 2012 and 2017, these expenditures increased from €220 to 1,500 million, but then dropped again in the following two years (see Figure 8). In contrast with the wholesale and balancing power markets described in Sections 1.2 and 1.3, assets involved in the grid congestion management are only reimbursed for the additional costs incurred. This is due to the geographical requirements that an installation must fulfil in order to be eligible for such a deployment – the location is of crucial importance for the effectiveness of measures counteracting grid congestion. Nearby actors thus have an advantage over remote participants as well as over the requesting TSO, which is dependent on the adaptation of the service.

[31] *Our own representation based on data from BNetzA (2014), BNetzA (2015), BNetzA (2018b) and BNetzA (2020).*

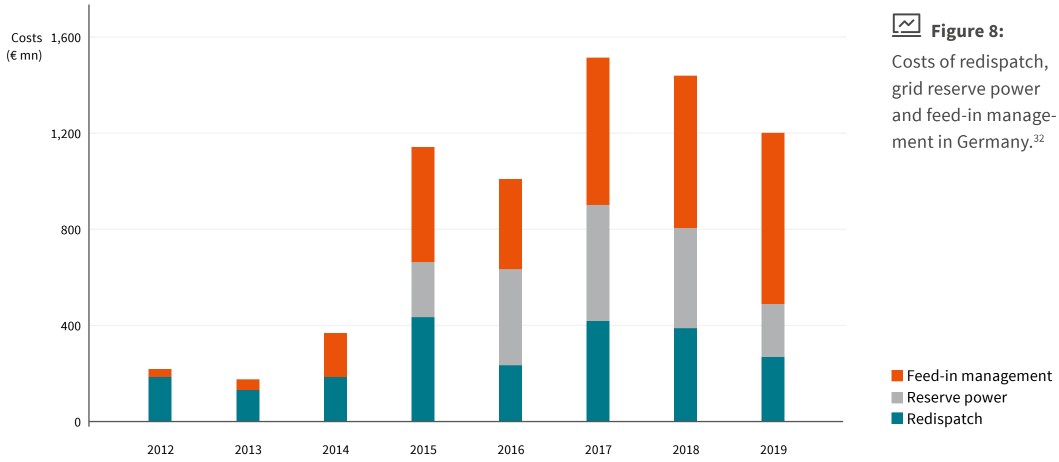



**Figure 8:** Costs of redispatch, grid reserve power and feed-in management in Germany.[32]

## Side note: Adaptation of grid congestion management under the amendment to NABEG

The amendment to NABEG specifies measures for the reform of grid congestion management that must be implemented by 1 October 2021. First, the capacity limit for plants which must participate in redispatching will be reduced from 10 MW to 100 kW, which means that more conventional plants and storage facilities will be available for this purpose. Furthermore, renewable generators and CHP systems from 100 kW and up will be transferred to the plan value-based method. These can be used to resolve grid congestion in situations where that results in significantly lower costs compared to conventional systems (by a factor of 5-15). The imputed costs that should apply when a request is made are currently being determined by the BNetzA and will be uniform across Germany. The amendment states that balance sheet compensation of the reduced feed-in will also be carried out for renewable energy and CHP systems by the instructing grid operator. The transfer of the processes means that feed-in management in its current form will no longer be necessary, and the regulatory equality in grid congestion management will reduce the priority given to feed-in from renewable energy sources and CHP systems. This expansion of the potential of regulated redispatch demonstrates a choice by the legislature to not strengthen market-based measures. However, the amendment to NABEG still does not implicate flexible consumers in grid congestion management.

The planned changes will include adjustments to the cooperation between and tasks carried out by grid operators in Germany. DSOs will have to manage congestion according to the new redispatch rules from October 2021. Furthermore, redispatching measures will in the future be carried out in a coordinated manner across the relevant grid levels. Coordination between the grid operators is meant to increase the efficiency of the grid congestion management and thus the security of supply. At the same time, there will be a rise in the requirements for the determination of cost-optimised grid congestion management and for the handling of the administrative processes when the facilities are requested to act. The first experiences related to the new rules are presented in chapter 3.

[32] *Our own representation based on data from BNetzA (2014), BNetzA (2015), BNetzA (2018b) and BNetzA (2020).*

## 1.5 Flexibility in the low-voltage grid

The abovementioned fields of application for the use of flexible installations relate to the TSO level of the energy system. The short-term trading markets and the balancing reserve markets are intended to ensure the balance of the system throughout Germany. The instruments described above (redispatch and feed-in management) are primarily used to remedy congestion at the extra-high, high and medium voltage levels. However, the increasing number of electric cars and heat pumps can lead to problems in the low-voltage grid as well. The design of power grids takes into account the maximum amount of power that consumers request at a given time through the simultaneity factor. If a lot of consumption occurs at the same time (due either to the behaviour of new consumers or to situations caused by new electricity products), there will be increasing simultaneity in the electricity grid and this will be reflected in higher demand than would be expected statistically or is provided for in the grid planning.

At the moment, these challenges remain hypothetical: there are still no acute problems in the low-voltage grid. This makes it possible for participants to smoothly adapt to new technological and regulatory developments so as to avoid problematic situations in advance. Flexibility options can be deployed as an additional tool if the grid expansion temporarily cannot keep pace with developments. An amendment to Section 14a EnWG currently being discussed to this effect is intended to adapt and expand the regulatory basis to encourage behaviour by flexible consumers in low-voltage applications that would be beneficial to the grid. The aim of the discussion is to subdivide grid use into a conditional and an unconditional part. Under this regime, classic consumers would receive their electricity without restrictions, or unconditionally, while defined new consumers would be given a share of conditional grid use. Within a framework that is acceptable for consumers, the grid operator could reduce output, for example the charging power for the electric car, in a way that avoids excessive simultaneity and guarantees reliable grid operation.

When solutions to congestion in low-voltage applications are developed, it is important to note that markets cannot generally be assumed to be liquid: there are too few consumers that can have an effect on congestion in terms of grid technology. In addition, only small-scale flexibility can be deployed at this voltage level. If these consumers are used to deal with congestion at higher voltage levels, a sufficient system effect can only be achieved if a comparatively large number of power installations are involved. A broad feasibility therefore requires that technical and regulatory tools be characterised by the smallest possible level of complexity. A practical example of a technical solution that was developed and tested within WindNODE is presented in chapter 5.

### Main takeaways from chapter 1

‘Flexibility’ describes the ability of various elements within an energy system to actively adapt to an external signal. It is required for the electricity system to equalise portfolio deviations and achieve system balance and is sold for this purpose on wholesale and balancing reserve markets. While the number of hours with particularly high or low prices on the day-ahead and intraday markets has increased in recent years, power prices on the balancing reserve markets have fallen. Flexibility is also used to resolve grid congestion, albeit so far only in regulated redispatch. The continuous renovation of the German power plant park has led to a sharp rise in the amounts of energy and costs required for this purpose between 2012 and 2018. One of SINTEG’s and WindNODE’s essential goals was to develop and test more efficient market mechanisms for providing the flexibility required in the system. Grid congestion may eventually also become an issue in the low-voltage grid as the number of consumers grows, and technical solutions and regulatory tools are currently being developed to respond to this.

# 2

# Theoretical technical flexibility potential (Status quo)

This chapter examines how much flexibility is theoretically available in the WindNODE region. The main hypothesis is that the supply of flexibility already significantly exceeds demand from the fields outlined in chapter 1.[33] Leipzig University used public databases as its source and supplemented them with its own research. The evaluation was carried out with a special focus on the WindNODE region.[34]

[33] *Cf. WindNODE (2019).*
[34] *An extended presentation of the methodology is given in a separate report.*

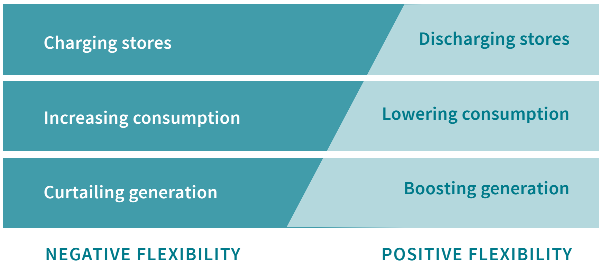
# 2.1 Introduction

The research findings are categorised in specific types of flexibility (flex types).[35] One flex type comprises several flexibility options, each of which in turn represents a certain number of technical units. A technical unit does not have to be clearly assigned to a single flex type, however. For instance, the battery of an electric vehicle could belong to both the flex types 'storage' and 'sector coupling'.[36] The data was aggregated in the following flex types:

- generation (power plants based on fossil and renewable primary energy sources),
- consumption (flexible loads in households and the sectors industry, trade, commerce and services)
- storage (stationary batteries and pumped storage) and
- sector coupling (electrolysers, power-to-heat systems in district heating grids, electric vehicles).

The technical flexibility potential of a data point is evaluated in parallel with a qualitative classification of the ability of the technical installation to react to balancing signals. Regarding the current status of the grid it may be necessary to increase or decrease the power fed in or drawn. Depending on the desired effect on the flow of current in the grid, a distinction is made between positive and negative flexibility. The possible applications of this concept are shown in the following figure:

**Figure 9:**
Qualitative classification of technical flexibility potential with regard to the desired effect on load flow in the power grid.[37]




The summary of the results shows that the highest (theoretical) technical potential is currently to be found on the generation side, where some 54 GW of negative flexibility can be achieved through reductions. However, significant potential could also be identified on the consumption side and with the flex type 'storage'.

The results of the investigation of potential for the respective flex types are examined in more detail and evaluated with regard to their regional distribution below.

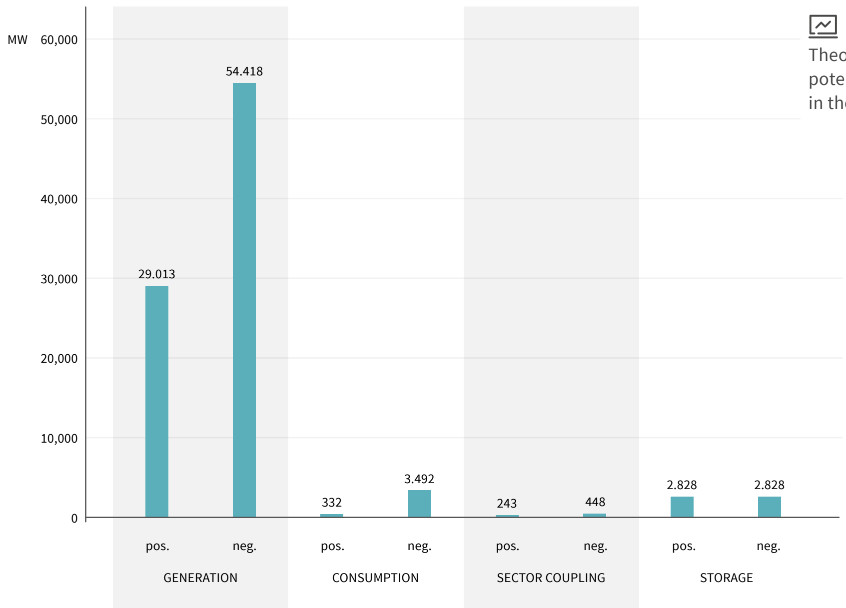



**Figure 10:**
Theoretical technical potential by flex type in the WindNODE region.[38]

[35] *Cf. Müller (2017).*
[36] *For the purposes of this report, we separate stationary and mobile batteries and assign electric vehicles to the flex type 'sector coupling'.*
[37] *Source: IIRM, Leipzig University.*
[38] *Data collection by Leipzig University on the basis of Germany's core energy market data register, the power plant list of the Federal Network Agency and market research.*

## 2.2 Detailed analysis and regional distribution of potential

### Consumption

This flex type was studied through the evaluation of the locations of larger electricity consumers from the sectors industry, trade, commerce and services, as well as the number of households in a given postcode area. A total of 2689 data points were recorded for the flex type 'consumption' in the research by Leipzig University. Among these, 32 industrial sites in the cement, paper, iron and chlorine industries were identified for the provision of negative flexibility (load increase, starting the industrial process) totalling 3.16 GW. The study also estimated the number of retail stores of large discounters in the retail sector and, based on findings from the Schwarz Group, assumed a potential for flexibility of 40 kW per site. This flex option contributes 79 MW to the total potential in the WindNODE region. The data collection by Leipzig University also recorded airports and trade exhibition locations, with a total of 14 MW, as larger consumers within the trade, commerce and services sectors. Private households contributed another 239 MW to the theoretical technical flexibility potential.

The greatest technical potential could be found in the federal states in which industry consumes a comparatively high share of total electricity:

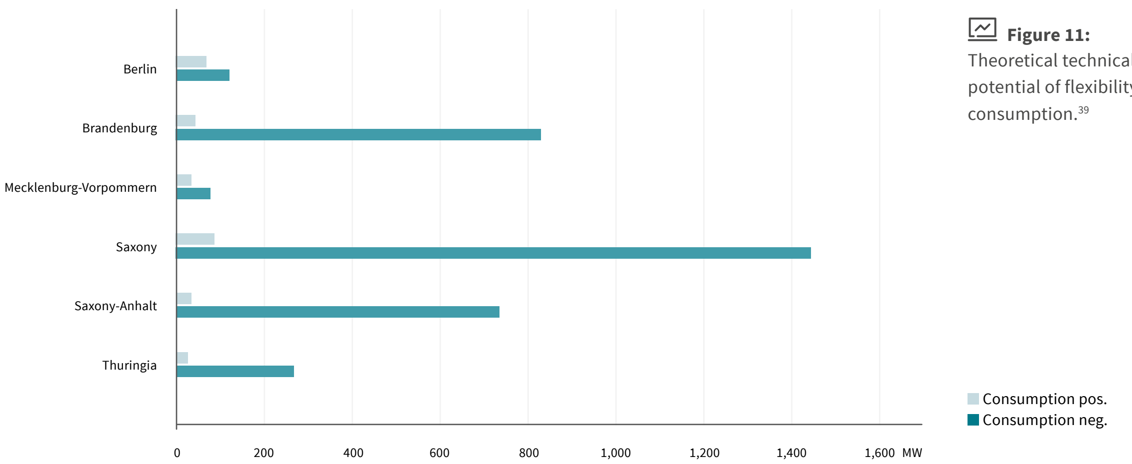



**Figure 11:**
Theoretical technical potential of flexibility in consumption.[39]

### Generation

The flexibility options linked to generation include combined heat and power (CHP) and biomass power plants, the management of intermittent renewable power plants, and flexibility provided by conventional power plants. The catalogue was based on the power plant list of the Federal Network Agency (BnetzA) and the core energy market data register. As expected, most generation flexibility today is provided by conventional power plants.

The technical potential for negative flexibility from renewable energy systems is assumed to be 100% of their installed capacity. This is due, among other things, to the fact that the need for flexibility occurs primarily at times when renewable energy systems feed in most of their available capacity. Positive flexibility is represented by the fact that these systems normally only operate up to 70% of their installed capacity while the remaining 30% are switched on as required.[40] However, this is only a guideline for what is technically possible and not guaranteed available potential in the sense of a capacity credit.

In total, the installed capacity of generation plants in the WindNODE region is around 54 GW. Under the assumptions above, around 29 GW is available as for positive flexibility. Among the federal states, Brandenburg occupies the top position: some 75% of its around 20 GW of generating capacity are produced by the renewable energy sources wind and solar. Only in Saxony is the overall potential for technical flexibility dominated by fossil fuels.

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[39] *Source: Universität Leipzig, IIRM.*
[40] *Cf. Asanalieva et al. (2017).*

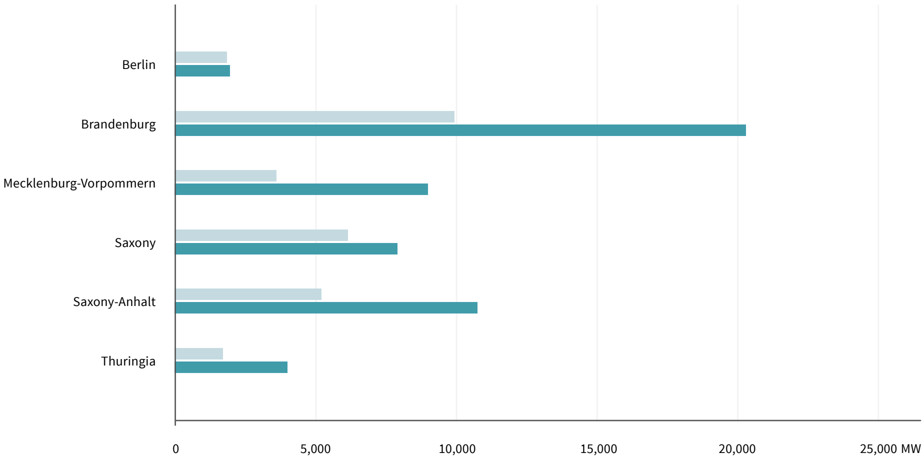



**Figure 12:** Theoretical technical potential related to generation in the WindNODE region. It is assumed that wind and solar systems only contribute 70% of their installed capacity to the positive flexibility potential.[41]

## Storage

The data collection by the University of Leipzig included a calculation of stationary electricity storage (pumped storage, battery storage) via 6,411 data points in the WindNODE region drawn from the power plant list of the Federal Network Agency, the core energy market data register and market research. Pumped storage accounts for 2.68 GW. Electrochemical storage systems are represented by lead-acid, lithium-ion and redox flow batteries with an average charge capacity of around 24 kW and a total technical potential of 154 MW, of which some 100 MW are represented by the 10 largest plants.

