Being Part of the Future Energy System
Dear readers,

Energy is us – with this motto, we are on the way to the energy system of the future. This year our association is celebrating its centenary. The more than 430 VGB members from 33 countries are united in their knowledge that the joint work of the association creates valuable impulses for the development of their own company. These additional benefits result from the exchange of experience, knowledge transfer, standardization and innovations that are only possible through a collaborative platform such as VGB PowerTech.

We are firmly convinced that with our know-how and our experience – as a technical voice, so to speak – we can make an important contribution to shaping the energy system of the future. We made this claim clear in 2019 by publishing our new mission statement. In this White Paper, we formulate how we envision the energy system of the future, what contributions we as operators of energy systems can make to its design and which technological and regulatory framework we believe are necessary for this. To this end, we have defined eight strategic fields of action, for which we explain our view of technical implementation options and potential and link them with the position of our members, the plant operators.

The plants of our members – which currently have installed capacity of more than 300 GW – already ensure that energy as the central lifeline of society is available at all times. In order to implement a sustainable, environmentally friendly, safe and economical energy supply in the long term, cooperation between players in the energy sector is essential. We at the VGB are ready for this – we will master this challenge together with technical reason, a measured view and foresight!
With eight strategic fields of action towards a sustainable, environmentally friendly, secure and economical energy supply

The VGB is the international technical association of energy plant operators. Our members are companies that operate facilities for the generation of power, heat and cooling as well as for energy storage and sector coupling worldwide. We are committed to the goal of developing the economy and society in a climate-neutral and sustainable way, and with our know-how and activities we are contributing to the Paris Agreement and the European Green Deal – climate neutrality in Europe by 2050 – being attained.

Pointing out and actively shaping the way towards a sustainable, environmentally friendly, secure and economic energy supply system is how we contribute. We take a technology-neutral view and support the development of the future energy system based on our technical competence and expertise.

In the view of the VGB eight strategic fields of action are of central importance in shaping the future energy system. All stakeholders of the energy sector – from politics, industry and society – are asked to contribute to the implementation of these fields of action.

The content of this brochure describes what these fields of action look like and how the VGB and its members are actively involved.
1. Further share increase of renewable energy – specially in the areas of biomass, solar, water and wind

2. Strengthening of flexibility in the energy system: utilize all flexibility options – dispatchable generation, energy storage, grids and Demand Side Management

3. Security of supply in order to fulfil the energy needs of each and every consumer and cover them through dispatchable generation and energy storage

4. Recognition of the key function of sector coupling and use of the potential resulting from the linkage of technologies and processes

5. Affordability of energy supply, leading to socio-economic benefits

6. Establishment of reliable framework conditions that offer incentives for a sustainable, environmentally friendly, economic and secure energy supply

7. Use of digitalization as a technological enabler for the future energy system

8. Development and expansion of a modern energy infrastructure as the foundation of an increasingly decentralized energy system
As a hydropower operator, we appreciate the international exchange on technical and environmental issues relating to the efficient operation of renewable generation plants – this is possible in the VGB thanks to the Europe-wide competence network.

Dr. Karl Heinz Gruber, Managing Director of VERBUND Wasserkraft, Member of the VGB Executive Board and Chairman of the Strategic Forum “Hydro”

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Increasing of share of renewable energy

Renewable energies are the central driver for the development of the energy system of the future. It is only through their further development that CO₂ emissions decrease and the foundation for a climate-neutral energy supply is created. The most important renewable resources are water, wind, sun and biomass. Thus, hydropower alone currently represents almost half of the renewable electricity generation capacity installed worldwide. At the end of 2019, renewable capacities were 2,516 GW – which corresponds to a share of around 27 percent of the global electricity mix ¹.

To achieve climate protection goals, this share should be further increased. It can therefore be assumed that current annual growth rates of around 8 percent will increase. The growth is due above all to the addition of onshore and offshore wind and photovoltaic systems.

