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How digitization will help ready Germany’s energy sector for the future

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Distributing the surplus – how digitization will help ready Germany’s energy sector for the future

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Executives in many industries perceive digitization as a threat. In the energy sector, there is no need for that. On the contrary. In Germany's energy sector, digitization will help executives address a series of pressing challenges. Power consumption is set to increase because of the electrification of transport, heating, and a growing number of industrial processes. At the same time, the share of energy derived from renewable sources, such as wind and sun, is growing. As a result, power supply is becoming more volatile. These developments make it more difficult to manage and balance the power system. Digital technology is the catalyst that will allow the sector to ready the power system for the future. Intelligent feed-in points, smart devices, and smart storage solutions will help uncouple demand from supply, while digital trading platforms will enable the system to handle and distribute a growing power load in ever smaller increments.

DEMAND IS SET TO GROW

According to most estimates, demand for electrical power in Germany will grow, even if energy efficiency will keep increasing. Major drivers of incremental demand include the electrification of the transport and heating sectors. By 2050, total consumption could reach 700 TWh, up from 600 TWh today.[1] Additionally, Germany will have to electrify further industrial processes to meet the country's ambitious targets to reduce the emission of greenhouse gases. This additional burden could bring total demand for electrical power in Germany to more than 1,000 TWh. According to one very extreme scenario, demand could eventually reach as much as 3,000 TWh.[2] Despite the high degree of uncertainty that the spread of these scenarios indicates, there is little doubt that the load on the system will increase (see Exhibit 1). The current power system is unfit to handle such loads, especially since it is already under stress from the growing share of variable decentral input. Smart solutions are required to ready the system for the future.

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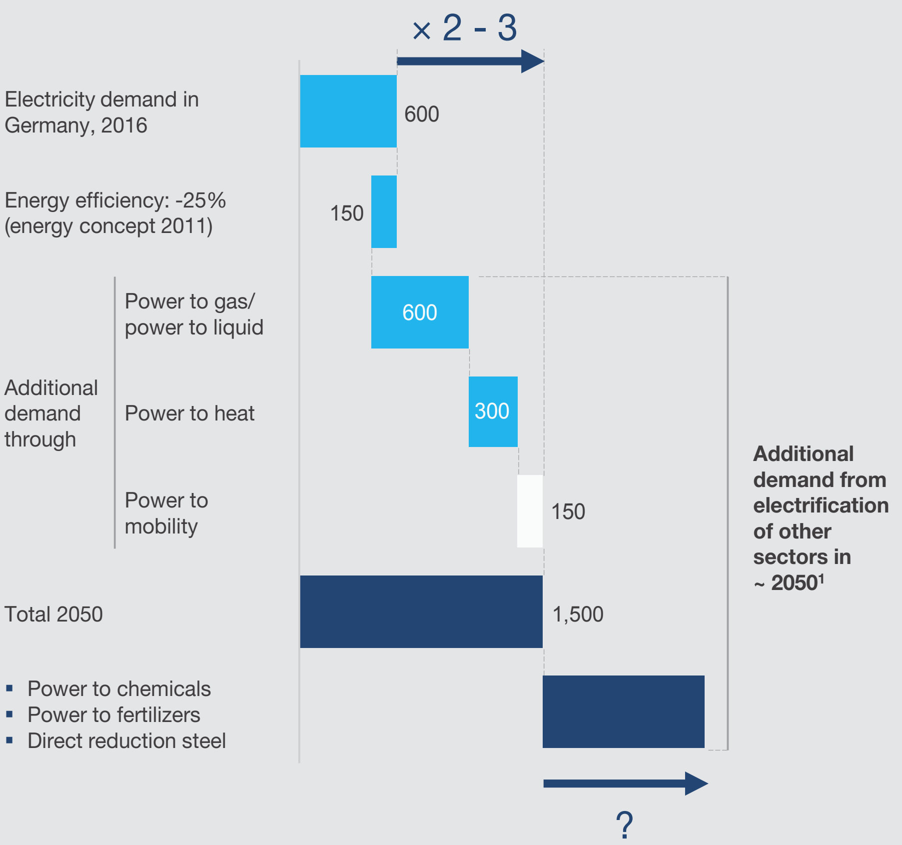
1 Agentur für Erneuerbare Energien. Flexibilität durch Kopplung von Strom, Wärme & Verkehr, Metaanalyse, April 2016, p. 4

