edf renewables

WHITE PAPER

Energy transition in Germany

Battery storage as key technology in the energy transition

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EDF Distributed Solutions GmbH
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1 Editorial

Dear readers, there is much discussion about the energy system transformation and how it can be successfully shaped. It is controversial who can, and wants to, contribute to it. What is clear, however, is that we are in the middle of a system transformation. It is not just a question of whether or when renewable energies will completely replace fossil fuels. Rather, it is a question of what needs to be done to make the energy system fit for future requirements – and affordable.

This white paper aims to provide an overview of the challenges that the energy transition will bring to the electricity supply. In the age of renewable energies, we, EDF Distributed Solutions GmbH, see the decentralized storage of electricity as the fourth pillar of the electricity supply, alongside generation, transport and consumption. In this context, we show that battery storage systems significantly contribute to the stabilization of the power grid, as they can flexibly balance loads, thus, making or keeping the network controllable. Battery storage systems help to reduce network costs because they can be used locally, and in line with demand. They can also replace network capacities when used throughout the country.

We are therefore investing massively in the implementation of battery storage solutions for trade and industry, thereby reducing the energy costs of the companies involved, and making an important contribution to the success of the German energy transition.

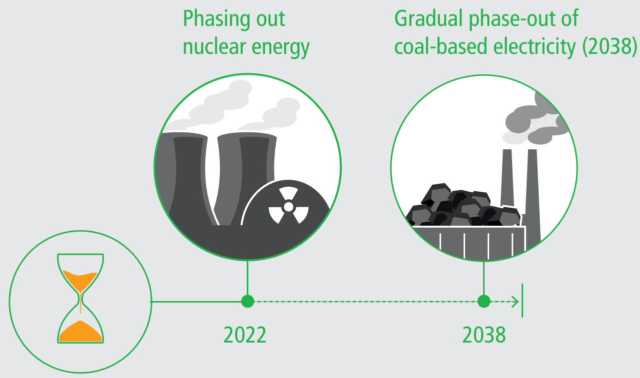
I hope you will enjoy reading our paper,
Clotaire François

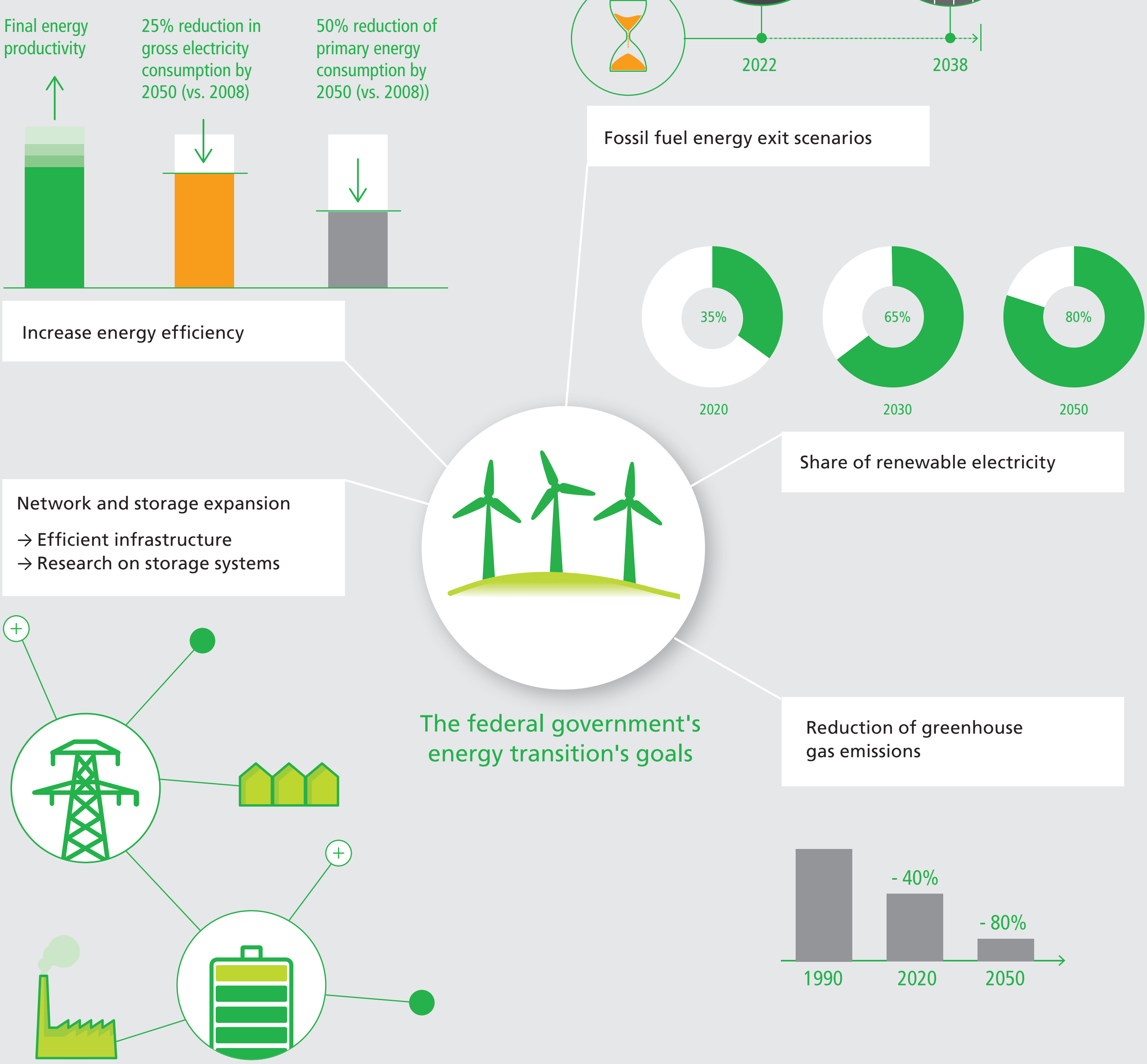
“We see decentralized electricity storage as the fourth pillar of the energy supply infrastructure.”