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(¹) REN21, Renewables 2020 Global Status Report, retrieved from: www.ren21.net
Technical assessment and potential

**Hydropower** plays an important role in successfully transforming the energy system in Europe. It is a reliable renewable energy source, one of the frontrunners in the generation of electricity from renewable energies, particularly due to its high efficiency and mature technology – in 2019 hydropower generated more than 379 TWh or 34 percent of all electricity generated from renewable energy sources. Run-of-river power plants ensure highly predictable and constant electricity generation; pumped storage and storage power plants are primarily used to provide reserve power and peak load. As a controllable generation technology, hydropower can provide all the system services required for stable electricity grid operation. Because of these properties, hydropower will certainly play a central role in the energy system of the future. The technically feasible potential of hydropower in Europe (EU-27 as well as Great Britain, Iceland, Norway, Switzerland and Turkey) is estimated at approximately 1,289 TWh – this is approximately 1.3 times the amount of electricity produced currently from these countries.

**Wind energy** plants have developed enormously over the past 20 years. While the output of a wind turbine was still around 500 kW at the end of the 1990s, today this value stands at around 5 MW. In addition, offshore wind turbines up to 10 MW are already in operation. The strong expansion of onshore and offshore wind farms is one of the main drivers for the decarbonization of the energy system. Technological developments are primarily aimed at increasing the performance and improving the handling of the systems. This includes larger and intelligent rotor blades as well as new material concepts for the towers. The latter primarily serve to simplify the transport and assembly of the systems. Another important development topic is the possibility of making a momentary reserve available as an important system service with wind turbines. In the case of offshore wind, the innovations are aimed not only at increasing performance, but also at the development of floating foundations – in order to develop ocean areas with greater water depths for wind energy. Another important development topic is the possibility of using wind to provide system services – such as inertia.

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(2) VGB PowerTech e.V.: Facts and Figures in Electricity Generation 2019/2020
(3) VGB PowerTech e.V., Eurelectric: Hydropower Fact Sheets, May 2018
The energetic use of *biomass* – solid, liquid or gaseous – is characterized by a high level of technological maturity. Thermal power plant technologies are used to convert the chemical energy of the biomass into heat, which is used in a thermal-power process to generate electricity. The use of biomass is a secure and dispatchable generation technology that is capable of delivering all system services. The expansion potential is primarily limited by the availability of biomass produced in a sustainable mode.

Technological development is all about increasing process efficiency and fuel flexibility and ensuring stable operation. The addition of biomass can reduce CO₂ emissions from coal-fired power plants. If the switchover is successful, existing coal-fired power plant infrastructures can continue to be operated in a climate-neutral manner.

The use of *solar energy* with the help of photovoltaics (PV) represents another central pillar of renewable energies. Here, solar or light energy is converted directly into electrical energy in the solar cells made of semiconductor materials. The cost of PV technology has decreased enormously over the past 15 years – for example, the average price of PV roof top systems (per kilowatt of installed power) shrunk to a quarter of the original price in the period 2006 to 2016.

Technological developments are aimed at more efficient solar cells: Perovskite solar cells – based on lead-containing ammonium halides – are an example of this. The PV technology is modular and can therefore be used in large, grid-connected systems, but also in small, decentralized off-grid applications as well.

Photovoltaics is a variable generation technology, which in certain regions with high sun intensity can at least partly contribute to secure electricity generation. The International Renewable Energy Agency (IRENA) assumes that photovoltaics will become the most widely used power generation technology in the world by 2050. The expansion of PV roof top installations in particular can make an important contribution to decarbonization in urban areas. According to IRENA, approximately half of the global PV capacities will then be in Asia.

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(4) VGB PowerTech e.V., Eurelectric: Hydropower Fact Sheets, May 2018

(5) IRENA: Future of solar photovoltaic, November 2019, retrieved from: www.irena.org
Along with PV, **concentrated solar power** (CSP) is another sun-based power generation technology. CSP uses solar energy to generate heat, which is then converted into electricity in a thermal power process. In sunny regions, combined with PV, it is an economical option for a climate-friendly and secure electricity supply.

**The operator view**

A constant and intensive expansion of renewable energies is essential for environmentally friendly and sustainable energy supply. Variable renewable energies (VRE) such as wind energy and photovoltaics, together with hydropower and biomass, will form the main pillars of the energy supply.

VGB members already build and operate a large number of renewable energy systems of various sizes and levels of maturity. In addition, operators are also actively involved in the further development of these technologies. VGB offers the platform for the exchange between manufacturers and operators and supports the innovation and optimization activities with various projects.