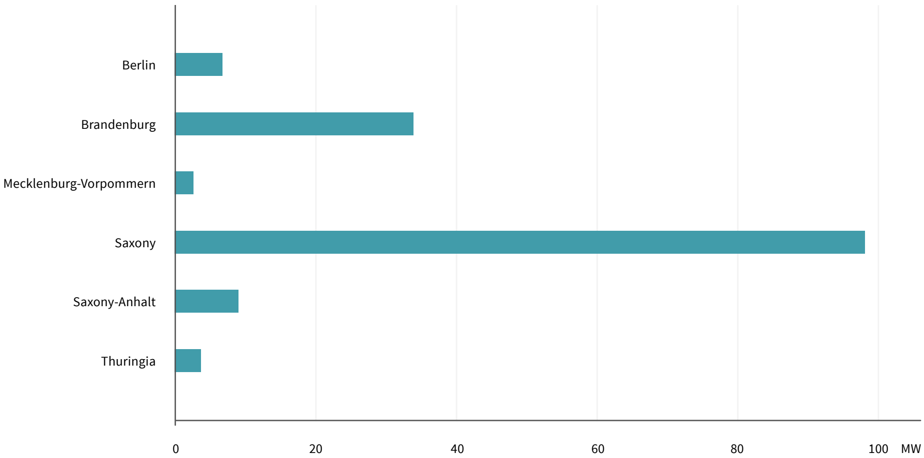



**Figure 13:** Technical potential of stationary battery storage in the WindNODE region.[42]

## Sector coupling systems

The future electrification of the heating and transport sectors may eventually create additional flexibility. The aim of sector coupling is to relieve the grid by connecting new electricity consumers close to where green power is produced, thus avoiding the need to shut down renewable power plants. The main types of sector coupling in terms of installed capacity are power-to-heat (PtH) plants connected to district heating systems, power-to-gas electrolysis plants, and mobile battery storage complexes. Leipzig University collected a total of 1,425 data points based on its own market research and the registration statistics of the German Federal Motor Transport Authority. When calculating the technical potential provided by pure e-cars and hybrid vehicles, the focus is on negative flexibility. The calculation is based on the number of registered vehicles and their average installed battery capacity (net nominal capacity). The total potential in terms of negative flexibility is 448 MW, of which 238 is attributable to power-to-heat systems and 205 to mobile battery storage.

[41] *Source: IIRM, Universität Leipzig.*

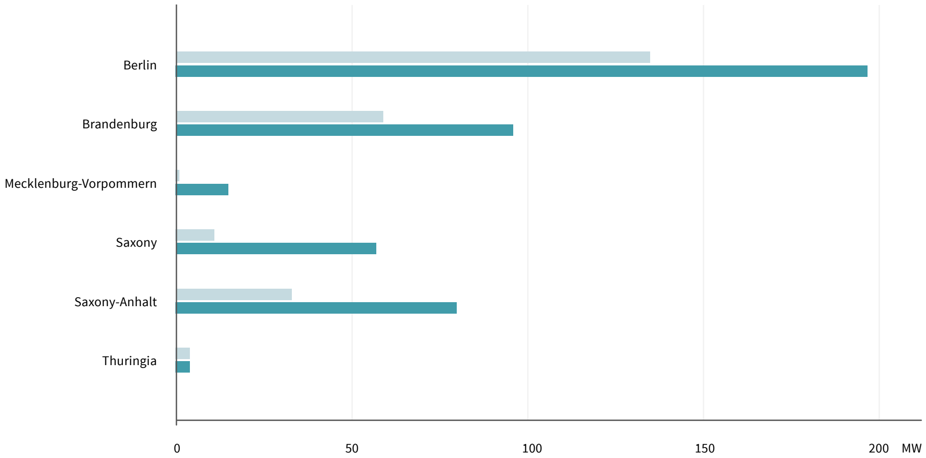



**Figure 14:**
Technical potential for sector coupling systems (power-to-heat in district heating systems, electrolysers and mobile battery storage) in the WindNODE region.[43]

## Main takeaways from chapter 2

Chapter 2 provided an overview of the theoretical technical potential for flexibility in the WindNODE region (the accessible potential will always be significantly lower). Leipzig University carried out an inventory based on an evaluation of available databases and its own market research as well as data points with a high spatial resolution at postcode level. The relevant technical systems were assigned to the categories generation, consumption, storage and sector coupling. The theoretical technical potential established for the WindNODE region was found to currently be around 61 GW of negative flexibility (increasing power consumption or curtailment) and 32 GW of positive flexibility (load shedding or feed-in) of around 32 GW. For its part, WindNODE focused on demand-side flexibility, and could identify over 200 MW of flex options. However, flex options related to generation currently make the greatest contribution to the overall theoretical technical flexibility potential. However, climate-political considerations mean that the best choice for responding to the need for negative flexibility, especially for grid congestion management, is not by curtailing wind or solar power. If these renewable plants are left out, there is currently a mix of flex options consisting of combined heat and power (CHP), pumped storage power plants, power-to-heat, biomass and demand-side management that amounts to a theoretical technical potential in the WindNODE region of around 12 GW. Grid simulation still needs to be used to investigate whether and to what extent this flex potential can eliminate critical grid situations, however.

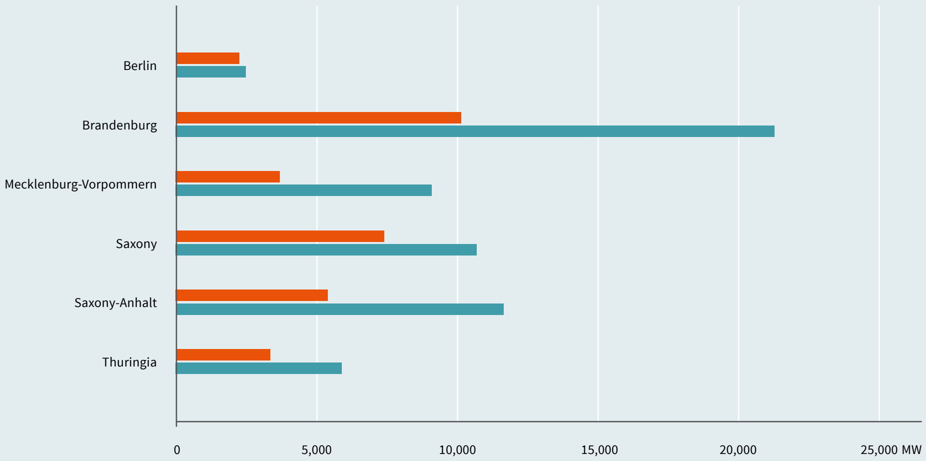



**Figure 15:**
Theoretical technical flex potential in the WindNODE region.[43]

[42] *Source: data collection by Leipzig University, IIRM.*
[43] *Source: data collection by Leipzig University, IIRM.*

# 3 New market solution for grid congestion management

The previous chapters introduced the topic of flexibility and flexibility options, presented options for bringing them to market, and assessed the theoretical technical potential in the WindNODE area. This chapter describes the new concept for using the flexibility platform to manage grid congestion in a cost-effective way. It starts by discussing the initial situation in which flexibility is used to manage grid congestion, and then explains the concept and functionality of the platform, to then finally present experiences from practical operation and the new legal situation.

# 3.1 Use of flexibility to manage grid congestion

## Initial situation

The electricity wholesale market does not currently take into account the transport capacity of the German electricity grid. Since there are advantages to a large price zone in terms of liquidity, competition and predictability compared to other models, that course of action is reasonable and correct. At the moment, however, congestion can occur in the power grid during the physical fulfilment of market operations. Even if it makes economic sense to expand power grids to remove grid congestion, the existing congestion must be managed during the transition period in order to guarantee security of supply. Right now, predicted congestion is eliminated in advance by means of so-called redispatch measures (according to Section 13 (1) EnWG). These measures currently only call upon conventional generation systems or electricity storage systems with a capacity of 10 MW or more.[45] If this potential is exhausted, additional feed-in management measures are deployed (according to Section 13 (2) EnWG), including the curtailment of renewable energy plants.

There is continued development of the processes necessary to ensure the most efficient congestion management in the distribution and transmission grid. Flexibility potential from small conventional power plants and connectible or shiftable consumption remains unused.

| | Conventional generation plants | Renewable and CHP generation plants | Electricity storage | Flexible and connectible loads |
|---|---|---|---|---|
| **≥ 10 MW** | Already part of the redispatch process | | | Remain unused |
| **≥ 100 kW** | Part of the redispatch process from 1 October 2021 | | | |
| **< 100 kW** | (When remote controllabe by grid operators) | | | |

**Figure 16:**
Distribution of the use of flexibility according to Redispatch 2.0.[46]

## Objectives

The possibility to harness additional flexibility potential for the grid congestion management process has been developed and tested in WindNODE. Providers should be able to make flexibility available in a way that is voluntary and open to different technologies. The use of the flexibility should be open to all grid operators involved and there should be coordination across different voltage levels. The deployment of this additional potential should enable greater use of renewable generation in the event of grid congestion (the ‘use instead of curtailing’ principle). The approach should follow market principles and be based on the most economically cost-efficient solution as far as possible.

It is particularly interesting from an economic point of view to consider further flexibility in the process of grid congestion management if this can lead to less expensive flexibility options or more use of renewable electricity. For this to work, the saved costs must at least compensate for the costs of the continued development and operation of the relevant flexibility platform. The frequency with which the flexibility is deployed and the output required can be very different depending on the location of the plant and the local situation in the power grid and must be assessed individually.

[45] *The legal framework for grid congestion management has changed significantly in the course of the project. These changes are discussed in section 3.3.*
[46] *Authors’ own representation.*

## 3.2 Concept and functionality

The development of the concept includes the design of the web platform, the formulation of a certification process, the definition of products, the determination of the course of the bidding process, the communication of the flexibility potential including coordination between the grid levels, the request process, and billing issues.

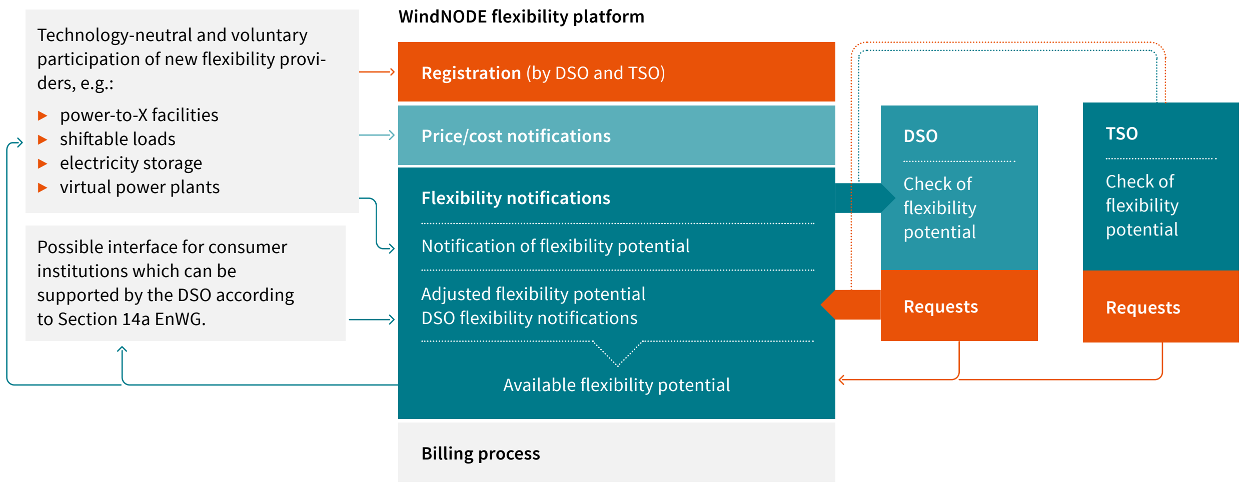
Communication between grid operators and flexibility providers is handled via a web platform, the flexibility platform developed by 50Hertz together with several distribution system operators (DSOs). This platform is necessary to keep the transaction costs low when a large number of providers participate. It should allow voluntary, standardised and non-discriminatory contracts to be concluded between providers and grid operators. For this purpose, the providers are first registered and the systems are prequalified in a joint process between 50Hertz and the DSOs involved. Providers on this platform can be operators or marketers of systems who are currently not legally obliged to participate in the redispatch process. Aggregators can also act as providers.

The flexibility products are defined based on the requirements of the grid operators and the possibilities of the provider. Redispatch requires knowledge of locations or links to a defined area within which power plants have a comparable grid-related effectiveness on defined congestion, and bids must be submitted according to a location or area. Providers can use the web platform to set system-specific request prices.

The flexibility available should be adaptable at short notice. The process required for this should also include coordination between grid operators in order to avoid critical states in other grid levels in requirement cases.

A requirement case occurs when a grid operator identifies congestion and the facility of a provider contributes to eliminating this congestion at minimal cost. The request costs, planned availability and system locations are processed ex ante and requirement messages are sent to providers as a result. Furthermore, when the operating status of the facility is actually adjusted, the requesting grid operator must compensate for the energy imbalance in the balancing group.

**Figure 17:**
Overview of the function of the flexibility platform.[47]




[47] *Authors' own representation.*

## Participation possibility for providers

- Participation in the project is voluntary, technology-neutral and without restriction on size or voltage level (alternative solutions are also being discussed for low voltages).
- Aggregators can also participate and bring third-party systems to market.
- A minimum size of 100 kW for individual bids is conceivable.
- Providers must be able to plan the operation of their systems reliably.
- The process lasts 15 minutes. The flexibility provided must be verifiable through a suitable measurement concept.
- Providers must register themselves and the systems they sell on the platform.

## Definition of products

**Principles:**

- The bids are used exclusively for the management of grid congestion.
- There must be a commitment or capacity to plan for providers and grid operators.
- The possibilities of the providers must be taken into account for the ability to forecast, among others.
- The needs of the grid operators related to things like existing processes must be taken into account.

| | Time | Name | Description |
|---|---|---|---|
| Execution: daily | **Previous day 13:00** | Gate Open | Providers can submit bids |
| | **Previous day 16:00** | Gate closed | Bids can no longer be changed |
| | **Previous day 16:00-18:00** | DSO processes | Sensitivity information, limitation of bids, request information |
| | **Previous day 18:00-22:00** | TSO processes | Request information |
| | **Previous day 22:00** | Request transmission | At 22:00 the providers are informed of bids awarded |
| | **Date of delivery** | No interaction with the platform | |
| | **From 00:00 on the next day** | Transmission of time series on actual delivery | Providers can register actual delivery |

**Figure 18:** Day-ahead-product on the flexibility platform[48]

| | Time | Name | Description |
|---|---|---|---|
| Execution: hourly rolling | **16:00 on previous day** | Gate Open | Providers can submit bids |
| | **t-2 h** | Gate closed | Bids can no longer be changed |
| | **t-2 h to t-1.5 h** | DSO processes | Sensitivity information, limitation of bids, request information |
| | **t-1.5 h to t-1 h** | TSO processes | Request information |
| | **t-1 h** | Request transmission | One hour before delivery, the providers are informed of bids awarded |
| | **Hour of delivery** | No interaction with the platform | |
| | **From 00:00 on the next day** | Transmission of time series on actual delivery | Providers can register actual delivery |

**Figure 19:** Intraday product on the flexibility platform.[49]

[48] *Authors' own representation.*
[49] *Authors' own representation.*

The close cooperation between the transmission network operator 50Hertz, the DSOs involved and various flexibility providers made it possible for processes, platform functions, interfaces and products to be designed in a way that would ensure the lowest possible entry barriers for technology-neutral participation in the flexibility platform. Defining the products and processes allowed for the requirements of the various grid operators to be reconciled with the options offered by the providers. The concept can also easily be expanded to include additional product variants.

## 3.3 Experiences, changed legal situation and outlook

### Experiences from test operation

The operation of the flexibility platform, with bids, coordination and requests, underwent extensive practical tests during the project period. The results were consistently positive. The providers evaluated the products and processes and found that the design of the processes matched their operational and technical requirements. Bids were submitted successfully and the systems were deployed in practice to eliminate congestion. The evaluation also showed that more complex products can make sense, especially for storage systems or generally for systems with a limited service life. Instead of focusing on a fixed flexibility potential for a given time slice, such more complex products could specify an amount of energy that can be freely moved within a certain period of time and within a given capacity band. Technically speaking, the platform could reproduce such complex products, but there would be a need to extensively adjust the optimisation calculations for grid congestion management. More freedom in the optimisation would require new algorithms and lead to significantly longer computing times.

When evaluating the implemented IT interfaces, the providers made it clear that they found most application programming interfaces (APIs) to be useful, since they make it possible to automate processes quite comfortably. There are also more advantages in terms of the IT security of such interfaces, since they make suitable security concepts easier to implement.

The processes, interfaces and products were initially developed within the WindNODE consortium. As there is at least a nationwide need for harmonisation on this topic, the consortium partner DIN started a standardisation project in DIN SPEC 91410-1 entitled ‘Energy Flexibility Part 1: Provision of Flexibility for the Congestion Management of Electricity Grids – Requirements for the Voluntary Participation of Suppliers in a Flexibility Platform’. This project was open to all stakeholders in the energy industry, and ultimately all SINTEG showcases in which flexibility platforms were developed took part. DIN SPEC 91410-1 was eventually published, presenting the various proposed solutions.

It is important to underline that the cooperation between grid operators at different voltage levels was particularly successful. Since congestion and the flexibility potential available to eliminate it can sometimes be found at different voltage levels, coordinated processes can be necessary to bring them together. In the WindNODE consortium, a solution for the test phase of the flexibility platform was developed, implemented and tested through the cooperation of 50Hertz, Stromnetz Berlin, E.DIS Netz, ENSO Netz and WEMAG Netz. Such a coordination mechanism will become more and more important for future processes too, such as those planned in NABEG 2.0 for redispatch from October 2021.

## Testimonials

**Dr. Georg Meyer-Braune (50Hertz)**
The pluralistic composition of the WindNODE consortium, in which transmission and distribution system operators were joined by a heterogeneous group of flexibility providers, provided a foundation for the successful development and testing of the flexibility platform. The unique requirements of flexible loads, storage, virtual power plants and so on in the design of processes and products could be discussed and implemented in joint workshops. The aim was to harmonise the requirements of the grid operators with the possibilities of the flexibility providers in a way that would ensure the lowest possible entry barriers to participation.

In the tests, various installations enrolled on the platform and set up a technical interface for information exchange. Extra flexibility potential could thus be offered on days with congestion in the power grid, that is, flexibility could be bid on and made use of in practice, thus helping reduce the curtailment of renewable power plants.

**Dr. Sandra Maeding (Stromnetz Berlin)**
Practical field tests clearly demonstrated the usefulness of the joint development work. The DSOs and TSOs must work closely together to deploy flexibility and resolve grid congestion. It was possible to establish common processes in the development phase, which was successfully tried out during practical field tests.

Bids made on the platform in the pilot phase were initially received by the distribution system operator that checked whether the flexibility supplied could usefully be deployed to eliminate congestion in the distribution grid and, if necessary, generated calls for bids. Furthermore, the flexibility bids were verified for their effect on the transmission grid and the results made available on the platform. This enabled the necessary coordination between the grid levels and made it possible to deploy flexibility options to manage congestion instead of curtailing renewable power plants.