Clotaire François, CEO
EDF Distributed Solutions GmbH

2 The energy transition – a system transformation

In addition to phasing out nuclear energy, the energy transition decided by the German government is primarily aimed at avoiding greenhouse gases such as carbon dioxide (CO_2), thus at massively expanding renewable energies and increasing energy efficiency. By 2050, the target share of renewable energies is 80% and CO_2 emssions are planned to be reduced by 80%.





Source: Federal Ministry of Economics and Technology (BMWi): Energy concept for an environmentally friendly, reliable and affordable energy supply (2010), Berlin.

This rapid transition to renewable energy supplies, i.e. to unsteady energy sources such as wind and sun, poses numerous innovations and challenges in terms of investments, infrastructure, resources, politics, society and science. Various so-called megatrends are emerging, such as [1]:

- Decentralization: Electricity generation and consumption are unevenly distributed in space (i.e. wind power generation in the north vs. high electricity consumption by industrial sites in the south and west or millions of renewable energy plants of various sizes vs. a few large producers in the traditional energy system).

- Digitization: An increasing amount of feed-in and load data as well as an increasing degree of observability, controllability and automation. Within the framework of the SINTEG support program, research is currently being carried out into concepts as to how the energy transition can be promoted with the help of digitalisation.

- Degression of costs: Both wind & solar power generation systems and storage technologies are becoming cheaper.

- Democratization: Public participation is increasing, with new players such as "pro-sumers", energy cooperatives or local power plants emerging. The population is registering its rights to have a say in the nationwide expansion of wind and solar energy.

Parallel to these developments, various sectors, such as heating, cooling, and motor technology, will become more electrified (sector coupling). The most prominent example at the moment is probably electric mobility – which is expected to lead to an additional increase in electricity consumption.

The trends described and the rapid development towards fluctuating and decentralized renewable energy sources imply a profound change of the current energy supply system, combined with many challenges in terms of investments, infrastructure, resources, politics, society and science. Many of these challenges arise due to the unique physical properties of electricity as well as the restrictions on its transport, and distribution. Concerning the infrastructure of electricity generation, current discussions and public debates mainly focus on the need for new high-voltage lines to transport renewable electricity from north to south Germany. The challenges are but far beyond that and include topics such as the provision and optimal use of flexibilities, sector coupling, the responsibility of market participants, or the fair distribution of costs and the profitability of the necessary investments.

In this context, the present white paper aims to provide an overview of the challenges that the energy transition will bring for the supply of electricity, and how the development of flexible solutions can on the consumer side – for example, with batteries – contribute to their management.