VGB advocates using the potential of all available renewable energies as efficiently and sustainably as possible thereby taking into account their contributions to system stability and security of supply. In this context appropriate regulatory frameworks are also important.

VGB has expanded its RDS-PP® (formerly KKS) power plant designation system, which is known worldwide, for photovoltaic systems. This means that these systems can now also benefit from a consistent designation.
Strengthen the energy system’s flexibility

Variable energy resources such as photovoltaics and wind contribute approximately 10 percent of the global electricity generation today. That share will grow to around 60 percent by 2050, according to IRENA. The need for flexibility in the energy system, caused by fluctuating residual loads, also increases. The residual load refers to the total power requirement minus the feed-in of variable energy resources.

The ability of the energy system to balance electricity supply and demand at any time is what characterizes flexibility. It is essentially guaranteed by four options:

- dispatchable generation
- energy storage
- power grids
- demand side management

The more flexible an energy system, the better the integration of increasing shares of photovoltaic and wind.
Technical assessment and potential

Dispatchable generation technologies currently form the backbone of system flexibility – in Europe, for example, they represent 80 percent of the available flexibility capacities. Dispatchable generation primarily includes thermal power plants and hydropower plants. Their flexibility can be characterized on the basis of three parameters: minimum load, load ramps, and start-up and shutdown times. The minimum load represents the lowest load at which a power plant can be operated under stable conditions. In thermal power plants this means without using start-up fuels. The load ramp is how quickly a power plant can change its output within a certain period of time. The start-up time is measured from the moment when the power plant starts to operate until the minimum load is reached; the shutdown time is the time required until the shutdown is complete.

Pumped storage plants have excellent flexibility parameters – low minimum loads, high load ramps and short start-up and shutdown times. In the case of thermal power plants, it is primarily gas and coal-fired power plants that make a significant contribution to system flexibility. Gas power stations also have very good flexibility parameters. Lignite and hard coal power plants can now also be operated in an extremely flexible manner. Nuclear power plants can also make an important contribution to the implementation of large load ramps.

Energy storage refers to all technologies that store energy at a certain point in time and make it available again at a later point in time. Pumped storage power plants – they store electricity in the form of potential energy in a reservoir – are currently the most mature and most widely used storage technology worldwide. They are classified as mechanical storage systems, a grouping that also includes compressed air storage. Their expansion is primarily limited by geographical conditions. Electrochemical storage, such as lithium ion batteries for example, is another important storage technology. The IEA forecasts that batteries will be the fastest growing flexibility option over the next 20 years, largely because the cost is likely to shrink by half over that period. Battery storage is primarily used for short-term smoothing of electricity production – its contribution to security of supply is limited.

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(6) IEA, World Energy Outlook 2019
(7) ibid
Chemical storage technologies convert electricity into chemical energy sources (e.g. hydrogen), which can be used in large quantities for long periods in a variety of ways. These processes, known as Power-to-X, form an important basis for sector coupling (field of action 4). Another promising option is electricity-heat-electricity storage, in which salt melts, rockfills or shaped bricks for example, serve as a heat storage medium. The heat is generated using electricity, stored and, if necessary, converted back into electricity using heat engines.

**Power grids** are system enablers, as they smooth out fluctuations by aggregating variable renewable energies on a large scale. The power grid includes high-voltage transmission lines, medium and low voltage lines in the distribution system as well as transformers and substations. Precisely forecasting variable electricity generation – with the help of weather forecast data for example – is essential for networks to operate efficiently. It is this which makes it possible for the system operator to use operating reserves flexibly, according to the residual load requirements. Connections to neighboring compensation areas – so-called interconnections – are advantageous.

In addition to expanding the transmission network, it is especially important to increase intelligence in the distribution network. This is necessary so that electricity can flow in both directions and decentralized systems that use renewable energies can be efficiently integrated into the distribution network via a connection.

**Demand Side Management (DSM)** is another flexibility option. Private, commercial and industrial consumers adapt their electricity needs to the requirements of the energy system. DSM includes:

- postponing electricity consumption; for example, by charging electric vehicles or using household appliances at a later time
- adjusting the setpoint of devices and plants to work with reduced consumption for a certain period (e.g. air conditioning, wastewater treatment and lighting)
- interrupting electricity consumption in production (e.g. in large energy-intensive industries)
Certain technical requirements must be met to realize the potential of DSM, including the accurate measurement of electricity consumption and digitalized infrastructure for remotely controlling loads. In addition, a supportive political and regulatory framework with corresponding price signals and incentive systems is necessary.

