WindNODE

Best practice manual

Identifying flexibility options

LET'S TALK ABOUT FLEX

Contents

Executive summary

One of the main goals of the WindNODE project is to develop innovative ways to accommodate fluctuating electricity generation and demand. Working in various coordination committees, project partners reviewed the many valuable contributions of individual subprojects and compiled a manual of best practices that can be used as a blueprint for applications outside WindNODE. Two of these coordination committees examined the overarching issue of flexibility from different angles. Work by the Identifying Flexibilities committee culminated in the manual you now hold in your hands, which provides guidance on the identification and use of flexibility options. In early 2021, a second coordination committee – Flexibility, Market and Regulation – published a report broadening this perspective: rather than examining specific flexibility options in individual companies, it considers the available marketing options and their regulatory framework in the WindNODE region and beyond.

'Best practice manual: identifying flexibility options' provides accessible information to assist readers – especially prospective flexibility providers – in the identification and practical use of flexibility potential in their business environment. The experience that WindNODE partners have gained in specific real-world applications can serve as a resource for future flexibility providers in various branches and industries.

Some highlights from our work at WindNODE:

- At two branches of the Schwarz Group-owned supermarkets Lidl and Kaufland, tests were performed to evaluate the potential for a battery storage system to relieve the grid by storing energy during times of peak production. A decentralised energy management system in these showcase stores could be used to control electricity consumers – particularly cooling units – and thus respond to energy requirements by increasing or decreasing output. In 2019, the battery storage system at the Lidl branch in the district of Berlin-Schöneberg was connected to day-ahead and intraday markets, allowing it to participate in fully automated marketing. The storage system also successfully provided flexibility in the test run of the WindNODE flexibility platform.
- In the industrial sector, Siemens used modern measuring devices and an energy management system to record and categorise industrial processes. This demonstrated that it is possible to deploy flexibility options in accordance with various optimisation goals, such as the maximum integration of renewable energy or compliance with limits on electricity withdrawals and peak load time windows. Marketing has already been carried out on a test basis via the WindNODE flexibility platform.
- The Fraunhofer Institute for Machine Tools and Forming Technology (IWU) collaborated with Deckel Maho Seebach to develop the 'ZIEL' system for intelligent energy and load management. The system shifts the timing of energy-intensive production orders depending on energy price and actively controls decentralised energy infrastructure in factories. This allows manufacturing companies to design future-proof production methods with the flexibility to respond to changing energy needs.
- In the mobility sector, Berliner Stadtreinigung (BSR) updated the energy software developed by WindNODE partner ÖKOTEC.

BSR used the software to analyse the potential for flexibility optimisation in its fleet and create a prototype integrating this potential into regular operation. This made it possible to reduce grid fees and identify three flexibility options: supply optimisation on the electricity market, on-site dynamic load management and use of the 50Hertz flexibility platform.

- In a Berlin neighbourhood equipped with smart building technology, the Borderstep Institute cooperated with partners to test the market-oriented and grid-friendly control of a combined heat and power (CHP) plant and power-to-heat (PtH) elements. The building stock and local heating grid and heating network were used as thermal storage. Flexibility created in this process can be made available via the 50Hertz flexibility platform or on the energy market as a virtual power plant. This best practice manual elaborates on the examples listed above. It also provides a checklist for identifying flexibility, which allows users to compare available flexibility options based on simple, readily identifiable evaluation criteria. But flexibility providers will still need adequate incentives to utilise these options in practice. In the next phase of the energy transition, the main political and regulatory challenge will be to reconcile profitable marketing options and suitable rules for flexibility in the energy system with the available supply and existing demand. This manual can help readers optimise the integration and use of renewable electricity in a range of environments – from residential neighbourhoods to factories – and adapt demand to the availability of local renewable energy. In this sense, 'Best practice manual: identifying flexibility options' provides an important roadmap for the journey to an intelligent energy system.

Editorial

WindNODE is charting a path towards a future in which renewable energy meet almost all of our electricity needs. Current estimates indicate that Germany derives more than 40% of its electrical energy from renewable energy sources, primarily the wind and sun.[1] That's more than the most optimistic among us would have dared to hope just a few years ago. This figure is calculated as a yearly average because of natural fluctuations in the supply of wind and solar energy. On windless nights, there is very little renewable electricity, but on sunny, gusty days, wind and solar power plants in some regions can generate many times the amount of electricity required. The risk of overloading the power grids can then be so severe that renewable energy generation must be curtailed.

The volatility of green electricity generation points to the most challenging aspect of further renewable energy expansion: system integration. We must develop the tools to ensure that the energy system can supply the right amount of electrical energy in the right place at the right time. As a general principle, even systems with the capacity to generate large amounts of renewable energy must guarantee the balance between electrical energy generation and consumption at all times. Grid expansion and upgrades play a pivotal role in maintaining this equilibrium, but they are by no means the only significant factor. Flexibility options, in particular, are becoming an increasingly important part of this process.

In the context of the energy system, the concept of flexibility has a fairly straightforward definition. It refers to the ability of elements in this system to accommodate fluctuations in electricity generation and consumption by adjusting output in response to an external signal. By utilising flexibility, a factory can shift a portion of its production to coincide with the movement of strong winds across the country. A supermarket can tap flexibility potential to heat and cool its facility 'in advance', using the mass of the building itself as thermal storage.

In the WindNODE project, we have systematically identified flexibility on the user (i.e. consumption) side in companies from various segments of the economy: the tertiary sector (trade, commerce and services), industry, mobility, and household and neighbourhood management. This best practice manual highlights some of these examples. Our goal is to demonstrate that an oversupply of renewable electricity can be utilised in intelligent ways.

But this manual doesn't just present successful case studies. It also introduces key concepts and provides tools to help readers answer basic questions about flexibility. The examples featured in the main sections of this manual outline the most important factors for readers to consider when identifying flexibility. They also provide concrete resources, including checklists and recommendations for internal communication, to assist in this process. In addition, this manual offers guidance on evaluating and marketing flexibility options in the existing legal and regulatory framework. It supplements these recommendations by looking ahead to the marketing opportunities for flexibility that may emerge in the near future.

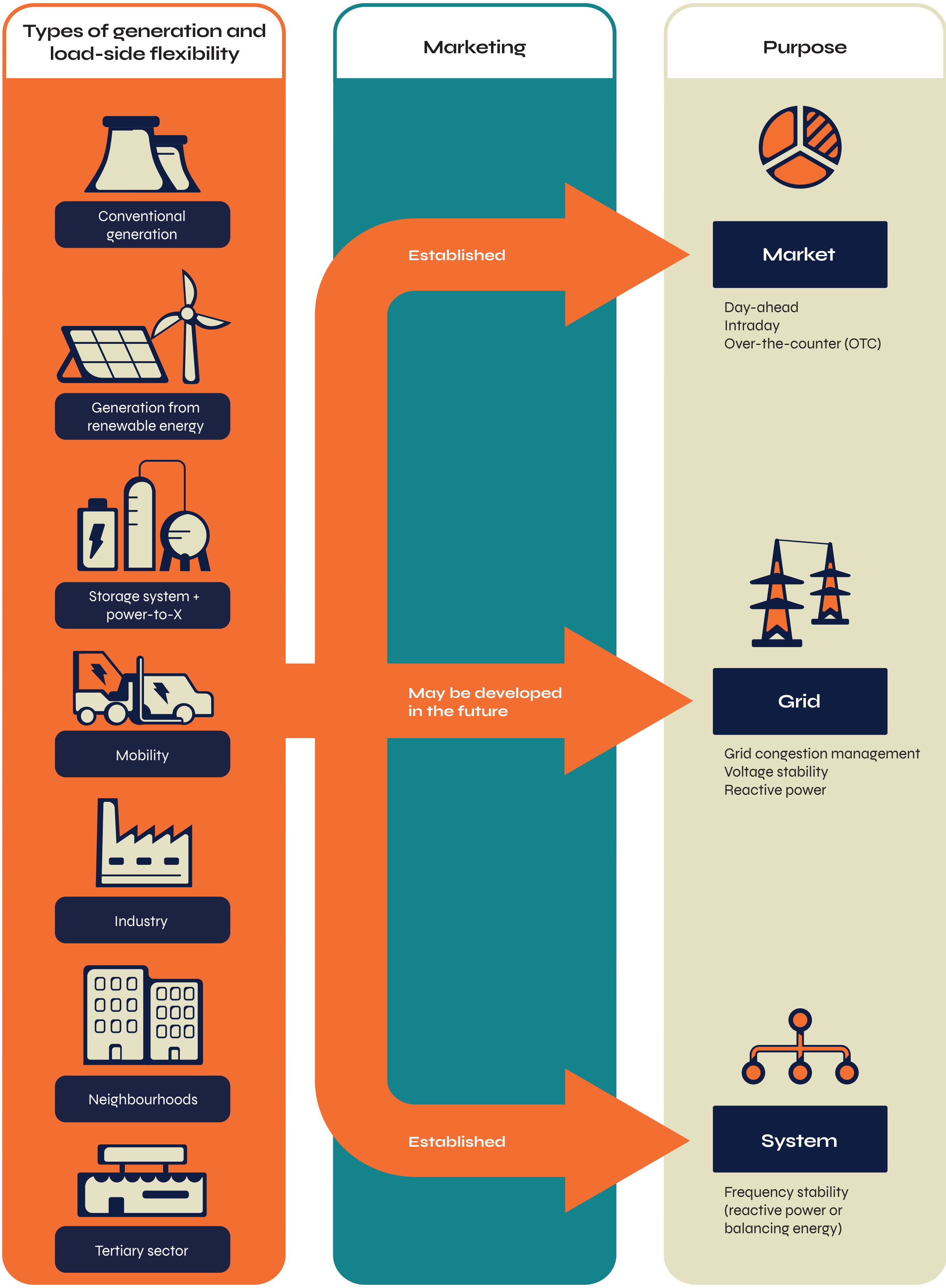
We believe that the issue of flexibility must be examined in terms of its potential environmental and economic implications – a perspective that, we realise, diverges from the more sober, business-oriented standpoint on the subject. The distance between these perspectives can be explained in part by the absence of effective, technology-neutral incentives for companies to market flexibility in ways that stabilise the system by relieving the burden on the grid. In the coming years, decision-makers will face a major challenge: how to design framework conditions that harmonise these perspectives while maximising benefits. The task ahead, in other words, is to develop economically feasible methods to meet energy system needs.

We hope that you will join us in this effort – as innovators in the identification of flexibility and as allies in the regulatory debate for successful system integration. Above all, however, we hope you enjoy reading this guide.

The Authors
Berlin, July 2020

[1] At the time of publication, no reliable estimates were available for the share of renewable energy in Germany's gross electricity consumption in 2019. Based on the figures for the first three quarters of 2019, the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) and the German Association of Energy and Water Industries (BDEW) estimate the share at roughly 43% (BDEW, ZSW 2019). For more information, see https://www.bdew.de/presse/presseinformationen/erneuerbare-decken-fast-43-prozent-des-stromverbrauchs/ (in German).

Applications and marketing opportunities for flexibility in the electricity system



Flexibility in the electricity system

The following pages introduce basic concepts related to flexibility, beginning with a definition of the term. Individual sections then describe specific applications of flexibility in the electricity market, ancillary services and grid congestion management.

What is flexibility?

In order to guarantee an affordable and accessible energy supply, systems must have the flexibility to adjust their electricity production or demand. Why is flexibility so important? For one thing, it can restore the required balance between production and consumption in the event of short-term disruptions. It can also help relieve the load on critical grid resources to maintain the transmission of electricity. In the long term, flexibility will play a crucial role in achieving climate change targets. That's because expanding renewable energy, especially from wind power and photovoltaics (PV), is an essential step in decarbonising the energy system. Natural fluctuations in the supply of these energy sources demand greater flexibility in the electricity system. Flexibility options are necessary to achieve each of the energy industry's three goals for the energy supply: affordability, security and environmental sustainability. For all of these reasons, flexibility is a key component of the energy system.

No universal definition of 'flexibility' has emerged from the debate on the future of the energy industry. WindNODE participants developed the following definition in an internal discussion process. This definition guided our analysis of project findings.

"“Flexibility” refers to the ability of elements in the energy system to accommodate fluctuations in electricity generation and consumption by adjusting capacity in response to an external signal. Elements that provide these abilities are referred to as “flexibility options”. Wholesale markets (day-ahead, intraday) and measures to eliminate grid congestion can create demand for flexibility. Flexibility can also be requested on the balancing markets or for the provision of additional ancillary services. The technical

potential of a flexibility option in the energy system can be quantified by determining the following minimum parameters:
- the value range of the change in capacity (positive/negative),
- the duration of the change in capacity and
- the lead time before the change in capacity.

The technical flexibility potential of the energy system is based on supply and demand. When calculating the economic flexibility potential, it is important to consider the costs and benefits achieved by providing flexibility within the existing regulatory framework.'[2]

As this definition indicates, flexibility in the electricity system has multiple applications. It can be deployed to compensate for short-term changes in residual load on the wholesale markets, to provide ancillary services and to eliminate grid congestion. The processes and measures necessary to manage these applications – some of which proceed in parallel – are explained in greater detail in the following sections.

Flexibility in the electricity market

The primary objective of electricity markets is to balance generation and consumption in the overall system at all times. This is necessary in order to maintain supply services. Supply and demand are aggregated for a given time period to preserve equilibrium. Resources are then deployed as cost-effectively as possible to align the supply with the demand.

Regardless of the specific type of marketing or service, actors must be assigned to a balance group to participate in the market. Each balance group must restore balance in the best possible way within 15 minutes. This means that the total amount of electricity generated and purchased within the balance group must correspond to the total amount consumed and sold. The market participant tasked with managing imbalances in each group – called the balance responsible party (BRP) – must submit a schedule in advance for every quarter-hour billing interval. This schedule provides information on the amount of electricity generated and consumed, as well as the amount purchased and sold to the relevant transmission system operator (TSO). The TSO serves as the balance group manager (BGM) and is responsible for transmitting energy through the grid.

Electricity can be traded in various ways. Individual parties can create a bilateral contract called an over-the-counter (OTC) transaction. Another possible approach is trading on an electricity exchange. Long-term trading is conducted on the futures market; short-term trading is carried out on the spot market. Due to the higher temporal resolution of its pricing model, the spot market is an indicator of the amount of flexibility required in the electricity system. In the German market area, short-term trading is initially conducted in the day-ahead auction on the European Power Exchange, EPEX SPOT SE. Bids for amounts of electricity can be submitted on an hourly basis until noon on the day before delivery.

Electricity providers use information about awarded bids to develop a plan for the dispatch of electricity from their power plants. They must submit a timetable communicating these plans to the responsible TSO by 2.30 p.m. Deviations from the day-ahead forecast can be offset later on the intraday market. Like the day-ahead market, the intraday auction makes it possible to trade products at quarter-hour intervals, with bids accepted until 3.00 p.m. on the day before delivery. Schedules for each balance group can then be prepared in 15-minute blocks to maintain the balance between supply and demand.

Actual delivery occurs 9–36 hours after the two auctions. (The precise

Fabian Stein
formerly of Green Cycle Umweltmanagement GmbH

> As part of the WindNODE project, the Schwarz Group is offering its battery storage system on the spot market. Its 252-kWH/100-kW battery is available as a flexibility option on the day-ahead and intraday markets. Day-ahead forecasts are used to develop plans for battery deployment, and over the following days, the output is regulated in accordance with these plans. This makes it possible to use the battery at the precise times when prices on the day-ahead market are low or even negative, which reflects an oversupply of renewable energy. Energy can be stored in the battery until it is used at a later time. When spot market prices are high, the battery is discharged, which means that the retail store draws less power from the grid. This process has been in use since the beginning of 2019 and has proved to be very reliable, as trading on the day-ahead market is fully automated.

[2] Cf. WindNODE (Ed.): Marktdesign, Regulierung und Gesamteffizienz von Flexibilität im Stromsystem – Bestandsaufnahme und Herausforderungen (April 2019), p. 12f. Available online at https://www.windnode.de/fileadmin/Daten/Downloads/Publikationen/PRP_Marktdesign__Regulierung_und_Gesamteffizienz_von_Flexibil-it%C3%A4t_im_Stromsystem.pdf (in German).

timing depends on the auction and the traded product.) During this period, market participants receive updated forecasts of load and feed-in from renewable energy sources, and power plant outages may occur. Continuous intraday trading can compensate for the resulting deviations. In contrast to the auctions described above, tenders on intraday markets are awarded based on an order book. This means that prices are not uniform for a certain hour or quarter-hour, but are calculated individually for each successful trade. Exchanges close 30 minutes before the settlement time. Bids from the same control area can be awarded until five minutes before the delivery time.