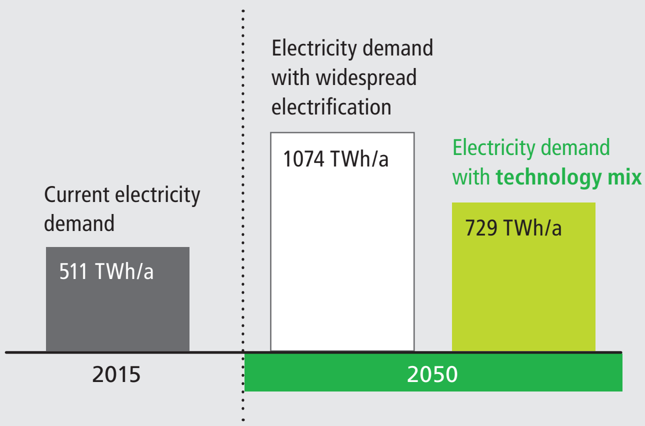
SINTEG – Showcase intelligent energy

With the support program of the Federal Ministry of Economics and Energy "Showcase Intelligent Energy – Digital Agenda for the Energy Transition" (SINTEG), model solutions for future energy supply are being developed in five large-scale model regions. More than 300 project partners are working on the intelligent networking of power generation and consumption and the use of innovative network technologies and operating concepts.

The dena pilot study “Integrated energy system transformation”

The dena pilot study [2] provides recommendations on how to shape the transformation of energy systems based on the German government climate goals. It describes various scenarios which include targets such as reducing greenhouse gas emissions by 80 or 95 % by 2050, but also factors such as energy efficiency, technological developments and the electrification of additional areas (sectors) to show, amongst other aspects, the costs of an “integrated energy system transformation”. According to this study, which examines various climate scenarios for reducing greenhouse gas emissions, electricity consumption could double by 2050. The study considers two scenarios: one of widespread electrification **(EL 80)** and one of a technology mix **(TM 80)**.

Growing electricity demand until 2050



The Electrification scenario (EL 80)
Intending to reduce greenhouse gases by 80 %, this scenario assumes a broad electrification of all sectors and a simultaneous increase in energy efficiency. The demand for electricity in this scenario doubles. The higher the degree of electrification in each area, the higher the respective investment costs.

The Technology mix scenario (TM 80)
This scenario also assumes an 80 % reduction in greenhouse gases by 2050 and a significant increase in energy efficiency. However, a broader variety of technologies and energy sources used is deliberately permitted. The dena pilot study advocates this broad mix of energy sources and technology, as it is associated with lower additional costs and a greater planning security for all parties involved.

Electricity demand TWh/a	2015	2050	
		Widespread electrification	**Technology mix**
Construction sector	213 TWh/a	285 TWh/a	234 TWh/a
Industry	286 TWh/a	532 TWh/a	248 TWh/a
Mobility	12 TWh/a	110 TWh/a	86 TWh/a
Power to X	0 TWh/a	147 TWh/a	161 TWh/a
Sum	**511 TWh/a**	**1074 TWh/a**	**729 TWh/a**

3 From a centralized to a decentralized energy system

Discussions on the decentralization of energy system transformation are diverse and can be confusing, since there is no uniform definition of this term. Despite the numerous approaches to the concept of decentralization, many studies contain similar aspects that can be described by the following dimensions ([3], [4]):

- Technical dimension: Large power plants connected to the transmission networks are being replaced by many small generation plants connected at the distribution network level. In 2015, the share of power plants connected to the distribution grid level was already higher than that of power plants connected to the transmission grid, at 60%. This share is expected to rise to almost 80% in the future to meet the government's renewable energy targets.

- Spatial dimension: The decentralization of the system also means a shift in the spatial distribution of generation and consumption. An example of the decentralization of the renewable energy system is the homeowner with a solar system generating and consuming her own electricity.

- Integration dimension: This dimension considers the development of flexibility options such as battery storage and so-called "sector coupling".

- Coordination dimension: Not least because of the increasing digitalization of energy change – which leads to a growing number of feed-in and load data and to increasing observability – new actors can play a more important role in a decentralized system. On the one hand, it is expected that distribution system operators will have to assume new tasks and responsibilities, especially in ensuring grid stability. On the other hand, the traditional scheme of electricity suppliers and end consumers is increasingly being challenged by the development of local market models or citizens who can produce and distribute electricity themselves.

Since renewable energies now account for almost half of all electricity generation, both spatial issues and questions of system decentralization are becoming increasingly relevant. These questions are mainly linked to the expansion of the electricity grid and are controversial in Germany considering the planned development of the transmission grid. To keep this grid expansion affordable and efficient, the Federal Government and the regulatory authorities demand options: "One thing is certain: the grid expansion is not geared towards the largest possible volume. That would not only be inefficient, but simply impracticable." [5] An efficient grid expansion is hardly possible if the flexibility issue has not been solved. "If generation takes place almost exclusively close to consumption, while flexibility can only be provided at a distance from consumption, corresponding grid expansion is still necessary from a technical point of view." [6]

3.1 Significant additional investments due to delayed grid expansion

With the adoption of the EnLAG Act in 2009, the need to develop the electricity grid was acknowledged and addressed at an early stage with the adoption of the EnLAG Act in 2009 [7]. The more conventional generation plants are decommissioned and replaced by renewable energy plants, the higher the demands on the distribution grids, as generation and consumption are often far apart.