2 Agentur für Erneuerbare Energien, Flexibilität durch Kopplung von Strom, Wärme & Verkehr, Metaanalyse, April 2016; Öko-Institut, Treibhausgasneutraler Verkehr 2050: Ein Szenario zur zunehmenden Elektrifizierung und dem Einsatz stromerzeugter Kraftstoffe im Verkehr, 2013

Exhibit 1
Electrification could increase Germany's electricity demand to much beyond 1,000 TWh

Potential development of electricity demand, TWh



1 Frequently referred to as "sector coupling": coupling different sectors' energy systems, allowing to supply energy from one sector to fulfil demand in another. Coupling the transportation sector by electrification to the electricity sector is one example, electrifying heating and industrial processes are others.

Source: Bundesministerium für Wirtschaft und Energie: Agentur für Erneuerbare Energien; Fraunhofer-Institut für Windenergie und Energiesystemtechnik; Fraunhofer-Institut für Bauphysik; IFEU – Institut für Energie- und Umweltforschung Heidelberg; Stiftung Umweltenergierecht; McKinsey analysis

ELECTRIFICATION OF INDUSTRIAL PROCESSES BEYOND TRANSPORT AND HEATING

In Germany's transport and heating sectors, electrification is already in progress. But this will not suffice to reach Germany's ambitious climate goals. Germany aspires to reduce greenhouse gas emissions by at least 80 percent until 2050, relative to 1990. Many experts believe that the electrification of some of the industrial processes that currently rely on fossil fuels is the cheapest and least controversial pathway to reduce greenhouse gas emissions when compared to alternative options, such as carbon capture and storage (CCS). For example, heat sources for steam production that are currently powered by fossil fuels could soon be replaced by electrical boilers that operate when power supply is high and prices are low. Subsequently, electrical heat pumps could become relevant in other sectors, such as food production and processing.

Hydrogen production is another process that will increase demand for electrical power. Hydrogen can be used across a variety of sectors, such as transport and logistics. Hydrogen fuel cells can generate electricity to power the engines that drive heavy trucks, ships, and aircrafts. For example, powering all trucks with payloads greater than 3.5 tons in Germany by hydrogen would add around 40 TWh of new power demand, increasing total demand by around 6 percent.[3] Hydrogen can also be used in steel production to reduce iron ore directly and decrease the dependence on coal. Currently, the steel industry accounts for 30 percent of Germany's hard coal demand.[4] Hydrogen-based steel production is currently the subject of feasibility studies in Europe.[5] In the long run, it could become viable under favorable regulatory conditions. The same applies to the electrification of cement pro-

3 Analysis based on Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles, FZ Jülich for H2 Mobility (2017), data from Statista and Kraftfahrtbundesamt

4 World Energy Council, Energie für Deutschland 2016 – Fakten, Perspektiven, Positionen im globalen Kontext, 2016

5 International Energy Agency (IEA), Renewable Energy for Industry, 2017, p. 39 to 42

duction, the second-largest source of CO_2 emissions globally. As with steel, cement producers could use hydrogen to substitute fossil fuels with solar or wind power.[6]

POWER GENERATION FROM RENEWABLE SOURCES DRIVES VOLATILITY AND COMPLEXITY

The share of electricity generated from renewable sources in Germany, such as sun and wind, has grown from 6.6 percent in 2000 to 33. 1 percent in 2017.[7] On a sunny, windy day with little consumption, renewable power sources can already cover 100 percent of total power demand. The share of power generation from renewable sources will keep growing. According to current plans, it will reach 65 percent by 2030.[8] Power generation from renewable sources will help cut carbon emissions and make the energy system more sustainable, but it also brings two challenges, volatility and complexity.