## Influence of legislation since the start of the project

During the project period of WindNODE, both the amendment to NABEG[50] and the adoption of the Clean Energy Package (CEP) resulted in a number of relevant changes in the political and market framework affecting the flexibility platform.

The amendment to NABEG made extensive adjustments to the German Energy Industry Act and reorganised the redispatch from October 2021. Some of its especially interesting elements are i) the consideration of CHP and renewable power plants in the redispatch process, which can also be used by the distribution system operators to remove congestion, and ii) the lowering of the minimum threshold for mandatory participation in the redispatch system from 10 MW to 100 kW for all power plants. Before the amendment, there was substantial capacity that was not obliged to participate in the redispatch process. It was precisely these non-included systems that were targeted by the flexibility platform, thus giving them a certain incentive for voluntary participation. The amendment to NABEG means that much of this capacity will now be included in the redispatch obligation and will receive a reimbursement for its participation. Small systems with a capacity below 100 kW (other than those that can already be remotely controlled by the grid operator) or connectible or shiftable loads will also not be compelled to participate. However, the amendment to NABEG also stipulates mandatory coordination of grid operators, for which the WindNODE consortium has done important preliminary work.

The Clean Energy Package stipulates a market approach as the standard solution for the procurement of redispatch potential. However, country-wide exceptions to this rule can be agreed if certain conditions are met. An example is a situation in which i) the current grid situation causes congestion so regularly and predictably that market-based redispatch would lead to regular strategic bidding behaviour which would further worsen the internal congestion situation, while ii) the Member State in question has either adopted an action plan to deal with the congestion or ensures that the minimum available capacity for inter-zonal trade complies with Article 16(8).[51] According to current assessments based on studies commissioned by Germany’s Federal Ministry for Economic Affairs and Energy (BMWi), this condition applies

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[50] *See text box on the amendment to NABEG in section 1.5.*
[51] *Cf. European Union (2019).*

in Germany.[52] The authors of these studies thus recommend not implementing market-based procurement for flexibility for the purpose of grid congestion management, either in the transmission or the distribution grid.

The main argument against the introduction of such a mechanism is the incentive for market players to change the operating plan of their installation purposely in a way that exacerbates congestion so that they can benefit from congestion management fees once they are called upon to contain it. According to the studies, such behaviour, which is also known as increase-decrease gaming (inc-dec gaming), does not require substantial market power and is not formally prohibited by the current legislation. This problem can generally be curbed or prevented by regulating the potential for extracting revenue, but since a certain knowledge of providers' cost structures is always necessary for effective regulation, such a method would only suit many small and micro-systems if it were organised with a sensible cost-benefit ratio. Another element to consider is the fact that the amendment to NABEG already obligates all power production systems and storage installations with a capacity of 100 kW and over to participate in a cost-based manner.

## Outlook for the period after 2030

The concept 'use instead of curtailing' obviously makes sense from an economic as well as environmental point of view. The conditions for introducing market mechanisms will probably have to be reassessed repeatedly over time. Relevant variables include the installed capacity for renewable power generation, the size of the grid and the transaction costs for the provision of flexibility services, even from small systems.

Above a certain installed capacity, there will not only be periods in which the power grid temporarily restricts generation, but also increasingly moments in which renewable power plants have to be curtailed via the market without grid congestion. In such situations, new mechanisms may be required to put unused renewable energy potential to good use. For the time being, the most obvious way, from an economic point of view, to reduce the curtailment of renewable energy systems is to expand the electricity grid. This assessment may change in the future if the cost of flexibility drops or the marginal utility of grid expansion decreases.

The flexibility available today is still mainly limited to larger systems. This is partly because the share of the transaction costs in the total expenses increases the smaller the systems are. The transaction costs, especially for measuring and steering installations, may, however, be greatly reduced in the future through intelligent metering systems and associated control technology, as long as this infrastructure is also available to smaller producers with a capacity of 7 kW or above, or consumers with an annual consumption of over 6,000 kWh. Under such changed conditions, market-based procurement of flexibility for grid congestion management may make sense. A technical solution to that effect realised and successfully tested on the WindNODE flexibility platform included the design of products, contracts and governance for the operation of such a system.

## Main takeaways from chapter 3

The procedural and technical feasibility of the flexibility platform has been successfully confirmed through real-life tests. The amendment to NABEG, however, already obligates a great part of the existing flexibility potential to participate in the regulated redispatch, reducing the strict value added by the platform. The remaining unused potential consists almost exclusively of flexible loads, which are affected by the inc-dec gaming problem. A regulatory solution to this issue currently appears to be an absolute prerequisite for this unused flexibility potential to be integrated within a market-based mechanism for managing grid congestion. However, especially in case of increasing redispatch volumes and, at times, a negative residual load in the future, the concept of the flexibility platform is fundamentally well suited to realising spatially differentiated incentives for the deployment of flexibility.

[52] *Cf. studies by Neon and Consentec for the BMWi: 'Kosten- oder Marktbasiert? Zukünftige Redispatch Beschaffung in Deutschland' (2019) and 'Zusammenspiel von Markt und Netz im Stromsystem' (2018).*

# 4

# Provider perspective: new forms of flexibility provision

The project and field reports presented here are a representative selection of WindNODE project partners who participated in the test operation of the flexibility platform and were thus able to successfully make use of its flexibility options for congestion management. The players also reported on their experiences in marketing flexible systems in the established markets. The use cases differ greatly and thus offer high added value both for interested potential flexibility suppliers likely to try out business models for flexibility provision and establish them in the future, and for players already participating in the electricity and balancing market who want to focus on congestion management in the future.


Load management in the serious game "Energie Tetris" in the **ZUKUNFTSRAUM***ENERGIE*

# 4.1 Provider perspective: Siemens AG, industrial load management

## Background

In the WindNODE work package 'Intelligent industrial load management in Berlin', Siemens developed a power market and power grid beneficial control system for flexible production and peripheral processes in four Berlin plants. Siemens demonstrated a connection between intelligent energy management and production & process control, as well as applications of information and communication technology that helps to integrate more renewable power generation and decrease energy costs. So far, flexibility has only been deployed to reduce peak load. In WindNODE, Siemens identified and publicised within its operations more economic potential for flexible industrial consumption – through the installation of a metering system and a range of evaluations. This included examining and testing concrete day-ahead options as well as static use cases for load profile optimisation.

## Characterisation of flexible industrial consumption

A study of flexible consumption at the Siemensstadt location found over 20 potentially suitable loads totalling some 20 MW. These primarily consisted of thermal and mechanical production and testing processes. The greatest challenge in making these processes more flexible was the difficult planning of when they had to be active and the lack of time flexibility due to tightly timed production. However, there are still ways of making electricity purchases more flexible. Creating a subdivision into different 'flexibility levels', from a static, fixed time shift to fully automated optimisation, enables flexibility potential to be raised within the possibilities of the underlying production process.

## Marketing options for flexible consumption

Industrial consumption can be more flexible if it can be planned with a lead time of more than an hour – preferably more than 24 hours. If this applies, there is no need to intervene in the production process and production planning can take into account power market and grid-related incentives (see Figure 20). Industrial loads that are flexible can be used for operation that benefits the grid (e.g., peak load limitation or atypical grid use) as well as to reduce costs in traditional electricity purchases that involve fixed electricity prices by smoothing or adapting the consumption profile to base or peak products. However, there is often greater potential for cost savings with static applications than with participation in short-term electricity markets. The technical requirements for static applications are also lower.

| | Suitability for production planning | Technical requirements | Compensation/ saving |
|---|---|---|---|
| **Balancing power market**<br>Short-term (activation time 5 s-50 min) | ● | ●●●● | ●●●● |
| **Intraday electricity trade**<br>Medium-term (activation time 45 min-24 h) | ●● | ●●● | ●● |
| **Day-ahead electricity trade**<br>Longer-term (activation time 12 h-36 h) | ●●● | ●● | ● |
| **Static**<br>Peak load reduction, intensive and atypical grid use and load profile optimisation for power purchasing | ●●●● | ● | ●●●● |

**Figure 20:**
Subdivision of the marketing options for flexible loads according to activation time.

## Flexibility platform

The availability for use of further innovative application platform options is important to the success of industrial load management. This includes participation in measures to reduce feed-in management events, which has been tested in WindNODE. A market mechanism for using industrial flexibility options to manage grid congestion is a useful instrument for bringing more renewable energy sources online and can also represent a source of income. It is important in this context that the product design offered by the platform be suitable for production planning.

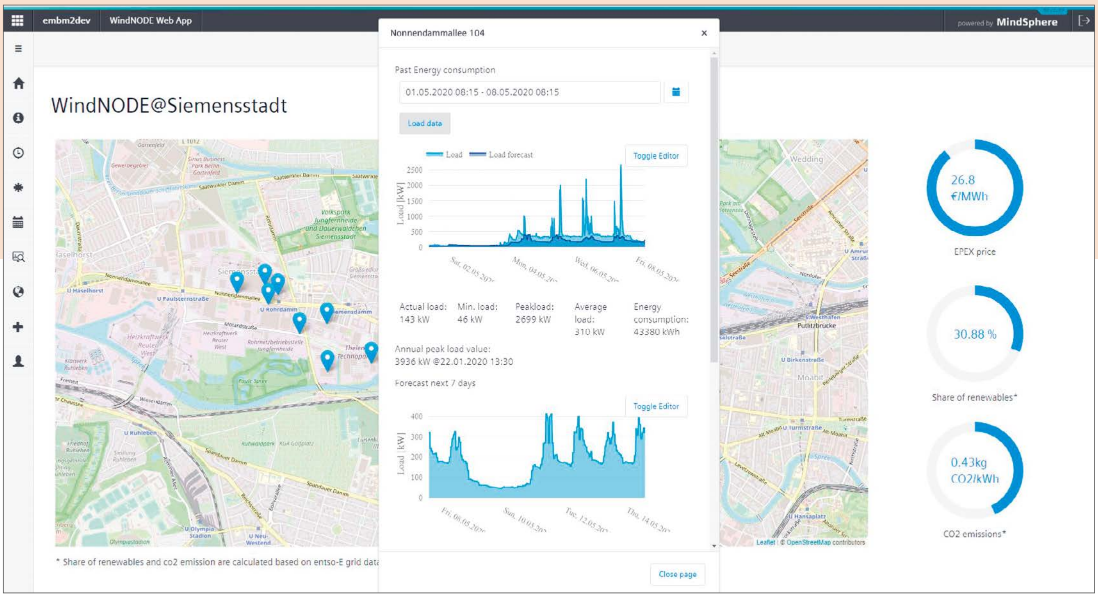
## Testimonial

**Jörn Hartung (Siemens AG)**
Electricity purchase costs can be reduced through measures such as load profile optimisation in almost any medium-sized or large company. However, companies have so far often received their electricity at a fixed price, which leaves no options for short or medium-term optimisation, such as in day-ahead trading. This prevents them from benefiting from the economic savings potential of existing flexibility options. In contrast, this is exactly the option provided by spot market trading, whether directly or via a trader. Automation and digitalisation make it possible to activate more and more processes to provide flexibility.

In some cases, it is difficult to make processes more flexible due to regulatory barriers such as the high fixed electricity price components or the incentive to reduce peak loads, which remains even when there is a large supply of renewable electricity. Another challenge to using flexible loads in a way that benefits the market lies in the currently low price fluctuations on the electricity market. Other measures, such as peak load reduction or atypical grid use, therefore result in significantly greater financial savings at this time. Lowering peak load by 1 MW saves around €30,000-90,000 per year, depending on the grid level. To realise the same savings on the electricity market, and assuming a price spread of €20/MWh, 1,500-4,500 MWh year would have to be shifted every year. It will be interesting to see how electricity prices fluctuate in the future. The reduction in controllable power generation due to the decommissioning of nuclear and coal-fired power plants, as well as the expansion of intermittent renewable electricity generation, may come to significantly increase price fluctuations. New flexibility options on the demand side, as well as new flexible gas-fired power plants and an increase in electricity trade with neighbouring countries may, in turn, dampen price fluctuations.

The greatest motivation for industrial load management is the increased automation and digitalisation of production, which significantly facilitates the implementation of such management and, in some cases, makes it possible in the first place. In addition, the energy transparency of load management enables further versatile usage options, including the use of self-generated electricity (from sources such as solar), process monitoring, improvement in the settings of the installations, predictive maintenance, consumption-based billing and the detection of energy efficiency potential. Since consumers with high power demand are common in the industrial sector, it is often more lucrative to deploy flexibility there than in homes.

Another motivation for load management in general lies in the fact that a load shift can integrate intermittent renewables without causing significant energy or exergy losses or additional demand for valuable materials, as is the case with applications such as hydrogen technology, power-to-heat or batteries. In contrast to the exclusion of flexible loads from the compensation for disadvantages under Section 9 (1) No. 2 SINTEG-V, future legislation should promote flexibility technologies that are particularly environmentally friendly, for example through the electricity fee and levy system.




The "Industrial Energy Transparency and Flexibility App" was developed in WindNODE and is being used in many Siemens production areas.

## Main takeaways from chapter 4 for Siemens

The industrial loads considered in WindNODE are mainly suitable for optimised grid usage and cheaper day-ahead procurement. The latter can be used to respond to forecasts of particularly cheap or particularly expensive electricity prices due to weather events and high or low demand for electricity. Multiple use of the necessary infrastructure as well as a higher economic value of flexibility are of central importance for industrial load management. This can be made possible through a fee and levy system that encourages flexibility as well as through a significant increase in the share of intermittent renewable energy sources in the power grid.

# 4.2 Provider perspective: BMW, combined deployment of a battery farm

## Background

The power storage farm in the Leipzig plant of the BMW Group houses some 700 new and used BMW-i3-batteries, currently with a capacity of 60 Ah and 94 Ah and a total output of up to 13.6 MW. The BMW Group carries out a plug-and-play removal of the used batteries from the vehicles and then repurposes them in the storage farm without any technical adjustments to the hardware. The battery farm also uses new batteries, which must be kept as spare parts anyway, thus including future generations of storage as well.

The specific location of the power storage farm on the premises has the advantage of both bringing flexibility benefits to the public electricity market and tapping into the complex interplay between generation and consumption within the factory infrastructure. The farm was built in a modular manner, with each of the four transformers corresponding to a partition. This structure has the advantage of allowing each of the four partitions to be controlled separately and thus deployed for different use cases. The power flowing among the partitions can be clearly delimited – for instance, each transformer has its own metering point allowing calibrated measurement.

## Experience with deployment options

The power storage farm at the BMW Group plant in Leipzig can be used both for participation in use cases organised on the market and for local optimisation. It is connected to the public power grid and currently provides flexibility in the form of frequency containment reserve. In addition, it has the technically capacity to help lower the plant's energy costs (grid fees or internal electricity maximisation behind the grid node and towards the balancing group) on site by avoiding load peaks and to reduce its $CO_2$ footprint in conjunction with locally generated renewable power. The local conditions enable flexible use of the storage farm in the ideal use case.

The BMW server farm consists of old and new i3-battery-storages and provides a new use case.

## Providing flexibility in the electricity market

For participation in the electricity market, it is essential that the power storage system be exempt from grid fees and levies. If this is not the case, these expenses will represent such a burden on the use case that a deployment would not be profitable in the current circumstances.

In principle, the regulatory requirements for a far-reaching exemption are in place, but it is important to take into account restrictions affecting the connection of storage systems set up within a factory location. A more detailed description of these restrictions can be found below in the section 'Description of regulatory problem'.

In this segment, the intraday market in particular offers ideal conditions for trading flexibility at short notice in an organised and continuous manner. The liquidity on the intraday market is largely sufficient for the implementation of the relevant business model. The value of the flexibility option is largely determined by the volatility both of a given product (e.g. a quarter of an hour) during trading hours and of neighbouring products.

The main challenges involved in participating in the electricity market lie in the ideally automatic trading strategy, which can be guaranteed using available systems. In commercial operations, the decision between the deployment options is largely made on the basis of an assessment of expected profits. The first tests in this market segment have already been carried out successfully.

## Providing flexibility for the performance of ancillary services

To prequalify a power storage farm for the balancing power market, a performance concept must be submitted to and accepted by the TSO responsible. The concept must elaborate the following topics:

- Description of the TSO connection
  - Control system connection / steering concept
- Description of the installation
  - Technical specifications
- Proof of compliance with regulatory requirements
  - Steering concept
  - Security operations centre management conceptManagements (SOC)
  - Operating simulation
  - Key parameters

The Leipzig storage farm, which is deployed for frequency containment reserve (FCR), successfully passed the above prequalification process in 2017.
The regulatory requirements include a compliant connection and technical suitability, as well as the so-called 30-minute criterion, and, more recently, 15-minute criterion. The latter means that the power storage installation must be able to provide at least 15 minutes of the maximum performance that can be absorbed in a positive or negative direction at every moment of its obligation to maintain capacity during ongoing FCR performance. To meet these obligations, the storage farm must be able to use charging management to feed electricity in or out. This requirement is met by means of recharging management, which is implemented through an automatically generated performance request from the installation control by the balancing power provider on the intraday market.

## Providing flexibility for grid congestion management

The rules and techniques for grid congestion management today are predominantly designed to suit conventional power plants, pumped storage and wind turbines. The WindNODE flexibility platform can help bridge this gap so that new flexibility providers and technologies can also be used for grid congestion management.

## Description of regulatory problem

The ideal solution to the increasing need for flexibility in the power grid are power storage facilities. They can be deployed on the electricity market (e.g. intraday), on the market for ancillary services (e.g. balancing power market) or in local optimisation (e.g. smoothing load peaks, generating atypical load profiles at the grid node or possibly maximising the use of self-generated electricity). Whether all three options are available depends on the location of a storage facility. Facilities that are directly connected to the distribution grid ("greenfield" storage) are linked to the electricity market and can be used in ancillary services, while facilities embedded in a plant grid also have the third option of use for local optimisation.

In principle, all three deployment options are available to BMW's storage farm in Leipzig. However, the regulatory framework puts up considerable restrictions to the flexible use of storage systems in the relevant fields of application. The current regulations can be interpreted to allow all power storage systems to be exempt from grid fees. This is particularly relevant for the use of storage systems on the electricity market and in ancillary services. Special requirements, for example in the metering and billing concept, must be taken into account in this context to ensure an exemption from grid fees and levies.

