# Roland Berger Focus

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## Business models in energy storage

Energy storage can bring utilities back into the game

Roland Berger

50 YEARS navigating complexity

# Management summary

While energy storage has been around for a long time, only now is its role becoming crucial for the energy system. With the rise of intermittent renewables, energy storage is needed to maintain balance between demand and supply. With a changing role for storage in the energy system, new business opportunities for energy storage will arise and players are preparing to seize these new business opportunities.

Energy storage should address the needs of players in the system, which may vary per time unit and per step in the value chain. Storage might be needed only for a few seconds, or to bridge demand and supply over the seasons.

Different storage technologies may best meet these various needs. However, most of these storage technologies are not yet mature. They cannot yet compete with alternatives to storage, like flexible power generation, more interconnections and demand-side management. Neither clear nor convincing business models have been developed. The lessons from twelve case studies on energy storage business models give a glimpse of the future and show what players can do today.

Traditional utilities have experience in balancing demand and supply and should build on these capabilities to start operating their storage assets now to pre-empt the competition in order to stay in the game. New entrants designing energy services solutions around storage and digital offerings are knocking on the door. For these players energy storage is a mode to enter the market. Some players may only offer storage capacity and will act as independent storage operators, as opposed to the independent power producers we know today. Other players may offer new energy services and trading concepts while having no need to own or operate storage facilities themselves. And anything in-between could also arise.

**With energy storage becoming an important element in the energy system, each player in this field needs to prepare now and experiment and develop new business models in storage. They need to understand the key success factors of future market leaders and reinforce those in the next five years to contribute value to storage and the overall system.**

# Contents

## Section 1:

# Introduction

Energy storage has the potential to disrupt business models.

Energy storage has been around for a long time. Alessandro Volta invented the battery in 1800. Even earlier, in 1749, Benjamin Franklin had conducted the first experiments. And the first pumped hydro storage facilities (PHS) were built in Italy and Switzerland in 1890.

Their first intended use was not only to generate power, but also to better manage the water resources. PHS facilities were mainly built in the 1960s, where they supported the rollout of nuclear power plants that delivered stable output not in line with demand fluctuations over the day.

Until recently, the role of energy storage has been beneficial but secondary to our daily life. Batteries provide power at those locations where no grid connection is present, like for starter motors in cars, mobile phones, laptops and other electronic devices or for emergency power for computer servers. In addition, large energy storage facilities, like PHS, still play a modest and supportive role to utilities.

This modest role for energy storage will end. Energy storage will become a crucial element in our uninterrupted energy supply. The ongoing transition with higher shares of renewable and intermittent energy sources and distributed generation applications requires ways to store and release energy when needed. New energy storage technology can deliver this.

Energy storage holds a large promise for the future. The equipment used in energy storage has to be manufactured, installed and operated. And new service models will arise. Storage solutions will create new connections between power generation and energy users, and between producing/consuming players ("pro-sumers") as well. Trading and arbitrage over time will create new business opportunities for the existing and new players in the energy field.

However, we are not there yet. Despite this apparently bright future for energy storage, no convincing business models have yet been established. Except for PHS, technology is not yet mature and storage technology still needs to conquer its space in the energy world, where alternatives can still address the needs of the energy system at lower costs.

Nevertheless, the first experiments with storage business are being conducted. Now is indeed the time for experimenting with business models in energy storage. The lessons and insights obtained now will position the players well to benefit from energy storage in the future.

Energy storage is about maintaining balance between supply and demand – a core activity of the traditional utility. Energy storage may therefore bring utilities back into the game.

In this report, we highlight the various needs for energy storage. We will also examine the first cases in deploying energy storage. We will sketch outlines of the future business models that may arise and draw recommendations for the players in the energy value chain.

## Section 2:

# Role of energy storage

Energy storage will become mandatory in the new renewable and decentralized energy system.

The energy transition will disrupt the traditional energy system. Intermittency and decentralized energy production creates larger imbalances between supply and demand. Energy storage will restore the balance. In this section we will identify the rationale for storage, and show that storage needs differ over time and per type of player. Different storage technologies are available to address all these needs. However, alternatives to storage are still more economical than energy storage, which is not yet a mature technology. Consequently, business models for energy storage are still in an exploratory phase.

## The energy transition is driving the demand for energy storage and storage technologies will be required in each step of the energy value chain.

### The energy transition creates a need for energy storage across the entire energy value chain

The energy transition will be the next and largest driver ever of energy storage. Variation in wind speed and differences in solar irradiation during the day will cause intermittency in power generation. Maintaining the balance between supply and demand will become more difficult. At the same time, the renewable energy generation assets will be installed at different and decentralized locations, leading to changes in grid utilization. Costly changes to the layout of the grid might be necessary to accommodate peak power flows.

The energy transition will be swift and the need for solutions to cope with renewables in the energy system will surely arise. In Figure A, solar and wind capacity combined in Europe will already be close to 90% of peak demand by 2025. This implies that renewable sources could meet all energy demand a substantial part of the time. And that sufficient backup must be available to provide power when renewables do not deliver. Even worse, the backup must be flexible, contrary to the optimal characteristics of all current fossil-fired power plants.