Volatility

While the output of a conventional power plant can be controlled and adjusted as needed, the output of renewable energy sources is intermittent. Specifically, the power produced by wind generators and photovoltaic systems is contingent on weather conditions and the time of day. As a result, power flows become more volatile and less predictable. Until the capacity for power generation from renewable sources is ramped up to handle peak loads, it will have to be supplemented with power generated from conventional sources. But volatility will remain an issue even when wind farms and photovoltaic systems are ubiquitous. Assuming we had enough capacity to satisfy the bulk of today's demand from renewable sources even on overcast days, at night, or during periods of low wind, there will inevitably be a power surplus on sunny, windy days. According to a thought experiment, this surplus energy

6 International Energy Agency (IEA), Renewable Energy for Industry, 2017, p. 42 to 44

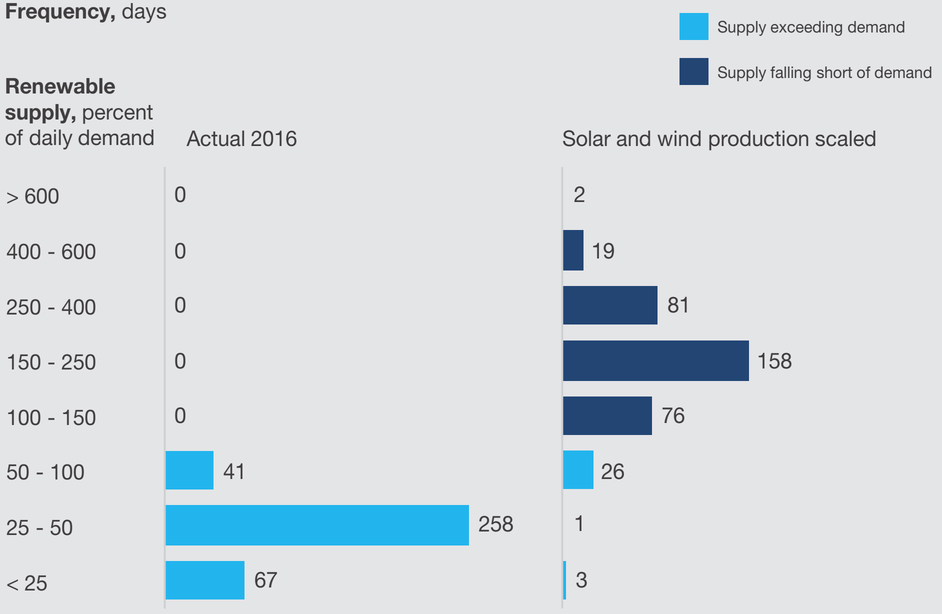
7 Destatis, Arbeitsgemeinschaft Energiebilanzen (AGEB), preliminary data, status December 21, 2017

8 Provided Germany's incoming new government sticks to the target set down in coalition negotiations in early 2018. www.handelsblatt.com/downloads/20936422/4/koalitionsvertrag_final.pdf (February 19, 2018). McKinsey tracks the development of power generation from renewable sources in Germany closely. For details, see www.mckinsey.de/energiewendeindex#uebersicht (February 19, 2018).

generated from wind and sun could eventually exceed current annual demand by a factor of two (see Exhibit 2).

Exhibit 2
Renewable-energy-dominated supply implies energy surplus on majority of days in a year

Daily demand vs. renewable energy supply balance, Germany, 2016
Frequency, days



Renewable-energy-dominated supply scenario → **Outcome**

- Wind and solar production increased by 9x
- Intra-day storage available
- Remaining undersupply to be covered by fossil backup or medium- to long-term storage