From the market structure described above, it's clear that flexibility is a necessary component of both phases of short-term trading – on both the supply and demand side. When supply is matched with demand on the hourly day-ahead market, flexibility can maintain the balance between the 'non-shiftable' portion of the load on the one hand, and the supply available from fluctuating renewable energy sources and must-run power plants on the other. High market prices reflect a shortage of supply, while low or even negative prices reflect a surplus and encourage the provision of flexibility. The number of hours with high market prices declined between 2011 and 2015 but has trended upward since 2016; hours with negative prices have increased over the entire period. Due to the lead time of several hours, many power plants, storage facilities and switchable or shiftable loads may be able to offer flexibility on the day-ahead market. In order for a unit to provide flexibility, however, it must be economically feasible to adjust production or consumption – even if only for a period of several hours – despite the start-up and shut-down costs or the expenses incurred from a shift in demand.

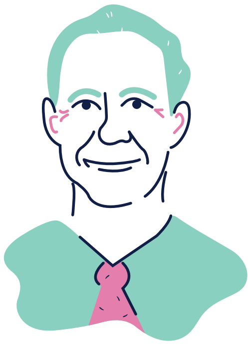
If real-time output deviates from day-ahead forecasts, the discrepancy can be eliminated on the continuous intraday market. There are incentives for the BRP to do so, including its contractual obligation to adhere to the expected schedules at all times ('balance group loyalty') and the need to purchase balancing power to compensate for any shortages in the balance group.

The shorter window of time between bidding and delivery increases the technical requirements for a given flexibility option. Restrictions on production planning can also preclude certain flexibility options,

	FCR	aFRR	mFRR
Activation time	30 seconds	5 minutes	15 minutes
Minimum bid size	± 1 MW	Usually 5 MW (positive or negative)	Usually 5 MW (positive or negative)
Tender period	Weekly (Tuesday for the following week from Monday–Sunday)	Daily (for the next day)	Daily (for the next day)
Time intervals per day	-	6 time slices of 4 hours each	6 time slices of 4 hours each
Compensation	Price per kW	Price per kW and price per kWh	Price per kW and price per kWh
Multiple marketing channels	Possible, as long as technical requirements can be met – even if the service is provided at the same time		

Table 1: Properties of balancing power products according to 50Hertz et al. (2019b), VDN (2003), VDN (2007) and VDN (2009).

especially flexible consumption systems, from participating in the intraday market. In addition, continuous trading demands greater effort from market participants than do auctions. These factors reduce offers of flexibility with shorter lead times. As a result, prices on the intraday market fluctuate more dramatically than those on the day-ahead market.



Dr Severin Beucker
Borderstep Institute

Today, we can already use the modular generating units and storage systems in residential neighbourhoods to provide flexibility for balancing power on the order of several 100 kW per neighbourhood. With intelligent energy management, this power can be integrated into buildings without requiring residents to sacrifice comfort. Although this order of magnitude seems small in comparison to other flexibility potentials, it is highly significant because it opens up the building sector, which needs to meet strict climate targets. Over the next few years, this potential could easily double or triple thanks to the expansion of electromobility and related charging infrastructures. However, the likelihood that this opportunity will materialise depends on incentives that reward flexible behaviour, and these are not yet offered on the energy market.

Flexibility to provide ancillary services

The Energy Industry Act (EnWG) of 7 July 2005 (section 11 ff.) obligates grid operators to '... operate, maintain and optimise a secure, reliable and efficient energy supply network without discrimination...' Grid operators are responsible for tasks including operations management, frequency and voltage maintenance, and the restoration of supply. For voltage maintenance, the acceptable voltage range must be maintained during normal operation (e.g. with reactive power), and excessive changes in the load on equipment must be preventable (with short-circuit power) in the event of a fault. In addition, for supply restoration, a sufficient number of power plants must be able to start up independently of an existing power supply.

Different kinds of balancing services are activated to stabilise the grid.[3] These can be divided into three categories: frequency containment reserve (FCR), automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR). Activation times for these services range from 30 seconds to 15 minutes (see Table 1). FCR is tendered on a weekly basis. The minimum bid size falls in a control range of ±1 MW, and provision is compensated per kW. In contrast to FCR, aFRR and mFRR are separated by positive and negative gradients, and tenders begin at 5 MW.[4] Tendering takes place daily in six time slices of four hours each. Prices are calculated per kW for the provision of aFRR and mFRR, and per kWh for the actual retrieval.

Due to the market design for the procurement of balancing power products, ancillary services are a key marketing channel for flexibility. The tendered FCR is set at a total of 3,000 MW for continental Europe and is distributed to the individual grid operators on a percentage basis according to load. Since 2012, Germany has participated in an international FCR cooperation. Over time, this led to the development of a joint call for tenders with Switzerland, the Netherlands, Austria, Belgium and France.

Although renewable energy (and the fluctuating feed-in associated with it) has expanded in Germany in recent years, the tendered capacity for aFRR and mFRR has fallen. This seemingly contradictory correlation is the result of improved efficiency on the part of the BRP and grid operators. It has been facilitated by various developments, including more sophisticated weather forecasting, the formation of an International Grid Control Cooperation (IGCC) to avoid opposing requests for balancing power, and greater use of the intraday market for balance group management. The number of providers has risen significantly at the same time. These factors have led to increased competition and a sharp decline in service prices. In contrast, the price per kWh has risen dramatically in the same time period. This is partly due to the inclusion of new technologies like PtH and biogas plants. Although these technologies can be offered at low costs per kW, they must be provided at high costs per kWh because of the electricity prices to be paid or the lack of compensation available under the EEG.

[3] Interruptible loads can also be used for this purpose. These loads are consumption units that can reduce their power consumption by a certain amount at the request of the TSO. Quickly interruptible loads (SNL) are distinguished from immediately interruptible loads (SOL). Since these products are rarely requested, they are not discussed here.
[4] Tenders can begin at 1 MW if only one offer is submitted per product and control area.

Flexibility for grid congestion management

Section 13 of the Energy Industry Act (EnWG) specifies a cascade of measures that can be taken by TSOs for operations management and the maintenance of system security. In general, operators must comply with the sequence prescribed by law. First, grid-related measures – particularly network switches – are used to relieve heavy loads on equipment, in accordance with sections 13(1) and 13a(1) EnWG. The TSO may then order redispatch measures, which reduce generation at power plants in certain areas while ramping up production by a corresponding amount in others. If these measures are not sufficient, section 13(2) allows the TSO to demand adjustments to electricity feed-in and consumption. In conjunction with section 14(1) of the Renewable Energy Sources Act (EEG), this provision also explicitly applies to renewable energy systems, CHP plants and mine gas plants. The procedure initiated by the grid operator to reduce feed-in from these systems is called feed-in management ('EisMan' or 'EinsMan').

Andreas Hüttner

Siemens AG

Here at Siemens, we've mainly focused on identifying flexibility for the purpose of peak shaving, i.e. to smooth out peak loads. But we still believe that a market-based mechanism for increasing the use of flexibility in grid congestion management is an effective tool to facilitate the integration of renewable energy; it can also provide another welcome source of revenue for flexible loads. That's why, as part of the WindNODE project, we participated in marketing flexibility for grid congestion management via the innovative WindNODE flexibility platform. The platform design, which enables users to carry out day-ahead and intraday management, met our needs for production planning. It was interesting to see that flexible loads are more valuable near grid bottlenecks. Of course, some aspects of the platform can be improved: for example, when bids are submitted, the platform operator should consider block bids and conditions, such as the selection of three out of eight possible hours. This would increase the supply and the value of flexibility. It would also be interesting to reverse the pay-as-bid auction procedure so that users have an opportunity to react as a system operator to a price signal given by the platform.

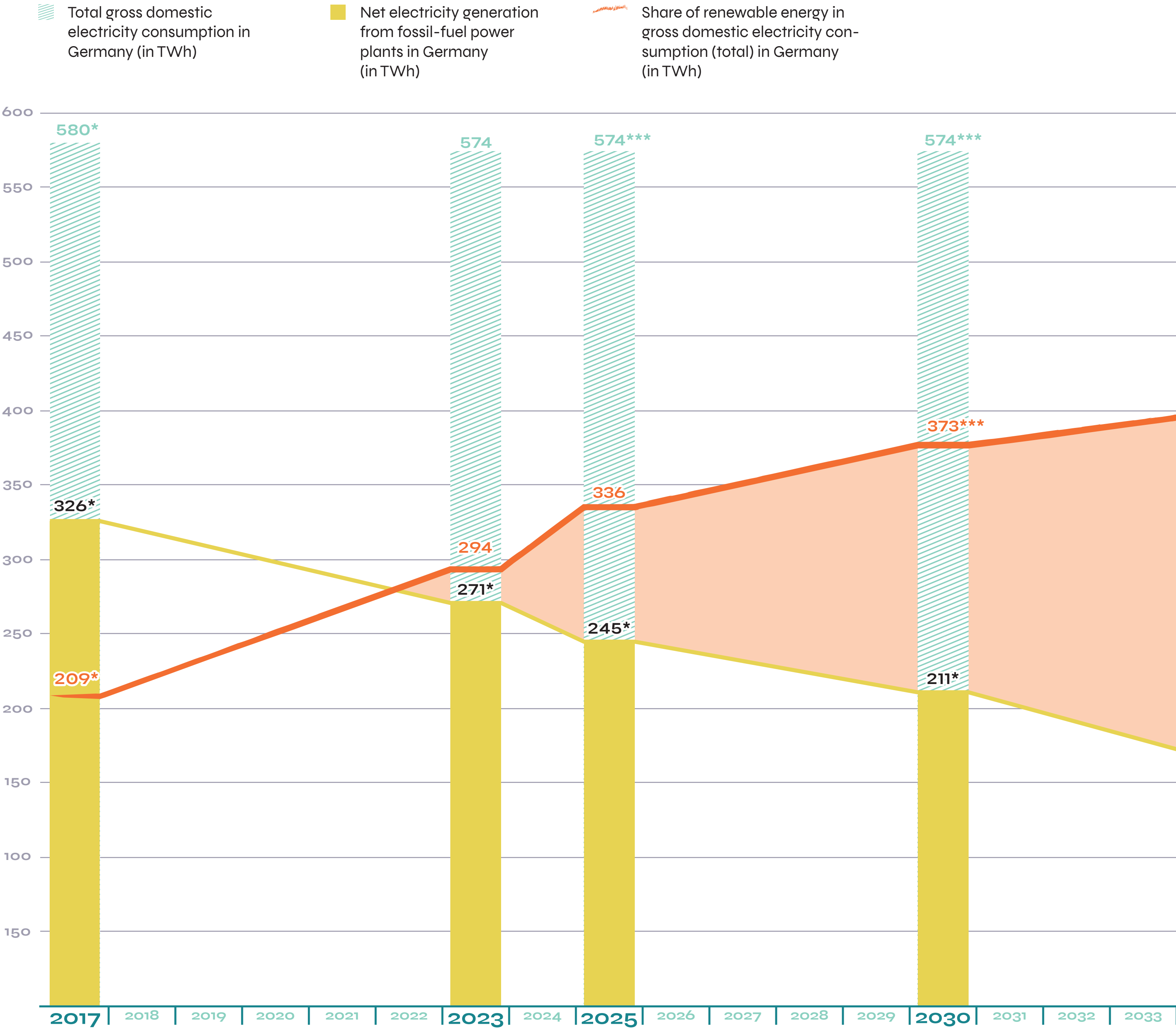
Due to the existing grid topology and the dependence of renewable generation capacity on supply, grid congestion is increasingly common along the transmission lines that connect wind farms in the North to load centres in the South. Thus far, TSOs have mainly relied on large power plants and feed-in management to eliminate congestion. Much of the potential of small and medium-sized flexible plants to serve this function has remained untapped. However, the amendment to the Network Expansion Acceleration Act (NABEG) that took effect on 13 May 2019 includes new requirements for grid congestion management, which must be implemented by grid operators by 1 October 2021. The regulations on feed-in management for renewable energy plants and CHPs established under the provisions of the EEG and the Combined Heat and Power Act (KWKG) will be repealed on this date, and a uniform redispatch regime (Redispatch 2.0) will be introduced in accordance with sections 13, 13a and 14 EnWG. In concrete terms, this means that, in the future, renewable energy plants and CHP plants with an installed capacity of 100 kW and above will be required to provide their services for redispatch, as will plants that can be remotely controlled by a grid operator at all times. Flexible consumers will still be excluded from this process.

In contrast to the wholesale and balancing markets described in the previous sections, facilities are only reimbursed for additional costs incurred for grid congestion management. As a result, there is no competition for the activation of flexibility to eliminate or prevent congestion. Competition is also limited by the fact that units must meet certain geographical criteria to be considered for use. In the case of redispatch measures, a unit's ability to relieve congestion on a specific line depends on the location of that unit in the grid. This gives local actors a competitive advantage over more distant participants and over the TSO, which is reliant on a reduction in output.

To supplement the marketing channels for flexibility discussed above (i.e. the electricity market and provision of ancillary services), WindNODE designed a flexibility platform to develop and test the potential to utilise voluntary flexibility potential for grid congestion management. This allowed providers to offer flexibility voluntarily, with no preference given to certain types of technology. Flexibility options were available to all grid operators participating in the platform, and implementation was coordinated across voltage levels. This additional potential was intended to enable greater utilisation of renewable energy production in cases of grid congestion, demonstrating the principle of 'using instead of curtailing'. The approach adhered to market principles as closely as possible and prioritised the identification of the most cost-effective solution.[5]

[5] For a more detailed description of platform features and a summary of results, see 'Flexibility, markets and regulation: insights from the WindNODE reality lab', which was published in January 2021

Flexibility generates more environmental and economic added value!



2023

Nuclear energy has been phased out completely.

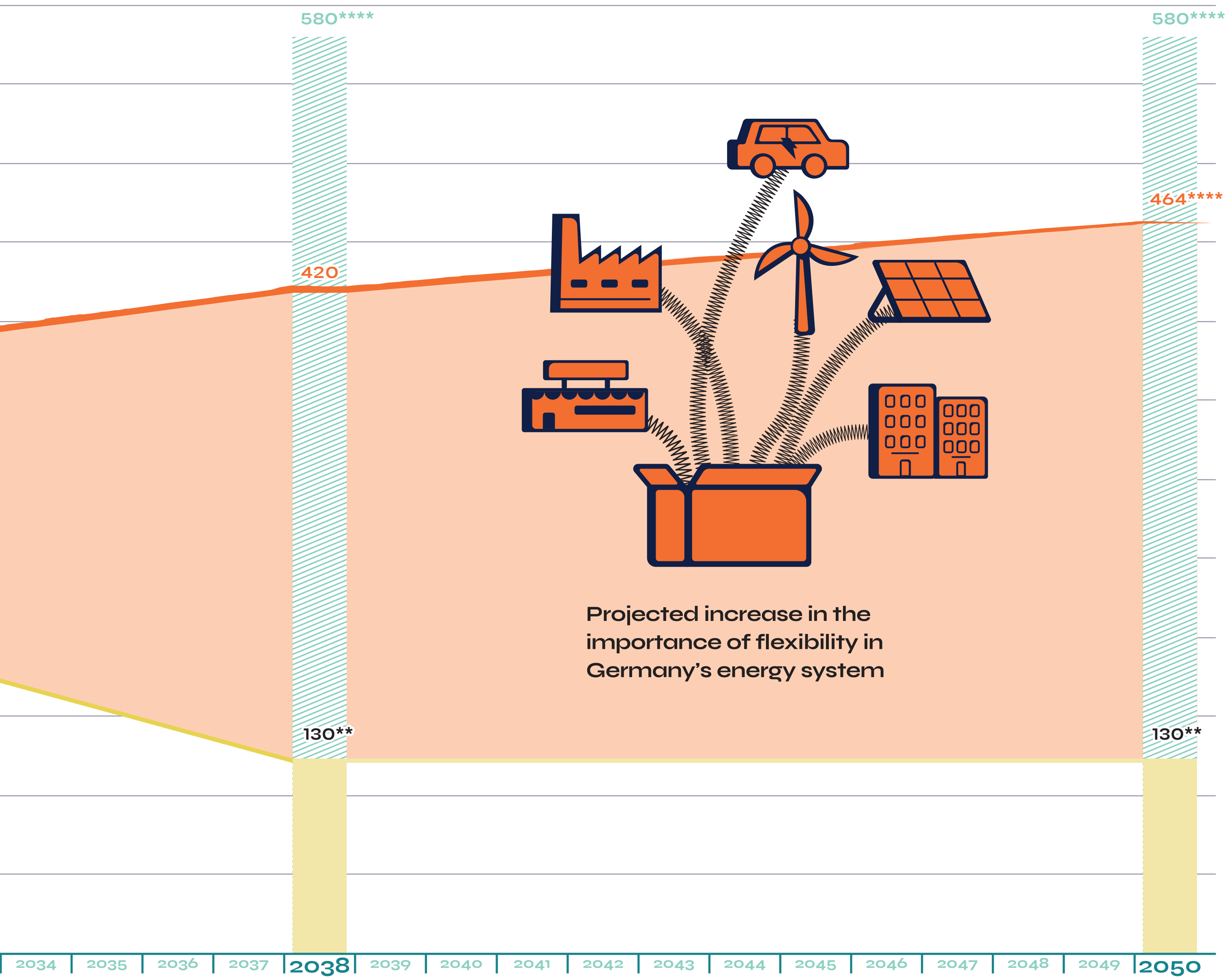
2030

Current grid development plans dimension the transmission grid for a renewable energy expansion of 65% by the year 2030. There are currently no official plans for a renewable energy expansion >65%.