**The operator view**

Flexibility will be of central importance in the energy system of the future. With their plants for dispatchable generation and energy storage, VGB members provide the necessary flexibility to cover residual load requirements. Intelligent framework conditions with corresponding remuneration mechanisms for flexibility and incentives to innovate are important in order to exploit existing potential – e.g. in the field of hydropower – and to ensure the marketability of new technologies such as Power-to-X.

This is why the VGB and its member companies are involved in research projects and initiatives aimed at further developing energy storage technologies and networked infrastructures. The latter form the basis for making full use of the possibilities of DSM – especially with a view to e-mobility and the need-based control of private electricity consumption.
Keeping security of supply

The increasing share of variable energy resources not only requires a high degree of flexibility in the energy system, but also special attention being paid to security of supply. It must be ensured that electricity requirements are met at all times and at all locations. Fluctuations in the feed-in of wind and photovoltaics have to be compensated not only in the short term, but also in the long term. There are also meteorological situations in Europe in which there is no wind nor sun for several days or weeks. During this time, it is up to dispatchable generation and energy storage capacities, or both, to ensure security of supply.

The graph below shows the development of generation capacities in Europe up to 2040. At the moment the maximum peak load in Europe is approximately 540 GW. The dispatchable generation technologies currently planned will not be sufficient to cover these needs in the future. If this planning remains, this gap would have to be closed by building up energy storage capacities in the GW area.

Development of Power Generation Capacity in the EU-28

Technical assessment and potential

In a study, the VGB analyzed wind power production in Germany and 17 European countries in the period 2015 to 2017 to determine whether there are sufficient compensation options in the European network in times of low wind power generation. In other words, whether low wind power production in southern Europe could be compensated for by higher production in the northern countries. The analysis showed that there is no noticeable smoothing of the total production. Only about 5 percent of the total installed wind capacity is available for secure power generation.

The graph below, which relates to the situation in Germany, shows a similar picture. From the German figures, the conclusion again can be drawn that an enormous expansion of storage capacities as well as dispatchable and secured generation will be required in the next decades. Especially gas turbine and gas engine power plants will play an important role with respect to dispatchable generation. They can be operated with natural gas and, in future, also with climate-neutral fuels such as hydrogen.
In this context the “Carbon Capture, Usage and Storage” technology (CCUS) may prove useful. CCUS helps thermal power plants – and thus dispatchable and secure generation plants – to drastically minimize their carbon dioxide emissions.

**CCUS technologies** include the capture of carbon dioxide – *capture* – from combustion (e.g. thermal power plants or industrial processes), the transport of this carbon dioxide by ship or pipeline and its use – *usage* – as a resource for valuable products or its permanent underground storage – *storage* – in geological formations. When it comes to storage, a distinction is made between offshore and on-shore storage. The latter in particular is currently still in the research stage. Around the world the potential of CCUS technology is assessed differently. However, in its sustainable development scenario, the IEA assumes that global use of CCUS will save 0.7 billion tons carbon dioxide by 2030 and 2.8 billion tons of carbon dioxide per year by 2050 – the CCUS use is divided equally between the energy and industrial sectors. In 2019 global energy related carbon dioxide emissions amounted to 33 billion tons.

**The operator view**

Security of supply is one of the most important quality criteria of an energy system. To ensure security of supply in the future as well, it is essential to build dispatchable, secure generation and energy storage capacities. With their systems, VGB members are already an important pillar for energy supply. Stable framework conditions and a suitable market design are essential for members to continue to fulfil this mission in the future. These give operators the security they need for large, long-term investments in new energy systems.

In addition, extensive innovation activities are required to develop storage and sustainable dispatchable generation technologies, e.g. based on climate-neutral fuels. The VGB and its members are working on various national and European projects to bring these technologies cost effectively to market.