Figure A also shows the impact of intermittency. Solar PV only provides power during the day with a peak just after noon. Maximum production differs per day. Wind production is more volatile, but can deliver 24 hours a day. Nevertheless, total output can vary dramatically; for example there can be close to a 20 GW change over the course of a day in one region of Germany alone.

At the same time, the system inertia of traditional power plants provides frequency control. In Europe, the capacity of traditional power plants will decline by 11%. → A

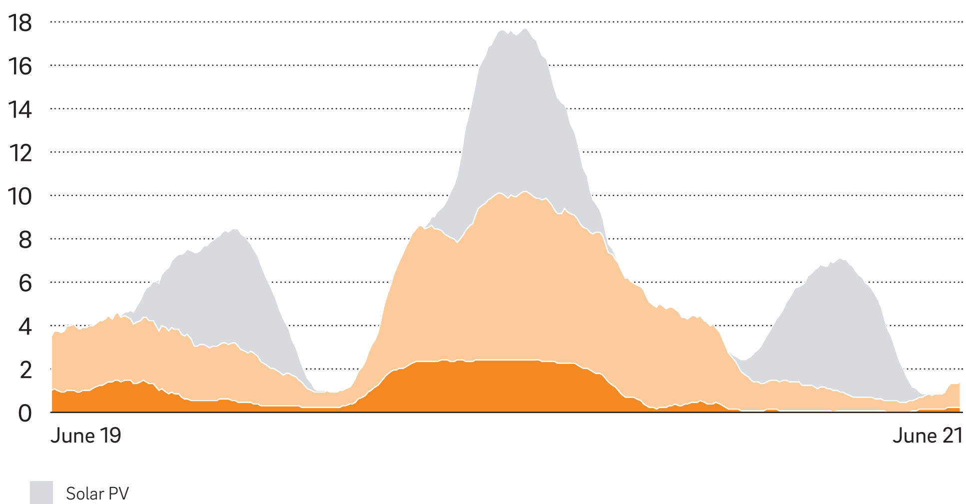
National Grid in the UK is already taking measures. As an island with limited interconnection capacity and an increasing share of renewables, matching demand with supply will become more difficult. National Grid has contracted 200 MW of batteries for its advanced frequency response system, a function that would otherwise have been provided by the system inertia of conventional power plants.

New renewable energy assets will also be built in different locations from those where traditional power plants are now being closed. This will lead to a change in origin and direction of power flows in the network and greater use of distribution networks, requiring reinforcements along the way. The costs of network up-

## A: Need for energy storage.

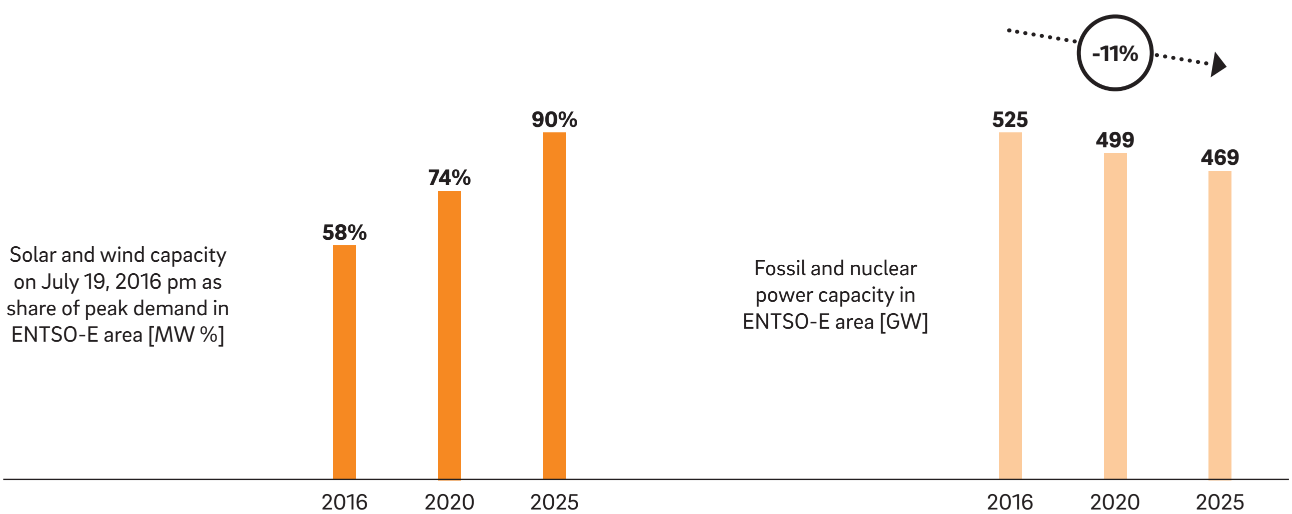
The rise of intermittent renewables leads to challenges in maintaining balance between supply and demand and the closure of traditional power plants reduces frequency control capacity.