Practical implementation of the regulations, however, does not actually take into account certain individual levy components (e.g. levy under Section 19 StromNEV, concession fee and offshore grid levy) – that is, these levies are in fact incurred for grid use by the storage systems. This is due especially to the case-by-case classification of power storage systems as end consumers (see also chapter 6). In the special case that a storage system is behind the plant node and has been connected with the aim of participating in the electricity market and/or ancillary service provision, the third option – local optimisation – becomes considerably more difficult. The main differentiating feature of this business model is that the storage facility temporarily renounces its exemption from grid fees and levies in order to use countermeasures against load peaks to smooth out the purchase of performance and thus have a positive influence on the service price components at the grid node.

To ensure overall economic optimisation of all three domains, it is important to choose the most effective option in each period. If the storage facility is set up behind the plant node, the processes for switching between the balancing groups may have to be taken into account. This is the case if the plant is located within the energy supplier's balancing group while the frequency containment reserve is provided by a market party, and the storage system is therefore in that market party's balancing group. The current deadlines for the switching processes thus massively restrict time flexibility, since a switching period of one month is provided for in each balancing group in accordance with the applicable 'market processes for power-generating market locations' ('Marktprozesse für erzeugende Marktlokationen (Strom)' or MPES). Even if the power storage system is within the same balancing group, the metering and billing concept have to be designed dynamically in order to delimit the quantities relevant to the grid fees, something which is currently considered to comprise considerable legal uncertainties (see also chapter 6).
In addition to the points mentioned above, if power storage systems within existing infrastructure are made more flexible, this may raise questions about effects on the core energy market data register, offsetting regulations in the event that CHP and renewable power plants are involved, and repercussions on the possibility of exemption from grid fees.


The storage farm is offered in combination for plant energy purchase optimization and on the electricity and balancing power market.

## Testimonial

**Alexander Funke (BMW)**
There are far-reaching legal issues involved in the dynamic deployment of storage systems. This raises the question of whether the current legal framework is suitable for upgrading this essential component of the energy transition to the point where its flexibility can always be used at the time where it is most effective, useful and profitable.

To promote the dynamic inclusion and use of flexibility from power storage facilities, the regulations on grid fee and levy exemption must also apply to stationary storage facilities located in plant grids or households, that is, behind the main meter. The aim here is to promote the flexible integration of storage facilities within supply structures while keeping market opportunities (e.g. balancing power) open. In my opinion, success will depend greatly on whether we can lay a foundation for making change processes as well as metering and billing concepts more dynamic.

It should be noted that it is not clear how the change in use described above has to be documented. This leads to considerable uncertainty among market participants when it comes to the classification of exemptions from grid fees and levies. The actual implementation can comprise documentation requirements in the form of offsetting regulations or meters. The partners concerned, such as the facility operator and distribution system operator, certainly must have a high-performance IT infrastructure for this purpose, and this is currently not always the case.

In this context, it can be very helpful to establish your own legal definition for power storage. This can help make it simpler to adapt regulatory provisions for battery storage systems. The current approach of treating storage facilities as generating plants and/or end consumers on a case-by-case basis is, at any rate, quite an obstacle to inclusion within the complex energy industry regulations.

**Dominik Becks (BMW)**
To begin with, I can confirm that almost everything Mr Funke has to say about stationary storage essentially also applies to mobile storage, that is, to batteries within electric vehicles. Given the current circumstances, it is difficult to imagine directly connecting batteries to the grid and allowing them to be exempted from grid fees: the differing definitions of end consumers between the EnWG and EEG prevent such a simple classification. Moreover, additional definitions of charging current, such as in the German Electricity Tax Law (StromStG), add to the complexity.

The idea that electromobility should make a significant contribution to grid stabilisation and the balancing of loads from renewable generation, especially in a dynamic and market-driven way, is highly attractive. However, under the preconditions described above, there are a number of regulatory obstacles that make this difficult in practice. If those are not remedied, it will be difficult to adequately use the considerable flexibility potential of e-vehicle batteries.

## Main takeaways from chapter 4 for BMW

The dynamic deployment of power storage systems currently still faces numerous obstacles and open questions. If they are to make a real contribution to the energy transition, power storage systems must be able to provide flexibility at the times and in the places where it is most effective in terms of benefits and profitability. The complexity of the regulatory framework means this is a real challenge, but it should nonetheless be a key objective in the further development of the energy industry framework. Regulations for exemption from grid fees and levies should therefore also take into account the dynamic deployment and comprehensive use of storage facilities, especially when they are located within plant grids or in households, that is, behind the main meter. The aim is to promote the flexible deployment of storage systems in supply structures while maintaining market opportunities (e.g. balancing power). Creating a foundation for increasing the dynamic of switching processes, as well as metering and billing concepts, is a decisive success factor.

The EUREF-Energiewerkstatt by GASAG Solution Plus is a visitor site of the energy transition and can be visited during operation.

## 4.3 Provider perspective: GASAG Solution Plus, first combined PtH and PtC plant

### Background

The EUREF Energiewerkstatt by GASAG Solution Plus supplies the EUREF Campus in Berlin-Schöneberg with carbon-neutral heat and cooling.[53] In addition to having a visibility function as a WindNODE visitor site, it is hosting tests on how neighbourhoods can be supplied with energy through an efficient interaction of different energy converters and forecast-based operating modes in a climate-friendly manner and at the same price as conventional energy concepts.

The site produces heat using a large combined heat and power (CHP) plant running on biomethane, two additional CHP plants, two low-temperature gas boilers for peak loads, and an electric boiler thus opening the possibility to choose between different modes of electricity generation and electricity consumption. The EUREF Campus receives cold from two compression refrigeration machines operated with green electricity, which provide the option of free cooling, that is, to draw in cold outside air for more efficient cooling.

The higher-level smart control of the energy system was developed within another research project by Geo-En Energy Technologies GmbH, a subsidiary of the GASAG Group. The scheme ‘Development and testing of a control centre technology for central monitoring and for the efficient and predictive control of hybrid energy systems in inner-city buildings’ (funding code 1137-B5-O), funded by the Berlin Programme for Sustainable Development (BENE) implemented a process in three stages within the operations management IT solution Geo-En | EnergyNode. The first step involves a self-learning process to create a digital fingerprint of all energy consumers based on historical measurement and weather data. The second step creates a demand forecast using this fingerprint and current weather data. The third step builds on this demand forecast and deploys a stochastic optimisation algorithm taking into account current market forecasts to calculate the best possible operating plan and transfer it to the controller.

### A flexible system

A special feature of the system is the power-to-heat/power-to-cold storage system funded under WindNODE. This consists of two storage tanks which measure 22 $m^3$ each and are hydraulically designed so that each can individually be set to heat or cold. The number of energy converters also makes it possible to determine the optimal order in which the energy converters should be used in every quarter hour of the day based on market and weather forecasts.

### Market conditions

Biomethane is produced from renewable raw materials in a biomethane plant. This biomethane is fed into the gas grid

[53] *EUREF is a European energy forum. The Campus is operated by the company EUREF AG.*

and taken off the balance sheets at EUREF-Energiewerkstatt by GASAG Solution Plus. It enables the biomethane CHP plant in the Energiewerkstatt to participate in fixed remuneration under EEG, which is accompanied by full feed-in. The large number of energy converters means there are many prioritisation options for heat generation. Whenever electricity on the intraday market is cheap enough and the marginal price for producing heat with the electric boiler falls below that for producing heat with another unit, it makes sense to activate the electric boiler. However, this is seldom the case given the heat production costs of the biomethane CHP plant. For this reason, it makes economic sense to use both tanks for storing cold produced by compression refrigeration systems, especially since there is a data centre on the EUREF Campus that needs cooling throughout the year. Electricity required to operate the compression refrigeration machines can be procured in advance on the day-ahead market.

The prospects on the balancing energy market appeared to be even more attractive a few years ago during the conceptualisation of the WindNODE contribution. The Energiewerkstatt currently focuses on the intraday market. It is quite likely that spot market prices as well as price volatility will continue to rise due to the introduction of more renewable energy sources into the power grid, leading to a further increase in the profitability of flexible installations of this type. As part of the project, GASAG Solution Plus also helped test the sale of flexibility for the management of grid congestion via the WindNODE flexibility platform. Depending on economic viability, this is a very interesting market opportunity that can, for instance, harness the flexibility of more complex thermohydraulic systems coupled to environmental energy, such as heat pumps or refrigeration machines. The technically relatively simple power-to-heat system (PtH) can, for example, very easily be given a performance specification with which well-defined negative flexibility potential can be offered in every market. This is more difficult with the power-to-cold (PtC) installation or the two compression refrigeration machines, as they can – for technical or service life reasons – only adjust to the specified flow temperature, and this may lead to fluctuating power consumption in the event of fluctuating return flow. One reason for this typical scheme is the possibility of the heat exchangers freezing, which can cause irreparable damage. The precise driving down of load ramps with such systems is an example of a challenge linked to participation in certain markets.

## Testimonial

**Dr. Michael Rath (GASAG Solution Plus)**
Sector coupling and digitalisation are prerequisites for a decentralised energy transition. Intelligent, forecast-based controlled energy systems, such as the EUREF-Energiewerkstatt by GASAG Solution Plus, will help the energy industry increase its flexibility potential and contribute to decarbonisation in the future. We assume that electricity market prices and price volatility will increase as the share of renewable energy sources in the power grid rises, leading to a boost in the profitability of flexible systems of this type.


The power-to-heat / power-to-cold plant reacts to the current market situation by means of intelligent control.

What is left after the end of the project? Next to the conception, construction and commissioning of the first combined power-to-heat/power-to-cold installation in Germany, a particular challenge and key for the project turned out to be the mastery of automation technology across the entire process chain. This ranges from data measured by sensors and the control signal to the automated combination of various machine learning techniques for the prediction of heat and cold loads and subsequent optimisation of operating plans.

More comprehensive use of renewable energy sources and flexibility requires more economic incentives, however. The basic prerequisite is an orientation towards electricity market prices, which do not yet reach the typical end consumers who are not exempt from fees and levies. Instead, they are overlaid with rigid and regulated electricity price components imposed by the government, such as taxes, grid fees and levies, which make up more than 75% of the electricity price paid by ordinary consumers. The use of storage and consumption management is not sufficiently encouraged because consumers incur high taxes, fees and levies even with low or even negative wholesale prices.

From the consumers' point of view, there is room to expand on the incentives to technically enable flexible electricity price orientation. Moreover, the levellised cost of energy depends to a large extent on the political framework, and fossil fuels continue to be structurally and politically favoured. This also applies if, for example, a large power plant supplies electricity with a high level of efficiency and economic efficiency against the nationwide electricity price while the situation in the regional grid looks very different.

The profitability of projects such as the EUREF-Energiewerkstatt by GASAG Solution Plus, and thus also indirectly decarbonisation, would in any case continue to increase if the high end-consumer charges were lowered. We expect the political leaders to further improve the conditions for a more widespread use of flexibility.

## Interim conclusion

The point of such a research project, from GASAG Solution Plus's point of view, is primarily to test products for the energy supply of the future. The EUREF-Energiewerkstatt by GASAG Solution Plus will remain a visitor site that illustrates the energy transition after the end of the project period, and will continue to supply carbon-neutral services to the EUREF Campus.

The transfer of the knowledge gathered to other projects and fields of application has already begun. However, there is a lack of economic incentives for a more comprehensive increase in renewable energy and flexibility. More demand-side flexibility on the part of consumers in the energy system largely depends on a stronger orientation towards electricity market prices. The corresponding necessary price signals in the electricity market do not currently reach the simple, non-energy-intensive consumers, as they are overlaid by rigid and regulated electricity price components imposed by the government.

There has also not been enough encouragement of storage and load management. Consumers therefore still lack sufficient incentives for a flexible orientation based on the electricity price. In addition, energy production costs still largely depend on the political circumstances, and fossil fuels continue to be structurally and politically favoured. The prices on the electricity exchange lead to action patterns across Germany that are oriented towards supply and demand, and therefore often served by large power plants, even though the local situation in the electricity grid can be quite different.

### Main takeaways from chapter 4 for GASAG Solution Plus

There is a lack of economic incentives for boosting flexibility and allowing a comprehensive increase in renewable power. To activate this flexibility potential, the fixed and inflexible apportionment and remuneration system must be revised. The aim must be to lower the fixed cost component in the consumer electricity price in times of electricity surpluses and low electricity prices so as to stimulate demand behaviour by electricity consumers that would benefit the system.


Scheme of energy management in the Berlin-Prenzlauer Berg model neighbourhood.

## 4.4 Provider perspective: Borderstep Institute for Innovation and Sustainability, intelligent urban neighbourhoods

### Background

Work Stream 8 of WindNODE examines the contribution residential buildings can make to flexibility in the energy system. The aim is to use smart building technology in neighbourhoods to develop installations for flexible operation. Heat pumps, combined heat and power installations and electrical direct heating provide a range of options for the sector coupling of electricity and heat. Electromobility offers extra potential for flexibility in the transport sector. In addition, there are other systems in neighbourhoods, such as storage or solar installations, which can be intelligently made part of the optimisation process through energy management. A range of models were developed to connect the neighbourhoods to flexibility markets, with some implemented as prototypes. WindNODE carried out investigations in urban neighbourhoods in Berlin, Zwickau and Dresden.

### Characterisation of flexibility options in urban neighbourhoods

SUrban neighbourhoods vary greatly in their energy-related properties. Flexibility options they deploy in practice thus often differ fundamentally in type and composition: there are flexible electrical consumers, generators and storage systems. Possible flexibility options for the energy system include combined heat and power plants, charging infrastructure for e-mobility, electricity storage, and electric heating rods in hot water storage tanks. The range of services depends heavily on the size of the neighbourhood and its facilities.
Since these systems each primarily serve a supply purpose, their availability as electrical flexibility is subject to restrictions. A decentralised, intelligent energy management system that brings the various systems in a neighbourhood together in a network can have an aggregating function. It can forecast

how an installation will operate, and, in the event of a request for flexibility, optimise the availability of the installations together with other neighbourhood parameters, so that supply to a given building is not impaired.

## Deploying flexibility options in urban neighbourhoods

The capacity of flexibility options in urban neighbourhoods can vary, but tends to be in the two-to-three-digit kilowatt range. This output, which is rather small compared to most energy generation structures, can be difficult to deploy in practice under current circumstances, as its use is associated with relatively high connection and transaction costs. In addition, the existing funding/remuneration mechanisms do not provide sufficient monetary incentives for making use of flexibility – sometimes they even stand in its way.

In the future, flexibility may be activated via an aggregator. This can take place on the electricity spot market or be deployed as balancing power for frequency maintenance. Flexibility options in neighbourhoods can also help eliminate short-term local congestion caused by high simultaneity factors in solar power or electromobility. The remuneration mechanisms required for this are still pending – an ordinance is, for instance, currently being drafted in accordance with Section 14a of the German Energy Industry Act (Energiewirtschaftsgesetz).

Economic optimisation or deployment planning for the various uses of flexibility cannot be carried out at the neighbourhood level due to the high ratio of expenses to revenues. Aggregators or flexibility platforms can play a key role in mitigating this issue (see Figures 21 and 22).

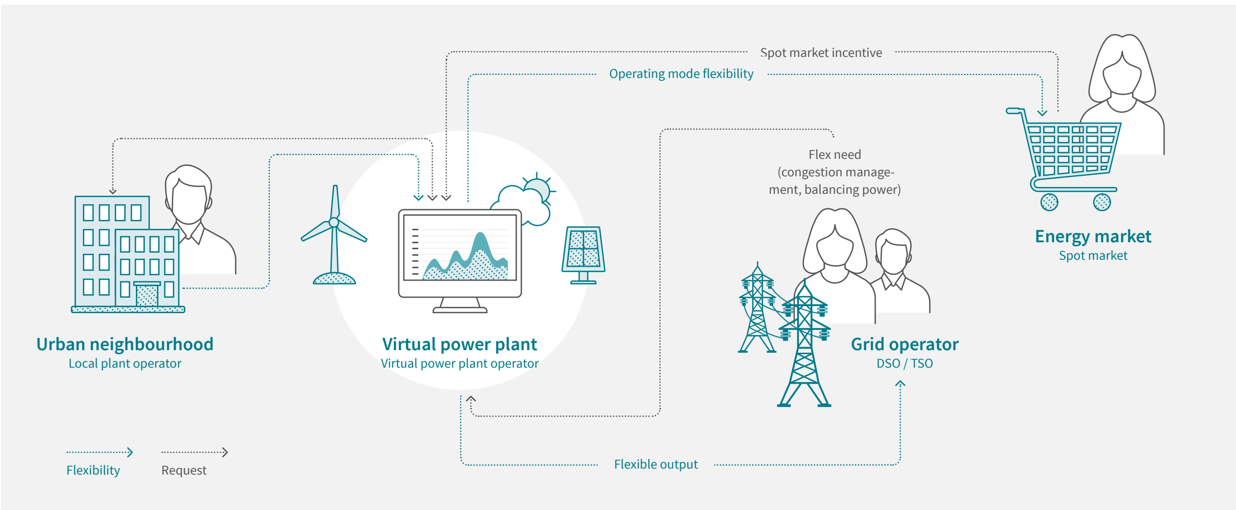

Combined heat and power unit in the boiler room

Hot water storage tank


Access to local heating grid

The combined heat and power plant, the hot water storage tank and the connection to the local heating network, together with the energy management system, enable automated control and thus supply of heat and electricity to the neighbourhood.

**Figure 21:**
Deployment through virtual power plants.



In addition to external fields of application, flexibility is also used locally more and more: to increase the self-sufficiency of local producers such as solar/CHP plants and tenant electricity projects, for instance, or to limit the burden on cables in e-mobility charging infrastructure.

The German Fuel Emissions Trading Act (Bundesemissionshandelsgesetz or BEHG), which was passed in December 2019, may boost flexibility in neighbourhoods. It increases the incentive to shift energy consumption to sectors with lower greenhouse gas emissions. In addition, a carbon price supports the operation of low-carbon flexibility options as opposed to those that cause more emissions.