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(8) IEA: World Energy Outlook 2019
(9) IEA: Global CO₂ emissions in 2019
Recognize sector coupling as a key function

Sector coupling is the linking of the energy industry with other sectors such as transport, industry as well as heating and cooling. The goal of sector coupling is to use renewable electricity to reduce fossil fuel use in other sectors. A distinction is made between direct and indirect sector coupling. Direct sector coupling relates to electrification in other sectors, for example, in the transport sector through e-mobility or in heat supply through heat pumps. Indirect sector coupling plays an especially important role for the stability of the energy system. Combined heat and power (CHP) – using the (waste) heat of thermal power plants for heating purposes – is an established example of this. The Power-to-X approach will play a central role in the energy system of the future.

The main step of Power-to-X is the generation of hydrogen through the use of electricity from renewable sources. The process of electrolysis, in which water is broken down electrochemically into hydrogen and oxygen, is used for this. Due to its high energy density in terms of mass, hydrogen can be used in a variety of ways – this is what the X in Power-to-X stands for. It can be used directly to generate electricity and heat with gas turbines or fuel cells, for example. Furthermore, hydrogen can be converted into methane in a so-called methanization reaction with carbon dioxide. Liquid products or fuels can be obtained from synthetic methane or directly from hydrogen using various chemical processes (“gas-to-liquid”). When carbon dioxide, arising as a result from a capturing process, is employed, this conversion process is a central step in the CCUS concept (see field of action 3).
Technical assessment and potential

Electrification is clearly ahead when one compares the energy efficiency of direct and indirect sector coupling. A battery-powered electric vehicle, for example, has an energy efficiency of 69 percent; a hydrogen-based fuel cell vehicle, on the other hand, only has 26 percent. The overall efficiency of a heat pump is more than six times higher than that of a fuel cell heater 10.

Nevertheless, Power-to-X will play a key role in the energy system of the future because by converting electricity (from renewable sources) into hydrogen – and thus by decoupling electricity generation and consumption – an important storage technology on GW scale becomes available. In order for Power-to-X to assume this role, especially the economic efficiency of the process chain must increase. It is particularly important to make electrolysis operations more efficient and dynamic for applications on an industrial scale (e.g. in the range of 50 to 100 MW of installed electrical power per system). The main focus of dynamic operation is to adapt the electrolysis process to the irregular supply of electricity, which is caused by the feeding in of variable renewable energies. The possibility of flexible operation is also a central task in further developing methanation and gas-to-liquid synthesis processes.

The high-water consumption in electrolysis is another hurdle. To survive a two-week absence of wind and PV power in Germany with Power-to-X, for example, would require a quantity of water that corresponds to the annual consumption.

10 acatech/Leopoldina/Akademienunion: Sektorkopplung – Optionen für die nächste Phase der Energiewende, 2017
of a city with 200,000 inhabitants. Various national and European demonstration projects are currently underway to put Power-to-X technology through a large-scale practical test and to further develop it to market maturity.

The following aspects are particularly important to optimally integrate Power-to-X plants in the energy system:

- Power-to-X plants should be integrated into both the electricity and gas infrastructure.
- The locations of Power-to-X plants should be at suitable junctions between the electricity and gas networks.
- The control of Power-to-X plants should equally take into account the actual feed-in of renewable energies, the residual load as well as the gas volume flows and the level of the gas storage and consider it as an integrated system.

The operator view

In order for the switch to renewable energies to be a success, there is no way around sector coupling. With a view to flexibility and security of supply, indirect sector coupling plays an important role. The hydrogen generated from renewable energies is an energy source that can ensure stability in the energy system.

With their cogeneration plants and projects on electromobility and the use of heat pumps, VGB members are active players in sector coupling. They see it as their role to operate sector coupling systems and thus to guarantee flexible and secure energy supply. Working in partnership with companies along the industrial value chain is a key success factor.

That is why they are also involved in many innovation and demonstration projects that aim to commercialize Power-to-X technology on an industrial scale. In addition to technical solutions, appropriate framework conditions and incentives that enable investments in the required magnitude are necessary for the large-scale use of Power-to-X. Initiatives such as the European Commission’s Hydrogen Roadmap and the German Federal Government’s National Hydrogen Strategy are therefore appreciated.

With its hydrogen platform, the VGB will make its contribution to the successful implementation of Power-to-X technologies.