Investments in grid infrastructure have already increased significantly at both the transmission and distribution grid levels. However, despite the adoption of several ordinances throughout the years, the transmission grid's development has been considerably delayed. The main reasons cited are lack of coordination between the parties involved, strenuous approval procedures, and low social acceptance [8].

The current grid development plan (NEP 2030 (2019)) [9] of the transmission system operators describes the necessary grid expansion until 2030 with a share of 65% renewable energies. The assumed scenarios range from moderate sector coupling and centralized structures to strong sector coupling and decentralized structures.

The volume of measures required in the scenarios is still comparable to the previous grid development plan (NEP 2030 (2017)) [10], which is explained by developments in the market and grid area as well as by assumptions on flexibility options and storage possibilities. However, the costs have almost doubled: from 32 to 61 billion euros [9]. On top of that, offshore connection costs of 18 to 24 billion euros have to be added.

The reasons given for the increase in costs are inflation, market price adjustments, changes in the scope of projects and measures (e.g. additional laying of underground cables, which should lead to greater social acceptance) and the first-time inclusion of planning and approval costs.

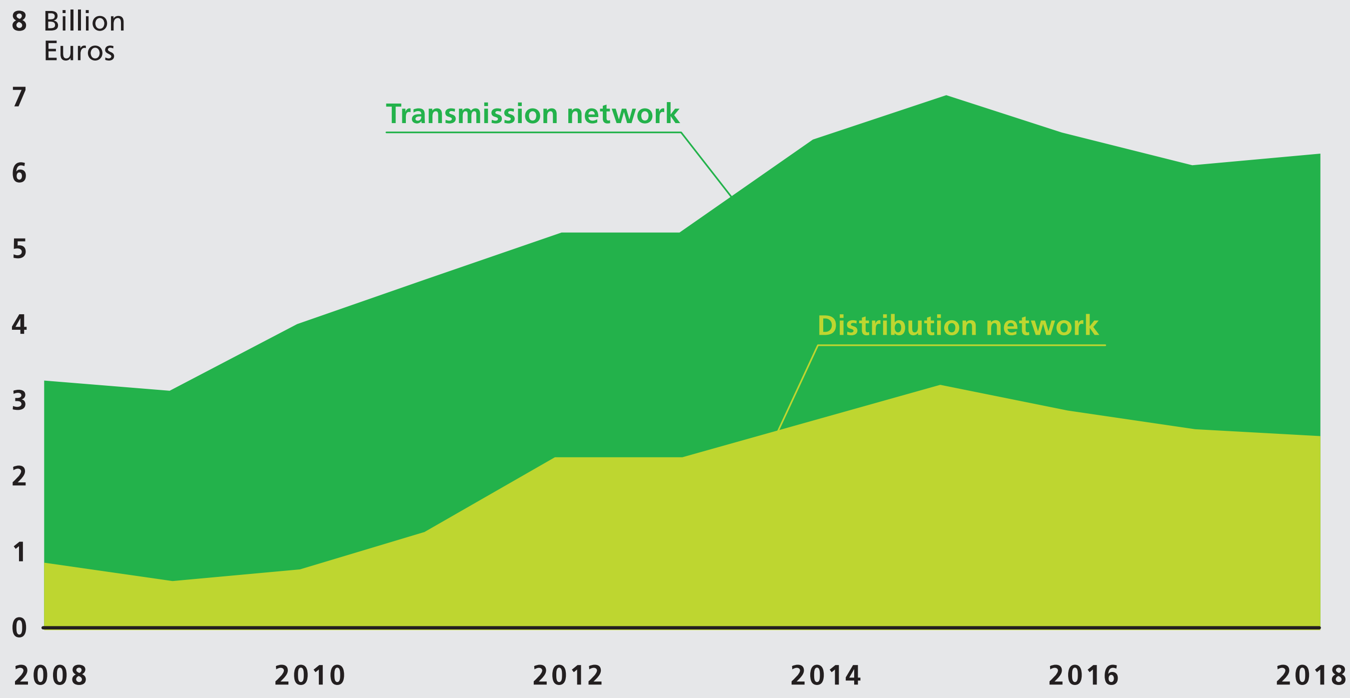
In 2011, with the adoption of the NABEG (Netzausbaubeschleunigungsgesetz Übertragungsnetz – Transmission System Expansion Acceleration Act), the Federal Network Agency was given central responsibility for the main areas of network expansion. The Agency currently considers 68 of the 164 grid development measures proposed by the transmission system operators up to 2030 to be unnecessary. Discussions on the necessary network expansion are therefore continuing.