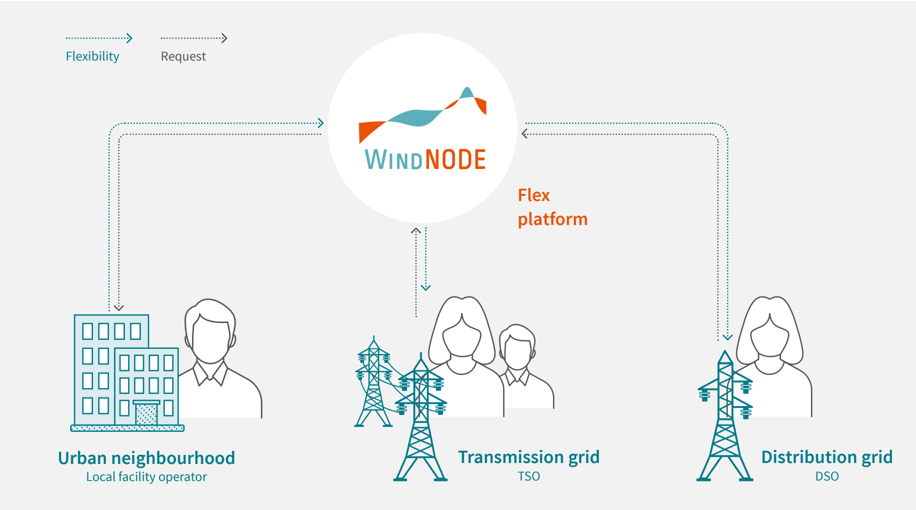



**Figure 22:** Deployment through flexibility platform.

## Testimonial

**Dr. Severin Beucker (Borderstep Institut)**
Residential neighbourhoods participate in all the opportunities and challenges of the energy transition. They are located at an intersection of the electricity, heating and mobility sectors, and ask for them to be managed efficiently. The environmental policy goals for the building sector are very ambitious: by 2030, emissions are to fall by more than 40% without reductions in living comfort or excessive additional costs for inhabitants. This can only be achieved if a multitude of measures are implemented in parallel.

At the same time, the needs of residents and landlords are changing, and numerous new technologies are being deployed. Digitalisation affects the energy supply as well as flats and buildings. This creates unprecedented opportunities to support the energy transition. The conversion and storage of surplus renewable energy in buildings or the targeted connection of self-generated heat and electricity to the public grids are now all feasible with the help of intelligent technology. Buildings and neighbourhoods can act in ways that benefit the grid and react to incentive signals for flexibility on the market without imposing any restrictions on residents. We were able to demonstrate this with our trial neighbourhoods in WindNODE, where large amounts of emissions could be prevented or energy consumption shifted in time and space. This potential will increase further very soon through the fostering of self-generated energy in buildings and electromobility. It is hard to imagine a functional energy transition that does not make use of these flexibility options.

The testing also made it clear that we need to further incentivise behaviour that benefits the grid or market if we want to make use of this potential. The introduction of a carbon tax in Germany represents a first step toward lower-emission behaviour. We cannot yet foresee whether the tax will have an effect in the building sector or what magnitude the effect will have, but we assume that stronger signals will be needed and therefore ask the following questions: Does it make sense to reward energy consumers or producers in neighbourhoods for behaviour that benefits the grid or system? What is the best way to lower the economic, legal and organisational entry barriers for the participation of neighbourhoods in energy trading? What role can aggregators and service providers play in implementing flexibility within neighbourhoods?

Networked energy generator: a modulable combined heat and power unit in the test quarter.

## Main takeaways from chapter 4 for the Borderstep Institute

Buildings and neighbourhoods can in principle behave in a way that benefits the grid while reacting to market incentive signals. It is difficult to introduce flexibility options in neighbourhoods due to high transaction costs and a lack of monetary incentives. Aggregators can allow many small units to be bundled into larger ones, however, making them attractive for trading on the spot or balancing power markets.

Operators of virtual power plants or the flexibility platform currently have options to participate in flexibility mechanisms that benefit the grid or market. Section 14a of the German Energy Industry Act (Energiewirtschaftsgesetz) should be further developed so that neighbourhoods can come to represent a reliable source of balancing power in the future. The introduction of carbon pricing in the building sector accommodates flexibility that benefits the market and encourages lower-emissions behaviour.

# 5 Controllable consumers in low-voltage applications – using flexibility potential in the distribution grid

Chapter 3 discussed options to increase flexibility across grid levels by DSOs and TSOs through the flexibility platform concept, while chapter 4 looked at practical ways to implement this concept and other measures that benefit the system and grid. This chapter will deal with the situation in the low-voltage grid.

Grid congestion in Germany is usually caused by the ongoing changes in the structure of power generation. At the low-voltage level, new consumers are also increasingly playing a role. A prominent example is electromobility, which is expected to eventually make an important contribution to achieving climate action goals. Familiar consumers such as heat pumps and storage heating are also expected to grow in importance. Moreover, new products can influence consumption behaviour – for instance, while it makes sense to use as much renewable electricity as possible at moments with plentiful wind energy, the positive effects for the system at large may come at the cost of a problematic situation for the local grid.

This is why an amendment to Section 14a EnWG is currently being discussed. The idea is to adapt and expand the regulatory basis for behaviour that benefits the grid by flexible consumers or flexible consumer devices in low-voltage applications. A control technology for low-voltage applications was developed and tested in the WindNODE reality lab called the ‘DX pager’. Future viability and scalability for this technology will be based on the goals and circumstances related to the use of flexibility in low-voltage applications.

## 5.1 Background conditions for low-voltage applications

Transmission and distribution system operators (TSOs and DSOs) are thoroughly familiar with the extra-high and high-voltage levels thanks to their long use of actuators and sensors in this domain. There is therefore already plenty of transparency in this domain: the operators can assess grid conditions with great precision, and statistical elements such as load profiles or individual operating modes for larger systems are easy to use. Since current in traditional systems flows from high to low voltage levels, there is no operational need to monitor other voltage levels. But this may well change in the future.

The voltage levels greatly differ in the number of grid points. The Berlin distribution grid, for example, has 106 grid points at the high-voltage, around 11,000 at the medium-voltage and 1.3 million at the low-voltage level. In other words, the levels differ by a factor of around 100 when going from high to medium voltage and 1,000 when dropping from medium to low voltage. In addition, standard load profiles, which can still largely be used at the medium-voltage level, do not fit lower voltages. Each power line at a local distribution station usually links to far fewer than the minimum 400 houses required to use standard load profiles. Furthermore, low-voltage applications are much more sensitive to changes in human habits and the use of household devices. In addition, no grid operator today has implemented grid monitoring at the low-voltage level. Instead, they look at drag indicators which record the maximum output on the power line since the last reading.

Historically, low-voltage grids were designed for statistical simultaneity, which assumes that the use of end devices is dispersed and not synchronised. In addition, there is a surcharge for expected potential output increase, as well as enough reserve to enable switching from surrounding stations while one is undergoing maintenance. Since the distribution stations in the low-voltage grid were not traditionally relevant for grid monitoring, no data cables were implemented at this level. Only a few grid operators have their own communication network that extends into the local grid stations.

Many applications, including some developed in the course of WindNODE, are within a low-voltage area. In this part of the power grid, grid operators do not have private data networks, and improving communication in the systems is a challenge. In addition, cable connection spaces are placed in very different places within buildings. This heterogeneous structure makes it very difficult to develop the relevant systems with just one connection technology. For example, information relevant to data protection is transmitted securely via an intelligent metering system. This is mostly relevant to billing, but not time critical. Since the security requirements of the Federal Office for Information Security (BSI) specify that only broadband technologies may be used to transmit this data, and broadband transmission technologies often do not have ideal properties for building penetration, compromises must be made in the accessibility of the individual systems.
The low individual output of installations in low-voltage applications means that it makes sense to cluster them in groups large enough to be relevant within the grid. This grouping has the added value of not being problematic in terms of personal data protection. However, it is important to ensure that the highest possible proportion of this grouped output can be achieved and that it can only be managed by authorised market partners.

Since the flexibility required to remedy congestion in the low-voltage grid is highly location-dependent, its technical and regulatory availability to the DSO must normally be sufficiently reliable to make it safe enough to deploy in the framework of grid operation. However, things may look different if the demand for flexibility in the low-voltage domain originates from a higher voltage level – and, as there is more potential flexibility, both vertically and horizontally, that can have an effect on the grid, that involves a different challenge. If flexibility in the low-voltage grid is called upon to relieve the extra-high-voltage grid, a large number of consumers are implicated. An individual consumer connecting to the low-voltage grid would not cause any technical problems – but an entire synchronised group could very well create issues in the grid. It is only when a group is seen and assessed as a whole that the consequences really become apparent. This is why it is necessary to consider low-voltage consumers in groups: they are relatively small systems and thus have small-scale flexibility potential – but they are numerous. There is therefore a need for technologies that are highly scalable and suitable for mass deployment.

### Summary of challenges and success factors

In summary, it is clear that technological development must take into account the following success factors:

- Regulatory instruments must be easy to apply on a large scale and must offer sufficient planning security. The lowest possible complexity is recommended.
- The process must take into account group and individual switching.
- Low-voltage grids are currently not observable. In addition, control technologies must be suitable for a large number of small consumers.
- In terms of information technology, a high level of security must be guaranteed in accordance with the rules of the Federal Office for Information Security (BSI).

## 5.2 Practical example: development of the electricity pager in WindNODE

Stromnetz Berlin uses a so-called electricity pager as a technical solution for controlling purposes. The current pager-based ripple control (PRC) system has been in operation in Berlin since 2014, when it started replacing audio-frequency-based ripple control (AFRC). The pagers are controlled via a high-availability transmitter network, with the transmitted data protected by the BSI's signature process. Since this is a unidirectional technology, there are much fewer avenues for malicious interference than in the case of point-to-point connections. Groups of any size can be switched using this technology. For individual commands, however, it may be more efficient to use an intelligent metering system.

Since 2018, the AFRC technology has been completely replaced by PRC in the urban area of Berlin. Since this system went live, there have been repeated inquiries from various market partners who wished to use it themselves. The electricity pager was developed within WindNODE as a response. The existing control system uses a so-called broadcast signal, which sends a control command to the entire transmitter network. The receivers then authenticate the signal, verify whether they belong to the addressed group, and, if so, execute it. The advantages of this technology are the very high transmission power and the resulting high penetration depth of the signal through to cellars or junction boxes. In addition, the recipients cannot be located by any attackers because they are not themselves emitting a signal. This eliminates the risk of a 'man-in-the-middle' attack. Moreover, all control commands carry a signature and are only valid for a short time. This also applies to the system time in the network. After all, the groups are so dispersed in the grid area that even if a control signal is hijacked, no critical grid states can be generated.

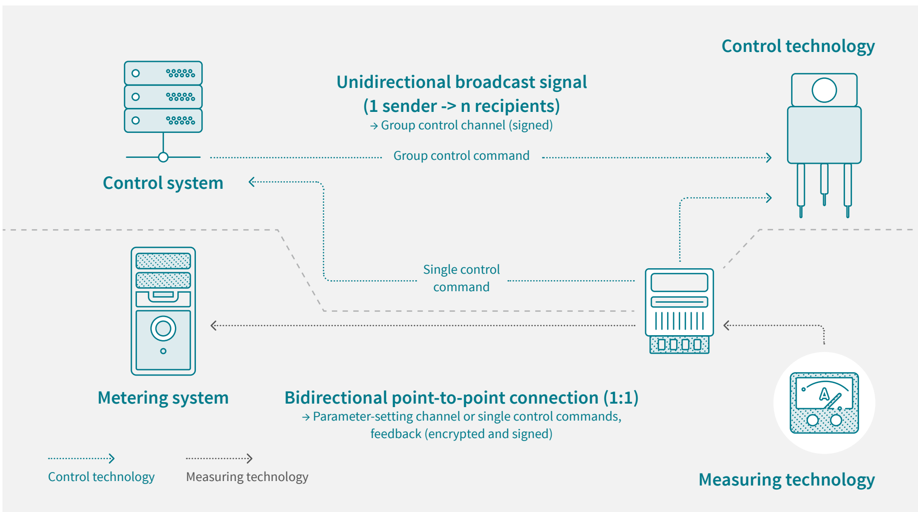
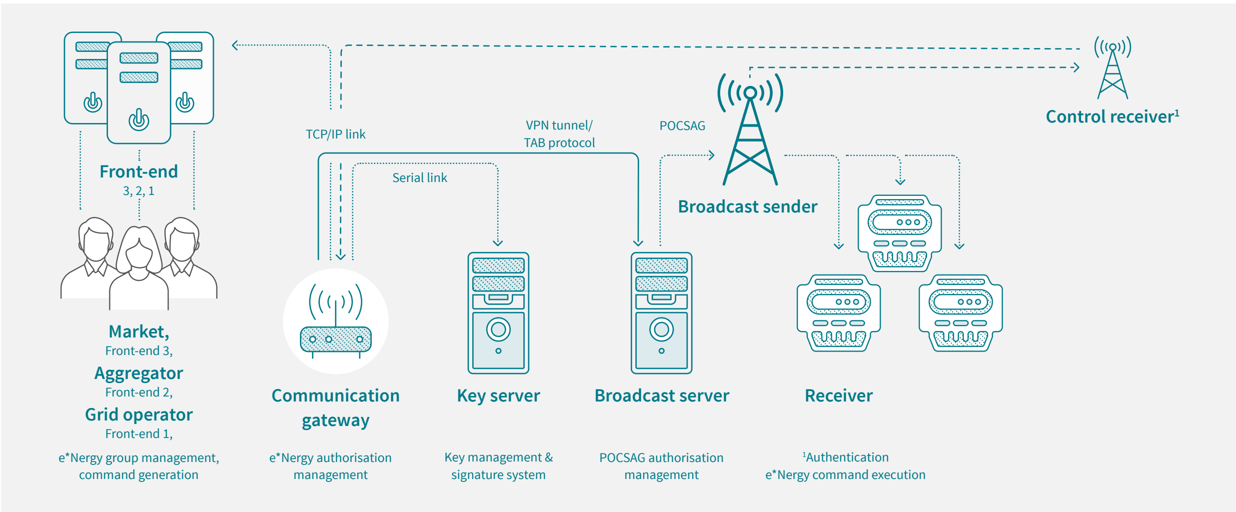



**Figure 23:** Control system in simplified view.

Physically, the electricity pagers use unidirectional technology with very little bandwidth. In the existing system, the individual commands are also distributed throughout the transmitter network. From a technical point of view, this is extremely inefficient, especially since the high latency of the system makes parameterisation quite complex. This function would be more efficient with a broadband point-to-point connection. The future smart meter gateway can provide such a connection via secure infrastructure. If the electricity pager can be connected through such a channel, it could benefit from the advantages of both technologies. This would make it possible to control plant groups and this control would be difficult to attack. Parameterisations such as a 'certificate exchange' in the field could be implemented more quickly via the smart meter gateway connection than via individual telegrams in the broadcast transmitter network. But it was more than just the field level that had to be adapted to the new requirements: the provision of connections for other authorised market partners also had to be developed. Moreover, the fact that group switchings must be checked by the connection grid operator before being implemented – to prevent them from causing local congestion – had to be taken into account.

**Figure 24:**
Previous functional levels of the pager-based ripple control system.

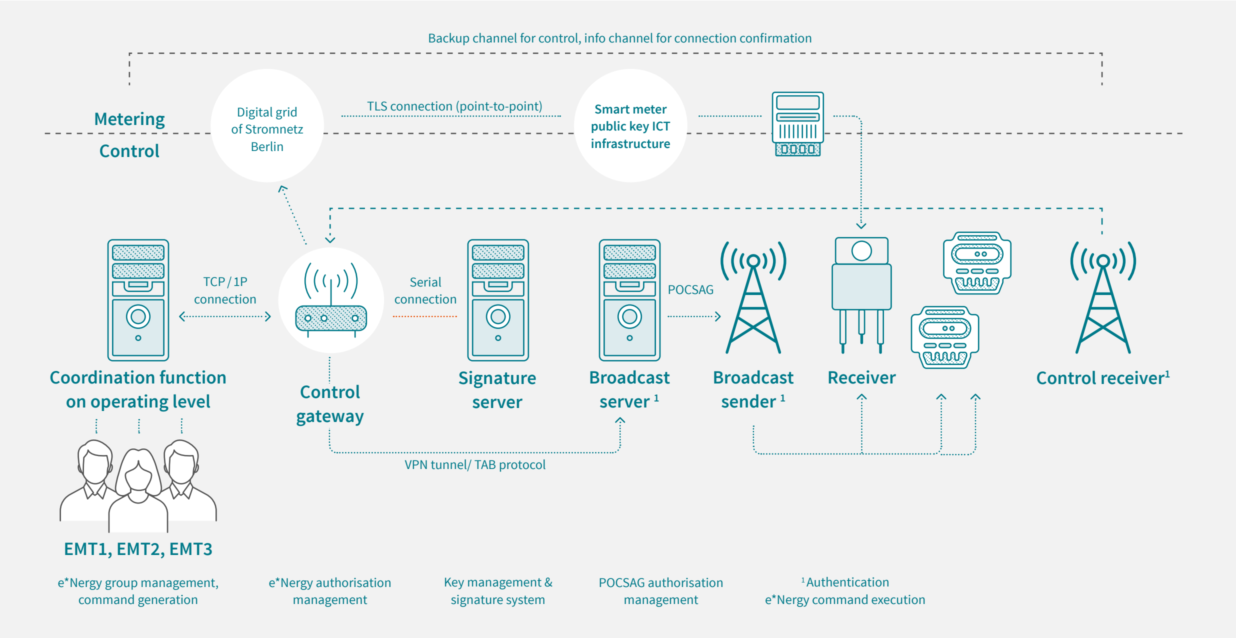



The previous PRC system included a physical division of the front-end computer systems that made it possible to share control if necessary. However, this would have required market partners to have a matching system at their disposal. The PRC back-end system was therefore changed over the course of WindNODE to enable external market participants to access the control units authorised for them via a secure front-end. They can organise these according to their own criteria. The parameterisation takes place after approval by the grid operator, guaranteeing that there are no grid-critical concentrations of grouped plants in the system.

This way, a first-stage of the coordination function at the operating level has emerged in parallel with discussions in the different associations. This function enables every authorised market partner to send control commands down to the low-voltage level without operating a certified control system as an active market participant under the BSI's technical directive TR-03109. Instead, the market partners share a device in the field without having to be familiar with the underlying technology. All they need to do is agree on a service level with the relevant operator of the coordination function. Due to the need for a private key to sign the control packets, this is the only possible variant of the system structure based on the premise of shared field devices. The anchor of trust lies with the connection grid operators, as the operator also bears responsibility for secure grid operation.