* BNetzA 2018, p. 5
** BNetzA 2019, p. 35
*** Bundestag printed paper 19/13900, p. 26
**** Bundestag printed paper 19/13900, p. 26 (projected values)

* Öko-Institut 2019, p. 21.
** According to the Kohleausstiegsgesetz (Coal Phase-out Act), use of lignite and hard coal for electricity generation will be discontinued by 2038 and 2050, respectively. It is highly likely that natural gas and other fossil-based energy carriers (e.g. mineral oil) will still be used for electricity generation, although the share of these fuels in total electricity generation is unknown. The 123 TWh cited here is based on the share of natural gas and other fossil energy sources in electricity generation as of 2030. See Öko-Institut 2019, p. 21.

* BNetzA 2018, p. 9
** BNetzA 2019, p. 35
*** Coalition agreement, p. 14
**** Section 1(2)(1) EEG



The graph above shows the projected increase in the significance of flexibility in the German energy system based on changes in three indicators over time. The focus is on changes in power generation in Germany associated with a gradual phase-out of coal-fired power generation by 2038 (with a simultaneous phase-out of nuclear power by 2023) and a gradual expansion of renewable energy through the year 2050. The graphical representation of the coal phase-out (downward yellow curve) is based on an expert interpretation of the recommendations issued for the relevant years by the Commission on Growth, Structural Change and Employment ('Coal Commission') established by the federal government. Changes in the share of renewables in gross domestic electricity consumption over time (upward red curve) are shown based on the trajectories established by law or set as political targets for the expansion of renewable energy by 2050. These trajectories are represented relative to the change in gross domestic electricity consumption since 2017. There are different perspectives on the projected change in gross domestic electricity consumption for the period shown. The German federal government assumes a gross domestic electricity consumption 'slightly below the current level' at least until 2030; other sources expect consumption to reach 748 TWh by 2030. The determination of a specific projection for gross domestic electricity consumption is irrelevant to the graph presented here if the gross electricity consumption is assumed to remain roughly constant or increase – but not decrease. If consumption remains nearly constant until 2030 (and from 2030–2050), the growing importance of flexibility in the overall energy system in Germany is clear from the shaded area between the two curves, which show a decrease in conventional generation and an increase in renewable energy generation. Flexibility may also become more important as the costs of flexibility or the marginal benefit of grid expansion declines. It is important to note that the confirmed grid development plan (NEP) for the transmission grid is dimensioned to accommodate an expansion of renewable energy to 65% of gross domestic electricity consumption by 2030.

What to consider when increasing system flexibility

Which units are best suited to flexibilisation, and how can these be identified? Prospective providers can begin the identification process by considering certain economic and environmental factors.

Key economic factors to consider when identifying systems for flexibilisation

The previous sections summarised what flexibility means in the context of the electricity system, as well as which marketing channels for flexibility already exist (flexibility in the electricity market and flexibility to provide ancillary services) and which could emerge in the future (flexibility to manage grid congestion).

When prospective flexibility providers consider whether to identify or use flexibility, business indicators naturally play a decisive role. It's impossible to generalise about the specific revenue or return on investment that can be obtained for particular technical systems through different marketing channels. Such outcomes vary on a case-by-case basis, depending on the technical system, market conditions and intended use.

It is possible, however, to provide general guidance on the characteristics that make certain units more suitable for flexibilisation. The optimal units are technical installations or processes that can be deployed for the purposes described above with no additional investment required for flexibilisation. This generally includes facilities and processes that can operate at any time of day without negatively affecting the original purpose of use (e.g. refrigeration or volume per day). In such cases, no costs or losses are incurred beyond those associated with normal operation. Because most technical units are already purchased and operated to maximise resource and process efficiency, however, these flexibility options account for only a minor portion of the available potential.

Most of the available flexibility potential will require prospective providers to invest in developing or refining current capabilities. Experience has shown, however, that the revenue currently generated from 'peak-shaving' (i.e. smoothing out peak loads) or marketing balancing power is generally not sufficient to justify the required investment or to provide an adequate economic incentive for flexibilisation.

At the same time, the flexibilisation of company facilities may produce secondary effects that are economically desirable. For example, an increase in process flexibility can boost the satisfaction and efficiency of employees by allowing them to take more frequent breaks and rearrange working hours and shifts. This can have a positive effect on key figures, including the number of units produced. In this respect, increased flexibility can provide direct qualitative advantages in the workplace that indirectly contribute to a company's economic success.

Irrespective of this potential benefit, incentives should be offered to encourage investment in control technology (sensors/actuators). Demands for such incentives are often accompanied by calls to reform the existing system of taxes, fees and surcharges.[6] Incentives should be designed to target potential flexibility providers. In the future, the same kinds of incentives that have promoted energy- and resource-efficient systems may be used to promote flexible systems that benefit the grid. This could significantly increase the supply of usable flexibility.

In order to identify flexibility in practice, both objective and subjective parameters of the load (e.g. machine, repository and storage) must be recorded and evaluated. For an overview of technical parameters, please consult the 'Toolbox for identifying flexibility: checklist for flexible loads' included in this manual.

Key environmental factors to consider when identifying systems for flexibilisation

As the economic considerations summarised in the previous section suggest, the motivation for flexibility providers to identify flexibility is generally environmental in the short term, and economic only in the medium to long term (if at all). This is because providers assume that the marginal utility of grid expansion will decline beyond the target year 2030 (65% renewable energy) or at the point when 2050 targets are reached for the share of renewable energy in gross electricity consumption (80% renewable energy). A reduction in the costs of deploying flexibility would bolster support for flexible systems as a mechanism to benefit the overall system and to mitigate climate change. This would increase the economic value of flexibility in the future, and there is much to suggest that the utilisation of flexibility could generate economic profits (see the graph on page 12, 'Projected increase in the importance of flexibility in Germany's energy system').

From a systemic perspective, the crucial question today is whether identifying and activating flexibility can create environmental value added in the form of reduced life-cycle resource consumption and emissions. From an environmental standpoint, companies that are considering an increase in system flexibility should focus any such efforts on systems that can provide flexibility for the energy system with little to no additional resource consumption.

These considerations indicate that flexibility options within existing processes in industry, trade, commerce, services, the housing industry and the mobility sector have environmental benefits. As shown in the following examples (see 'Best practices' section), flexibility in existing units or processes can be tapped with little to no modification. From a life-cycle perspective, the only factor influencing net savings is thus the additional technology required (e.g. for communication, measurement and control).

As the level of flexibility falls and the resources required for regulation rise, energy consumption by the technology itself becomes more likely to offset the environmental value added (e.g. emissions reductions). It's important to note, however, that in many cases the activation of small amounts of flexibility has yielded a positive environmental balance, even at the household level. The mobilisation of this potential is therefore not so much a technical challenge as an economic and organisational one: as outlined above, current market structures do not reward such measures, and price advantages can't be passed on.

From an environmental perspective, a more complex question is whether the mobilisation of flexibility increases or decreases energy consumption and whether this has positive or negative implications for the energy system or system-wide CO_2 reduction. In a fossil-based energy supply, multi-step energy conversions (e.g. old night storage heating technology: fossil-based primary energy sources → electricity → heat) are environmentally disadvantageous because they reduce efficiency. This need not be the case in a supply based on renewable energy, however, especially if peaks in renewable energy production are only temporary or are limited to certain locations or regions. Surplus renewable energy can then be used as negative balancing power for flexibility or storage (power-to-x), provided that the grid infrastructure can accommodate it ('using instead of curtailing'). The loss in efficiency resulting from energy conversion processes does not have significant environmental effects, because the generation systems (wind turbines,

[6] For a closer look at promising steps in this direction, see the WindNODE report 'Flexibility, markets and regulation: insights from the WindNODE reality lab', which was published in January 2021.

solar panels, etc.) 'pay it back' by fulfilling their primary purpose of electricity production. The surplus electricity is thus nearly CO_2-neutral on the balance sheet. The conversion of this energy makes it unnecessary to curtail wind or solar generators in response to insufficient grid capacity or the need for voltage stabilisation. As a result, negative balancing power contributes little to CO_2 emissions.

Flexibility can also be used to provide positive balancing power. This occurs when units in the sectors listed above feed electricity into the grid during periods of low renewable energy production. Whether this practice makes environmental sense depends on the unit, its primary use and the type of energy source. If electricity is fed back into the grid from a battery storage unit, for example, the environmental assessment will depend on the share of battery resources available (allocated) for grid stabilisation and the environmental impact of this capacity (e.g. resource consumption, CO_2 emissions) relative to that of possible alternatives (e.g. supply from biomass, fossil fuels or grid expansion). If, on the other hand, battery storage is used for other purposes as well (e.g. as an emergency power source or as a local energy supply for electric vehicles), it's important to clarify how much of the environmental impact is due to the provision of flexibility. Evaluations of flexibility with positive balancing power are always more complicated, because a higher-level assessment is required to allocate environmental impacts.

Clustering of flexible systems

in the tertiary sector (trade, commerce and services), industry, mobility and neighbourhoods

Measurable indicators help determine which systems or processes in a company can be identified and activated as flexibility. The following pages develop 'clusters of flexibility' by examining relevant indicators in four specific areas: the tertiary sector, industry, mobility and neighbourhoods. Clustering can help plant operators gain important insight into existing technical potential.

Tertiary sector (trade, commerce and services)

Due to the heterogeneity among grid users in the tertiary sector (including trade, commerce and services), it's difficult to generalise about the flexibility of systems or processes. Specific load characteristics, installed technology and cumulative annual energy vary considerably across branches, which means that intensive analyses of internal processes must be conducted before flexibility can be identified and utilised. Nevertheless, certain indicators make it possible to assess the suitability of commercial processes. These include the level of inertia in plants (e.g. temperature gradients of cooling systems), specific methods of production (e.g. batch-based, workshop production) and the general ability to plan energy-consuming processes.

Commercial facilities often meet the technical requirements for coupling infrastructure (e.g. electricity, heating, cooling). This enables conversion systems to provide flexibility through cross-sector energy flows.

Industry

From an energy perspective, industrial production sites always consist of components and systems of production (e.g. processing machines), production infrastructure (e.g. compressed air treatment) and building infrastructure (e.g. air conditioning). Increasingly, decentralised systems for energy conversion (renewable energy) and storage must also be taken into account. The goal is to control or regulate the entire system of 'industrial grid users' in a (partially) automatic and flexible manner – with support from market incentives – in order to create economic added value. This is difficult, however, because variation at the different layers of existing automation pyramids (from enterprise resource planning (ERP) through production planning and control systems to the field level) makes real system landscapes extremely heterogeneous. As a result, relevant systems must be equipped with adequate electrical and communication technology. The creation of these new networks allows the 'factory of the future' to function as an independent energy system.

Flexibility can be activated throughout the industrial landscape, not just in energy-intensive processes and technologies like container glass production, raw and cement grinding, chlor-alkali electrolysis and raw material melting. Although these processes typically provide very large amounts of energy for load management, they can often only be influenced as a whole due to their considerable dependency on subprocesses. This means that they can cover only a small portion of the necessary demand profiles. When considering the expected 'multiplier' effects of energy use, it's important to give particular weight to the many small and medium-sized manufacturing companies that help maintain Germany's role as a business centre. Because energy demand is generally low, there is significant potential to aggregate and coordinate the partial amounts that require greater flexibility.

Mobility

The electrification of public and private vehicle traffic offers many crucial opportunities to provide electrical flexibility. There is already significant technical flexibility potential in the form of charging capacities of up to 22 kW (in some cases even higher) and relatively small battery capacities of 50–100 kWh. Bidirectional charging, which is often mentioned in this context, does not seem technically or economically attractive at present and is rarely offered on the market. Short- and medium-term flexibility potential is created primarily by shifting the times at which (partially) discharged vehicle batteries are recharged. For this flexibility potential to be usable in practice, however, it's necessary to define more or less plannable time windows within which charging can be shifted. This makes it unlikely that 'on-the-road charging' or 'in-between charging' – such as at motorway service stations, at bus stops (along a regular bus route) or during a short break in shifts – will be suitable to provide flexibility.

In commercial fleets (and in bus transport), on the other hand, the time intervals between vehicle deployments are longer, which offers better opportunities for flexible charging between clearly defined shifts. This also applies to private vehicles that are seldom or never used outside of scheduled hours, such as overnight or while standing idle in the employer's car park. The aim is to increase the flexibility of vehicle charging while continuing to satisfy all usage requirements – and without restricting the mobility of vehicle users.

Especially in the aggregate, flexibility that can be mobilised in this way is considerable and, 'in principle', can be achieved at low cost, provided that the charging infrastructure or vehicles can be controlled as needed and are connected to a suitable system for energy management and optimisation.

Neighbourhoods

By definition, measures for demand-side integration (DSI)[7] in households, residential buildings and neighbourhoods must maintain comfort, and residents shouldn't notice any limitations. Storage systems (thermal, electrical and building mass) and modulable energy generators (e.g. CHP unit or heat pump) can be used to meet this requirement. Because flexibility conflicts with energy efficiency in neighbourhoods, energy consumption must be shifted in ways that will optimise cost and comfort. Intelligent building networking (smart building technology) is an effective means to record and predict thermal load behaviour as well as the behaviour of individual users. This makes it possible to assess neighbourhoods and their possible contribution to flexibility (e.g. schedules). If many individual grid users are aggregated, compensation effects may occur, and economic efficiency can be increased through central and optimally dimensioned equipment.

[7] Demand-side integration is a term that encompasses demand-side management (i.e. external influence on load-side consumption) and demand-side response (i.e. the consumer's reaction to an external signal that is designed as an incentive). For the definition, see: Energietechnische Gesellschaft (ETG) im Verband der Elektrotechnik, Elektronik, Informationstechnik e. V. (VDE) (Ed.): 'Demand Side Integration – Lastverschiebungspotenziale in Deutschland', Frankfurt am Main 2012.

Characteristics of flexibility clusters

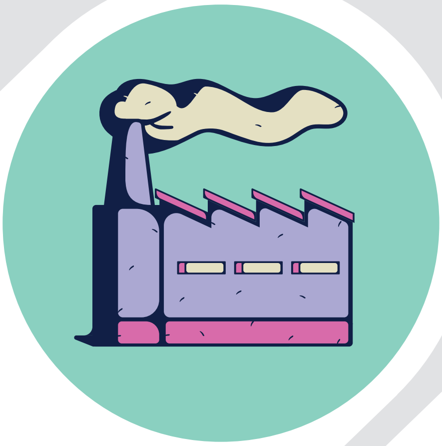
Cluster	Tertiary sector (trade, commerce and services)	(Energy-intensive) industry	Mobility and transport sector	Neighbourhood solutions
Prerequisites for the provision of flexibility	Compliance with customer requirements/fulfilment of customer preferences/no influence on customer experience	No negative influence on production or manufacturing/ fulfilment of customer preferences, compliance with peak load limits	Guarantee of required transport capacity	No adverse effect on user comfort
Previous market participation	Generally none (upstream power utilities)	Generally flexible purchase of electricity, in certain cases balancing market	Generally none (charging stations supplied by power utilities)	Generally none (upstream power utilities)
Typical annual energy consumption	400–1600 MWh	(Registered load profile measurement (RLM) beginning at 100 MWh)	-	Approx. 3–8 MWh per household
System engineering requirements	Mainly non-controllable loads, controllable or shiftable loads or processes available, emergency power generators as needed	Controllable load and generation units, (temporarily) autonomous operation possible as needed	Controllable charging stations, no higher-level control, and benefits to the grid	CHP plant or PV system available as needed, low generation by consumers, non-controllable loads, small storage systems for heat and electricity
Monitoring, control and information technology for flexibility	Partially to widely available, but not designed for flexibility	Energy monitoring and management available	Energy monitoring and management available	Available to some degree via networked central heating systems and smart building technology
Technical measures required	Installation of system-specific smart meters and devices for intelligent control and networking	-	Creation and operation of a mobility control centre for the coordinated management of energy flows	Installation of smart building technology and smart meters, system-specific controls
Organisational measures required	Transparent tracking of energy flows	Integration of flexibility into the value chain	-	Transparent tracking of energy flows

Best practices

In the WindNODE project, we have systematically identified flexibility on the user (i.e. consumption) side in companies in various segments of the economy, including the tertiary sector (trade, commerce and services), industry, mobility and household and neighbourhood management. As the following sections show, there are intelligent options for the flexible use of renewable electricity in each of these areas.