3.2 Congestion management as contribution to decentral flexibility

Among the numerous measures required to ensure the security and reliability of electricity supply, network operators carry out several processes known as congestion management. In Germany, the most common action is called “redispatch”. In this process, the transmission system operators instruct specific power plants to increase their power input while commanding others to reduce it. In this way, the amount of power fed into the grid remains unchanged, and the relevant grid bottleneck is relieved. However, such measures are not free of charge: power plants receive compensation for carrying out such processes. Ultimately, these costs are passed on to end consumers as grid charges.

According to dena [11], there is considerable potential for savings by integrating decentralized flexibility into the redispatch process. By expanding the redispatch portfolio with decentralized flexibility, the need for grid reserves could be reduced and a performance-reducing redispatch could be intensified, thus cutting down the need for scarce performance-enhancing redispatch in Southern Germany. For this to be possible, local development costs (such as smart meters) and costs for TSO-DSO coordination must be borne. According to experts, a total annual cost savings potential of between EUR 100 and 150 million would be realistic for 2023 (including savings potential in the grid reserve). [12]. However, an appropriate regulatory framework that would allow efficient solutions to solve network congestion at the distribution level is not yet in place.

Evolution of investment in the German network infrastructure



Source: Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (2020): Monitoring Report 2019, Bonn. p. 129–130

3.3 Distribution and development of network charges

The investments in network expansion and maintenance, but also the costs for system services such as redispatch, control energy and feed-in management measures are ultimately passed on to end consumers as network charges. Grid fees have risen sharply since 2012 and account for around 25 percent of a household electricity tariff, although the amount varies notably from region to region. The highest network fees are to be found in northeastern Germany. They are partly due to renewable energies – historical and structural reasons are also decisive here. As a result of the debate about the unequal distribution of grid fees, a partial reform (NEMoG) passed in 2017, which included several measures to redistribute costs.

The network charges for the transmission network of the four TSOs will be gradually harmonised between 2019 and 2023. The costs of offshore grid connection will be deducted from the grid fees and included in the offshore liability levy, now called offshore grid levy. Despite various measures that are generally intended to reduce grid costs, such as the abolition of "avoided grid fees" and the reduction of the return on equity of the grid operators, no noticeable relief for end consumers is to be expected by 2030 against the background of the necessary investments in the expansion and reconstruction of the grids.

In contrast to household customers, industrial and commercial customers have the opportunity to significantly reduce their grid costs through various measures such as the provision of balancing energy or feed-in management (see 4.3 for further information). Ultimately, however, the system of grid fees is criticized as being intransparent and too complex [13].

Avoided network fees

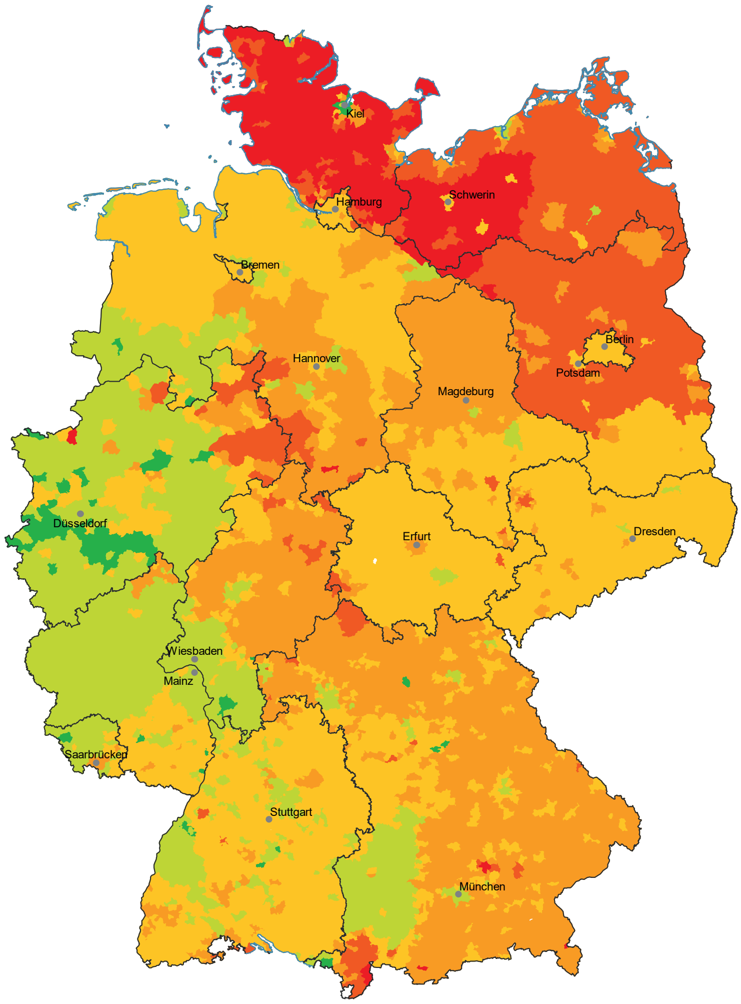
Compensation for the decentralized production of electricity, which is paid by the network operator to the respective producer because it was assumed that locally generated and locally consumed electricity reduces the costs of network expansion.