In the WindNODE reality lab, the DX pager is tested together with several network partners. The new devices are to be deployed in different communities to implement the partners' respective use cases. An example is the specification of a switching direction via relay, which can orientate energy management on site. This makes it possible to align plants with a higher-level influence such as the renewable energy forecast deviation at the TSO level. Consumers could be switched on with a higher feed-in (positive deviation) or switched off with a lower feed-in (negative deviation) than expected.

**Figure 25:**
System structure according to WindNODE.




## Outlook

Making use of the mentioned opportunities through an increased integration of flexible consumers in the low-voltage grid while also mastering the relevant challenges requires an effective legal basis for a use of flexible consumer devices that benefits the grid. For this reason, all affected stakeholders are currently discussing new legal conditions for the constructive use of flexible consumer devices together with politicians. Lessons should be learned from the experience gained in the expansion of renewable energy sources and the new regulations should be established in good time before the use of electric mobility fully takes shape, so that the technical and procedural requirements can be satisfied from the outset. In terms of technology, the electricity pagers can contribute to making flexibility in low-voltage applications useful safely and efficiently.

## Testimonial

**Oliver Schaloske (Stromnetz Berlin)**
The development of the electricity pager in WindNODE enables the joint use of a control technology in the field by all market partners. The upstream testing of individual and group switching (first stage of the coordination function) prevents grid-critical switching and at the same time creates a secure and low-threshold option for switching by third parties. The hybrid solution consisting of an intelligent metering system and a secure broadcast system fulfils all operational requirements for low-voltage control in the grid and opens the door for value-added services via a future smart meter gateway infrastructure.

**Lisa Hankel (Stromnetz Berlin)**
The further development of the legal framework is intended to help integrate new, flexible consumers, such as charging infrastructure for electromobility solutions, into the power grids quickly and efficiently by making optimal use of existing grid capacity as well as to optimize the necessary grid expansion. From the perspective of the grid, the security of the power supply is, of course, crucial at all times. If network planning already takes into account the fact that power consumption by new, flexible consumers can be reduced in an emergency, this must also function safely and reliably in practice.

## Main takeaways from chapter 5

For the low-voltage level, challenges potentially arise from new consumers, for example from electromobility. Operating states in low-voltage grids are currently not observable, and the control technologies must be suitable for a large number of small consumers. It is therefore important that regulatory instruments be easily suitable for mass deployment and that they offer sufficient planning security. Things should be kept as simple as possible and the process must consider both individual and group switching. Only a large number of small consumers would be able to offer a relevant contribution to the system. In terms of information technology, a high level of security must be guaranteed in accordance with the rules of Germany's Federal Office for Information Security (BSI). From a technological point of view, the electricity pagers ('DX pagers') contribute to making flexibility in low voltage applications safer and more efficient.

6

# Continued development of the regulatory framework

The previous chapters dealt with the definition, the potential and the practical deployment of flexibility options identified in the WindNODE subprojects. Chapter 6 focuses on the continued development of the legal framework required to enable or simplify the use of flexibility in the future.

Section 6.1 describes the parts of the current legal framework that represent obstacles to the use of flexibility. Section 6.2 considers findings from SINTEG-V, a regulatory experiment that modified the legal framework and addressed certain aspects of these obstacles to flexibility. Based on the first two sections, section 6.3 formulates recommendations for action to ensure an adaptation of the flexibility-related rules that would be evolutionary, that is, organically based on the current framework, while section 6.4 focuses on fundamental future adjustments to the regulatory framework, for example with regard to the grid fees and the pricing of carbon emissions.

## 6.1 Obstacles to flexibility in the current legal framework[54]

Current energy law hampers the use of flexibility and sector coupling in several ways. Where electricity is concerned, there is a distinction between obstacles related to consumption or to generation, with the former being more significant than the latter due to the state-regulated end consumer charges linked to the purchase of electricity. Furthermore, in the area of sector coupling, there are obstacles on the product side in that it is hardly possible to declare the products generated (for example hydrogen or heat) as "green" when electricity is drawn from the grid.

There are infrastructure-related obstacles in the gas sector as well, especially since there are legal uncertainties as to whether hydrogen from renewable energy sources can be treated unreservedly like biogas, for example with regard to priority grid access. The legal framework for hydrogen feed-in quotas in the natural gas grid within the framework of the 'generally recognised rules of technology' under Section 49 EnWG, and the technical rules of the German Technical and Scientific Association for Gas and Water (DVGW), lag behind the state of the art.

### Electricity-related obstacles

It should be noted that electricity producers base their operation more on electricity market signals than on consumer behaviour. This is due to the fact that the former are less affected by signal-overlapping effects from final consumer charges, although the legally stipulated feed-in tariffs and the market premium, which are based on average electricity prices on the exchanges, do not send real market signals. In the case of intermittent power from renewable plants, the feed-in priority shifts the question of flexibility essentially to the electricity consumers, although NABEG 2.0 and the inclusion of renewable energy and small CHP plants in the redispatch regime mean that these also increasingly contribute to flexibility on the generation side, even if these contributions are not organised in accordance with the market.

Obstacles linked to sector coupling can be found in business models that are based on self-sufficiency for plants, the value of which was determined through tenders. If operators of such systems wish to make use of funding under the EEG, Section 27a EEG 2017 specifies that the electricity may not be used for self-supply over the entire funding period. Exemptions from this business model-inhibiting norm are given for market-oriented purposes, for example in the case of negative electricity prices under Section 27a No. 4 EEG 2017 or in redispatch situations according to Section 13 EnWG (new).

Despite adaptations to the feed-in management regime introduced by NABEG 2.0, it is still unclear whether system control is also permissible at the grid connection point and whether a plant can use excess electricity for sector coupling instead of being curtailed, for example (following the principle 'use instead of curtailing'). In this context, there are also obstacles to flexibility in the regulations on how electricity can be sold according to Section 21b EEG 2017. This specifies that plants must be assigned a clear single method of sale under the EEG or at least designate percentages for different methods. A change in the method is only permitted on a monthly basis and the percentage distribution must be adhered to. This prevents business models in which renewable power plant operators switch between subsidised direct sales and other types of sales, for example.

For dispatchable plants, market-oriented flexibility is only incentivised under the German Combined Heat and Power Act (KWKG) through subsidies for a certain number of hours of full use performance[55] and under the EEG by the fact that maximum outputs for biomass plants are specified[56] and supported by instruments such as the flexibility premium and the flexibility surcharge.[57] The relatively low flexibility incentive that these instruments provide is limited to biomass plants – natural gas CHP units that fall under the regulatory regime of the KWKG are not included.

For consumers, the legal framework inhibits the use of flexibility options and sector coupling, especially through high end-consumer charges that are due when purchasing electricity. Signals from the electricity market are heavily distorted by these charges. The current structure of the electricity price components has little to no effect in encouraging an operation of electricity consumption systems that would be beneficial to the grid or system or market oriented. The existing regulatory regime even prevents consumers from making use of flexibility by, for example, applying rigid time windows within the framework of Section 19 (2) sentence 1 StromNEV and not making the relevant real grid status a prerequisite for privileges. The determination of grid charges can also inhibit the provision of flexibility, at least to the extent that it is accompanied by an increase in annual maximum output. Under Section 17 (2) StromNEV, the grid fee consists of an annual service price and a commodity price. The annual service fee is the product of the relevant annual service price and the

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[54] *For a more comprehensive description of the regulatory barriers to flexibility, see the paper produced in the context of WindNODE by Doderer, H. and Schäfer-Stradowsky, S. (2019).*
[55] *Cf. Section 8 KWKG.*
[56] *CF. Section 39h (2) EEG 2017.*
[57] *Cf. Section 50 et. seq. EEG 2017.*

annual maximum consumption in kilowatts in the accounting year. If the annual maximum consumption is increased due to an electricity purchase that benefits the grid, the annual service price and thus the grid fee to be paid increase accordingly, which can inhibit the provision of flexibility.

The few existing incentives to flexibility in the regulatory framework are focused on selected flexibility or sector coupling technologies and thus prevent a technology-neutral level playing field in terms of flexibility in consumption. For example, i) power-to-gas systems can benefit from a grid fee exemption even without reconversion under Section 118 (6) sentence 7 EnWG, ii) operators of renewable power storage systems under Section 19 (4) StromNEV can negotiate individual grid fees and iii) power-to-heat plants under Section 13 (6a) EnWG or Section 9b StromStG can under certain circumstances receive selective or sector-related support. Section 14a EnWG, which provides for special grid charges for controllable consumer devices, is limited to the low-voltage level alone, and an ordinance to specify these privilege options is still pending. In addition to the grid charges, there are also the grid fees and levies passed on via the grid charges, which also influence electricity purchase costs and thus the incentive for flexible consumption behaviour.[58] Individual privileges for flexible electricity consumption with regard to individual fees and levies are barely considered in the legal framework. In mid-2017, the Federal Court of Justice (BGH) rejected the idea that the elimination of the obligation to pay grid charges (for example from Section 118 (6) EnWG) means that the fees and levies passed on via the grid charges also automatically cease to apply.[59] Accordingly, there are no flexibility incentives with regard to the fees and levies passed on via the grid charges.

The current legal framework also privileges individual end consumer groups without requiring them to maintain flexibility potential in return, for example in the context of the special compensation scheme according to Section 63 et seq. EEG 2017 for cost-intensive electricity companies. It is therefore very difficult to establish fee or levy-related incentives for the provision of flexibility for these consumer groups, although they comprise significant flexibility potential.

In the context of WindNODE, regulatory challenges have also emerged with regard to the deployment of electricity storage in commercial and industrial areas in ways that are beneficial to the grid or market oriented. The profitable operation of power storage systems depends in particular on whether they can provide their flexibility on different markets or for different purposes and whether they have an operating model that defines the individual and cost-optimal use of the storage capacity. For example, power storage systems can be used on the spot market, the electricity balancing market and to optimise the local load situation (e.g. through peak shaving). Compared to storage systems that are connected directly to the power grid, storage systems in commercial and industrial areas are often located behind the plant node and can thus – depending on financial incentives – also be used for local load optimisation.

If the plant or the commercial or industrial area as a whole and the electricity storage system are assigned to different suppliers and thus also to different balancing groups, for example in situations where balancing electricity comes from a special provider, a change of supplier and balancing group is often required to optimise overall storage capacity. To ensure the most flexible use for such a storage system, it should be simple and quick to change the balancing group. At present, however, the ‘market processes for power-generating market locations’ (MPES) are preventing the kind of dynamic change of supplier or balancing group that would be required for these business models, because a given market location can only register such a change on the first day of the month and must announce the change a month in advance.[60]

## Product-related obstacles (sector coupling)

The flexibility potential of sector coupling technologies is limited not just by the high end-consumer charges, but also the lack of product-related incentives (for example for hydrogen, heat and mobility) that could guarantee efficient plant operation. The legal framework provides for only partial transfer of the ‘green’ quality of electricity and of the related potential for value enhancement on to other sectors. In principle, this is only possible if the electricity is obtained from a renewable power plant via a direct line. If the electricity is drawn from the grid, it loses its ‘green’ quality in the legal sense, and so do any products it is used to create.

There are recognisable individual attempts to remedy this in the legal framework, such as the option to offset electricity-based fuels against the greenhouse gas reduction quota under the 37th Ordinance for the implementation of the Federal Immission Protection Act (37. BImSchV). There are no large-scale recognition possibilities as of yet, however. This, coupled with the high end-consumer charges on electricity purchases and competition with conventional sector-specific technologies (e.g. heat from natural gas or fossil fuels) which are cheaper due to being partially subsidised, has meant that sector coupling does not yet make economic sense in practice.

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[58] *This includes the concession fee, the CHP levy, the levy under Section 19 StromNEV, the offshore grid levy and the connectible load levy.*

[59] *Federal Court of Justice, Decision 20/06/2017, EnVR 24/26.*

[60] *BNetzA (2018a).*

**Figure 26:**
End consumer charges and declaration possibilities for sector coupling products in the current legal situation.

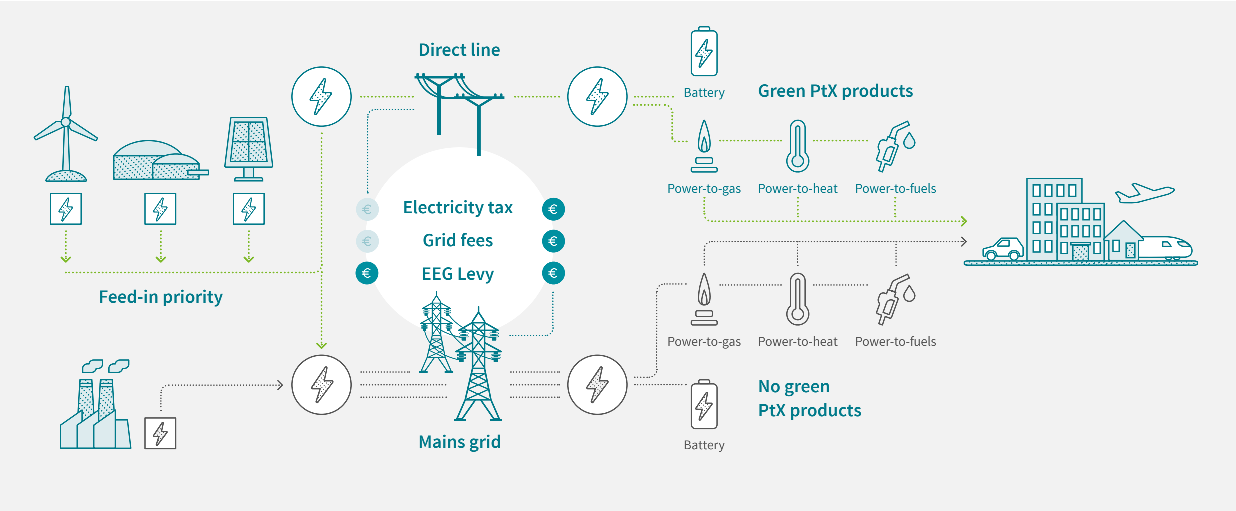


Figure 26 gives an overview of the end consumer charges with demand-side flexibility as well as the declaration possibilities for sector coupling products.[61]

From left to right, the figure shows the generation, delivery and conversion of electricity in the other sectors. Depending on whether the electricity comes from the mains grid or directly from a power plant, the end consumer charges (in the middle of the figure) are due to varying degrees: a darker euro symbol indicates that full costs apply while a paler one shows that costs are not incurred. When it comes to the question of whether products generated with electricity are considered 'green' or not, the decisive factor is whether the electricity is obtained from the mains or directly from a renewable power plant.

## 6.2 Findings from SINTEG-V[62]

The applicable regulatory framework can become an obstacle to systemically sensible and technically available solutions for the energy system of the future. Although the problems outlined here have long been known in specialist circles and are in fact also discussed by politicians, there is a long and arduous road ahead on the path towards energy law modernisation.

This has direct consequences for R&D projects like SINTEG. Regulatory obstacles can be so severe that certain innovations are not even implemented as model projects. Examples include any flexibilisation of industrial loads that would benefit the grid and system or sector coupling (power-to-heat, power-to-gas, power-to-X): these are all technically feasible, systemically sensible and even financially supportable during construction – but a regulatory headache in operation. The German Bundestag created a way out of this dilemma at the end of 2016 with Section 119 EnWG, which authorised the issuing of special exception ordinances. This enabled the BMWi to issue the Ordinance establishing a legal framework for the accumulation of experience in SINTEG (SINTEG-V for short). This ordinance represents a so-called 'regulatory sandbox', because it allows those involved in the SINTEG showcase to test applications that would otherwise be impossible under existing legislation.

[61] *Graph and idea originate in the IKEM study 'Experimentierklauseln für verbesserte Rahmenbedingungen bei der Sektorenkopplung' (2018); https://www.ikem.de/wp-content/uploads/2019/03/Experimentierklausel-f%C3%BCr-verbesserte-Rahmenbedingungen-bei-der-Sektorenkopplung.pdf.*

[62] *See papers produced within the framework of WindNODE: Doderer/Medert: 'Merkblatt zur SINTEG-Verordnung', 2017 (internal to WindNODE); Doderer/Schäfer-Stradowsky: 'SINTEG-WindNODE – Bestandsaufnahme der rechtlichen Hemmnisse und Anreize für die umfassende Flexibilisierung des Energiesystems', July 2018 chapter E.*

### Regulatory sandbox creates space for energy system innovation

At its core, SINTEG-V is a way to compensate for disadvantages. Normally, companies and organisations which provide flexibility – which is a service that benefits the system and the grid – must accept a monetary disadvantage in the form of the EEG surcharge or the loss of grid fee privileges. To make up for this, SINTEG-V guarantees monetary compensation to participants in SINTEG, which is paid out by the responsible grid operator at the end of a year following an application to the Federal Network Agency (BNetzA).

SINTEG-V enables operators of energy installations to effectively proceed as if providing flexibility did not incur increases in grid fees or an EEG levy. To reduce the financial obstacles, it treats system operators who provide flexibility as if though they did not. This is achieved by fully refunding the grid fees that are initially paid over the reference state. SINTEG-V also partly applies to sector coupling systems or power storage systems, where the EEG surcharge can be reimbursed up to 60%. The ordinance explicitly does not allow for economic advantages, that is, its use may not result in additional profits (cf. Section 10 SINTEG-V). The main focus is on end consumer charges, which make flexibility options especially hard to implement. Product-related aspects of sector coupling are not addressed by SINTEG-V.

The following paragraphs carry out a comprehensive analysis of SINTEG-V. The aim is to make the experiences linked to the practical deployment of the ordinance within WindNODE available to politicians, legislators and society at large, so that the findings can be considered in future reality labs and regulatory sandboxes.

## Acceptance/use of SINTEG-V in WindNODE

Five plant operators within WindNODE have notified the Federal Network Agency (BNetzA) of their intention to participate in SINTEG-V in accordance with Section 3 (3). In August 2020, one of the partners submitted an application for compensation for economic disadvantages. Another partner's disadvantage compensation application is being examined in accordance with Section 12 SINTEG-V. The number of organisations using the regulatory sandbox, however, is still too small to allow an objective judgment about its overall usefulness. Within WindNODE, the SINTEG-V was used specifically for its original purpose – trying out regulatory innovations and assessing their effect on business models based on the provision of flexibility and deployment of renewable energies. In this case, excess wind power could be used for local heating instead of being curtailed: a sensible use that saves primary energy and contributes to the acceptance of the energy transition and wind energy in local communities. This demonstration project provided valuable insights into the effects of the fee and levy system. In other words, the guiding principle of SINTEG-V has clearly been 'quality instead of quantity'.