Implement an affordable energy supply

In addition to environmental compliance and security of supply, low cost is the third part of the target triangle of sustainable energy supply. As the central lifeline of society, energy supply should be affordable for private consumers and should not restrict the competitiveness of commercial and industrial consumers. In the area of power supply, the price per unit of performance is decisive for consumers and users. This price is made up of the costs for electricity procurement and distribution, taxes and duties, and network usage fees. In Europe, the distribution of the various electricity price components differs from country to country. In Germany, for example, the price of electricity for private households in 2019 consisted of 53 percent from taxes and duties, 24 percent from network usage fees and 23 percent from electricity procurement and sales costs. This means that less than a quarter of the price is determined by market-based mechanisms. This shows that, at least in Germany, the provision of electricity has only a limited influence on the price of electricity.

(12) BDEW-Strompreisanalyse, Januar 2020

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<th>Country</th>
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Source: Eurostat (online data codes: nrg_pc_204)
Technical assessment and potential

In Europe, electricity is sold primarily through wholesalers. According to a current report by Agora Energiewende, day-ahead prices in 2019 fell in almost every EU country compared to the previous year – on average by around 5.3 euros per MWh\(^\text{13}\). The fierce competition places energy plants under immense cost pressure. To operate them more economically, optimized operating and maintenance concepts are particularly important. A high degree of automation and intelligent control are essential for implementing these concepts. Manufacturing costs for the energy systems and components is another important lever for economic viability. New and innovative technologies such as PV systems or batteries have a particularly high potential for reducing costs.

The operator view

An affordable energy supply is essential for the functioning of society. The economic operation of energy plants is a central concern of the VGB. With the sharing of experience, knowledge transfer and standardization, the VGB significantly contributes to its members being able to operate plants for power generation, storage and sector coupling as efficiently as possible.

In this way, VGB members do their part to keep energy prices affordable – the leverage they have with their electricity supply costs depends on the respective regulatory framework and the market design.

\(^{13}\) Agora Energiewende and Sandbag: The European Power Sector in 2019. Up-to-Date Analysis on the Electricity Transition, March 2020
Create a reliable framework

Energy systems are assets with a long lifespan that usually require high investments. The level of investment depends in particular on the size of the plant and the marketability of the technology used. Planning security with predictable, reliable regulatory framework conditions is therefore of fundamental importance for the investment decision. A decisive factor is a market design that creates incentives for a sustainable, environmentally friendly, economical and secure energy supply. The mechanisms that ensure flexibility and security of supply in the energy system are particularly important here. This requires a level playing field for all relevant technologies.

Technical assessment and potential

The lifespan for most energy plants is several decades. The table below shows selected plant types with their average lifespan and capacity-specific investment costs.

### Lifespan and investment costs for different energy plants

<table>
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<th>Plants</th>
<th>Technical lifespan in years</th>
<th>Investment costs in EUR per kilowatt (2018)</th>
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<td>PV</td>
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<td>3,100–4,700</td>
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<td>Biogas</td>
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<td>2,000–4,000</td>
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<tr>
<td>Gas and steam turbine</td>
<td>30</td>
<td>800–1,100</td>
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Source: Fraunhofer-Institut für Solare Energiesysteme ISE: Stromgestehungskosten Erneuerbare Energie, März 2018
The market design is decisive for the revenue situation of the energy systems. In open markets there are various elements or building blocks that can be differentiated, according to duration and products or deliveries – from long-term contracts based on installed capacity to intra-day energy trading. Short-term markets can play an important role in the flexible operation of energy systems, by offering incentives to operate systems closer to real-time or actual needs.

In addition to the supply of electricity, other services that contribute to the stability of the energy system can also be remunerated. These include control energy and system services such as reactive power provision. Control energy trading has been successfully implemented in several countries such as France, Germany and the United States.

Carbon dioxide trading is a vital instrument for the design of the energy system. It provides a market-based mechanism that provides incentives for decarbonization.

**The operator view**

For VGB members, reliable framework conditions are the foundation of their entrepreneurial activities, as they are also the foundation for a customer centric and market driven economy. These should be designed in such a way that they provide incentives for a sustainable, environmentally friendly, economical and secure energy supply. Therefore, all system-related services – from electricity to system services – should be remunerated.