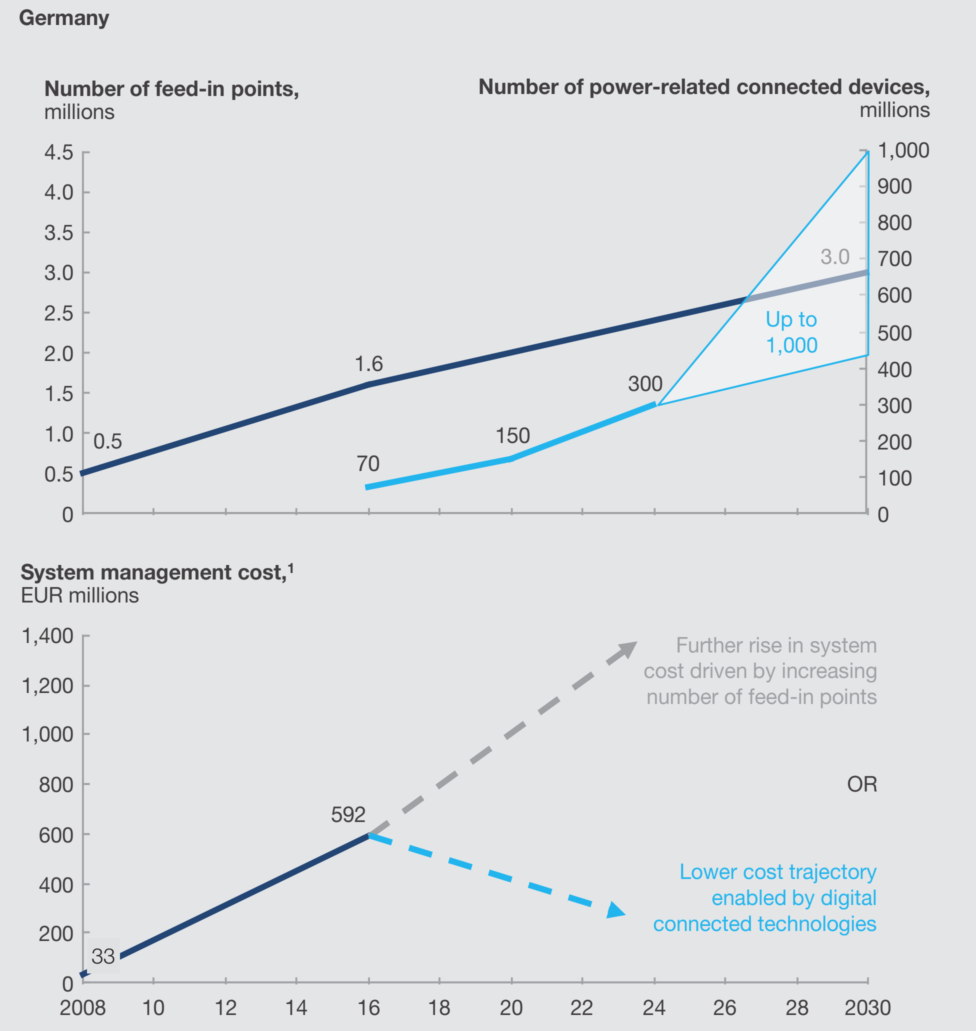
Outcome

- Significant annual surplus – total production twice today's demand
- Peaks up to 6x daily demand
- Only 30 days with insufficient supply

1 In 2016, average daily demand was 1.38 TWh. Therefore, for a day with 0.5 - 1 average daily demand, actual surplus was between 0.69 and 1.38 TWh

Source: ENTSO-E

Exhibit 3
Digital technologies enable lower system management cost by smart steering with connected devices



1 Cost trajectory illustrated by data from 2008 and 2016

Source: Bundesnetzagentur; McKinsey analysis

Complexity

Power is no longer exclusively produced centrally in large power plants. Increasingly, power is fed into the system from many small-scale sources, such as wind farms and photovoltaic systems installed in private households, transforming the grid into a decentral mesh. In tomorrow's power system, local imbalances will increase, and the incremental unit of power that needs to be managed will be smaller. In the past, the common currency was GWh, reflecting the output of large coal or nuclear power plants. In the future, the dominant unit of measurement will be kWh, reflecting the output of wind farms and residential photovoltaic systems. Very soon, today's grid architecture will no longer be able to handle the growing complexity. The effects are visible even today. The cost for congestion management has risen from an average of EUR 33 million in the years 2007 to 2009 to EUR 592 million in 2016[9] (see Exhibit 3). While investments in grid infrastructure are necessary, such investments should only be part of the solution. This is because grid upgrades are costly, planning cycles are long, and new infrastructure often faces resistance by affected residents. The growing complexity calls for more flexible, adaptive solutions.

Taking advantage of the surplus

The excess energy that will arise from the coming increase in decentral power generation from renewable sources has to be put to immediate use or stored. There are currently five approaches to handle the growing surplus:

- Heat. Surplus electricity is used to create heat, which can be stored. This heat is used for processes, such as steam production, that previously relied on fossil fuels; see the insert above.

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9 Redispatch and feed-in management cost. Sources: Deutscher Bundestag (2010), Congestion Management in Germany – The Impact of Renewable Generation on Congestion Management Costs, F. Kunz, May 2011, p. 5, and Bundesnetzagentur, Quartalsbericht zu Netz- und Systemsicherheitsmaßnahmen, viertes Quartal und Gesamtjahr 2016

- Hydrogen. Surplus energy is used to produce synthesized fuels, such as hydrogen, or, via further steps, methane; see the insert above. Hydrogen can be stored until it is used, either as a compressed gas or as a cooled liquid.