## Evaluation of the scope of SINTEG-V

The creation of SINTEG-V was a welcome initiative on the part of legislators and regulators. An especially positive aspect is the fact that the periods in which a compensation for economic disadvantages is possible under Section 6 (2) SINTEG-V are defined based on how beneficial and market oriented the relevant activities are, thus setting the right incentives to boost flexibility provision.

Taking into account grid fees and the EEG surcharge means that the end-consumer charges, which are the most significant cost element, are also addressed in the compensation for disadvantages. There would be stronger incentives for operating plants in a way that is beneficial to the grid or market oriented if SINTEG-V addressed not only the end-consumer charges – which belong to the BMWi's area of responsibility – but also the electricity tax, which can only be modified by the Ministry of Finance (BMF).

With regard to the EEG surcharge, of which only 60% can be reimbursed as an economic disadvantage under Section 8 sentence 2 No. 2 SINTEG-V, the European Court of Justice (ECJ) made an important decision after the SINTEG-V came into force, stating that the EEG surcharge and related limitations are not state aid in the sense of Art. 107 Treaty on the Functioning of the European Union (TFEU).[63] Accordingly, from the point of view of European state aid law, there was no need to limit the reimbursement of the EEG surcharge to only 60% – SINTEG-V could have established more extensive reimbursement for relevant project activities. This case law should be taken into account in future regulatory sandboxes.

Furthermore, it can be noted that SINTEG-V is – deliberately – designed to only compensate for economic disadvantages that arise from project activity. If its application ends up creating financial incentives, these are subtracted from the amount given in compensation according to Section 10 SINTEG-V. This means that participation in the SINTEG-V procedure – including research-related grants – will logically only be based on non-material motives.

Where content is concerned, there is considerable potential to increase flexibility – in particular with regard to industrial connectible loads, which can have the best environmental impact among a range of flexibility options – which goes

[63] *Cf. ECJ, Decision 28/03/2019, Case C-405/16 P.*

without being exploited, since such consumers regularly only postpone their electricity purchases under Section 9 (1) No. 2 SINTEG-V.[64]

The five-year term of SINTEG-V, which is relatively short, also makes it more difficult to invest in innovative system technology: once the ordinance expires, system operators again have to bear the full brunt of the economic disadvantages caused by operating modes that are beneficial to the grid or market oriented.

## Assessment from a procedural and administrative perspective

It should be noted that actually getting the compensation for economic disadvantages promised under SINTEG-V requires considerable administrative effort on the part of project participants. First of all, as specified in Section 3 SINTEG-V, the Federal Network Agency (BNetzA) has to be notified of the project activity, and has to confirm receipt of the notification.

The application for a claim has to be submitted to the BNetzA in accordance with Section 12 (1) SINTEG-V, which stipulates that this can only take place in the calendar year following that in which the project activity took place. Furthermore, in accordance with Section 12 (2) SINTEG-V, applicants are required to provide evidence of eligibility and must state all creditable advantages in accordance with Section 10 SINTEG-V. Applicants must also have the correctness of this information confirmed by an auditor, for whose services they must pay in advance.

Once the BNetzA establishes that the claims are valid, the applicants must forward them to the responsible grid operator, who, after subtracting any economic advantages that arose from the application of the ordinance, finally provides the actual compensation for remaining economic disadvantages.

Only half the amount of the expenses incurred through the notification or claim determination procedure can be covered by a deduction under Section 10 (2) SINTEG-V. The cost of the auditor certification can be deducted fully – however, according to the BNetzA, the costs of legal advice related to the application are not deductible at all. Since auditor costs can only be deducted from theoretical economic advantages and are not in themselves considered part of the pre-existing economic disadvantages, they can only be reimbursed if creditable economic advantages are in fact generated with the new operation.

In addition to this complex reimbursement procedure, the use of SINTEG-V is hampered in particular by legal uncertainty as to the extent to which applicants have to bear the burden of proof for the reimbursement periods according to Section 6 SINTEG-V as well as the further eligibility requirements according to Sections 7-9 SINTEG-V. It is also unclear how applicants are to provide evidence that the use of their system in fact benefits the grid in the sense of Section 6 (2) No. 1 SINTEG-V. Next to this legal uncertainty, the disadvantage compensation mechanism entails applicants making payments in advance and being reimbursed ex post, and thus having to have considerable liquidity, especially since the procedure for cost compensation by the grid operator according to Section 12 (4) SINTEG-V does not include a time limit for reimbursement.

## Assessment of legislative and other innovations

This section describes SINTEG-V's degree of innovation based on Schäfer-Stradowsky/Kalis (2019).[65] The legal criteria considered are linked to effectiveness – whether the scheme is conducive to its stated goal and efficiency – and proportionality – whether the same effect could be achieved through other instruments (whether actual or potential) that would be less intrusive or otherwise simpler or would have a more beneficial effect. The results of the innovation evaluation were grouped under 'hostile to innovation', 'open to innovation' and 'encouraging innovation'.[66] SINTEG-V was evaluated for its degree of innovation as a regulatory sandbox on the one hand and as a substantive source of technical/economic legal consequences on the other.

### Evaluation of SINTEG-V as a regulatory sandbox

If one looks at the SINTEG programme (for which SINTEG-V was created on the basis of Section 119 EnWG), the competitive tender for the SINTEG programme, and the fact that SINTEG-V represents the first regulatory experiment of its type in German energy law, SINTEG-V clearly appears effective and efficient in terms of inventiveness. The goals of SINTEG, in particular the testing of new procedures for a power supply that is safe and stable while comprising a very high proportion of renewable energy, are supported by SINTEG-V and there are no obvious alternatives that would achieve those goals more easily than a regulatory sandbox.

From the point of view of the practical introduction of new approaches, it is clear that the regulatory sandbox introduced

[64] *Cf. IKEM, Leipzig University, TU Berlin, Siemens (2019).*

[65] *Cf. Schäfer-Stradowsky, S.; Kalis, M. (2019), 'Innovationsgrad des Energiewenderechts', EnWZ 2019, 104.*

[66] *The choice of categories is derived from Schäfer-Stradowsky, S.; Kalis, M., 'Innovationsgrad des Energiewenderechts', EnWZ 2019, 104, 106. They are also used by Hoffmann-Riem, in: Sauer/Lang, Paradoxien der Innovation: Perspektiven sozialwissenschaftlicher Innovationsforschung, 1999, p. 13 et seq.*

by SINTEG-V was a genuine innovation. The innovation is spreading but the degree of diffusion cannot yet be predicted. The BMWi's reality lab strategy, which aims to foster existing and new spaces for innovation and regulation, suggests a treatment of regulatory sandboxes that is entirely open to innovation, even if they are unlikely to achieve the experimental quality of SINTEG.[67] SINTEG-V can thus clearly be described as open to innovation or even encouraging innovation.

SINTEG-V was also an important driver for the SINTEG funding programme in its function as a regulatory sandbox. It was specifically the freedom to dare try regulatory experiments in a protected way that caused many of the WindNODE partners to decide to participate in SINTEG. Compared to previous research programmes in the energy sector, this gave SINTEG a boost that should not be underestimated and made a significant contribution to bringing the highly qualified and highly motivated WindNODE consortium into being.

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From the point of view of the practical introduction of new approaches, it is clear that the regulatory sandbox introduced by SINTEG-V was a genuine innovation. The innovation is spreading but the degree of diffusion cannot yet be predicted. The BMWi's reality lab strategy, which aims to foster existing and new spaces for innovation and regulation, suggests a treatment of regulatory sandboxes that is entirely open to innovation, even if they are unlikely to achieve the experimental quality of SINTEG. SINTEG-V can thus clearly be described as open to innovation or even encouraging innovation.

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### Assessment of SINTEG-V's technical/economic legal consequences

The technical/economic consequences resulting from the legal and content-related structure of the SINTEG-V give a different picture than its role as a regulatory sandbox. Where inventiveness is concerned, the regulatory effect of SINTEG-V can be rated as being at least moderately effective and efficient. For example, SINTEG-V modifies end consumer charges due on the purchase of electricity, which represents a fundamental deviation from the existing regulatory framework. For one thing, the definition of time periods that are beneficial to the grid and market oriented according to Section 6 (2) SINTEG-V is certainly new. The merely partial compensation for disadvantages foreseen by SINTEG-V (the fact that the EEG levy is only reduced to 60% and the electricity tax is unaffected) reduces its effectiveness, however. In terms of inventiveness, SINTEG-V can thus only be rated as moderately open to innovation.

When looking at the practical implementation or market launch of a new approach, there is much less openness to innovation. The purpose of the SINTEG-V is, among other things, to reduce the competitive disadvantages of systems which deploy sector coupling compared to conventional energy sources (e.g. heat from natural gas or hydrogen from steam reforming). The fact that the ordinance is limited to compensating for financial disadvantages only (while deducting any economic benefits) and has such narrow legal limits means that the goal of introducing new technologies and flexibility options to the market is only partly promoted. The procedural, administrative and bureaucratic obstacles involved in SINTEG-V (see above) further mean that this reduced effectiveness is not counterbalanced by higher efficiency in the market launch.

With regard to the diffusion phase, its limited duration means that SINTEG-V does not appear very open to innovation. Its experimental nature must be kept in mind in this context, however – after all, an experiment must be able to fail occasionally. In other words, the results of diffusion phase do not seem very significant.

In conclusion, the invention and implementation phases of SINTEG-V are overall less open to innovation when viewed through a lens that considers their content and legal consequences rather than their function as a regulatory sandbox. Greater openness to innovation, for instance through the granting of economic advantages, should by no means be excluded from the legal perspective, but rather depends on the participants chosen.

Experiments often comprise a limited number of participants, and the more realistic an experiment is (for example, by not offsetting economic advantages) the more significant its results can be expected to be. The most important feature is that essentially anyone should be able to benefit from the experience –for example through the tendering process. The decisive factor for legal compliance could still be the selection of the reference group. One could, for example, choose not to use the entire German energy industry as a reference group, but rather look at a group that is worse off, also within a research project.

[67] *Cf. BMWi (undated).*

# 6.3 Deriving recommendations for evolutionary adjustments to the regulatory framework[68]

This section is devoted to the possibilities for continued development of the regulatory framework for flexibility and sector coupling. The focus is on suggestions that tie in with existing legal standards and build on them in an evolutionary approach. In terms of content, the opportunities for continued development are based on the obstacles and findings identified within SINTEG-V. The present section is therefore divided into possibilities for continued development in terms of electricity and in terms of products.

## Possibilities for electricity-related continued development

Since flexibility and sector coupling technologies other than power-to-gas are also suitable for supporting the electricity grid through their electricity purchases, it is proposed that grid fee privileges under Section 118 (6) EnWG be extended to all flexibility and sector coupling technologies, thus creating incentives for a competitive situation in the field of flexibility that is open to different technologies ('level playing field').

Insofar as individual technologies, such as power-to-gas, need to be strengthened with political action, because they are (so far) quite expensive but still need to be available for uses like long-term storage in energy scenarios, it would make sense, from the point of view of boosting competition in the field of flexibility, to support them through funding programmes and not through privileges related to the input (i.e. electricity). This would also enable a realistic cost evaluation and boost cost transparency.

To counteract the obstacle linked to the determination of grid fees within the framework of Section 17 StromNEV, the legal standard could be supplemented with an exception stating that power peaks which relieve the grids not be taken into account when determining annual peak output. A similar mechanism can be found in Section 15 (4) of the German Interruptible Loads Ordinance (AbLaV), which stipulates that individual grid fees in accordance with Section 19 (2) sentence 2 StromNEV (grid fee privilege for consistently high electricity consumption) may not be denied based on requests for interruptible output within the scope of the Interruptible Loads Ordinance.

The obstructive calculation system under Section 19 (2) sentence 1 StromNEV (atypical grid use) could also be addressed by not taking into account electricity quantities that benefit the grid when calculating the peak load amount, so that they does not result in the loss of privilege under Section 19 (2) sentence 1 StromNEV. This proposal is based on current practice. In 2013, the Federal Network Agency (BNetzA) decided that power peaks that are demonstrably prompted by remedial redispatch on behalf of the grid operator or used to provide negative balancing electricity should not be taken into account when determining annual peak load within the high-load time window.[69]

The lack of flexibility potential in the context of the fees and levies passed on through the grid charges (concession fee, CHP levy, levy under Section 19 StromNEV, offshore grid levy and interruptible loads levy) could be remedied either through a legal link to the privilege requirements for grid fee exemption (e.g. Section 118 (6) EnWG) or through individual privileges based on benefits to the grid.

At 6.756 ct/kWh in 2020, the EEG surcharge represents a large potential lever for flexibility. The provision of flexibility could be incentivised more if EEG surcharge privileges were made less dependent on reconversion characteristics, but rather on benefit to the grid and market orientation. For instance, a standard could be established in the EEG – for example in accordance with Section 61 EEG 2017 and following Section 6 (2) SINTEG-V – stating that an EEG surcharge reduction can be granted if electricity is purchased during times in which the grid operator had to take measures to avoid grid congestion or some other danger to the safety and reliability of the power supply system, or in which the value of the hourly contracts for the German price zone on the spot market of the electricity exchange is zero or negative.

Flexibility potential linked to the EEG surcharge could be raised further through the special compensation scheme. Under Section 63 et seq. EEG 2017, only companies with an annual electricity consumption of more than 1 GWh can benefit from this scheme. Correspondingly, electricity-cost-intensive companies are also often electricity-purchasing companies with considerable potential for flexibility. For reasons of competition policy, the limitation of the obligation to pay the EEG surcharge is almost exclusively based on a company's electricity cost intensity. The provision of flexibility is not a criterion: the only prerequisite is a certified energy and environmental management system according to Section 63 (1) No. 3 EEG 2017 which makes it possible to raise energy savings and efficiency potential. To increase the flexibility

[68] *See IKEM (2020), 'Veröffentlichung im Rahmen von WindNODE: Denkbare Weiterentwicklungsoptionen für die umfassende Flexibilisierung des Energiesystems und die Sektorenkopplung.'*
[69] *BNetzA, definition BK4-13-739 of 11/12/2013, p. 3.*

potential in electricity-(cost)-intensive companies, consideration could be given to integrating flexibility into the special compensation scheme or making it a prerequisite for its use.

In addition to the economic effects of including flexibility in the special compensation scheme, it is important to take into account the interactions with the requirements for energy efficiency improvement according to Section 64 (1) No. 3 EEG 2017 (energy management system). Technical restrictions and similar measures in the operational process can mean that energy efficiency and the provision of flexibility do not go hand in hand, but may even counteract each other.
For the tax treatment of electricity purchases, it was determined that electricity tax privileges would be granted for certain industries, technologies or processes, but that the original provision of flexibility would not be stimulated by electricity tax law.

A legal framework for electricity tax that grants privileges in a technology-neutral way to end consumers whose electricity purchases correspond to grid and market situation would incentivise flexibility. Accordingly – similarly to the proposal for the EEG surcharge – an electricity tax reduction based on Section 6 (2) SINTEG-V could be included in the StromStG that would take effect at times when the grid operator takes measures to avoid grid congestion or any other risk for the security and reliability of the electricity supply system or when the value of the hourly contracts for the German price zone on the spot market of the electricity exchange is zero or negative.

A certain level of dynamism for the electricity tax is not contrary to the spirit of the StromStG. Section 9 (2a) of the old version of the StromStG specified a reduced electricity tax rate until 31 December 2006 for electricity taken from the power grid to operate a night storage heater. The aim of this rule was to stimulate electricity demand at times when low consumption was traditionally low (especially at night). A similar new regulation could also have a suitable nudging effect in times of grid congestion or negative electricity prices. When designing such a regulation, care should be taken to ensure that the relevant signals (grid status and market signal) do not lead to an undesirable interaction: for instance, the consumption of electricity at negative prices should not lead to local grid congestion.

Furthermore, flexibility potential could be raised if the calculation basis for the electricity tax amount were changed from a quantity tax to a value tax. The electricity tax would then not be statically set at €20.50/MWh as it is in Section 3 StromStG, but would depend on the price of electricity, similarly to value-added tax (19% of the sales price). In other words, when electricity prices are low, the electricity tax would also be low. The lower electricity price (including tax) would increase demand accordingly and thus lead to a stabilisation of electricity prices on the exchange. A closer investigation could determine whether it would make sense to create an electricity tax credit in the case of negative electricity prices or whether electricity taxes should then merely be capped at zero or some other amount.

It is important to note that such a reform of electricity taxation should be preceded by a study of any possible interactions with the grid situation so that a market-oriented operation of plants does not lead to local or wider grid congestion. Such a change in the electricity tax would also require adjustments in European law, in particular an amendment to Art. 4 Directive 2003/96/EC to the effect that the tax amount can be calculated based on the value of the electricity and not just on the amount.

For electricity storage systems that can be used flexibly and are operated in commercial and industrial areas behind plant nodes (see the end of section 6.1 on obstacles to flexibility linked to electricity for a description of the problem), the switching processes as well as metering and billing concepts must be made more dynamic so as to facilitate overall economic optimisation.