Distribution of network charges for industrial customers in Germany (2019)

Consumption 24 GWh/year, 4.000 kW (6.000 h/a), medium voltage

Network costs in cents/kWh

- 1,2 up to < 1,7 cents/kWh
- 1,7 up to < 2,2 cents/kWh
- 2,2 up to < 2,7 cents/kWh
- 2,7 up to < 3,2 cents/kWh
- 3,2 up to < 3,7 cents/kWh
- 3,7 cents/kWh or more



Map graphics: EasyMap
Source: Data from GET AG

4 Battery storage – a multifunctional tool for flexibility and stability of the system

One of the biggest challenges for safe and reliable operation of the electricity grid is to ensure a balance between generation and consumption at all times. Responsibility for this is shared between market participants and grid operators. With an increasing share of fluctuating renewable energy sources, maintaining this equilibrium is becoming increasingly difficult and requires flexible consumption or flexible generation

The development of decentralized flexibility, increased self-sufficiency, and a focus on a more locally oriented balancing can help to solve this problem. Improving the balance between generation and consumption within smaller grid clusters could relieve the transport demand of the transmission and distribution grid, thus support grid expansion. A prerequisite for such a concept is not only flexible generation, but also flexible consumption, which improves by coupling the heat and transport sectors. However, flexibility has its limits, to be overcome by decoupling the need for simultaneous consumption and generation through storage.

4.1 Storage technologies

Some of the key features that determine the applicability of different storage technologies are

- the storage capacity,
- the efficiency (i.e. the ratio between charged and discharged energy) and
- the time frame in which stored energy is available.

Among the available storage technologies, pumped storage is historically the most widespread. Such facilities can store considerable amounts of energy, but are usually large and far away from the consumers. In contrast to other countries, Germany does not have optimal conditions for the expansion and construction of pumped storage plants. In many cases, planned projects fail due to public resistance, and their operation is currently considered increasingly uneconomical. This is why battery storage technologies are now the focus of attention, as they offer an increasingly cost-effective and scalable solution for electricity storage.

What is flexibility?

In a system with a high proportion of renewable energies, it is particularly beneficial if consumers can adjust their needs and producers their output. The scale, time frame and speed at which this is technically possible is generally referred to as flexibility.

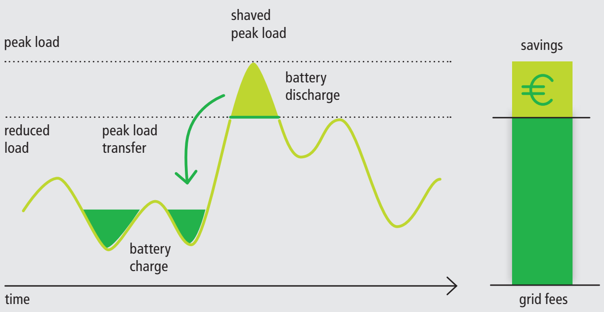
For an industrial site, flexibility refers to the ability to adapt its electricity consumption to external circumstances such as the availability of renewable energy or grid constraints.

All industrial sites can increase or decrease their production over time and thus increase or decrease their electricity consumption. In the energy sector, time flexibility is an essential aspect. Nevertheless, few industrial sites can react as quickly as they would need to. For example, to stop its consumption, a chemical plant has to wait until all chemical reactions are complete and the reactors have cooled down. Similarly, a food processing plant must empty and clean its tanks before it can adjust its consumption.

The main difficulty is therefore the time needed to increase or reduce electricity consumption. This delay should not necessarily meet the needs of the grid. But it is exactly what the battery does: it takes over the production of energy for 15, 30, 45, or 60 minutes, which gives the system operator enough time to react. With a battery that acts as a buffer, any industrial site can use flexibility and optimize the power grid.