Production from intermittent sources in TenneT area, Germany, June 19-21, 2016 [GW]




Solar and wind capacity on July 19, 2016 pm as share of peak demand in ENTSO-E area [MW %]

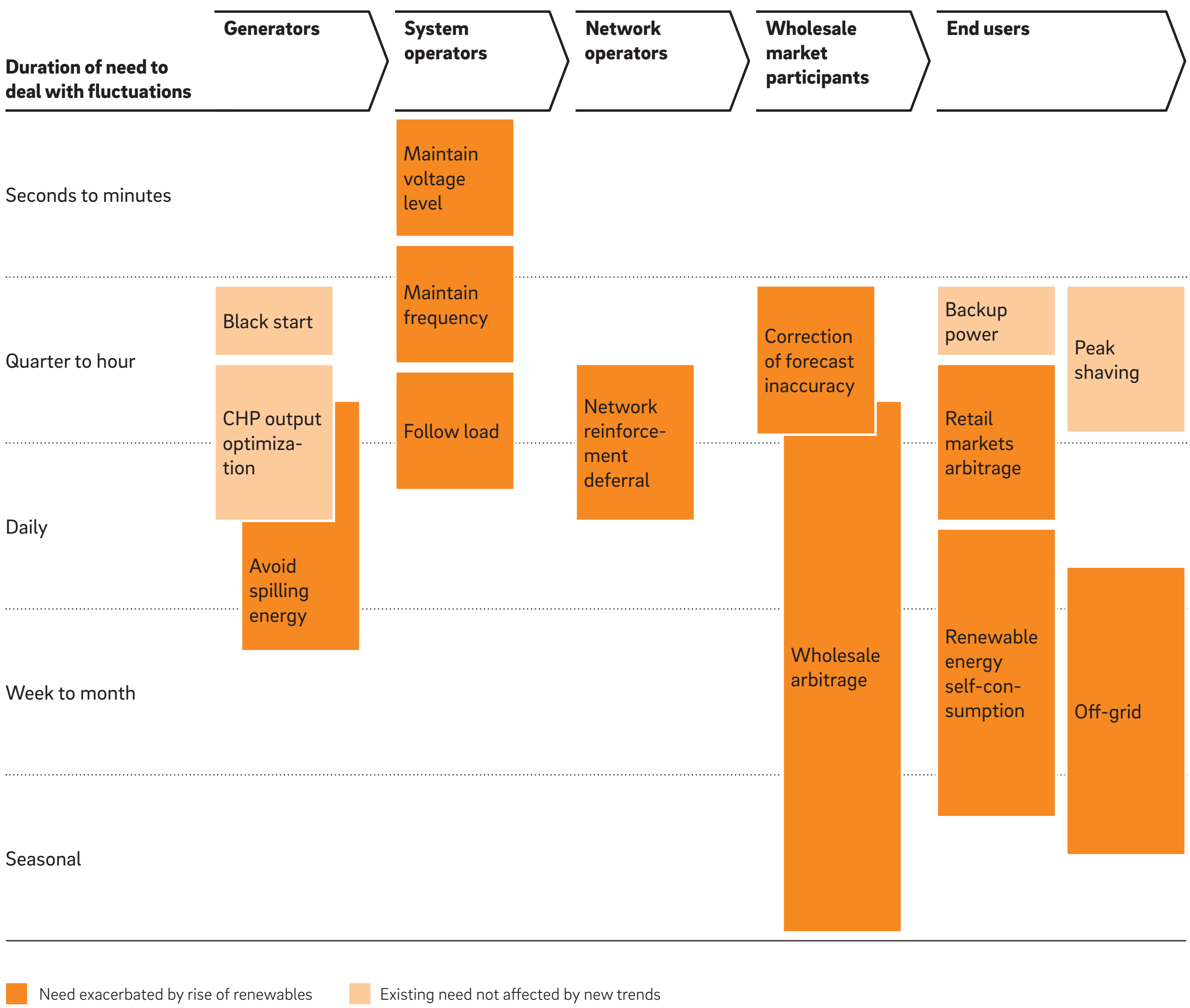
Fossil and nuclear power capacity in ENTSO-E area [GW]




Source: ENTSO-E, Bloomberg, EEX, Roland Berger

**B: Storage needs along the value chain.**

The predictable and unpredictable imbalance between demand and supply creates demand for storage solutions of different duration along the entire value chain of the energy system.




Source: IEA, Roland Berger

grades may be higher than of building energy storage, which can absorb peak demand on the network as well. Especially in congested urban environments, these network upgrade costs can be high.

### Storage needs differ over time and per type of player

Players active in the energy market will have different types of needs related to the more predictable or unpredictable imbalance between demand and supply over various time horizons. The underlying needs differ per time unit and per step of the value chain. → B

In the electricity generation step, power storage can support in black starts and in the optimization of the output of combined heat power plants. Those needs are not new. They existed well before the energy transition. Avoidance of spilling energy will be a new need brought by the transition. Without storage, excess power generated by onshore and offshore wind could be dumped in the absence of demand. Current negative electricity prices on wholesale markets already show that supply is often in excess of demand. Those energy storage needs, or cycles, have a duration of a quarter of an hour to a week at most.