- Batteries. Surplus energy is stored in chemical batteries until it is needed. Battery cost is expected to fall further, from EUR 220 per kWh in 2016 to EUR 95 per kWh in 2025.[10] See our article on battery storage for details.

- Smart consumption to match peaks in supply.

- Smart distribution, enabled by digital platforms.

The first three are part new, part established technologies. All strengthen the existing power infrastructure, the hardware of the power system. In what follows, we will look at smart consumption and smart distribution more closely – the software side of the power system.[11]

SMART CONSUMPTION WILL HELP MATCH DEMAND TO SUPPLY

In the past, power consumption was a linear process: You switch on a device, and it consumes electricity. You switch it off, and consumption ceases. Smart power-consuming devices are starting to change that pattern. Such smart devices are always connected and use the internet to send and receive information ("Internet of Things"). Examples of relevant data include power demand, status, electricity prices, and other environmental variables. Based on such information, smart devices can optimize their own consumption. Thus, they contribute to balancing the overall power load and can take advantage of peaks in energy supply. Examples include:

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10 Bloomberg New Energy Finance, Lithium-ion Battery Costs and Market, 2017

11 https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/battery-storage-the-next-disruptive-technology-in-the-power-sector (retrieved April 17, 2018)

- Smart appliances. Remote-controlled electrical water heaters have been used in some countries for decades, enabling a simple form of demand management. More recently, innovative local players, such as There Corporation in Finland[12] and Aquanta in the United States,[13] connect thousands of electrical water boilers and heating systems to the internet to allow for remote control.

- Smart homes. The number of smart home systems in Germany is projected to grow from less than 1 million in 2015 to 5.5 million in 2020.[14] Smart lighting is currently the most common application. Now, white goods and other appliances are becoming part of integrated smart home ecosystems as well. Leading manufacturers of white goods, such as BSH, LG, GE, and Whirlpool, make appliances that can be connected to a wide variety of platforms and devices such as Amazon Alexa, Google Home, IFTTT, Conrad Connect, and nest.[15]

- Smart industry. Industrial players are investing in innovation that will enable them to buy power when it is cheap and abundant, thus saving money and relieving the grid. In a recent case, a German aluminum plant upgraded all its electrical furnaces so that their output can be adjusted by 25 percent up and down, thereby creating a virtual storage facility with a capacity of 1.1 GWh, equivalent to a medium-sized pumped storage plant.[16] Many other players are investing in similar upgrades.

As such efforts spread, the demand side of the power system will become much more flexible and controllable. If smart consumption is combined with other approaches, such as battery storage, the need to supplement intermittent renewable power with power

12 www.therecorporation.com (retrieved in March 2018)

13 www.aquanta.io/ (retrieved in March 2018)

14 Statista Digital Market Outlook (October 2016)

15 For an example, see http://www.home-connect.com (retrieved in March 2018)

16 International Energy Agency (IEA), Renewable Energy for Industry, 2017, p. 20

from conventional sources will decrease. At the same time, temporary surpluses will be put to better use.

DIGITAL PLATFORMS ENABLE THE SYSTEM TO HANDLE GROWING COMPLEXITY

Cheaper storage and smart, data-driven consumption will allow the energy sector to adjust demand to supply in small increments. But smart consumption and storage will not suffice to ready the energy system for the complexity that arises from the continuing decentralization of power. To distribute the growing surplus at scale, it will take coordination across a vast number of generation and consumption points. Owners of solar panels and small batteries will not be able or willing to enter energy trading in their own right, and private consumers or SMEs don't have the means to source energy from thousands of small-scale suppliers.

Let's look at an analogy from another industry. Ten years ago, renting a holiday apartment was a hassle. It was so cumbersome, inconvenient, and risky to find and rent a place from a private owner that most vacationers ended up in hotels or centrally management apartment complexes instead. At the same time, thousands of rooms, apartments, and second homes were vacant during much of the year. In 2008, Airbnb changed all that. By bundling demand and supply, establishing a convenient booking platform, and introducing mechanisms to protect both renters and owners from fraud or damage, the company and its peers helped distribute a surplus of temporary accommodation to millions of grateful renters. To date, Airbnb has brokered 300 million check-ins.[17]

Today, the energy sector is on the brink of a similar revolution. Decentral generation of power calls for bundling, and the high number of players at both ends of the power line calls for coordination to achieve critical mass. This is where digital platforms come in. Digital platforms will enable the system to handle the new complexity, and they will give rise to new forms of collaboration and more trading relations (see Exhibit 4).