4.2 Applications of battery storage

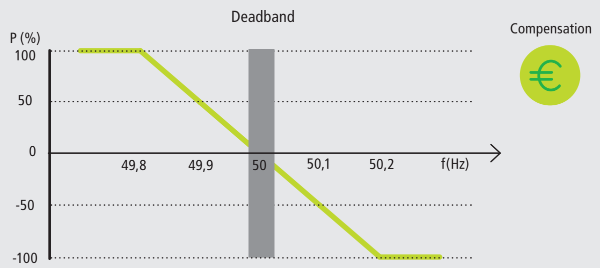
A Battery usage to shave the highest yearly load peaks



Source: own illustration

One of the most common applications for battery storage, often also for PV battery systems, is peak shaving, which consists of reducing consumption peaks or lows. This can be achieved by discharging the energy stored during periods of excess production or low load at times of peak consumption. For an efficient use of power, it is important to reduce the amount of energy stored in the battery. With the appropriate incentives, both the grid operator and the consumer can benefit from these applications. Benefits for the consumer include the reduction of electricity consumption costs and the reduction of grid fees. On the other hand, system operators could benefit from a more stable system due to flatter consumption profiles.

B Load frequency control with battery storage

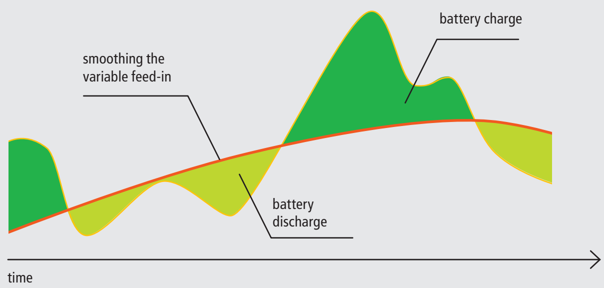


Source: own illustration

With reaction times of less than one second to frequency deviations, the battery storage is particularly suitable for providing short-term control power. Typically, short-term control power is provided by synchronous machines, which however have a slower reaction time than battery storage.

In continental Europe, short-term control power is provided by Frequency Containment Reserve (FCR). In Germany, several large batteries are involved in providing FCR. Control reserves exist as part of the grid services that the grid operator needs to maintain the balance between generation and consumption at all times. Usually, the grid operator or another institution sets up a balancing market where interested parties can be contracted and remunerated for participating in various control reserves. To be able to participate in these reserves, the interested parties must meet the requirements for the prequalification of reserves. In Germany, suppliers can meet the conditions either by a single unit or by aggregating several units within the same control area. It is therefore possible to participate in this market with a distributed portfolio of generation, consumption and storage units.