A level playing field for investments in climate-neutral technologies and in bridge technologies is required for the successful and efficient design of the energy system. The energy system of the future depends on a networked portfolio of different solutions. A suitable framework for strategic innovations in future technologies is essential. The VGB provides the technological and operational parameters for designing these framework conditions.
Use digitalization as a technological enabler

The energy system of the future is characterized by the interaction of a wide variety of technologies and actors. Digitalization – that is information technology networking in the entire energy value creation process – makes it possible to efficiently manage this complex system. Data exchange forms the basis for networking energy systems with one another and organizing system operation holistically. Highly automated individual systems, with transparent operating data and intelligent information processes, are required.

Energy supply plants are classified as critical infrastructure and are therefore subject to special security requirements. The topic of IT security plays a particularly crucial role.

Technical assessment and potential

The ongoing connection of control systems for plant control with corporate IT business processes is one of the main drivers for increasing demands being placed on IT security. Automation and control technology are coming more and more into the focus of cyber-crime. This is shown by a rising number of discovered security vulnerabilities and the appearance of specialized malware. The industry’s special requirements are specified in Europe, for example, in the corresponding Information Security legislation. This contains the minimum standards for IT security as well as guidelines for risk assessment and the implementation of measures.
Digitalization is a key instrument for optimizing plant operations. The use of highly complex modeling, e.g. for weather forecasts or for combustion optimization – or artificial intelligence – e.g. for evaluating a plant fleet’s operating data – makes it possible to implement flexible operating concepts as well as predictive maintenance and repair.

Systematic and uniform designation of energy systems is the basis for efficient data management – the reference designation system for power plants RDS-PP® or KKS from VGB offers the perfect basis for this.

The merging of many smaller, decentralized plants into a virtual power plant is another example of digitalization in the energy industry. Such systems can generate electricity from biogas, wind power, photovoltaic or hydropower plants, but also electricity consumers, electricity storage or Power-to-X plants.

In addition, digitalization is a prerequisite to smoothly integrate different system technologies. This especially applies to the flexibility options described in the field of action 2.

The operator view

For VGB and its members, digitalization is the focus of their actions – above all because it is an important driver for technological developments and system optimization. VGB members, as plant operators, are aware of the responsibilities of operating system-critical infrastructure. Therefore, they take the topic of IT security very seriously.

The future competitiveness of VGB members will depend all the more on their ability to generate added business value from the extensive amount of data they have. This applies both to the efficiency of plant operation and to interaction with customers and other players in the energy sector.
Develop and expand a modern energy infrastructure

In addition to power grids, a modern energy infrastructure also includes digital infrastructure, various systems and actors – e.g. in the form of virtual power plants – seamlessly interacting together in a network. The connection of neighboring transmission networks through interconnections contributes significantly to system flexibility and security of supply. The European Union has therefore set itself the goal of increasing the share of interconnections to 15 percent by 2030. This means that every EU member country should be able to transfer 15 percent of its electricity capacity to its neighboring countries.

In addition to network and IT infrastructure, the placement of the systems also plays an important role. The expansion of plants dedicated to renewable energies should go hand in hand with the expansion of the power grid and take into account the geographical distribution of the existing generation and load. Another example is plants dedicated to indirect sector coupling, which should be placed as close as possible to renewable energy plants and at junctions between electricity and gas networks.

Technical assessment and potential

The use existing power plant locations, e.g. decommissioned coal-fired power plants, should be considered in the design of new energy plants. The well-developed infrastructure with the appropriate connections for the media supply (e.g. water), to the transport...
system and to the power transmission network supports an efficient system integration of new plants. In particular, the water supply and the connection to the gas infrastructure can be used for new plants, e.g. for Power-to-X applications.

The so-called NOVA principle is used in the development of power grids: network optimization before reinforcement before expansion. High-temperature, low-sag conductors are used, for example, to reinforce the transmission networks. Their transmission capacity is 50 to 100 percent higher than conventional conductors. The further development of the distribution network aims to increase its capacity for connecting decentralized, smaller energy systems and to improve intelligence and controllability. This is necessary to control the “two-way flow” – a situation that occurs when the electricity generated in part of a distribution network exceeds consumption and the direction of the current flows deviates from the current standard. Power electronic equipment for load flow control is applied, e.g. FACTS (Flexible AC Transmission Systems).

The 5G network plays an important role in the expansion of digital infrastructure, supporting industrial applications with as many connections as possible with rather low data rates and low energy consumption.