System operators have needs of short duration. Operating the grid and maintaining balance between intermittency may lead to frequency deviations and voltage reductions. On a slightly longer time frame, load following is also becoming more important, where sudden changes in energy output from renewables cannot be matched as quickly by scaling up or down conventional generation output.

Network operators (those who are responsible for the assets themselves) may see new load points in new places in the grid with sudden changes in output. In addition, the increase in decentralized energy generation with solar PV rooftops and other renewable generation capacity attached to the local distribution grid may cause the power flows to go in different directions than initially foreseen with the outlay of the grid. Energy storage may prevent or defer some refurbishment and network reinforcement investments.

Trading on wholesale markets and fulfilling the portfolio management function of utilities also gives rise to new energy storage needs resulting from the energy transition. The ability to make accurate predictions about renewable energy output is needed for trading. Any deviations from the predictions would require on-the-spot sourcing of more electricity or selling of additional volumes. But longer term, energy storage enables more arbitrage. Major fluctuations in output will lead to larger price differences. Storage provides the means to take advantage of those differences. For instance, it will enable players to store energy in the summer at low prices and sell in the winter at higher prices.

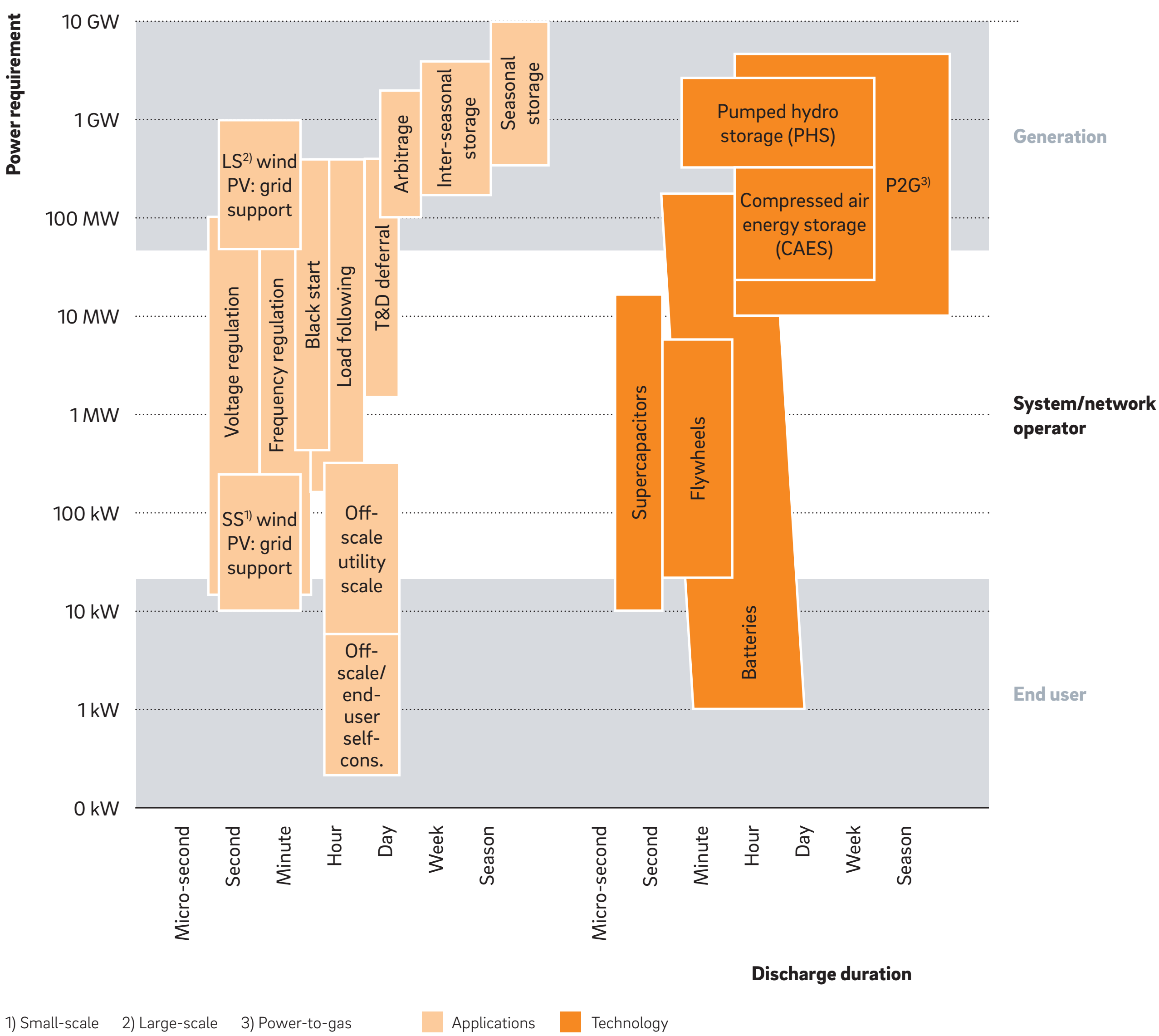
Finally, new needs have also arisen at the level of the end user. Using storage as a source of backup power has always been around. Hospitals and server rooms for instance have long relied on this. With storage, end users can now better manage their peak demand as well. In some cases, the energy bill depends on the total peak demand and significant savings can be made. Other opportunities for storage include arbitrage on retail markets – using and selling privately generated power or power from the grid.