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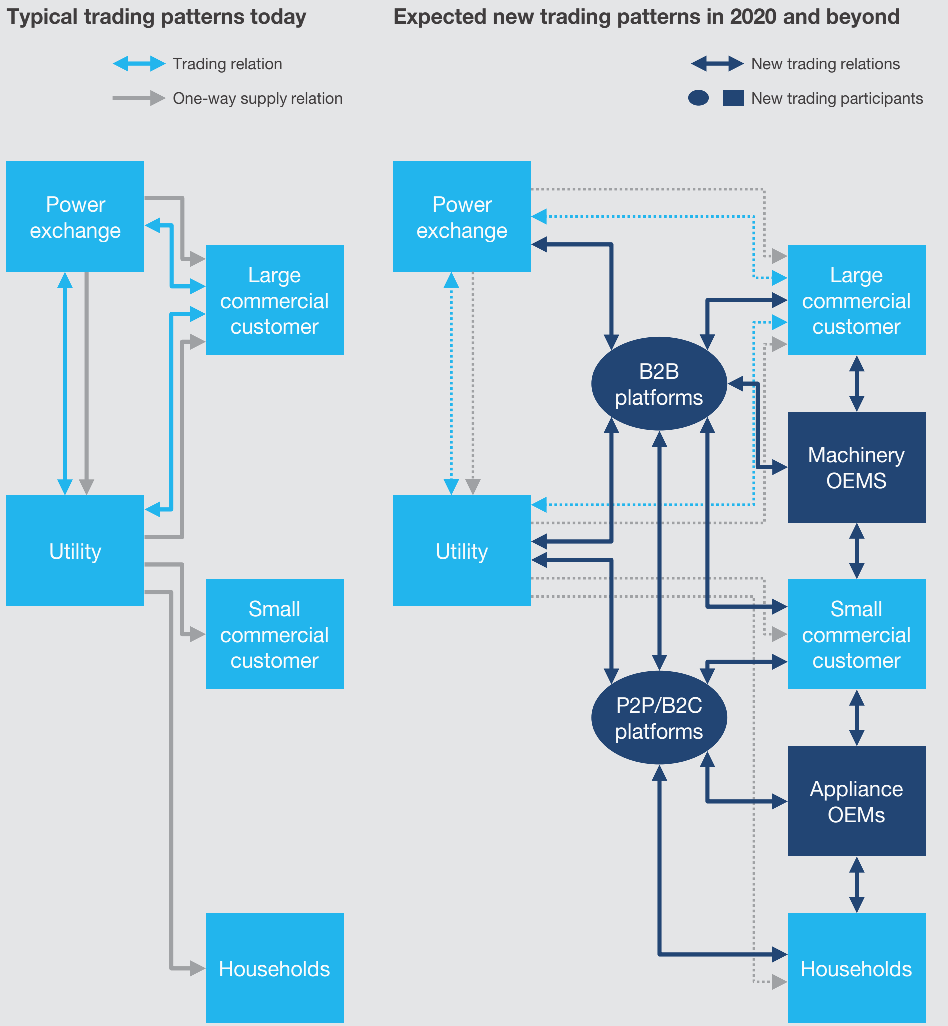
17 https://press.atairbnb.com/fast-facts/ (retrieved April 19, 2018)

Exhibit 4
Trading relations will proliferate



Source: McKinsey analysis

German utilities have been working with industrial customers to implement flexible power sourcing for quite some time. But until recently, the necessary processes were costly and time consuming. As a result, flexible power sourcing was restricted to large customers. Thanks to the advances in digital technology and falling transaction costs, the same trading opportunity can now be offered to smaller enterprises and even to private consumers:

- **B2B platforms.** Digital platforms can ease market access for smaller businesses by bundling demand and supply of multiple small-scale power producers and consumers. ETPA, a platform based in Amsterdam, caters to small businesses. Aggregators such as Germany's Next Kraftwerke pool the output of small photovoltaic systems and rural biogas power plants to create virtual power plants. This allows businesses to market their power on today's large-scale exchanges and contribute to the stability of the grid. Next's digital platform integrates almost 5,000 small to medium-sized power producers and consumers. The company effectively acts as a broker and provides related system services.