Tertiary sector (trade, commerce and services)

Industry



Mobility

Neighbourhoods

Best practice

Tertiary sector (trade, commerce and services)

Use of flexibility in a Schwarz Group-owned prototype store

(Lidl/Kaufland)

The testing environment

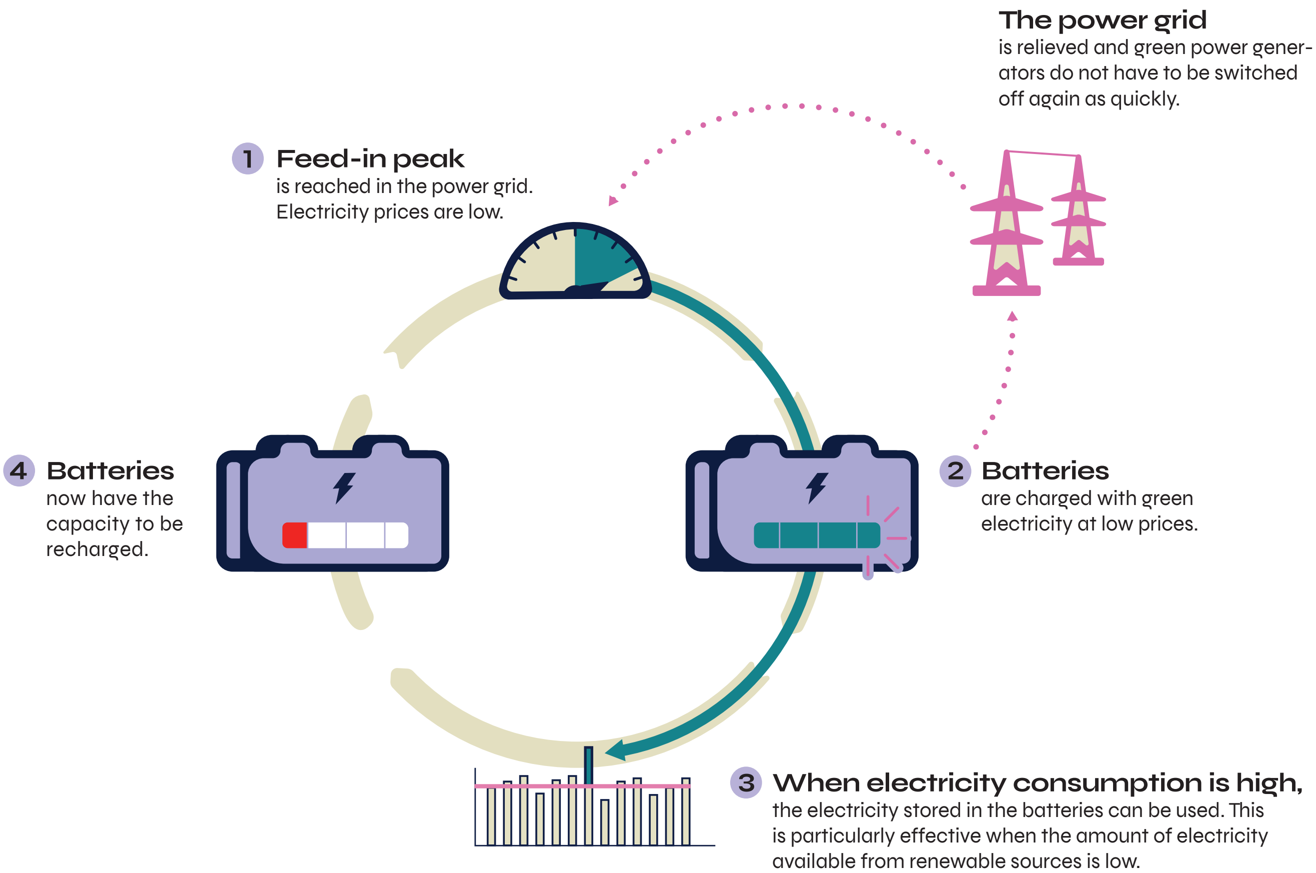
As part of the WindNODE project, the Schwarz Group is testing how the tertiary sector (trade, commerce and services) can provide flexibility to advance the energy transition. The retail giant, which owns the Lidl and Kaufland chains and numerous production plants, operates facilities at roughly 4,000 sites throughout Germany and more than 10,000 locations worldwide. Thanks to the large number of Schwarz Group-owned sites, the potential to stabilise the grid can be scaled up rapidly over a wide area.

One of WindNODE's main goals is to determine how small-scale consumers and producers can provide flexibility to accommodate fluctuations in the supply of renewable energy. The basic assumption is that this flexibility potential will help stabilise the electricity grid and compensate for peak loads. This would mean that consumers (loads) in stores, logistics centres and production sites would use electricity when the wind and sun generate large amounts of energy and reduce consumption when the amount of electrical energy available is low.

In the WindNODE project region, the Schwarz Group operates approximately 900 sites that can provide capacity to stabilise the power grid. The flexibility potential available at these locations is significant – enough to offer roughly 50 MW for cooling systems in the WindNODE region. At one Lidl and one Kaufland store in Berlin, models provide an opportunity for visitors to learn more about the company's contribution to the energy transition. These 'showcase stores' are located at Hauptstrasse 122, 10827 Berlin (Lidl) and Karl-Liebknecht-Strasse 7–13, 10178 Berlin (Kaufland). Both sites are open to the public during regular store hours (Monday–Saturday, 8 a.m.–10 p.m.).

Green Cycle: storage of green electricity using batteries

This process relieves the power grid and provides cheap, sustainable electricity when energy consumption is high.



The prototype store in Berlin-Schöneberg: central building control and decentralised energy management

A Lidl store in Berlin-Schöneberg is conducting practical tests of flexible behaviour that benefits the grid. The energy-efficient branch uses the heat recovered from refrigeration units for air conditioning and has a PV system for its own supply, as well as charging points for electromobility and a battery storage unit with a capacity of 252 kWh.

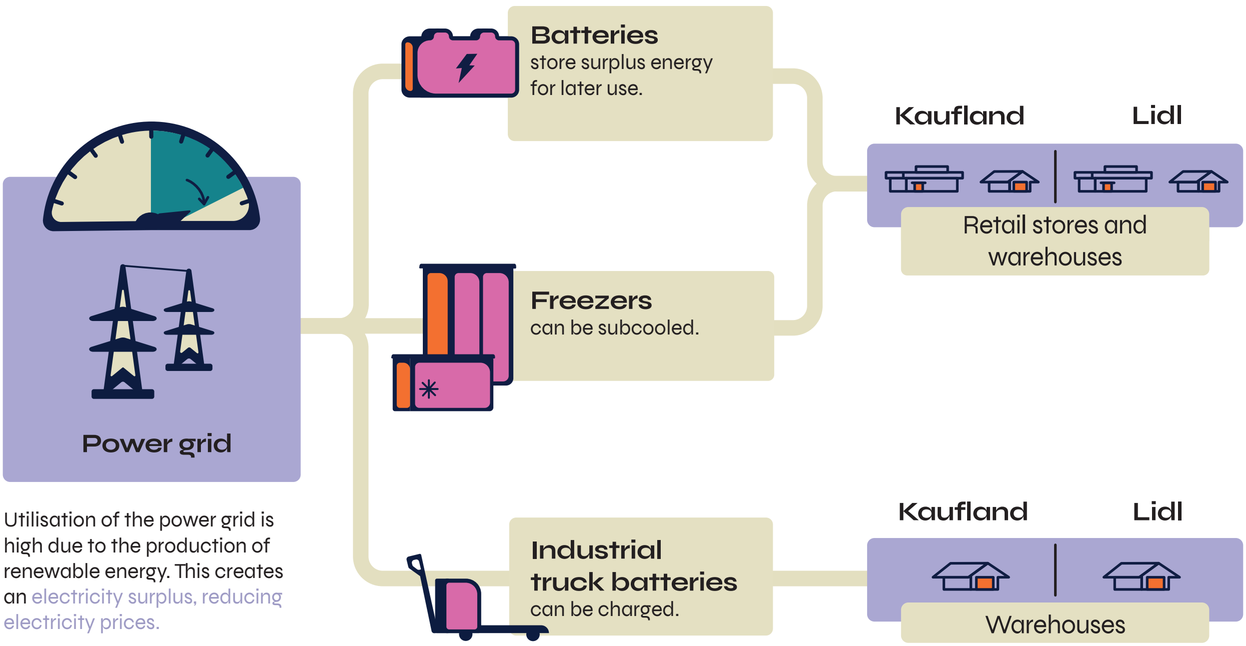
The store is equipped with a central building control system that allows for decentralised energy management. The building's automated control system ventilates and air-conditions the building on demand. No additional heat generation is necessary, because the waste heat recovered from the cooling units and refrigeration system can be used for heating. The PV system is mainly deployed to cover a portion of the building's own requirements. Feed-in to the external grid is carried out almost exclusively on Sundays, when the store is closed. This means that the renewable energy can be used almost entirely on-site. The battery storage system outside the branch currently serves to reduce peak loads and is fed by the PV system and the power grid. The load limit can be adjusted to meet requirements.

Flexibility potential in the prototype store: identification and marketing

In the analysis of available store facilities, both the battery storage and other consumers were identified as technical flexibility potential and then tested as a flexibility option on the market. Project participants were

The Schwarz Group's swarm flexibility

The large number of locations and small-scale electricity consumers helps stabilise the power grid.



Utilisation of the power grid is high due to the production of renewable energy. This creates an electricity surplus, reducing electricity prices.

Swarm flexibility allows surplus electricity to be drawn from the grid for use in various applications.

Consumers and locations participating in the Schwarz Group's swarm intelligence

careful to ensure that there were no adverse effects on customers or product quality.

The following consumers (loads) were also identified as potential sources of flexibility:

- freezers and freezer cells, which can be subcooled for use as thermal storage;
- electric charging stations, which charge vehicles primarily when large amounts of renewable energy are available; and
- the building mass itself, which can be used as thermal storage for heating and cooling.

Freezers and freezer cells were equipped with additional measurement technology for analysis. This made it possible to record temperature profiles and energy consumption at each plant and to perform a subsequent flexibility evaluation.

Practical testing of flexibility options: optimisation and marketing

In addition to identifying flexibility potential in each store, WindNODE project participants are testing options for control and marketing. Specifically, participants are collaborating with partners to test two marketing options in the prototype store in Berlin-Schöneberg. First, battery storage is offered as a flexibility option on the electricity exchange in cooperation with a marketing partner. The flexibility of the 252-kWh/100-kW battery is made available in the day-ahead auction. Day-ahead forecasts are used to develop schedules for battery deployment, and output in the following days is regulated based on these plans. This makes it possible to charge the battery precisely when prices on the day-ahead market are low or even negative. Such prices reflect an oversupply of renewable energy, which can be stored in the battery temporarily and used at a later time. When spot market prices are high, the battery is discharged, allowing the store to draw less power from the grid. This practice has been in place since early 2019 and has proved to be highly reliable, as trading on the day-ahead market is fully automated. In 2019, the storage facility generated approximately € 2,100 in revenue from the short-term electricity exchanges while smoothing out peak loads in the store and e-charging station. This demonstrated the multifunctionality of the storage system.

Flexibility for grid congestion management is also provided on a pilot basis in cooperation with project partner 50Hertz and participating distribution system operators (DSOs), who bid for these options on the WindNODE flexibility platform.

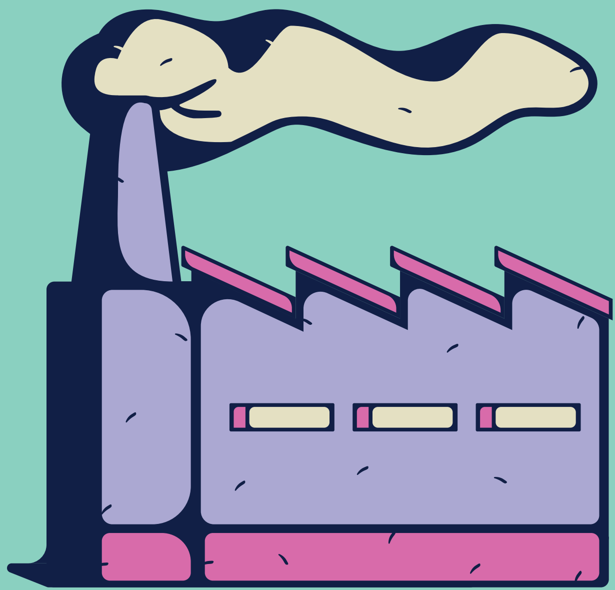
Increasing freezer flexibility without compromising product quality

Temperatures in supermarket freezers must remain between -24 and -18°C to guarantee the quality of our food. This is our top priority, and it's non-negotiable. We can create flexibility potential by using this temperature range to its full potential and by lowering temperatures even further. In the process of determining what was feasible – both technically and in terms of the energy management system – we needed to resolve some surprising questions. We first considered an obvious concern: whether food would be damaged if refrigerated below -24°C. We wouldn't expect this to be the case, at least with respect to food hygiene. Still, it was important to clarify whether any other damage could occur – to the packaging, for example. In collaboration with an independent research institute, we performed a series of practical tests that helped to dispel any concerns about food quality. Finally, there was the issue of occupational health and safety. Existing guidelines – for instance, on working hours and protective clothing for employees in cold rooms – only applied at temperatures down to -24°C; at lower temperatures, the guidance was unclear. We solved this problem by lowering cold-room temperatures below -24°C only when the store was closed, such as at night or on Sundays. This protected employees from any effects of the flexible cooling processes and maintained workplace safety. Customer contact remains a vital part of this effort, because when it comes to energy projects, few places affect the public as directly as a supermarket. We've converted two of our Berlin stores – a Lidl store in Schöneberg and a Kaufland store at Alexanderplatz – into 'showcase stores' that let customers experience our WindNODE solutions firsthand with models, light installations and a large 252-kWh battery. This has paid off: customers have become more aware of the energy transition and are interested in seeing how the supermarket they shop at each day contributes to this broader goal.

Thomas Tappertzhofen
Green Cycle Umweltmanagement GmbH

Best practice 1

Industry



Intelligent industrial load management in Berlin at Siemens

The testing environment

Siemens has made a valuable contribution to the WindNODE project by developing methods to shift loads in industrial production processes. In the course of its research, Siemens has analysed, automated and forecast the power requirements (load profiles) of thermal, mechanical and electrochemical production or production-related processes in four of its Berlin plants (dynamo, gas turbine, measuring device and switchgear plants). These assessments will be used to design a production control system that can create cost-optimised production plans for individual plants and control production or production-related processes with a total output of several megawatts.

Researchers first developed a detailed analysis of the relevant processes to meet all prerequisites for shifting consumers (loads) in industrial production plants. To identify the flexibility potential, it was necessary to determine certain key figures and assess the ability of the units to plan and shift loads.