### Different needs require different storage technologies – Most technologies are not mature yet

There are many energy storage technologies in existence. When it comes to meeting the needs described above, one size does not fit all – the characteristics of the technologies and their fit with the needs or applications, as described by discharge duration or power requirement, vary considerably. A variety of energy storage technologies will serve specific applications. → C

Most of these storage technologies are not yet mature. Some technologies are not fully developed and the tech-

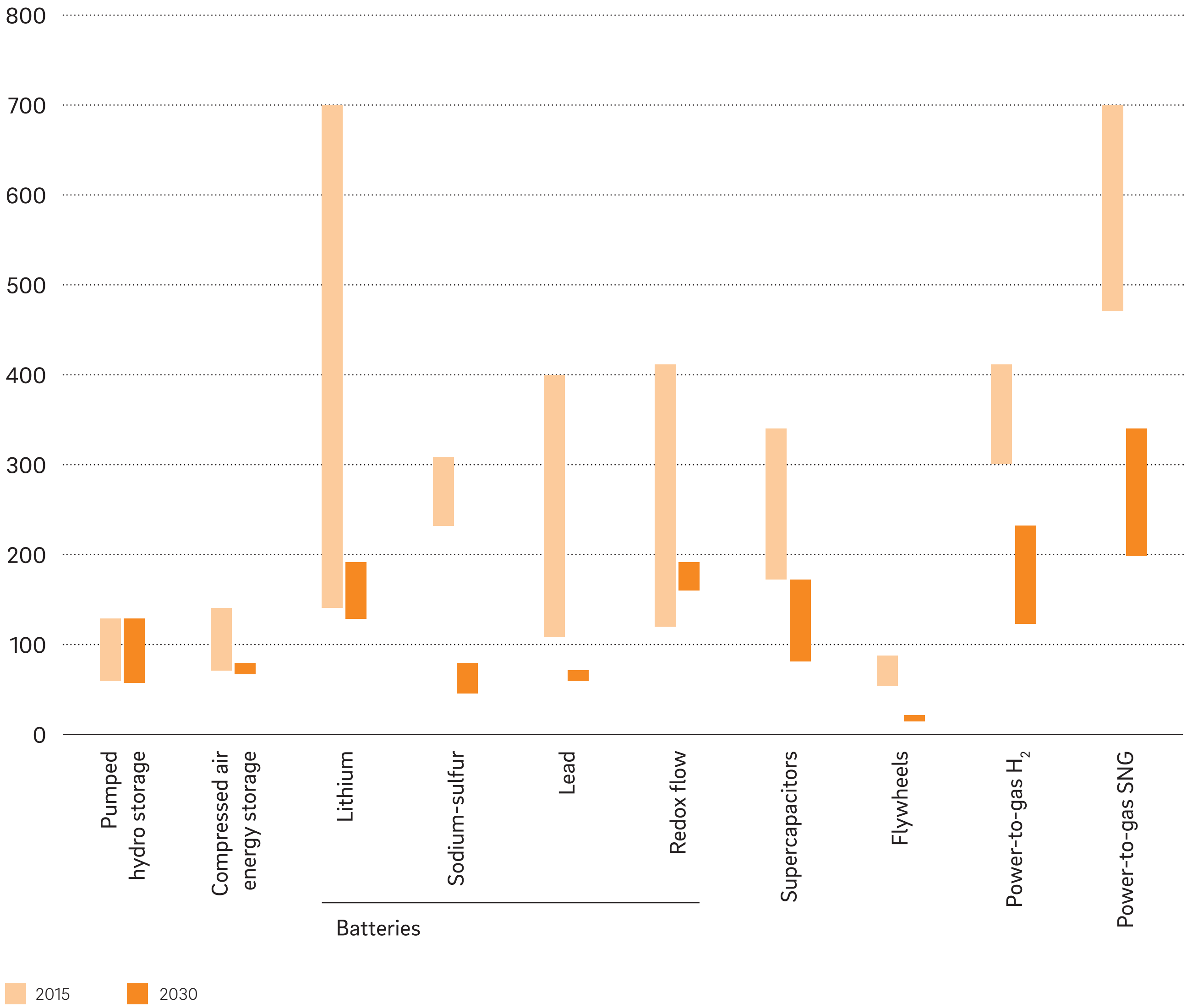
**C: Characteristics of storage technologies.**
A variety of energy storage technologies will serve specific applications.




1) Small-scale 2) Large-scale 3) Power-to-gas

Source: IEA, Roland Berger

**D: Costs of storage.**
Levelized costs of storage, 2015 vs. 2030 [EUR/MWh, 2014 price level].




Source: World Energy Council, Roland Berger nologies need to be further improved to become more reliable and secure. For other technologies, technological improvements are needed to make them cost competitive with other solutions for storage needs. At current costs (well above EUR 100/MWh) most storage technologies cannot yet compete with conventional generation capacity, like gas-fired peaker power plants. The outlook for the cost competitiveness of energy storage is positive. Technological advances, economies of scale and improvements in production processes are driving costs down. Operations and maintenance (O&M) and charging costs will fall as well, contributing to lower levelized costs of storage.