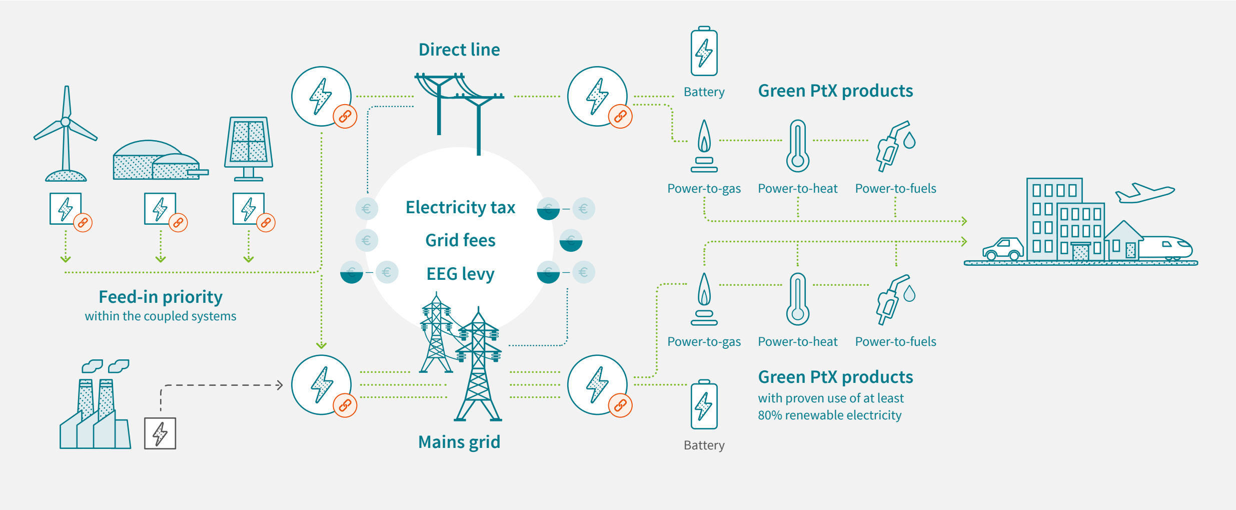
## Possibilities for product-related continued development (sector coupling)

In addition to high end-consumer taxes levied on electricity purchases, the sector coupling technologies face a particular obstacle in terms of products in the form of a lack of possibility to pass on the ‘green’ property of electricity. In the calculation of end consumer charges, the renewable power generation system and the sector coupling systems are considered by the legal framework as independent and not connected systems, quasi as a unit. When electricity is purchased via a direct renewable power line, the resulting sector coupling products can generally be declared ‘green’ – but the principle of exclusivity means this is not the case when electricity is purchased from the mains grid.

An IKEM report on regulatory sandboxes for improving the framework conditions in sector coupling suggested several remedies, which are outlined below.[70] They include, in addition to the legal and content-related topics relevant to this paper, a proposal to conduct an economic review of the approaches within the scope of a regulatory sandbox. The proposals moreover address not only the obstacles resulting from the lack of opportunities to transfer the ‘green’ property of renewable electricity to the other sectors, but also the hurdles that result from the high end-consumer charges on electricity used for sector coupling.

[70] *Cf. Kalis, M.; Yilmaz, Y., Schäfer-Stradowsky, S. (2019).*

**Figure 27:**
End consumer charges and declaration possibilities for sector coupling products, based on a proposal for continued development.




The first proposal is to introduce a new category of system into energy law, in which one or more installations for generating electricity from renewable sources are coupled – hence 'sector coupling' – with one or more systems for converting renewable energy into other energy sources (such as storage technologies, among others). This coupling can in principle be authorised regardless of any legal separation of the individual system operators (no obligation linked to personal identity like in the case of self-supply), the form of electricity delivery (no obligation to use a direct line), or any direct spatial interrelationship, in principle.

This would allow coupling via a physical direct line as well as virtual coupling of the systems via the mains grid. Despite spatial separation and possible difference in persons, the coupled systems could function as a legal unit and could be operated in a way that benefits the system and the grid through coordinated generation and distribution management. In addition, the coupling of generation and distribution systems, and the storage facilities between them, would make it possible to plan the supply of electricity generated from renewable sources. The provision of intermittent renewable energy could then take place in line with demand, and the feed-in priority for renewable power plants, which is normally justified by their fluctuating production, could be withdrawn. This would foster the market integration of renewable power, as would the waiver of an EEG-based remuneration for the electricity generated by the coupled systems.

To make sure that the virtual coupling has actual benefits for the local grid, it might be appropriate to define some spatial restrictions for the systems involved – for instance, limiting them to one district or adjacent districts (based on the Ordinance on joint auctions for onshore wind and solar installations (GemAV) and distribution grid expansion areas).[71] A coupling in front of a grid junction point or a 50 km radius in the framework of the guarantees of regional origin (Regionalnachweise) is also conceivable.

Depending on the amount of electricity passing between the two coupled systems, the onerous end consumer charges could be reduced or even completely eliminated. This could be ensured through a tendering system open to new technologies, in which the coupled plants bid for the relevant reductions and exemptions. In such a tendering process, the bidders could indicate how much energy they are converting with what reductions, thus making it available to the other sectors.

Figure 27 follows the same pattern as Figure 26. The coupled systems are represented by a link symbol. Here, unlike in the current legal situation, mains electricity can also be marked as 'green' and the related sector coupling products can benefit from an increase in value compared to conventional products thanks to the possibility of deriving a 'green' status themselves. The (now reduced) end consumer taxes are indicated by a half-full euro symbol.

To ensure that the sector coupling products can justifiably be declared to be 'green', the systems producing them should be proven to predominantly obtain electricity from renewable sources. Restricting the principle of exclusivity can enable a step-by-step activation of sector coupling. A starting point to satisfy the requirement of 'predominantly renewable electric-

*[71] German Ordinance on joint auctions for onshore wind and solar installations (Verordnung zu den gemeinsamen Ausschreibungen für Windenergieanlagen an Land und Solaranlagen).*

ity' can be the definition of biogas in Section 3 No. 10c EnWG, according to which hydrogen counts as biogas if 80% of the power used in its electrolysis is renewable. The single-type balancing groups already described in Section 20 (1) No. 4 EEG 2017 could serve as evidence for this quota.

To prevent the proposed system coupling approach from merely diverting electricity from existing renewable power plants to sector coupling plants, and instead promote the expansion of renewable energy and thus sector coupling, certain power quotas can be considered for the sector coupling systems. For example, the capacity share of sector coupling could be set at 30-50% of the renewable power generation capacity. This would ensure that the expansion of renewable power generation always progresses faster than sector-linked consumption.

## 6.4 Interim conclusion

In summary, it can be stated from a regulatory point of view that the current form of the electricity price components is especially problematic in that it provides little to no encouragement to consumers to deploy operating modes that would be beneficial to the grid – in fact, the existing legal framework is partly even an obstacle to flexibility.

To enable business models that encourage flexibility in the energy supply system, it is essential to adapt the regulatory framework. In particular, it is important to flexibly structure the amount of the end consumer charges for electricity also at the regulatory level. In any case, arrangements that reward constant electricity consumption regardless of the grid situation should be abolished. Flexibility-based business models can be strengthened if tailoring electricity to consumption in a way that benefits the grid is left out of the calculation so it does not end up having a negative effect on the level of end consumer taxes and surcharges.

To stimulate sector coupling, regulations must be created that enable the 'green' property of electricity to be passed on to other sectors. The creation of a new category of installation, a coupled system, in the EnWG can contribute to this.

## 6.5 Fundamental adjustment of the regulatory framework

Section 6.3 of this report was devoted to evolutionary options for a continued development of the legal framework, which are characterised in particular by the adjustment of individual paragraphs, laws or subordinate norms and can thus be implemented relatively easily by legislators and regulators. However, the energy transition and the associated challenges – in particular the conversion of the energy supply system to intermittent renewable sources and the associated need for flexibility – represent fundamental system change. Individual evolutionary adjustments to the legal framework may not be sufficient to adequately reflect this system change at the legal level, and even represent a risk of energy law becoming more complex and the regulatory landscape becoming further fragmented.

This situation calls for a legal examination of fundamental interventions in energy-related regulatory architecture. In particular, the system of grid charges and carbon pricing are currently a subject of debates, which are also part of WindNODE and should be accompanied by expert views coming from a range of perspectives within the consortium. To anticipate these discussions, it should be noted that, while the carbon emissions pricing instrument can lead to greater decarbonisation, it will affect a number of significant other challenges involved in the energy transition – such as making the overall energy system more flexible or adapting the grid tariff system – less or not at all. To achieve the goals of the energy transition, carbon pricing must therefore be one instrument in a whole package of measures.

## Testimonial

**Hannes Doderer (IKEM)**

With SINTEG, the BMWi launched a comprehensive funding programme that made it possible to test the energy transition in practice. From a regulatory perspective, the SINTEG-V ordinance, which was based on the ordinance authorisation mechanism of Section 119 EnWG, forms the most important basis for regulatory learning with the aim of enabling the integration of large amounts of electricity from renewable sources into the general-purpose energy system. This form of regulatory learning based on regulatory sandboxes is so far unique in Germany and a positive example to follow. The experience collected under SINTEG-V is extremely valuable for the energy transition and dealing with innovations and law.

However, it is important that SINTEG-V be understood as a starting signal for regulatory learning. The recommendations of the commission ‘Growth, Structural Change and Employment’ commission, which specified that regulatory sandboxes, reality labs and entire special funding regions are to be considered as regulatory measures, must be taken seriously and implemented in the corresponding laws.

The energy transition and accompanying topics such as structural change do not only touch upon technical and economic issues. The regulatory framework can set incentives or barriers for the energy transition and should therefore also be changed appropriately. Regulatory learning and reality labs should not be limited to mere retrospective evaluations of laboratory experiences. Instead, regulatory learning and innovations should be part of the reality labs and competitions about ideas right from the start.

Regulatory sandboxes such as SINTEG-V provide a basis for energy transition innovations and a new energy transition design. They go further than mere exceptional provisions and privileges in individual laws, which have the downside of making energy law increasingly complex. At the same time, regulatory sandboxes are subject to spatial, temporal and, above all, content-related limits. A broader framework for innovations could be created through special funding regions open to new technologies and topics, in which limited exceptions and deregulation could be tested across economic sectors. Specialised regulatory sandboxes are possible, but not absolutely necessary, instruments for creating such special funding regions on the basis of general laws.

Special funding regions would offer the opportunity to test and evaluate topics linked to the energy transition and the associated need for innovation in other economic areas in the protected area from a technical, economic and regulatory point of view and to formulate the adjustments necessary for the decisive second phase of the energy transition. We must not let this opportunity go unused!

## Main takeaways from chapter 6

The flexible consumption of electricity is strongly inhibited by the current system of fees and levies, as privileges regarding end consumer charges are granted to individual technologies or industries and the provision of flexibility is hardly incentivised – in some cases, it is even inhibited. A shared characteristic of the SINTEG showcases is that the legal framework was modified especially and exclusively for their participants with SINTEG-V.

This ordinance compensates for economic disadvantages that arise due to project activities or plant operation that are beneficial to the grid or market oriented. This applies especially to the EEG surcharge and the grid charges, which generally apply to purchases of electricity, but are reduced or waived under SINTEG-V. An important restriction, however, is that only disadvantages can be compensated and any economic advantages are deducted from this compensation: in other words, the incentives are limited. In addition to high bureaucratic, procedural and administrative hurdles linked to the use of SINTEG-V, this has meant that only a few participants have availed themselves of it. Nonetheless, the ordinance can be rated as a success, as its very existence was decisive for many partners' decision to participate in WindNODE.

In future, the legal framework should be modified with reference to the end consumer charges in a way that sets incentives that are open to new technologies for the provision of flexibility, thus creating a level playing field between the various technologies and encouraging competition. In addition, it is important to make it easier to transmit the 'green' property of electricity to other sectors to make sector coupling more economically attractive.

# 7 Outlook

Realising the vision of an environmentally friendly, sustainable energy supply based entirely on renewable sources requires many puzzle pieces to fall into place first. Flexibility and storage will play an important role, but only represent one of several important pillars of the coming green energy transition. The others include the expansion of renewable power sources, the participation and acceptance of local populations, increased energy efficiency and expanded grids. Flexibility can cushion the intermittency of renewable sources in ways that benefit the system and grid: together with grid congestion management, it must be a major part of the instrument mix for transforming the energy system.

In principle, however, the decline in conventional power generation means that flexibility becomes less available just as it is becoming more necessary to counterbalance the continued expansion in renewable power sources. The way flexibility options are deployed and brought to market will accordingly gain in relevance and will, in addition to the expansion of grids and storage facilities, represent another cornerstone of an Energy System 2.0. This suggests that the price at which flexibility is acquired will increase in the medium and long term. Nevertheless, one of the central political and regulatory challenges of the coming phase of the energy transition will be to implement the right rules of the game for new flexibility options such as flexible loads, storage and power-to-X technologies, so that providers can deploy profitable business models in a streamlined way.

The gradual introduction of carbon pricing will help increase competitiveness and thus profitability compared to technologies based on fossil fuels. In the future, it will be desirable to formulate regulations, in particular for end consumer charges, which set incentives for the provision of flexibility that are open to new technologies and paralleled by ecological criteria in order to create an environmentally friendly level playing field between the various flexibility technologies.

Regulatory sandboxes such as SINTEG-V provide excellent opportunities to try out legislative innovations that can gradually be integrated into the relevant legal framework. In addition to material modifications of the energy law, procedural and administrative themes should also be taken into account in future regulatory sandboxes. However, it is important that SINTEG-V be understood as a starting signal for regulatory learning. The recommendations of the commission 'Growth, Structural Change and Employment' to consider regulatory sandboxes, reality labs and entire special funding regions as fruitful regulatory measures should be taken seriously and implemented in practice.

In recent years, the number of interventions in the power grid has risen sharply due to the increasing spatial decoupling of generation and consumption. In the short term, grid expansion is the economically necessary measure to reduce grid congestion and especially the curtailment of renewable power plants. In the long term, however, the solution must also consist in creating incentives for a more even distribution of generation plants on the one hand and more use of other types of plants, such as power-to-X applications and flexible consumers, for grid congestion management on the other.

It is particularly difficult to integrate flexible consumption into the existing regulatory-cost-based redispatch system. This would only be possible if grid operators were able to estimate the subjective willingness of electricity consumers to pay for adequate compensation. The highly individual characteristics of operators and categories of installations imply that this is likely to be extremely complicated and therefore highly impractical. This problem does not apply in the case of a redispatch based on market mechanisms because the market participants can determine their desired remuneration themselves in the form of bids.

To ensure the efficient functioning of a market for grid congestion management by means of flexibility, it is imperative to formulate a regulatory solution for the problem of inc-dec gaming.[72] A number of solutions are currently being discussed, including a hybrid model in which flexibility is offered on a platform and the grid operator decides whether to resolve congestion with classic redispatch or by activating the flexibility option. Another solution is the statistical non-award, in which providers cannot be sure whether a given bid to remove congestion will be accepted and thus whether their strategic misconduct will pay off. Such measures can reduce the risk of inc-dec gaming and ensure that as-yet untapped flexibility potential can be used for an economically more efficient elimination of grid congestion.

The energy system of the future will reserve a decisive role also for the coordination of grid operators across all voltage levels. A sensible development of flexibility options originating in lower voltage levels requires coordination between transmission and distribution system operators, so that solutions on one voltage level do not create issues on others. It should be noted that the integration of electromobility and numerous prosumers will create new challenges, especially in the low-voltage sector. They will greatly change consumer behaviour and increasingly expose grids to a bidirectional flow of electricity.

Historically, it has not been necessary to lay data cables in the low-voltage grid: as a result, this voltage level cannot currently be observed. However, grid monitoring will become more important in the future because applications such as the charging of electric cars will lead to higher simultaneity effects and thus increases maximum loads in the absence of higher-level control. New solutions such as the 'DX pagers' and other actuator and sensor systems will be used to cope with these challenges. For low-voltage applications, it is of particular interest to find a solution that is simple from a regulatory point of view and characterised by low complexity overall which will facilitate flexible consumption and can be implemented quickly on a large scale.

[72] *Inc-dec gaming is explained in greater detail in chapter 3 (see 'Influence of legislation since the start of the project' in Section 3.3).*

# Appendix

# Acronyms

| | |
|---|---|
| **AbLaV** | German Interruptible Loads Ordinance (Verordnung zu abschaltbaren Lasten) |
| **aFRR** | Automatic frequency restoration reserve |
| **AFRC** | Audio-frequency-based ripple control |
| **Ah** | Ampere-hour |
| **API** | Application programming interface |
| **BEHG** | German Fuel Emissions Trading Act (Bundesemissionshandelsgesetz) |
| **BGH** | German Federal Court of Justice (Bundesgerichtshof) |
| **BMF** | German Federal Ministry of Finance (Bundesministerium der Finanzen) |
| **BMWi** | German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie) |
| **BNetzA** | German Federal Network Agency (Bundesnetzagentur) |
| **BSI** | German Federal Office for Information Security (Bundesamt für Sicherheit in der Informationstechnik) |
| **CEP** | Clean Energy Package |
| **CHP** | Combined heat and power |
| **DMZ** | Demilitarised zone |
| **DSO** | Distribution system operator |
| **DVGW** | German Technical and Scientific Association for Gas and Water (Deutscher Verein des Gas- und Wasserfaches) |
| **EEG** | German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz) |
| **EEX** | European Energy Exchange |
| **EMT** | External market participant |
| **EnWG** | German Energy Industry Act (Energiewirtschaftsgesetz) |
| **EPEX** | European Power Exchange |
| **EUREF** | Regional Reference Frame Sub-Commission for Europe |
| **FCR** | Frequency Containment Reserve |
| **GemAV** | German ordinance on joint auctions for onshore wind and solar installations (Verordnung zu den gemeinsamen Ausschreibungen für Windenergie-anlagen an Land und Solaranlagen) |
| **GW** | Gigawatt |
| **GWh** | Gigawatt-hour |
| **ICT** | Information and communications technology |
| **IGCC** | International Grid Control Cooperation |
| **IKEM** | Institute for Climate Protection, Energy and Mobility |
| **Inc-Dec-gaming** | Increase decrease gaming |
| **kW** | Kilowatt |
| **kWh** | Kilowatt-hour |
| **KWKG** | Combined Heat and Power Act (Kraft-Wärme-Kop plungs-Gesetz) |
| **mFRR** | Manual frequency restoration reserve |
| **MPES** | market processes for power-generating market locations (Marktprozesse für erzeugende Marktlokationen (Strom) |
| **MW** | Megawatt |
| **MWh** | Megawatt-hour |
| **NABEG** | German Grid Expansion Acceleration Act (Netzaus baubeschleunigungsgesetz) |
| **POCSAG** | Post Office Code Standardisation Advisory Group protocol |
| **PRC** | Pager-based ripple control |
| **PtC** | Power-to-cold |
| **PtH** | Power-to-heat |
| **PtX** | Power-to-X |
| **SINTEG** | Funding programme Smart Energy Showcase – Digital Agenda for the Energy Transition |
| **SINTEG-V** | Ordinance establishing a legal framework for the accumulation of experience in SINTEG (‘regulatory sandbox’) |
| **SOC** | Security operations centre |
| **StromNEV** | Ordinance on electrical grid fees (Stromnetzentgeltverordnung) |
| **StromSTG** | German Electricity Tax Law (Stromsteuergesetz) |
| **TCP** | Transmission Control Protocol |
| **TSO** | Transmission system operator |
| **TWh** | Terawatt-hour |

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