Recording the flexibility potential

The details for determining the flexibility potential were established in direct discussions with those responsible for the various production processes. To structure the analysis, project participants distinguished production-related processes from direct production processes, creating the following subcategories:

Production-related electrical processes/building energy supply processes

- Electricity storage system
- Cooling systems
- Compressed air generation
- Emergency power generation
- Air conditioning

Electrical processes in production

- Available production storage
- Processes that can be ramped down
- Processes that can be ramped up
- Shiftable processes

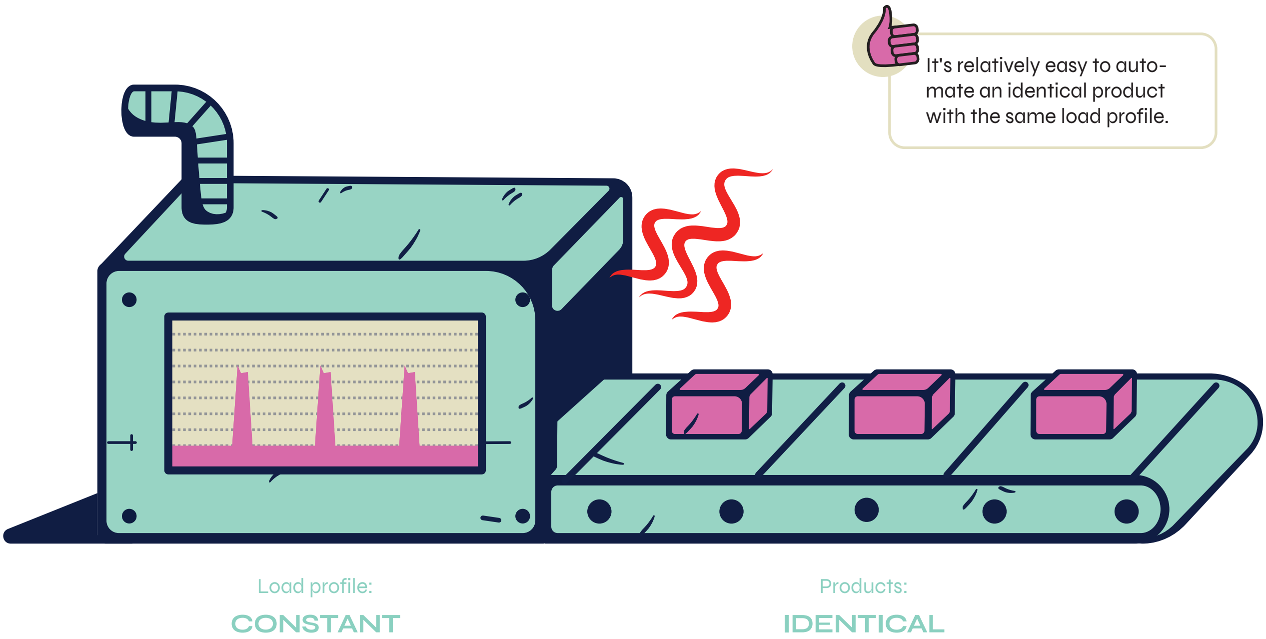
Additional factors were analysed for each subcategory. For example, the following factors were assessed for 'processes that can be ramped down':

- Is this process controlled in accordance with a production plan?
- Annual electricity demand?
- Maximum electrical output?
- Minimum power consumption when the process is ramped down?
- Typical electrical output?
- Preparation time required before output can be ramped down?
- Time required (from start to finish) for maximum ramp-down of output?
- Time required (from start to finish) for maximum ramp-up of output?
- Maximum interruption/ switch-on duration?
- Will the process be ramped back up after being ramped down?
- What would be the technical/economic consequences of a switch-off/switch-on with a ≤15-minute lead time?

The recorded factors for all processes with flexibility potential were then transferred to an Excel file for evaluation and summarised using an integrated evaluation matrix. This produced a flexibility indicator for each process, making it possible to compare the processes and determine the necessary automation. The electrical capacity, for example, only accounts for a percentage of the calculation; the realistic load-shifting potential is much more relevant to the assessment.

Based on capacity, available flexibility is distributed between the specific production areas in the Siemens plants that were included in the analysis.

Energy consumption of a furnace during a continuous combustion process



Process automation

For all of the processes examined, measuring devices were designed to record electrical parameters, with communication between devices made possible via the existing local area network (LAN). The IEC 61850 communication protocol was used to connect the devices to the central energy management system. This modern communication protocol offers significant advantages over serial commands between devices (e.g. Modbus): it reduces the communication load, enables time-stamped spontaneous data transmission based on defined threshold values in the device and provides multi-client communication capabilities. This allows several different systems to query data directly from the device. The protocol is also used to retrieve online measurement data from the WindNODE system, as well as data on energy quality in relation to the defined grid codes of the supply network and possibly a production planning system. In addition, a local command from the measuring device can influence the production process. For example, if the operator switches a firing process to 'wait for smart start' after the furnace is assembled, the device will start the process in accordance with the specifications of the energy management system, which are based on the feed-in from renewable sources or a predetermined schedule.

Energy management system

The installed energy management system was designed on the basis of the available standard software, Spectrum Power 5, in a cloud-based environment on Amazon Web Services (AWS). This offers the advantage of different communication channels for data acquisition, operation and flexible system performance.

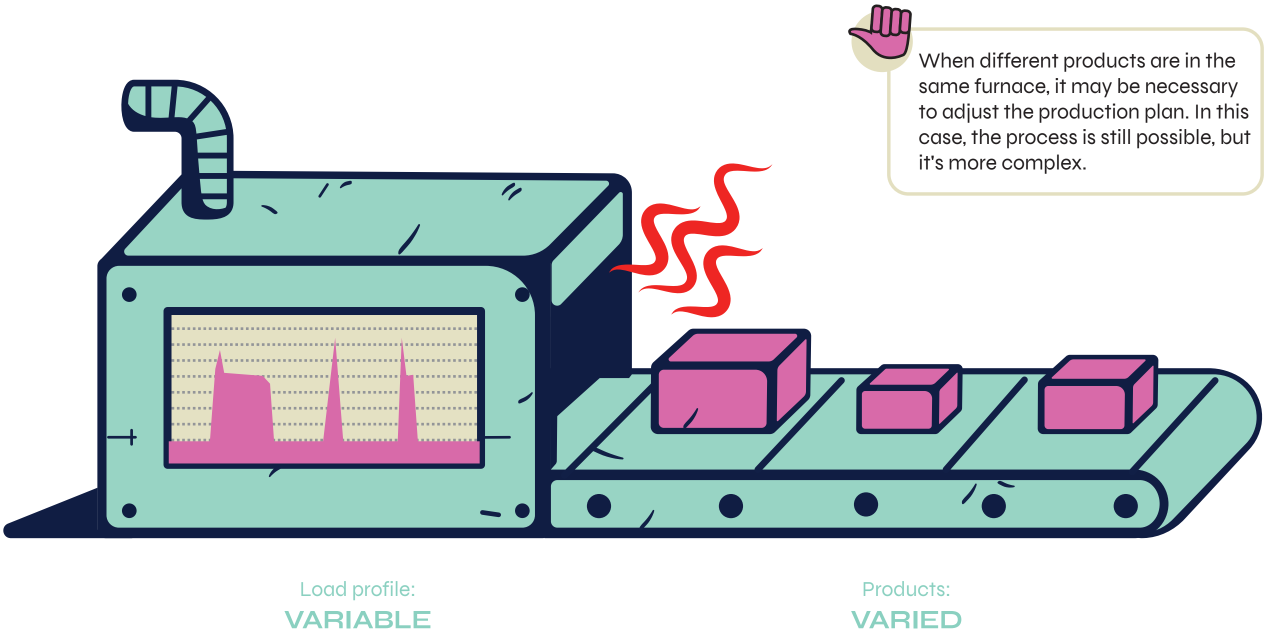
Data acquisition and analysis

The typical load profiles of the processes were determined during the initial evaluation of the operating data obtained from the connected processes. Possibilities included recurring profiles of 10 or more different load profiles depending on the products produced (for details on the data collection process, see 'Toolkit for identifying flexibility: checklist for flexible loads' on page 52).

Adjusting loads

Researchers defined four different 'types' of processes (levels) based on the knowledge gained from analysing production processes and the ability to control the timing of power consumption:

Energy consumption of a furnace during a variable combustion process



1. 'Fixed shiftable'
The fixed start time is shifted to a statistically favourable time.
2. 'Not plannable, but flexible'
An 'electricity price traffic light' is recommended (including a visual representation).

3. 'Plannable and manually controlled'
A schedule is calculated to determine the recommended start time.

4. 'Plannable and automated'
A schedule is calculated with 'closed-loop' control of the process.

Additional tasks in the WindNODE project

After the analysis of the specific load profiles is complete, the controllability of the processes must be coordinated with the individuals responsible for the production process. This is the most complex step in activating load-shifting potential. It requires providers to consider all constraints within the entire production chain and weigh the opportunity costs of shifting production against the financial benefits of doing so. For example, the analysis needs to incorporate the possible impact of a shift on other production processes as a 'secondary effect'. Thus far, analyses have suggested that shifting production-related processes is much easier than attempting to influence direct aggregates (loads) in a systematic production process.

One of the contributions that Siemens has made to WindNODE is the **ZUKUNFTSRAUM***ENERGIE* visitor site, which showcases the innovative solutions developed by Siemens in the course of the project. The 'Energy Tetris' scenario, for example, highlights the research methodology applied in the WindNODE subproject Intelligent Industrial Load Management, which focused on processes performed at the Siemens production site. Load profiles of real production processes can be shifted to begin at times with the highest potential feed-in from renewable sources and the lowest electricity prices. This calculation is based on time-series models that use real-time data on feed-in from wind turbines and PV systems, including the corresponding wholesale prices and grid fees. Our site is open to all members of the public who would like to take a closer look at our solutions and discuss their implementation with us. We look forward to your visit!

Plant managers must be on board

An important part of identifying flexibility in the industrial environment is getting the management and those responsible for the plant 'on board'. Of course, plant managers and employees won't necessarily break into applause if you propose another energy project. That's because plant managers' top priority is to avoid any interruptions in production, not to integrate renewables into the energy system as cost-effectively as possible. But as our example shows, it's possible to persuade those in charge of the plant to 'want' greater flexibility.

In our analysis at the dynamo, gas turbine, measuring and switchgear plants at the Siemens industrial site in Berlin, we initially encountered two major reservations about flexibility:
1. Spontaneous comments by the respondents: Flexible use is impossible because the plants in question are highly interdependent for the duration of the production process. The main priority is to keep the production process running without interruption.
2. What would be the financial incentive to align the process start times with the requirements of the energy management system?
A joint analysis of the operating conditions and electricity load profile showed that the introduction of flexibility had no significant effect on the overall process at most plants. This addressed the first concern. There are often unique aspects of industrial processes to consider when increasing flexibility, and it's important to recognise the kind of flexibility that a particular plant can provide. Specific applications can have processes ranging from 'fixed shiftable' (i.e. processes always begin at different times) to fully automated (e.g. the short-term power adjustment of ventilation systems). The use of previously untapped flexibility also makes it possible to implement simple concepts, such as avoidance of the 'most expensive' hours (e.g. when recharging e-vehicles) or targeted activation at the most affordable times.
Energy suppliers do not yet offer financial incentives to use flexibility as a standard part of the electricity price structure. However, some suppliers, like Next Kraftwerke, have deliberately made such incentives available. Our experience suggests that other suppliers may offer flexible rates on request.
Grid fees can be reduced by lowering the annual peak load at the feed-in point or in the price structure for 'atypical grid usage', which is not yet geared towards the current feed-in situation for wind power and PV.
We found that the installation of measuring technology and

an energy management system for detecting flexibility also had unanticipated benefits. For example, a setting for an air conditioning system proved to be suboptimal and could be corrected. System conditions could also be monitored. For example, rejection rates could be reduced in the production of a semiconductor component because the cause – a power quality problem – was found and eliminated. This kind of unexpected, positive 'by-product' of flexibility analysis is extremely helpful in creating acceptance among the people responsible for the plant. Suddenly, relevant parties develop an interest in 'taking a closer look'. For flexibility procedures to be viable in the long term, solutions must be highly automated and should not lead to significant cost increases. Plant managers should also benefit in some way from the savings obtained by utilising flexibility or through some other form of recognition.

Andreas Hüttner and Jörn Hartung
Siemens AG

Practical testing of flexibility options: optimisation and marketing

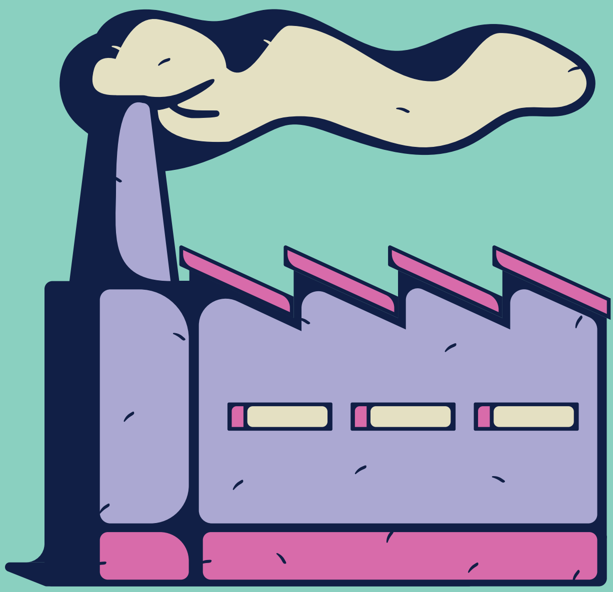
Different algorithms in the energy management system are used to optimise and request necessary load shifts. Forecast data can be imported into the system from any time series that has a lead time of up to seven days and is in 15-minute resolution. Various time series, such as prices on the European Energy Exchange (EEX), are used as data sources.

The optimisation target can be defined as maximum utilisation of the volatile renewable energy feed-in, compliance with grid withdrawal limits, compliance with peak load time windows for atypical grid usage (and, in the future, perhaps daily flexible time windows), or another reference time series from an energy supplier or BGM. Optimisation targets can also be combined.

Flexibility was marketed on a trial basis through energy sales to customers or through the integration of flexibility options into the pilot phase of the WindNODE flexibility platform.

Best practice 2

Industry



The ZIEL system developed by Fraunhofer IWU in cooperation with Deckel Maho Seebach

The testing environment

Deckel Maho Seebach GmbH (DMG), based in Thuringia, is the largest manufacturer of machine tools in the five 'new federal states' re-established after Germany's reunification. At the Seebach site, roughly 800 employees manufacture and continuously advance integrated technological solutions. Output is around 1,500 machines per year. DMG specialises in building outstanding machine tools and in networking, automating and digitalising these tools to create entirely new forms of production. The 'integrated digitalisation and automation solutions' made in Seebach enable machines and accessories to be fully networked at all stages, from planning and work preparation to production, monitoring and service.

Production at DMG is characterised not only by product-related innovation, but also by a willingness to lead the way on energy efficiency and fulfil the company's social responsibility. In this respect, DMG can serve as a representative case study of a typical discrete manufacturing process. Transparency about the requirements of manufacturing equipment and peripheral components is essential in order to identify flexibility in the production environment. DMG views the production process – which largely involves machines from its own product portfolio – as a testbed for the continuous development of the machines it offers. This enables it to respond to advancements in digitalisation on an ongoing basis. Thanks to these efforts, DMG has access to a versatile infrastructure that allows it to collect energy-related data.

Recording the flexibility potential and automating processes

In the WindNODE project, mechanical production processes at the Seebach site were equipped with stationary energy measuring technology, enabling the power and energy requirements of the machines to be recorded and monitored. Measuring points were installed on 22 different machines in the production area. The power input to the machines ranges from approximately 30–100 kW. All power and energy data were recorded over several weeks. The collected data are available on the state-of-the-art control software CELOS and are linked to the company's own Adamos IoT platform. This makes it possible to correlate energy data with process and production data, which helps determine the energy requirements of individual production steps and related operating conditions.

In cooperation with the Fraunhofer Institute for Machine Tools and Forming Technology (IWU), DMG is testing new methods for energy-efficient production planning and production control at the site. The goal is to develop a transferable and scalable industrial solution to synchronise energy (price) bids and industrial loads: the 'ZIEL' system for intelligent energy and load management. The system enables the targeted shifting of energy-intensive production orders and provides active control and regulation of decentralised energy infrastructure.