The levelized costs of storage (LCOS) enables comparison between different types of storage technologies in terms of average cost per produced or stored kWh. The LCOS of energy storage technology is still high as depicted by the costs of various technologies calculated by the World Energy Council. → D These levelized costs depend greatly on the intended use of the technology, which determines key variables like number of storage cycles, charging costs, etc.

It is important to note that storage technologies are competing with other solutions for dealing with the needs in the power system during the transition. Generally, the energy system is robust and other solutions that deal with intermittent renewable energy, decentralized energy or fluctuations in demand already exist. Basically, there are three main alternatives: flexible power generation, more (inter)connection capacity and demand-side management techniques. It is only at lower LCOS that new energy storage technologies can compete with these alternatives and their adoption will accelerate.

While the energy storage needs are there, alternatives to storage are still meeting these needs. Energy storage technology is not yet mature and its deployment is still often unprofitable. Indeed, existing PHS facilities are being used, but no new ones have been built for a long time under current market prices. Indeed, current market prices deter large-scale deployment of energy storage. Daily and seasonal variations are insufficient to deploy storage technology for time arbitrage.

Despite these current adverse market conditions for energy storage, the first pilot projects in energy storage are taking place in view of the clear potential of energy storage. Because of the unknown future economics of storage, no clear business cases or business models have yet been developed, however. Current activities seem to focus on identifying those and testing their applicability. Similar to the development of the internet, business models in storage are being set up, implemented and challenged, and will evolve into a sustainable business in time.

## Section 3:

# Cases

First applications of energy storage show potential new business models.

In anticipation of a bright future, the first projects with energy storage are being set up. We have analyzed some of these cases and clustered them according to their position in the energy value chain and the type of revenues associated with the business model. → E

Though the business models are not yet fully developed, the cases indicate some initial trends for energy storage technology. Energy storage is becoming an independent asset class in the energy system; it is neither part of transmission and distribution, nor generation. We see four key lessons emerging from the cases.

**Role of mature energy storage technologies adapts and shifts from balancing demand variation to enabling intermittent supply**

PHS has been installed in France, Japan and other regions to compensate for the inertia of nuclear reactors. Nuclear-powered reactors from the 1970s and 1980s have only a limited ability to modulate their power output. Hence, PHS has taken over this role and the revenues are based on storing power when prices are low during baseload periods at night and selling power when prices are high during the day. In addition, the only two compressed air energy storage (CAES) plants in the world play the same role – supporting baseload power plants to meet variable demand.

At the time of construction, these storage facilities were part of a system controlled by a single player. For instance, Electricité de France operated the full system, from nuclear power plants, transmission grid and PHS to distribution and could fully internalize the benefits of the PHS. Now, PHS and CAES depend on the transparent price signals provided by the wholesale markets. These plants currently participate in the wholesale market, though prices on the European continent are not yet offering sufficient incentives for the construction of new ones.

The business models for large energy storage systems like PHS and CAES are changing. Their role is traditionally to support the energy system, where large amounts of baseload capacity cannot deliver enough flexibility to respond to changes in demand during the day. Now, these large energy storage systems deliver the flexibility to respond to the intermittency of renewable energy sources. For instance, in northern Chile a proposed project for a 300 MW PHS will ensure a continuous power supply to mining companies from a 600 MW solar PV plant. Thanks to the low costs of PHS and solar PV, the system can run without subsidies.

In Northern Ireland a proposed CAES facility will exploit several revenue streams and support the full energy system. Intermittent wind energy in Northern Ireland requires substantial balancing efforts, as the grid is not well-connected to other regions. CAES will help reduce the current high overall system costs – so reliance on costly gas-fired backup capacity will be reduced – and it will provide ancillary services. Revenues will come from the spread on wholesale markets and ancillary services market.

**Power-to-gas and to other liquids are still in a pilot phase and will primarily target fuel production for the chemical industries and mobility**

Power-to-gas can deliver seasonal storage, supporting the general energy system when there is limited solar PV production in winter and less wind in summer. So far, the power-to-gas pilot projects have not yet delivered a convincing business case, as costs of power-to-gas are still too high. With more than 20 pilot projects, Germany is the country leading the pack. First applications are not purely focused on energy storage, however. While power-to-gas will convert excess electricity into hydrogen or other gases (like methane), these gases likely will be used as a fuel in mobility, industry or households. Consequently, utilities, car manufacturers and chemical companies are all involved in these pilot projects. Power-to-gas installations will run when