C Battery usage to flatten variable feed-in



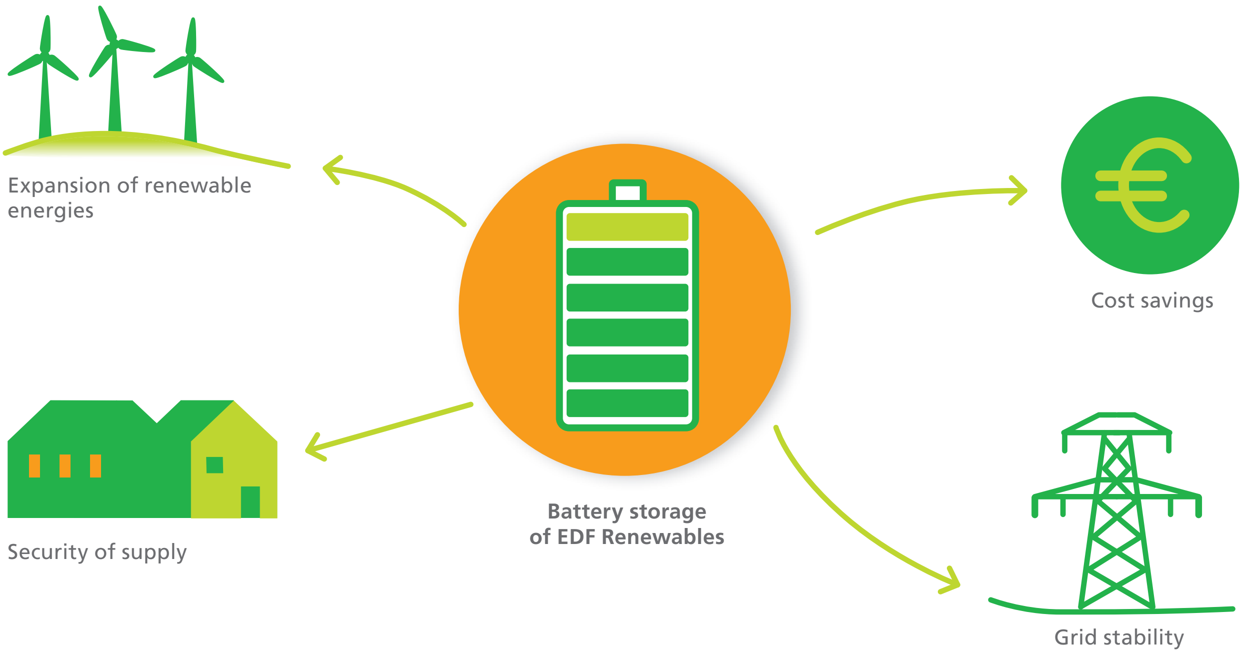
Source: own illustration

Battery storage can also be used to flatten the variable feed-in of renewable energies such as wind and solar. This means that rapid power changes causing unwanted voltage and power fluctuations can be reduced or eliminated. For producers and traders, this means a reduction of the uncertainties in generation forecasts. As a result, balance group managers can adjust their balance groups more accurately and reduce inequality and the associated costs.

5 Conclusion

In recent years, Germany has significantly increased the share of renewable energies in its energy mix. They already accounted for around 42% of net electricity generation in the first half of 2019. However, this rapid development is associated with many challenges that are part of a system change. Decentralized and flexible solutions are needed to prevent the investment costs for the conversion and expansion of electricity grids from getting out of hand, i.e. many smaller power generation units coupled with many smaller storage units.

Battery storage is proving to be a versatile, and above all, scalable storage technology. Battery storage makes it possible to compensate for the variability of some renewable sources and can act as a buffer between generation and consumption, especially by reducing consumption peaks. In this way, battery storage systems contribute to grid stability, reduce energy costs on the consumer side, thus significantly support the shift from a centralized to a decentralized supply, in which electricity generation from renewable energy sources and flexible consumption are locally interconnected.



References

[1] Agora Energiewende, “Energiewende 2030: The Big Picture”, Jun. 2017.

[2] T. Bründlinger et al. “dena-Leitstudie Integrierte Energiewende”, Jul. 2018.

[3] Reiner Lemoine Stiftung and Reiner Lemoine Institut, “Übersichtsstudie zur EnergieSystemWende”, Sep. 2019.

[4] Can be found on the website of the Federal Government (bundesregierung.de) under “Energy system transformation at a glance”.

[5] Flachbarth, Schmidt: Meta-study Decentrality, Regionalization, p. 22, Wissenschaftsdialog 2018, conference proceedings.

[6] EnLAG: Energy Line Expansion Act passed in 2009, which regulates the acceleration and simplification of the expansion of the extra-high voltage grid. The focus was on 22 grid expansion projects with a total length of 1,800 km. Of these, 6 are underground cable projects.

[7] D. F. C. Matthes, F. Flachsbarth und M. Vogel, “Dezentralität, Regionalisierung und Stromnetze”, Öko-Institut e.V., Nov. 2018.

[8] Bundesrechnungshof, “Bericht an das Bundesministerium für Wirtschaft und Energie nach § 88 Abs. 2 BHO zur Prüfung von Maßnahmen zum Netzausbau für die Energiewende”, May 2019.

[9] K. M. Rippel, T. Wiede, M. Meinecke und R. König, “Netzentwicklungsplan Strom 2030, Version 2019, 2. Entwurf”, German TSOs, Apr. 2019.

[10] K. M. Rippel, T. Wiede, M. Meinecke und R. König, “Netzentwicklungsplan Strom 2030, Version 2017, 2. Entwurf,” German TSOs, May 2017.

[11] S. Mischinger, “Perspektiven netzdienlicher Einsatz von Stromspeichern”, Deutsche Energie-Agentur GmbH (dena), Apr. 2018.

[12] S. Mischinger, E.-L. Limbacher, H. Seidl, Dr. M. Ritzau und D. Nailis, “Ergebnispapier des dena-Stakeholder-Prozesses: Höhere Auslastung des Stromnetzes”, Deutsche Energie-Agentur GmbH (dena), BET Büro für Energiewirtschaft und technische Planung GmbH (BET), Sep. 2017.

[13] A. Jahn and T. Lenck, “Netzentgelte 2019: Zeit für Reformen”, Agora Energiewende, Apr. 2019.

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