Energy management system, optimisation and marketing

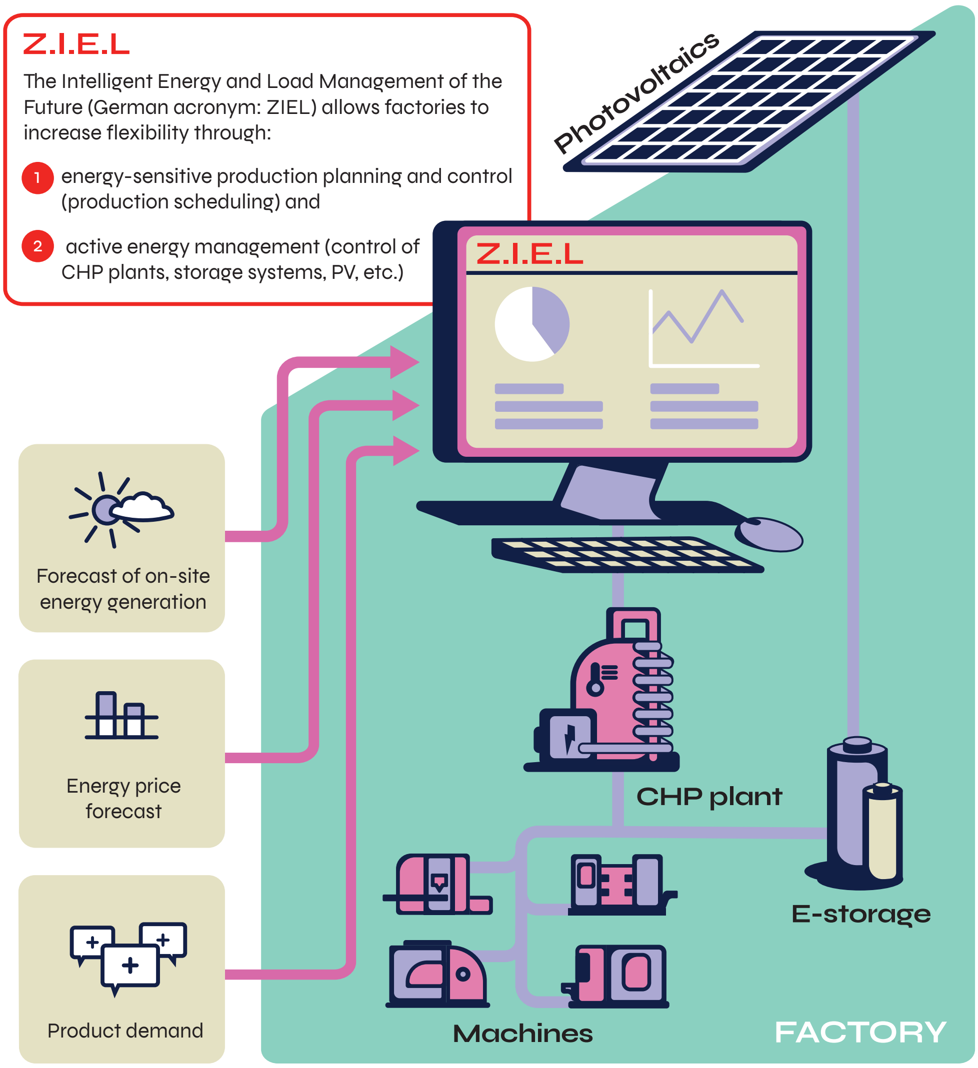
Energy-efficient production planning combines input values from various structures. This makes it possible to forecast the potential for on-site renewable energy generation (which is generally not controllable) and incorporate the price development for externally procured energy. A 'logic module' is used to develop a scenario linked to a target, which is formalised in an 'objective function' (e.g. energy demand below or above a limit value) in the subsequent optimisation process. Logistical criteria are used to organise order-specific energy blocks (demand) and optimise them based on the target defined for the scenario. The resulting order is then issued in the form of a production schedule. This process specifies a chronological sequence of production steps, which is simulated with a detailed power curve so that additional infrastructure controls can align the generating capacity with the objective function. If it proves impossible to avoid unacceptable 'violations' of the objective function, the schedule must be revised; otherwise, this is the production plan used in the simulation of factory operations. The simulation exposes the planned production process to stochastic disruptions and introduces a random deviation from the forecast values to ensure that the robustness and the production plan can be assessed under realistic conditions.

The logic module and the infrastructure simulation are implemented in MATLAB® and Simulink®. Actual optimisation is conducted in Python, and the production process is run using Siemens Tecnomatix Plant Simulation. A framework that uses a graphical specification language for describing business processes and workflows (BPMN) integrates the individual modules and corresponding tools into the target system, which is based on the open-source software JBoss jBPM.

In addition to analysing the role of flexibility in organising production processes, the project investigated the implementation of machine-level energy storage systems. The accuracy of the energy data collected made it possible to draw conclusions about the potential use of energy storage systems in mechanical production. Most of the machine tools cause highly dynamic, technology-related load peaks due to the acceleration and braking of the drives. This results in costly peak loads, which can be counteracted by implementing a stationary battery storage system at the sub-distribution level. The energy storage system is also designed for use by multiple parties for marketing or grid services. This feature can be enabled in the future. Thanks to the DMG case study and the ZIEL system, it's already possible to model a sustainable production method at a discrete manufacturing company.

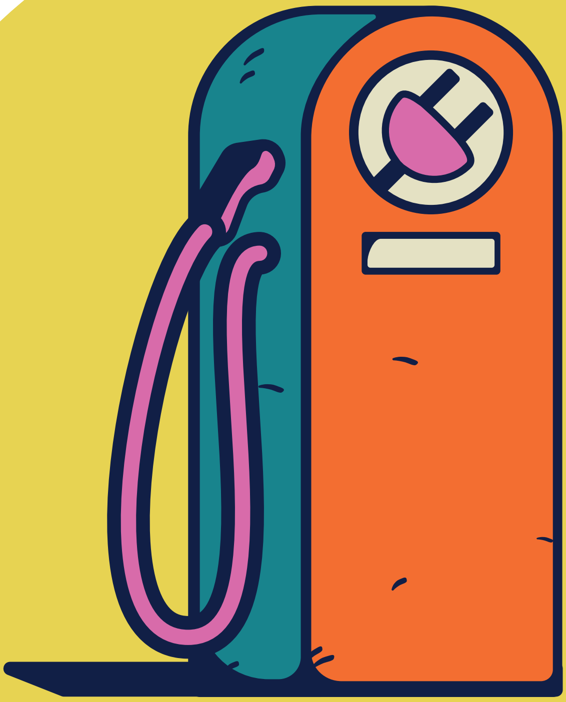
Flexible factory

The factory of the future is a smart grid



Best practice

Mobility



Intelligent vehicle charging at Berliner Stadtreinigung (BSR)

The testing environment

Berliner Stadtreinigung (BSR), Berlin's municipal waste company, currently operates an intelligent charging infrastructure for electric vehicles at seven of its properties. It has plans to expand the infrastructure, which today services 92 cars and 17 vans. In this project, WindNODE investigated whether charging infrastructure and electric vehicle charging can be controlled in such a way that vehicles integrated into the power grid provide benefits to the grid, the market and the system. This would make it possible to control the charging time and capacity in the future to smooth out peaks from high electricity demand. It would also allow surplus electricity to be used in productive ways. In total, the maximum charging capacity currently installed at all BSR locations is 86 x 22 kW = 1,892 MW.

Organisational framework

The electric vehicles in BSR's fleet are mainly used in shift work. This means that they are usually parked at charging stations within a definite time window and must be fully charged again at a precise, predetermined time. While the vehicle is idle, however, the charging process can be used as a flexible load – provided that it is ready to drive when the next shift begins.

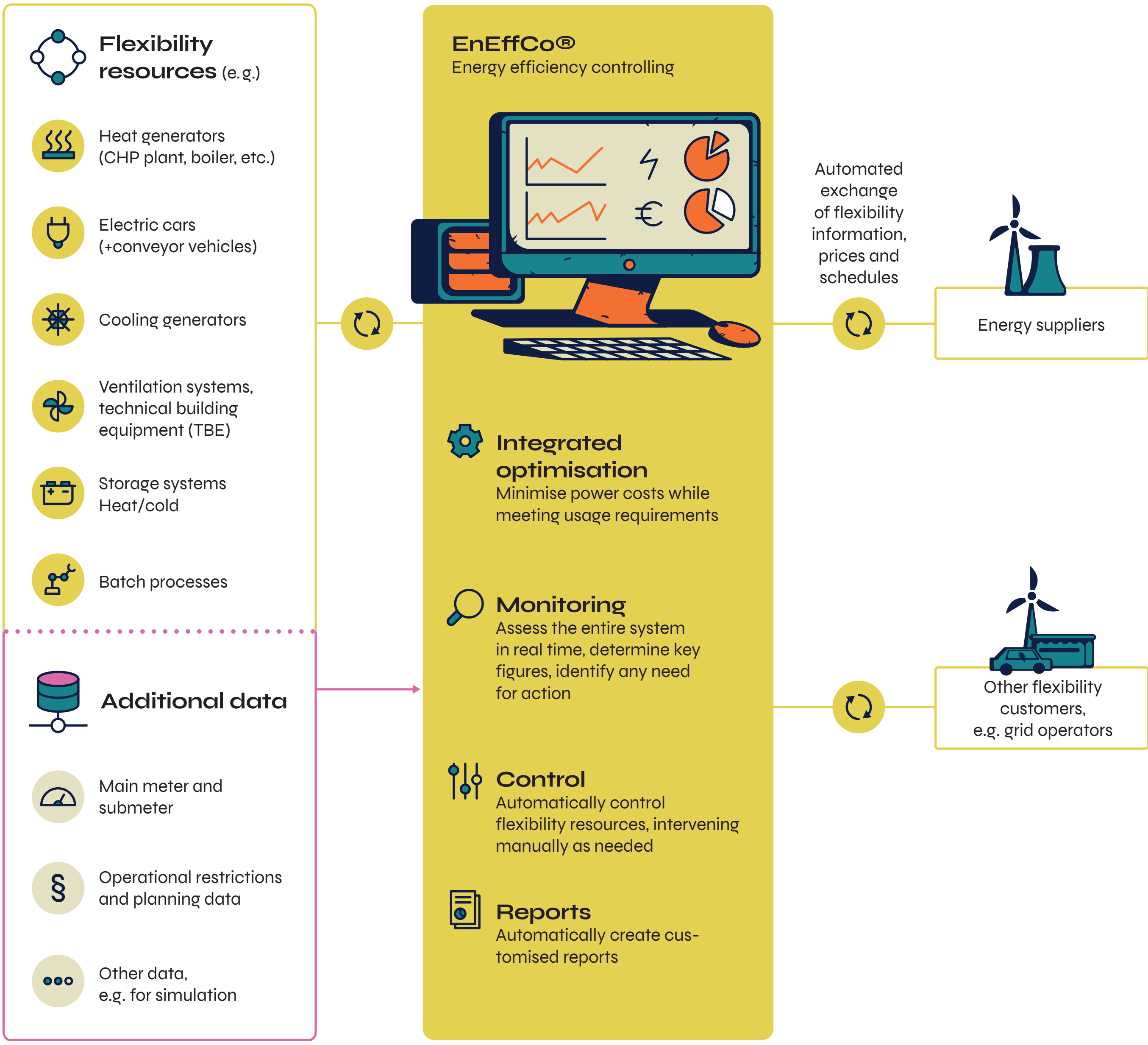
Each vehicle is also assigned a unique identifier that is recorded each time it is connected to the charging infrastructure.

Existing technology

The installed charging infrastructure was manufactured by Mennekes and supports the OCPP-1.5 Protocol. This protocol enables a downstream software application (backend) to detect the arrival of vehicles, charging capacity, charging time, the end of the charging process and other factors relevant to the charging session. As a transitional measure, BSR analyses data using the simple features available via the web interface supplied with the charging infrastructure. No other control technology or dedicated backend is available at BSR. The company records energy data in 15-minute intervals – from the main meter at each property and from each submeter in the charging infrastructure.

EnEffCo® for integrated optimisation

of the BSR fleet and other resources



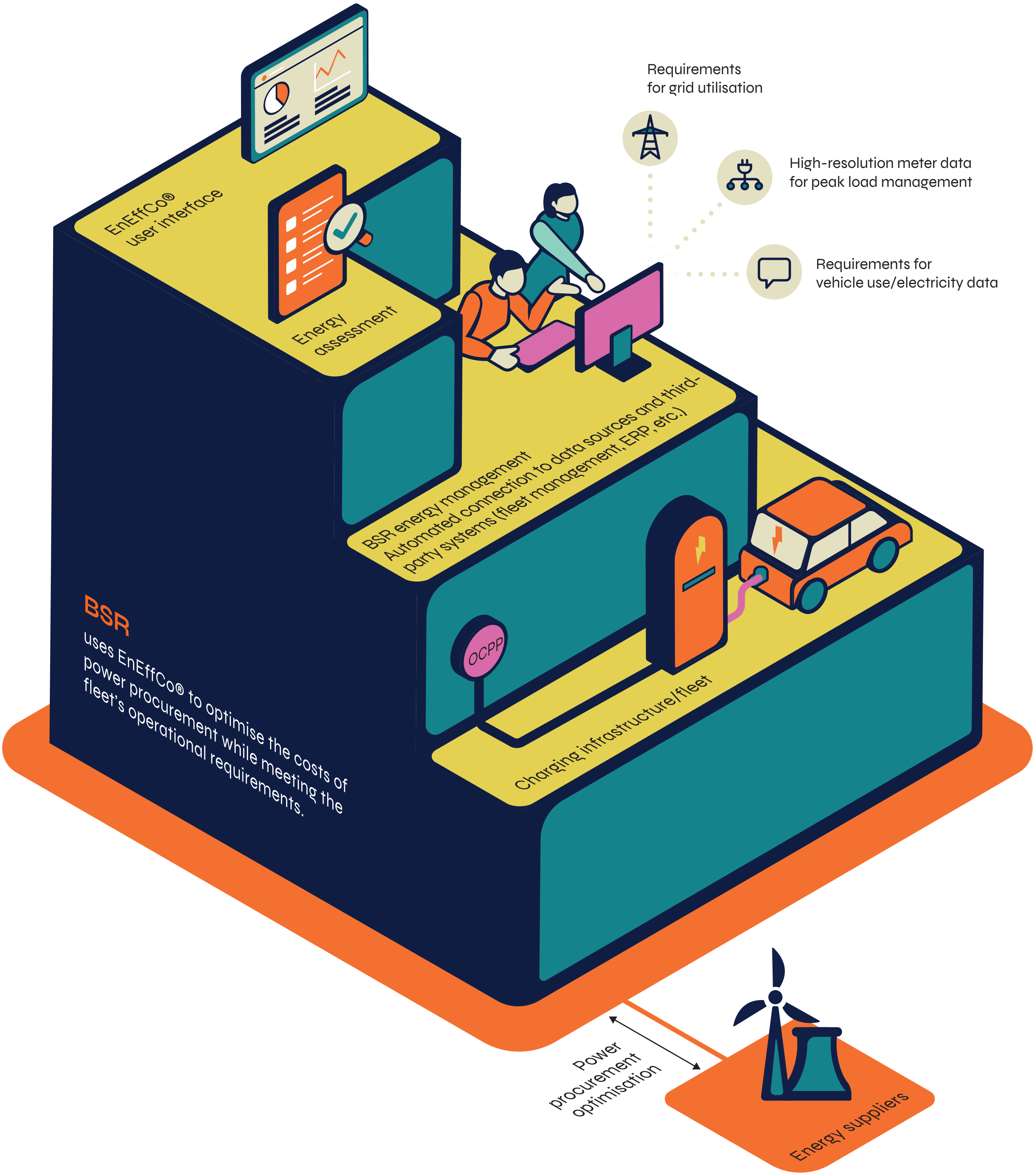
Potential for flexibilisation and necessary technical adjustments

In the project, BSR collaborated with WindNODE partner ÖKOTEC to examine and evaluate the potential of flexible vehicle charging from an energy industry perspective. Their research yielded important insight, such as:

- Integration into the balancing power market does not appear to be an attractive option because of the price level and the time slices required.
- An examination of optimisation potential on the spot markets for electricity (day-ahead and intraday) revealed opportunities to save up to 70%: charging vehicles during the hours or quarter-hours when electricity is cheapest can significantly reduce costs.
- For BSR, the use of flexible vehicle charging for peak load management is a reasonable approach to avoid unfavourable grid conditions.
- Participation in the flexibility platform created by 50Hertz and participating DSOs seems interesting, but opportunities to generate revenue could not yet be simulated due to a lack of empirical values.

Flexibility management at BSR

How the fleet can be fully utilised and still reduce costs



BSR assessed flexibility potential using the flexibility management features of the EnEffCo® energy management software, which was developed by ÖKOTEC. It also used EnEffCo® for the advance development of integrated flexibility optimisation, including the connection to charging infrastructure.

In order to manage peak loads effectively while minimising grid fees at the site, it was necessary to collect and centralise data from the medium-voltage main meter at a high temporal resolution. Because the previous meter only recorded data at 15-minute intervals, BSR is installing technology that can collect data more frequently and provide the metered values. It continues to use the existing interface infrastructure in parallel.

Practical testing of flexibility options with WindNODE partners

BSR is collaborating with ÖKOTEC to test the following three flexibility options at WindNODE pilot locations:

- Supply optimisation on the day-ahead and intraday markets. The Energiewirtschaftsstelle, Berlin's energy management unit, added an 'escape clause' to the tender for the city's electricity supply. This allows customers to have separately designated submeters supplied by third parties.
- Dynamic load management at the location.
- Use of the 50Hertz flexibility platform (planned).

The technical requirements on-site are the most important factor in load management. Still, suppliers need to be involved to optimise procurement. This will require the creation of appropriate contract models. Use of the flexibility platform is also dependent on availability.