**E: Energy storage cases.**
Classification of cases by revenue streams and position in the energy value chain.

<table>
<tr><th></th><th>Support to broader generation system</th><th>Support to power generation</th><th>Grid support</th><th>Consumption support</th></tr>
<tr><td>No revenues</td><td>DE<br>Pilots with power-to-gas to develop seasonal storage</td><td></td><td></td><td></td></tr>
<tr><td>Revenues dependent on subsidies</td><td></td><td></td><td>US<br>Ancillary services as a pilot</td><td>DE<br>Raising solar PV self-consumption</td></tr>
<tr><td rowspan="3">Single revenue stream</td><td>US<br>Peak demand support in urban areas</td><td>CL<br>PHS to complement solar PV production at night</td><td>UK<br>Frequency response to address intermittency in the UK's isolated network</td><td></td></tr>
<tr><td></td><td></td><td>IT<br>NaS batteries to relieve congestion in North-South grid</td><td></td></tr>
<tr><td></td><td colspan="2">US<br>A CAES system provides ancillary services and complements a coal-fired and nuclear power plant by storing excess production for later peak demand</td><td></td></tr>
<tr><td rowspan="2">Multiple revenue streams</td><td>UK<br>Balance demand and supply with high amount of wind energy</td><td></td><td colspan="2">DE<br>Connecting batteries in a virtual network to provide ancillary services and enable power trading between prosumers at prices between FiT and retail price</td></tr>
<tr><td></td><td colspan="2">US<br>Battery and solar system to provide ancillary services, T&D investment deferral and peak demand shaving for local community (tariffs are highest)</td><td>US<br>Support batteries when power demand suddenly jumps</td></tr>
</table>

Power-to-gas | PHS | Battery | CAES | Flywheel

Source: Roland Berger

wholesale prices are low or even negative. The aim of the German Energy Agency is to make power-to-gas an economically viable solution by 2022. Given that petrol and hydrogen are relatively more expensive than electricity, first applications of power-to-gas will target fuel production.

**Batteries mainly address a single purpose, but will increasingly be used for many different goals to optimize their value**

The areas of application for batteries are wider. Batteries can be used to support consumption, to support the grid by provision of ancillary services or to complement power supply. The sizes of battery systems thus differ. Small-scale batteries are deployed at the place of consumption. Larger-scale systems are connected to the grid. The applicable rules and regulations and the market system determine the revenues to a great extent.

First battery applications focus on single revenue streams, for instance on raising self-consumption for owners of solar PV panels. In addition, regulation could force owners of batteries to address only a single revenue stream. The value of batteries can be better monetized when several revenue streams are targeted, especially when the various storage needs are not concurrent. However, regulation of ownership should enable this; it will also give rise to new business models on the ownership and management of batteries.

Residential battery storage at homes enhances self-consumption from solar PV. Dependent on the regulatory environment and the electricity and network tariffs in a country, a battery could raise the overall value of the solar PV system. By raising self-consumption, the household saves the electricity that it obtains at the higher retail price and does not sell the self-generated solar PV at the lower feed-in tariffs. Using a battery for this purpose only is not yet profitable and the German government is currently subsidizing this.

Therefore, new business models are being developed to make better use of the battery. Sonnen and Lichtblick are developing peer-to-peer networks where consumers can share their solar PV production and battery capacity. Trade in power between consumers is feasible at lower-than-retail tariffs, but higher than the feed-in tariff. In addition, the community of batteries can be used to provide ancillary services to the grid, tapping into additional revenue streams.

Likewise, larger systems of batteries are mainly used to provide grid support functions and target a single revenue source. Application today is mainly in grids characterized by bottlenecks or those that are not well-connected to other regions. The revenues are highly dependent on rules and regulations.

For instance in Italy, sodium-sulfur (NaS) batteries have been deployed to resolve bottlenecks in the grid caused by oversupply of solar PV in the south that needs to be transported to the north. The batteries provide ancillary services. The national grid operator Terna received permission to own and operate the batteries, as energy storage is generally considered to be generation capacity that transmission system operators (TSOs) are not allowed to own under unbundling. The value of the batteries is therefore included in the regulated asset base of Terna, and Terna receives the regulated return via the fees it charges to the grid users.

In the United Kingdom, a different ownership model is in place. Being on an island, the UK network is not well-connected to other countries and significant shares of wind and solar energy are causing significant imbalances between demand and supply. National Grid in the UK has contracted 200 MW in battery capacity from an independent owner for its enhanced frequency response over a four-year term. Though the owners will use the batteries for these ancillary services only, it is expected that the batteries will also serve other applications in the future, given the very low prices offered in the tender.

Under different rules and regulations, a municipal utility in the United States has installed 7 MW of batteries with the aim of benefiting from several revenue sources. First, it uses the battery to provide ancillary services by selling energy into the PJM Interconnection frequency regulation market. It also benefits from deferring an investment in the grid. And the battery can provide power during peak demand, when the municipal utility would pay higher fees. Large-scale deployment will take place in Long Beach, California, where AES will build a 100 MW battery system. It will provide power during times of peak demand and will balance the intermittency from a growing share of renewable sources. Its location in the middle of a demand center also contributes to power quality and reduces the pressure on transmission lines. Here, a single 20-year power purchase agreement (PPA) between the owner AES and the utility Southern California Edison will determine the revenue streams.