- **B2C platforms.** Very soon, private end customers will be able to buy electricity directly from independent power producers through digital trading platforms. As a next step, such platforms will integrate a household's entire electrical ecosystem, including smart appliances, smart home technology, an electrical vehicle charging in the garage, and the photovoltaic system on the roof of the house. Some consumers will also be producers, and the batteries of electrical vehicles will double as small-scale storage facilities. Examples of innovative players in this area include GridX, Enyway, and Sonnen. Sonnen offers its members free electricity, provided they install a photovoltaic system with a Sonnen battery in their home and allow Sonnen to use and control some of the battery's capacity. Power produced by the community is shared across the network. Enyway aspires to become the "Airbnb of the power sector," enabling customers to buy power from independent producers. The platform charges a service fee.

In the future, digital platforms may even enable smart devices to act autonomously. Such autonomous devices could buy and sell electricity without human interference, based on smart contracts that are themselves entered into on a digital platform, e.g., using blockchain technology. For example, the European Enerchain project has developed a blockchain-based peer-to-peer energy trading system that is supported by more than 30 energy players.

On the one hand, the proliferation of such digital platforms will make the power system more complex. Thousands of new players will enter the market, new business models will arise, and energy will start bouncing around, rather than being delivered from suppliers to consumers. Energy will be produced, stored, consumed, and traded like a currency. On the other hand, digital platforms will help manage the growing variability and distribute the surplus. Producers and consumers will come together in new ways, and less energy will go to waste.

THE FUTURE OF ENERGY PRICING

How will electricity be valued and priced in the future? In the last few years, prices have kept eroding. Power prices at the European Energy Exchange have dropped from 5.6 cents per kWh in 2011 to 3.2 cents per kWh in 2017.[18] Are such low prices sustainable, given that the cost of balancing the system has increased? Are we headed for a world in which electricity itself is cheap, but in which customers pay a premium for flexibility and guaranteed supply? Will energy companies charge mostly for smart devices and services ("energy plus"), extract value from controlling the device's consumption, and provide electricity almost for free? The answers to these questions depend on the evolution of technology, digital capabilities, and regulation. Some current business models may well become obsolete. At the same time, new sources of competitive advantage and value creation will emerge.

18 EEX Phelix Base year futures, 2011 and 2017 (2017: January through November)

OUTLOOK: ELECTRIFYING PROSPECTS

The future is bright. The increasing electrification of mobility, heating, and industrial processes in Germany will bring opportunities for utilities, as the overall number of kWhs to be sold will grow. However, the digitization of power distribution will also create inroads for new players with digital credentials, such as equipment manufacturers technology companies, and start-ups. Equipment manufacturers will try to use digital platforms to generate aftersales revenues, leveraging their expertise to help consumers optimize the energy consumption of smart devices. Technology companies, such as internet giants and telecoms operators, could use their IT expertise and, potentially, the data entrusted to them by their users to build platforms for holistic smart home management. Start-ups will be active in all parts of this market, from power retail, a traditional stronghold of utilities in Germany, to establishing platforms or offering aftersales services. In Germany, real estate developers are offering prospective homeowners free energy for life, provided they opt for a low-energy house equipped with a photovoltaic system. As value pools are being redistributed, companies that want to keep or start playing a leading role in tomorrow's energy system[19] need to find new answers to old questions:

- In which segments or industries should we compete? Do we focus on private or industrial customers? Do we cater to large or small and medium enterprises?

- What is our future business model? Will we be a generator, a distributor, a retailer, a broker, or a provider of advanced solutions?

- What is our unique value proposition? How can we help customers create more value, or make the lives of consumers easier?

19 https://www.viebrockhaus.de/vorteile/energiesparhaus-bauen/energiekostenlos.html (retrieved April 20, 2018)

- Which digital capabilities do we need to deliver value? To what extent can we develop our workforce, and in which areas do we need to hire new talent?

- Which partners do we need to succeed? Which stages of the value chain should we own, and in which areas can we create more value through collaboration?

For utilities, there is a growing threat to be sidestepped as customers interact directly with independent power producers, aggregators, or specialized trading platforms. Utilities need to embrace digitization, overcome their fear of cannibalizing their existing businesses, develop new propositions, and forge new partnerships.[20]

20 See, e.g., www.mckinsey.com/business-functions/organization/our-insights/a-case-study-in-combating-bias (February 19, 2018)

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