One of the outcomes of the WindNODE project is a continued collaboration between BSR and ÖKOTEC. The goal is to introduce the pilot project at five other BSR locations and refine these measures for application in other areas.

Best practice

Neighbourhoods

Intelligent energy management in Prenzlauer Berg, Berlin

The experimental neighbourhood in Prenzlauer Berg

Because the building sector is responsible for roughly one-third of final energy consumption in Germany, it plays an important role in the energy transition. As part of the WindNODE project, the Borderstep Institute is cooperating with the Berliner Energieagentur, the Distributed Artificial Intelligence Laboratory (DAI) at the TU Berlin, Dr. Riedel Automatisierungstechnik GmbH and Wohnungsbaugenossenschaft Zentrum eG to test the potential for residential buildings and neighbourhoods to provide flexibility.

WindNODE research in this area explores whether and how residential neighbourhoods can act as flexible resources that facilitate the integration of fluctuating renewable energy into the energy supply. To do so, residential neighbourhoods would need to provide flexibility that benefits the grid by drawing more energy from the grid when the electricity load is high and feeding more energy into the grid when the electricity load is low.

Using a model neighbourhood in Berlin-Prenzlauer Berg as a test case, WindNODE partners are evaluating the amount of flexibility that buildings can provide and the technical and economic conditions required to mobilise it. Practical tests conducted in a local housing cooperative, Berliner Wohnungsbaugenossenschaft Zentrum eG, assess the potential for flexible behaviour to support the grid. The cooperative consists of six residential buildings, including a total of 224 flats. The buildings were partially renovated in the 1990s with the addition of mineral wool insulation in the façade and roof. In 2015, they were connected to a local heating network, and the individual heating units used to supply heat were replaced with a central heating system. The new system provides heating from a CHP plant (34 kW_{el}/78 kW_{t}), which can modulate output to maintain the baseload heat supply while producing electricity to cover the neighbourhood's own needs. Four additional peak load boilers with a total capacity of 520 kW_{t} ensure that the heat supply is sufficient to meet demand in the winter, when loads are higher. Substations were installed to supply heating and hot water to the individual buildings.

Power Save

How neighbourhoods can respond to grid fluctuations – and save energy in the process

1 Grid fluctuations

The supply of renewable energy (e.g. wind power) is volatile. Residential areas can respond to fluctuations by acting in ways that benefit the grid.

2 Neighbourhood manager

The neighbourhood manager is a control system that optimises the generation and consumption of energy (heat and electricity) in the neighbourhood. This reduces operating costs and lowers emissions.

3 CHP plant

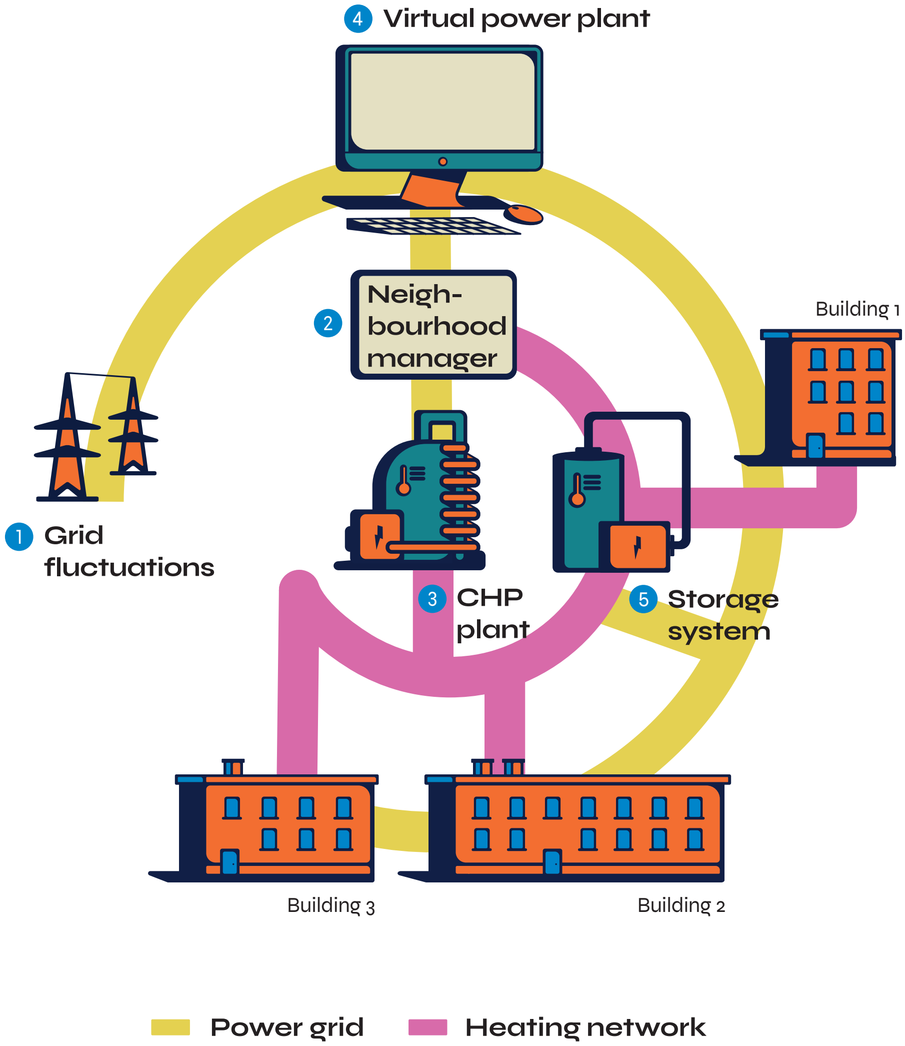
The CHP plant utilises gas in the neighbourhood to produce heat and electricity for residents. Surplus electricity is fed into the grid and can compensate for fluctuations.

4 Virtual power plant

A virtual power plant (VPP) combines smaller power plants (e.g. CHP plants) to form larger units. The capacity of the networked units can be offered on the energy market.

5 Storage system

In the hot water storage system, surplus wind power is used to produce heating and hot water for households. This reduces the use of fossil fuels.

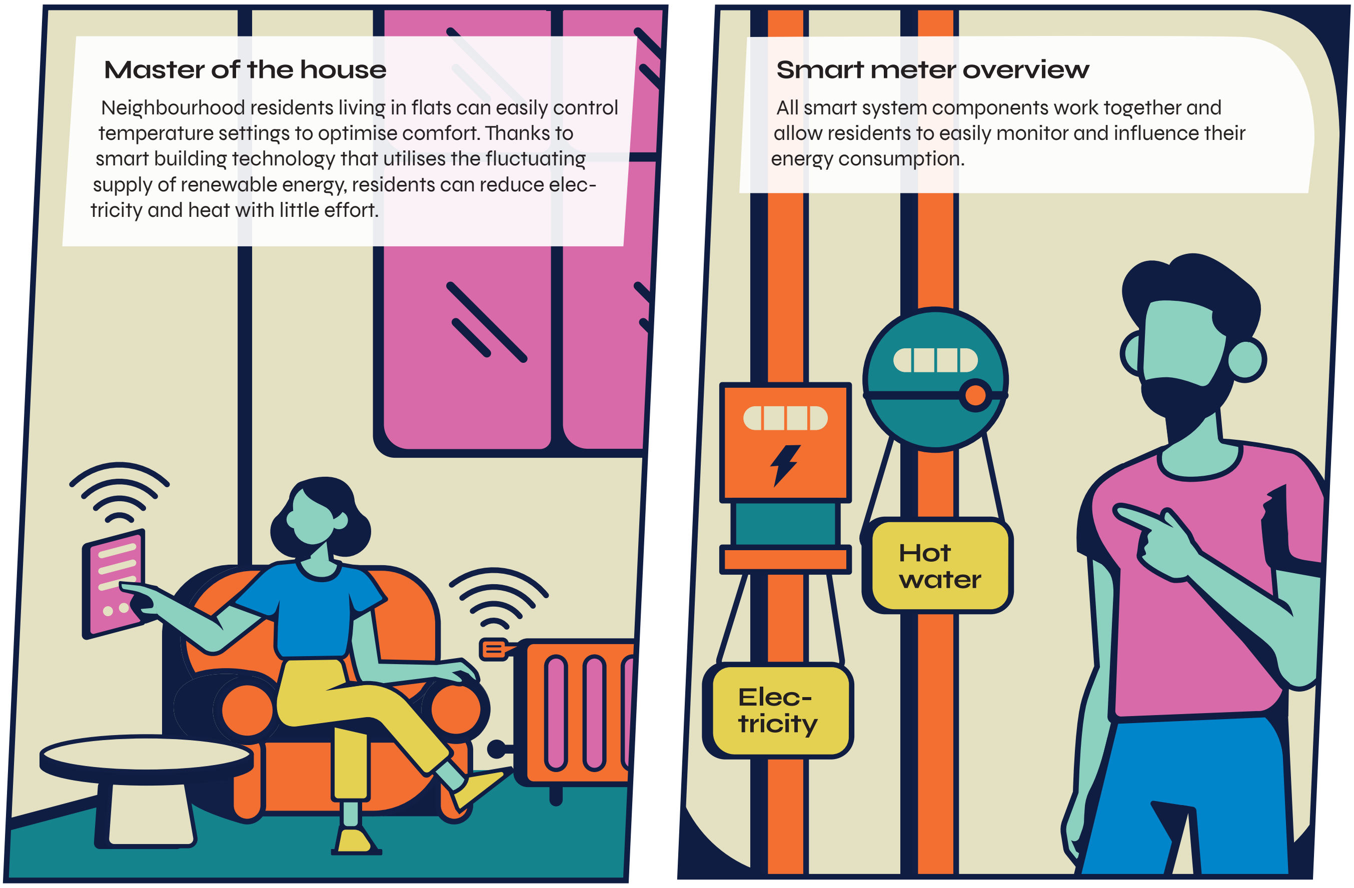


Distributed energy management and smart building technology

In 2015, the structures were also equipped with smart building technology, which makes it possible to manage distributed energy resources. The management system continuously adjusts the capacity of the generating units in the neighbourhood (CHP plant and peak load boilers) to residents' energy requirements (heat and electricity). The smart building technology in the neighbourhood operates at three levels:

- Flat: A flat manager is used to specify a desired setpoint temperature for individual rooms within flats. The device is networked with in-home sensors and actuators and regulates the room temperatures in accordance with settings selected by the occupants. The flat manager serves as the interface to the building control system (building manager). It can offer residents additional home networking services (e.g. notifications from the property management company, heating bills, assistive systems).
- Building: The building manager aggregates data from individual flats and controls the central heating and hot water supply according to the needs of building residents. Weather forecasts and building physics parameters are also integrated into the control system. This reduces the amount of energy consumed for heating by roughly 25%.
- Neighbourhood: The neighbourhood manager is responsible for energy optimisation in all buildings in the network. It optimises control of the entire heating system, which supplies the neighbourhood with heat and electricity (landlord-to-tenant electricity). The aim is to maximise the portion of total energy (heat and electricity) supplied to tenants from decentralised production in the CHP plant while maintaining efficiency, lowering emissions and reducing utility costs.

Power to end users



The neighbourhood's flexibility potential is evaluated based on the combination of CHP units, storage options and smart building technology. Because distributed energy management can provide accurate forecasts of neighbourhood energy requirements, it offers very precise estimates of the capacities available for flexibilisation.

Flexibility potential in the neighbourhood

This WindNODE project investigates the neighbourhood's distributed energy management system to analyse and expand flexibility potential in residential areas. This process requires the utilisation of existing potential and the installation of additional units to increase the capacities that can be mobilised. Existing flexibility potential in the neighbourhood includes:

- the CHP unit (34 kW_{el}/78 kW_{t}), which can be continuously adjusted to modulate output within the specified range;
- the building mass of the neighbourhood or of its six buildings, which can be used for thermal storage as materials heat and cool; and
- the entire local heating network (including pipes and buffer storage tanks), which can be used as a temporary storage system.

In the WindNODE project, electric heating elements (PtH elements) of 8 kW each were also installed in the six existing hot water buffer storage tanks. These can now be used as a flexibility reserve to generate hot water precisely when surplus green electricity is available.

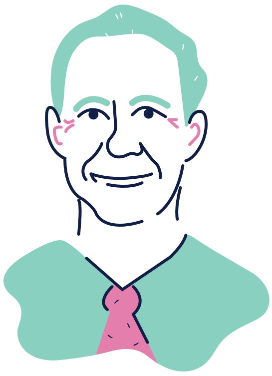
The distributed energy management system has also been expanded to include functions that not only optimise processes in the area, but also provide control that benefits the grid. The neighbourhood can be used for both positive load management (feed-in of CHP electricity when load is low) and negative load management (conversion of surplus electricity from renewable energy into heat).

Practical testing of flexibility options with WindNODE partners

Project participants worked with WindNODE partners to test two flexibility options in the experimental neighbourhood in Prenzlauer Berg. These options were:

- 'provision of flexibility for grid congestion management (via the WindNODE flexibility platform)' in collaboration with project partner 50Hertz and cooperating distribution grid operators; and
- 'marketing of flexibility on the power exchange via a VPP' in cooperation with project partner Energy2Market. As a VPP operator, Energy2Market was responsible for marketing flexibility supplied by the neighbourhood.

In both tests, the flexibility available in the neighbourhood was offered during specific test periods and under market conditions. The knowledge gained was used to draw conclusions about the flexibility potential available in the building sector and the requirements for its activation.



Good communication with tenants is crucial

Energy-saving measures in residential neighbourhoods are especially sensitive topics. That's because, when it comes to their own flats, people aren't only worried about climate change. They're also concerned about rising utility prices ('second rent') and modernisation costs – or they may just be apprehensive about changing the structure of their homes. This makes clear communication the most crucial aspect of mobilising flexibility in residential buildings and neighbourhoods. Of course, the housing company must be motivated to try something new, but it's difficult to implement the required changes without the willingness of the residents themselves. In the experimental neighbourhood, the tenants were involved in the decision about the renovation process and the implementation of the energy management system, and they approved the plans. Although this process makes planning and implementation more time-consuming, it ensures that residents will support and participate in the measures. It's important to explain exactly how tenants can benefit from the technology (e.g. stable utility costs) – and to take their concerns seriously.

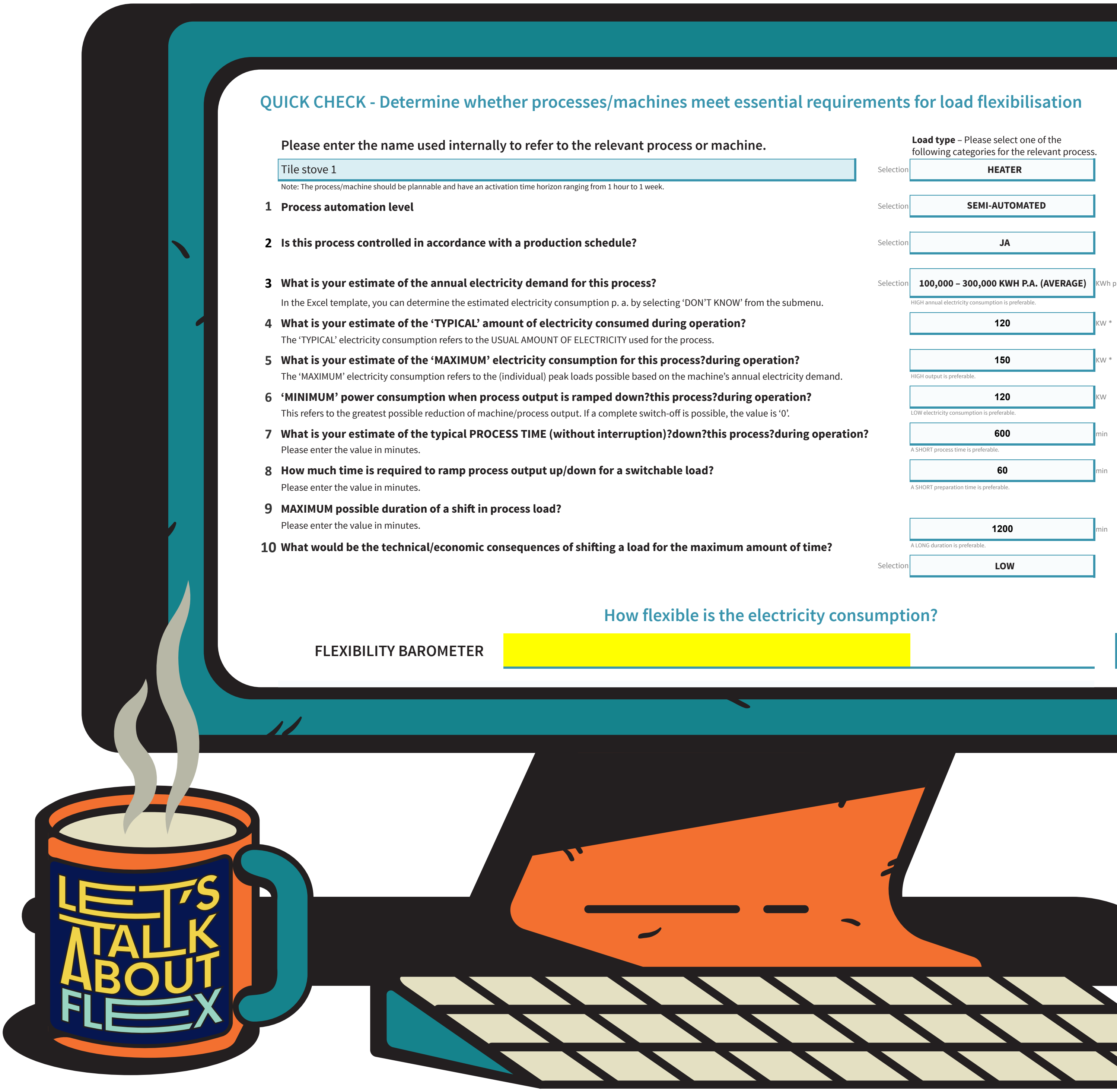
Project implementation was subject to one condition: at least 75% of the residents had to agree to the measure before the process could proceed. Our information sessions, mailings and on-site contacts (facility managers and technical building managers) provided extensive information – not just about the project and its benefits, but also about possible disruptions during the construction phase. This approach allowed us to meet our ambitious threshold of 75% approval. Even we were surprised to find such a high level of support for the project!