**The operator view**

VGB members are dependent on good energy infrastructure. Distribution networks are of fundamental importance for the expansion of renewable energies – their further development should be given high priority. A modern IT infrastructure is also an important prerequisite for using the potential of innovative technologies and concepts – for example in the field of artificial intelligence.

VGB members can actively contribute to shaping the energy structure of the future by choosing the location of their energy systems as well as with concepts for the conversion of existing power plant sites.

To exploit the potential of demand-side management (DSM), a networked IT infrastructure is essential. DSM is one of the topics of the VGB committee “Future Energy System”.
Our mission

As an independent technical competence centre and network, we support our international members in their operational business as well as in the implementation of innovations and strategic challenges. We are the voice of the operators, getting actively involved in the political and social debate on technical issues, using facts as our basis. Co-operation with all partners along the energy value chain, especially with manufacturers and service providers, is very important to us. We are also available to international stakeholders as the central point of contact for all technical issues relating to the operation of energy plants.
Our goals

Within the scope of our activities we

• strengthen and safeguard a high standard in operational and plant safety as well as health and safety at the workplace,
• increase the environmental compatibility of assets and improve the emission balance,
• ensure optimal availability and reliability of assets based on market requirements,
• optimise the efficiency and operating costs of assets at any point of their lifetime,
• implement innovations in energy technology into economic applications,
• pave the way for a market-oriented expansion of renewable energies,
• find solutions to secure the stability of the energy system.

With our activities we aim to

• provide our members with an international platform for the exchange and transfer of technical know-how,
• offer our members access to qualified expert knowledge, e.g. through operational and availability data bases for benchmarks,
• define best-in-class processes as well as technical and operational standards in close co-operation with all stakeholders, e.g. manufactures, service providers and authorities,
• offer technical services from technical consulting to laboratory services for materials, water and oil,
• identify, organise and coordinate joint Research and Development projects,
• work closely together with other national and international industrial associations, scientific institutions and public institutions.
Your benefit ...

- exchange and transfer of technical experience and know-how for the complete life cycle of power and heat generation: design, engineering, licensing, construction, operation, maintenance, health & safety, quality management, environmental compatibility and dismantling & decommissioning
- access to ‘fuel to grid’ know-how via committees and panels, databases, information pools
- “VGB PowerTech Journal” – VGB’s renowned technical journal, and events covering all generation technologies
- harmonisation of technical positions and support of international and national partner associations (e.g. Eurelectric, BDEW, WANO) within the EU and in relation to national legislation procedures
- harmonisation of technical positions through direct contact to ENTSO-E, EPPSA, VDMA and suppliers
- efficient execution of projects, improved plant operation, higher plant availability and cost savings through technical and operational standardization among operators and suppliers
- international collaboration to improve access to public funds
- direct access to a network of independent experts by personal contacts, by databases or by online reporting systems (e.g. benchmarks, damage analysis, expert assessment, mediation and arbitration, provision of expert reports for the management)
- independent and high quality assessment of the plants as part of the VGB expert network
- special condition for VGB events, the purchase of VGB standards and reports as well as for VGB’s Technical Services: Materials and Oil Laboratory, Water Chemistry and Quality Assurance and Supervision
- basic and advanced training organised by Kraftwerksschule e.V. (Power Plant Training Centre) ensuring qualification of operators’ staff and simulator training at KSG|GfS for nuclear power plants
Bibliography at a Glance:

• acatech/Leopoldina/Akademienunion: Sektorkopplung – Optionen für die nächste Phase der Energiewende, 2017
• Agora Energiewende and Sandbag: The European Power Sector in 2019. Up-to-Date Analysis on the Electricity Transition, March 2020
• BDEW-Strompreisanalyse, Januar 2020
• Fraunhofer-Institut für Solare Energiesysteme ISE: Stromgestehungskosten Erneuerbare Energie, März 2018
• IEA: World Energy Outlook 2019
• IRENA: Future of solar photovoltaic, November 2019, retrieved from: www.irena.org
• Pieper, C.: Transformation of the German energy system – Towards photovoltaic and wind power, Technology Readiness Level 2018, Dissertation, 2019; information has been included in the “Technical assessment and potential” sections
• VGB PowerTech e.V., Facts and Figures in Electricity Generation 2019/2020
• VGB PowerTech e.V., Eurelectric: Hydropower Fact Sheets 2018