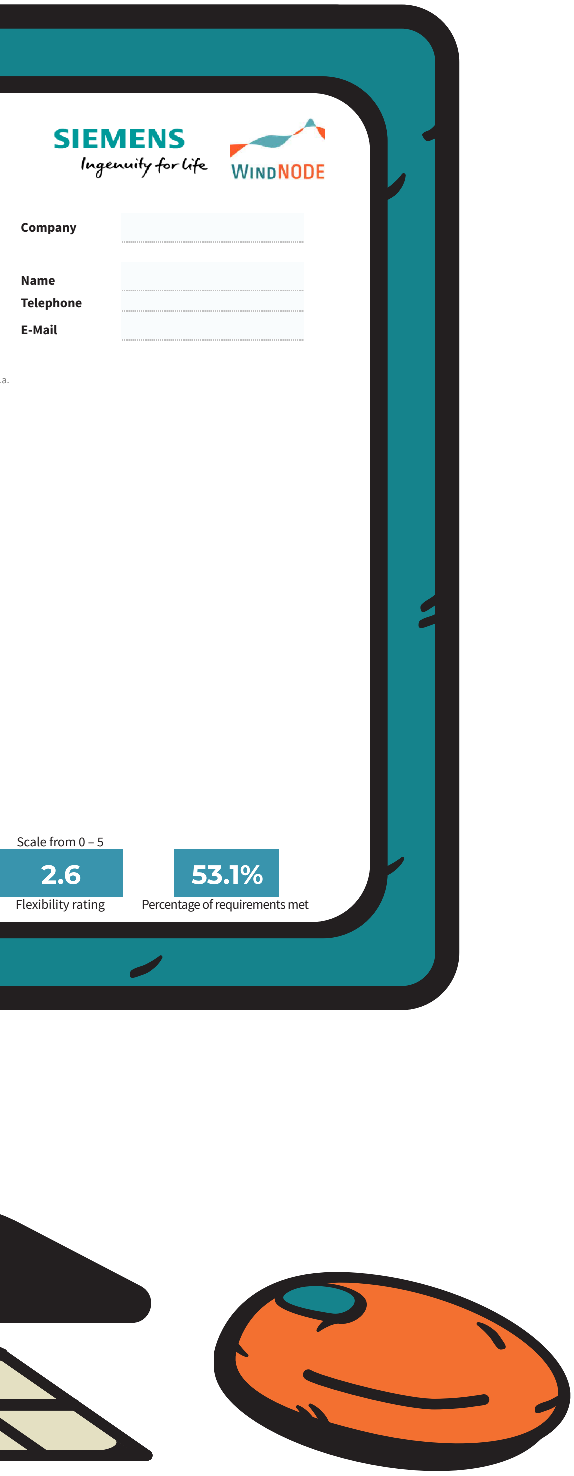
In my experience, many people are interested in making their energy supply environmentally friendly and in ensuring that it's used efficiently. Such measures should not compromise comfort; in fact, they can even improve it through intelligent technology. There are often good ways to implement flexibility, such as by integrating PtH systems into smart building technology. In the future, there will also be a seamless integration of electromobility and charging infrastructures into such systems. This process would be easier, however, if the legal framework were less complicated (e.g. for the landlord-to-tenant electricity supply model or self-supply systems) and if there were more economic incentives.

Dr Severin Beucker
Borderstep Institute

Toolkit for identifying flexibility

Checklist for flexible loads





Aside from basic economic and environmental considerations, identifying flexibility requires providers to record and evaluate objective and subjective parameters (e.g. machine, deposit, storage). The checklist depicted here summarises the most important factors for the load side.

Working through the checklist allows providers to compare existing flexibility options. It also provides a basis for decisions about whether a load can be mobilised and what level of investment (e.g. in automation) or organisational effort is necessary to activate it. When flexibility is evaluated, performance value is not the only relevant factor; activation of potential is equally dependent on organisational factors and processes. For an initial analysis of flexibility potential, however, it's important to apply relatively simple evaluation criteria that can be assessed quickly. The scientific literature hasn't yet specified a standard procedure for doing so.

Considering the wide variety of users, it's doubtful that any such procedure can exist. Providers should ensure that the evaluation process they use will allow them to compare existing loads and processes at a single site.

The approach presented here uses an Excel matrix ('Quick Check') to record evaluation criteria.[8] Internal calculations and standard measurement criteria determine a flexibility ratio and a degree of fulfilment. The factors included in the checklist were chosen based on roughly 100 evaluations in the industrial production environment (for more information on the process at Siemens, see 'Intelligent industrial load management', p. 33). Certain input fields for relevant parameters can be selected from dropdown menus. The remaining information can be easily identified by the individuals responsible for the plant and may be indicated on unit nameplates. Providers can then calculate and compare flexibility ratios for relevant loads in order to determine the next steps.

[8] The Quick Check described here is the product of collaboration between Siemens and the initiative 'Meine Energie für meine Stadt c/o Vereinigung Deutscher Wissenschaftler e.V.' as part of the WindNODE project. It is available online at http://mems.berlin/quick-check.

Communicating about flexibility

How can I be sure that increasing flexibility won't negatively affect clients and their purchasing behaviour/production processes and product quality/ad-hoc vehicle operation/tenants and the comfort of their living space?

One of the most challenging aspects of identifying flexibility options and increasing system flexibility is persuading decision-makers to take the necessary steps. Good preparation is key to effective communication with target groups.

Clarify the initial situation: answer questions before the interview

Before making an appointment, prepare for the conversation. Collect all relevant information and learn as much as you can about your conversation partner.

Available information may indicate how likely your partner will be to identify and use flexibility. Do you already know which (energy-intensive) technologies or machine/plant equipment is used in facility operation? How attuned are plant operators to energy-related issues? Is the plant operator's level of engagement with relevant topics evident from public sources (e.g. press, internet) – for example, through a reference to ISO 50001 on the plant website? Who supplies the plant operator with energy? Is the on-site energy supplier or grid operator interested in flexibility? This list of questions can be expanded on a case-by-case basis. Assessing these or similar factors in advance allows you to understand current conditions before the conversation begins and provides important information you can use to develop compelling arguments. Preparatory work will also make you seem more knowledgeable about the technologies, processes, machines, plants and energy-related issues relevant to the specific case.

Identify the problem: anticipate risks and reservations and prepare arguments to counter them

Though it may sound cliché, the key to success is identifying the right contacts and anticipating their questions or reservations about flexibility. This allows you to respond to specific concerns and present

If I increase flexibility, will I also need to provide costly employee trainings?

Won't the technology for sensors and actuators immediately become obsolete?

How does this benefit me or my company?

Am I eligible for a subsidy?

Will all this effort pay off?

convincing arguments later, during the most important part of the discussion. Tailor the argument to your audience: it makes a difference whether you'll discuss these issues with the branch manager of a supermarket, the plant manager of a small or medium-sized enterprise (SME) or a DAX-listed corporation, the representatives of a housing cooperative or the manager of a vehicle fleet. Before the meeting, try to tease out the specific concerns that your conversation partner may have about system flexibility, and then develop solid arguments to counter them.

An individualised list of frequently asked questions (FAQs) can be an important reference or starting point for follow-up discussions after the initial meeting.

Present the solution: clearly identify economic and environmental potential

It's important to identify the economic and environmental potential of increased flexibility as clearly as possible, regardless of the details of the specific case. You can explain that flexibility doesn't just introduce new marketing opportunities; it can also increase efficiency as a secondary effect. Citing successful examples or reference projects from the same or similar fields may be helpful. Depending on your discussion partner, you can also refer to the economic and/or environmental success of competitors who have already improved their position by marketing flexibility options – and competitors who have built a positive brand reputation by highlighting their use of flexibility in public relations campaigns. Last but not least, intensive engagement with the topic can increase plant operators' expertise in flexibility, a subject that will prove increasingly important in the near future.

Outlook

It's safe to assume that the supply of flexibility in Germany already significantly outstrips the demand.[9] Examples of flexibility options presented in this best practice manual introduce four possible use cases from the tertiary sector, industry, mobility and neighbourhoods. A closer look at these areas, and at individual industries, uncovers vast potential in a range of fields. The graphic above shows only a small sample.

The successful identification of flexibility is an important first step, but existing flexibility potential must also be usable in practice. If flexibility isn't integrated effectively into the overall system, it can play only a limited role in reducing the burden on the system – or in mitigating the effects of climate change.

Given the urgent challenges that lie ahead, it's important to take the second step as soon as possible. A results-oriented analysis is necessary to determine which modifications to the regulatory framework would be most conducive to harnessing flexibility potential in Germany. The implementation of incentives that are market-oriented, non-discriminatory and not technology-specific will be one of the central political and regulatory challenges in the second phase of the energy transition.[10]

Approaches to an expanded use of flexibility options are already visible – not only in the current political/regulatory debate, but also in the creation of specific standards, as in the NABEG amendment (2019) and the 'Clean energy for all Europeans' package (2019). These developments leave little doubt that the question is no longer 'whether' flexibility will be used, but 'how'.

In light of these developments – and the clear direction of our energy system – it has never been more important for plant operators to take the first step and identify flexibility options. We wish you great success in this process.

[9] For estimates of the generation and load-side flexibility potential for the WindNODE region (consisting of the 50Hertz control area, excluding Hamburg), see 'Flexibility, markets and regulation: insights from the WindNODE reality lab', which was published in 2021.
[10] Concrete proposals for a gradual development of the regulatory framework for the use of flexibility are included in the 'Flexibility, markets and regulation: insights from the WindNODE reality lab', which was published in 2021.


Services
Consumer goods
Chemical industry
Mobility
Public transport
Neighbour-
hoods
Controllable
loads

Abbreviations and acronyms

aFRR	Automatic frequency restoration reserve
AWS	Amazon Web Services
BDEW	German Association of Energy and Water Industries
BGM	Balance group manager
BPMN	Business Process Model and Notation
BRP	Balance responsible party
CHP	Combined heat and power
DSI	Demand-side integration
DSO	Distribution system operator
EEG	Erneuerbare-Energien-Gesetz (German Renewable Energy Sources Act)
EEX	European Energy Exchange
EisMan	Feed-in management
EinsMan	Feed-in management
EnWG	Energiewirtschaftsgesetz (German Energy Industry Act)
EPEX	European Power Exchange
ERP	Enterprise resource planning
ETG	Energietechnische Gesellschaft within the VDE
FCR	Frequency containment reserve
IGCC	International Grid Control Cooperation
IoT	Internet of Things
kW	Kilowatt
kW_{el}	Kilowatt-electric
kWh	Kilowatt-hour
KWKG	Kraft-Wärme-Kopplungsgesetz (German Combined Heat and Power Act)
kW_t	Kilowatt-thermal
LAN	Local area network
mFRR	Manual frequency restoration reserve
MW	Megawatt
MWh	Megawatt-hour
NABEG	Netzausbaubeschleunigungsgesetz (Grid Expansion Acceleration Act)
NEP	Grid development plan
OCPP	Open Charge Point Protocol
PtH	Power-to-heat
PV	Photovoltaics
SNL	Quickly interruptible loads
SOL	Immediately interruptible loads
TBE	Technical building equipment
TSO	Transmission system operator
TWh	Terawatt-hour
VDE	Verband der Elektrotechnik Elektronik Informationstechnik
VPP	Virtual power plant
ZSW	Centre for Solar Energy and Hydrogen Research Baden-Württemberg

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Publication details

About WindNODE

The WindNODE project is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) through the Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG) programme. The project operates in the six federal states of northeastern Germany, including Berlin, and is sponsored by the heads of government of the participating states. WindNODE is a joint initiative of over 70 partners, who have worked together over a four-year period (2017–2020) to develop transferable model solutions for the intelligent energy system of the future. Collaboration between WindNODE partners demonstrates the potential for networks of flexible energy users to adjust electricity consumption in response to natural fluctuations in renewable generation from wind and solar power plants. The goal is to integrate large amounts of renewable electricity into the energy system while maintaining grid stability.
For more information:
www.windnode.de/en

About SINTEG

The Federal Ministry for Economic Affairs and Energy (BMWi) launched the Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG) funding programme to research and develop technologies for the energy supply of the future. SINTEG supports initiatives that develop and demonstrate sustainable model solutions for a secure, economical and environmentally sustainable energy supply able to accommodate fluctuating power generation from renewable energy. Promising solutions from the model regions can provide blueprints for broad implementation throughout Germany and beyond. As part of the project, partners from the energy industry and the information and communications sector are collaborating to develop innovative approaches in the five showcase regions. Since 2017, more than 300 companies, research institutions, municipalities, districts and federal states have worked together to realise their vision for the energy transition.
For more information:
www.sinteg.de

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

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WindNODE-Verbundkoordination
c/o 50Hertz Transmission GmbH
Project Director: Markus Graebig (V.i.S.d.P.)
Heidestrasse 2
10557 Berlin

T +49 30 5150 2805
F +49 30 5150 2877
info@windnode.de
www.windnode.de

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50Hertz Transmission GmbH
Heidestrasse 2
10557 Berlin

T +49 30 5150 0
F +49 30 5150 2199

info@50hertz.com
www.50hertz.com

Chair of the Supervisory Board
Christiaan Peeters

Managing Directors
Stefan Kapferer (Chair), Dr Dirk Biermann,
Sylvia Borcherding, Dr Frank Golletz, Marco Nix

Registered office
Berlin

Commercial register
Charlottenburg District Court, HRB 84446

Contributing authors

Dr Severin Beucker
Borderstep Institute for Innovation and Sustainability

Christian Heyken
Berliner Stadtreinigungsbetriebe AöR

Andreas Hüttner
Siemens AG

Dr Sandra Maeding
Stromnetz Berlin GmbH

Christina Over
GreenCycle Umweltmanagement GmbH

Dr Marc Richter
Fraunhofer Institute for Factory Operation and Automation (IFF)

Mark Richter
Fraunhofer Institute for Machine Tools and Forming Technology (IWU)

Fabian Stein
Formerly of GreenCycle Umweltmanagement GmbH

Dr Alexander Weber
Ökotec Energiemanagement GmbH

Art direction and design

Ellery Studio, Berlin

Design and layout:
Gaja Vičić

Director of infographic design and illustration:
David Ramirez Fernandez

Infographic design and illustration:
David Ramirez Fernandez
Simon Schabel
Julia Zimmermann
Qixuan Chen
Gaja Vičić

Layout and design adaptation for English translation:
Odile Stabon
Institute for Climate Protection, Energy and Mobility (IKEM)

Editors

Dr Henning Medert
Former WindNODE Project Coordinator, 50Hertz Transmission GmbH

Niko Rogler
WindNODE Project Coordinator, 50Hertz Transmission GmbH

Translation

Kate Miller
Institute for Climate Protection, Energy and Mobility (IKEM)

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Disclaimer

WindNODE is a pluralistic project, especially with regard to the people who participate in and are addressed by it. For us, people count, regardless of their gender. The authors of WindNODE's 'Best practice manual: identifying flexibility options' are therefore committed to using gender-neutral language and have done so to the best of our ability.

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