**Flywheels will be used to quickly provide grid support, but are still dependent on subsidies and may have to compete with multi-purpose batteries**

Finally, flywheels are used to provide support to the grid. Flywheels have a faster response time than batteries, but have fewer alternative applications. Subsidies are still needed for flywheels. The largest flywheel is operated by developer Beacon Power in Stephentown, New York, and Hazle, Pennsylvania. The flywheels receive their revenues by selling their services into the ancillary services regulation market. Their business model was supported by a new federal rule requiring grid operators to pay higher prices to companies able to provide the fastest and most accurate injection of power into the grid.

Another example of the use of flywheels in a fairly typical situation is on Kodiak, an island in Alaska. There, batteries ensured the integration of renewable energy

## New business models are being developed to make optimal use of the battery – Peer-to-peer networks enable the sharing of battery capacity.

with the island's energy grid. A flywheel was needed to support the operation of two electric cranes in the port, whose power demands could destabilize the grid. Furthermore, the flywheel as the first provider of ancillary services would reduce the stress on the battery system and enhance its lifetime.

The cases above illustrate the observations made in section 2 on maturity and costs. They also show that the business models for energy storage are still marked by uncertainty. Energy storage is not yet fully adopted, except for PHS. There are several reasons for this:

### Immature technology

Most technologies are not yet mature. Technological advances are still required to increase efficiency, extend the lifetime of the technologies and reduce safety issues. The high costs are in part a result of these technologies not yet being fully developed.

### High costs of storage

Related to the immature technology, the costs of energy storage are still too high. Further optimization of the technology and production processes, and the exploitation of economies of scale are needed to enable large-scale commercial deployment. The high costs are caused by the considerable capital expenditures required, the O&M costs and the low efficiency of a store and recharge cycle.

### Low revenue base

In the current market with a relatively low daily spread between baseload and peakload prices and minor differences between summer and winter prices, energy storage does not yet deliver sufficient revenue. At the current high costs of energy storage technology, no convincing business case for arbitrage exists.

### Lock-in of alternative solutions

Energy storage technologies compete with other solutions to deliver or absorb power when needed. Existing solutions, like grid expansion or more interconnections, the establishment of a capacity market for gas-fired power plants or strategic reserves, still receive a great deal of attention from policy makers, regulators and system operators. Energy storage solutions are not yet included in their tool box, given that this requires a cultural shift as well.

### Immature policy stifling business opportunities

The value of energy storage depends to a great extent on rules and regulations that determine the revenue base. Current policies for the energy system do not yet acknowledge the specific role of storage and they are often seen as generation-only. Today's tariff structures, capacity and consumption fees for grids and taxation determine the revenue base of storage to a great extent and may not always lead to optimal outcomes. Also, in unbundled systems, rules on the ownership of the storage may prevent optimal application of storage assets, especially when a storage solution could provide several services. In addition, the market for ancillary services is not yet fully developed and many different pricing models exist in the European Union. Finally, not all of the benefits of storage are currently priced.

## Section 4:

# Implications

The advent of new energy storage business models will affect all players in the energy value chain.

No definite views on business models for energy storage have crystallized yet. Given the large expected cost declines, changes in revenue sources, adjustments in rules and regulations and reshaping of the power generation assets, only the outlines of the future business cases can be seen, indicating which developments will be critical to watch.

## SUPPORTING THE GRID WITH ENERGY STORAGE WILL BECOME A NEW ENERGY MARKET SEGMENT

**System operators and utilities need to find the right legal and business conditions to capture revenue streams from several storage applications at the same time to reduce system costs**

Energy storage is already being deployed to provide ancillary services to the grid. Deployment is so far limited, as existing power plants can still provide most of the required services. The cases have shown that energy storage is only needed in regions with limited interconnection capacity and higher shares of intermittent renewables to maintain balance in the system.

With increasing shares of intermittent renewables and interconnection capacity not keeping pace, the need for ancillary services provided by energy storage will increase in more countries across the EU in the next 15 years. → F

Most energy technologies can provide ancillary services. While the characteristics of flywheels make them ideal for the provision of these services, batteries, CAES and PHS are able to deliver power with fast response times as well. These technologies have the added advantage that they can also provide other services. As they can tap into more revenue sources, they could outcompete flywheels.

Uncertainty in the treatment of energy storage within the rules and regulations hampers the future deployment and appropriation of all value streams available to these assets. When a system operator (TSO and/or DSO) owns a storage device, commercialization of the revenue streams might not be feasible. On the other hand, when a system operator only procures the ancillary services, the system operator might not have sufficient operational control to guarantee security of supply.

### Implications

A single storage asset can and should be used to serve many different purposes and optimize its value. In an unbundled system, the owning and operating of these assets by system operators may lead to difficulties if the system operator were, for instance, to operate the technology to enable arbitrage on wholesale markets. System operators and regulators should make sure that a regulatory framework is designed that takes into account the specific nature of storage, distinct from normal generation capacity.

System operators should thus define a strategy on how to optimally use the services from energy storage. They can own and operate the storage assets, or procure the services over the long or even short term. Criteria on availability, quality and costs should lead to a policy that optimizes the management of the total grid. It is important to exploit all revenue streams available to the energy storage asset in order to lower costs.

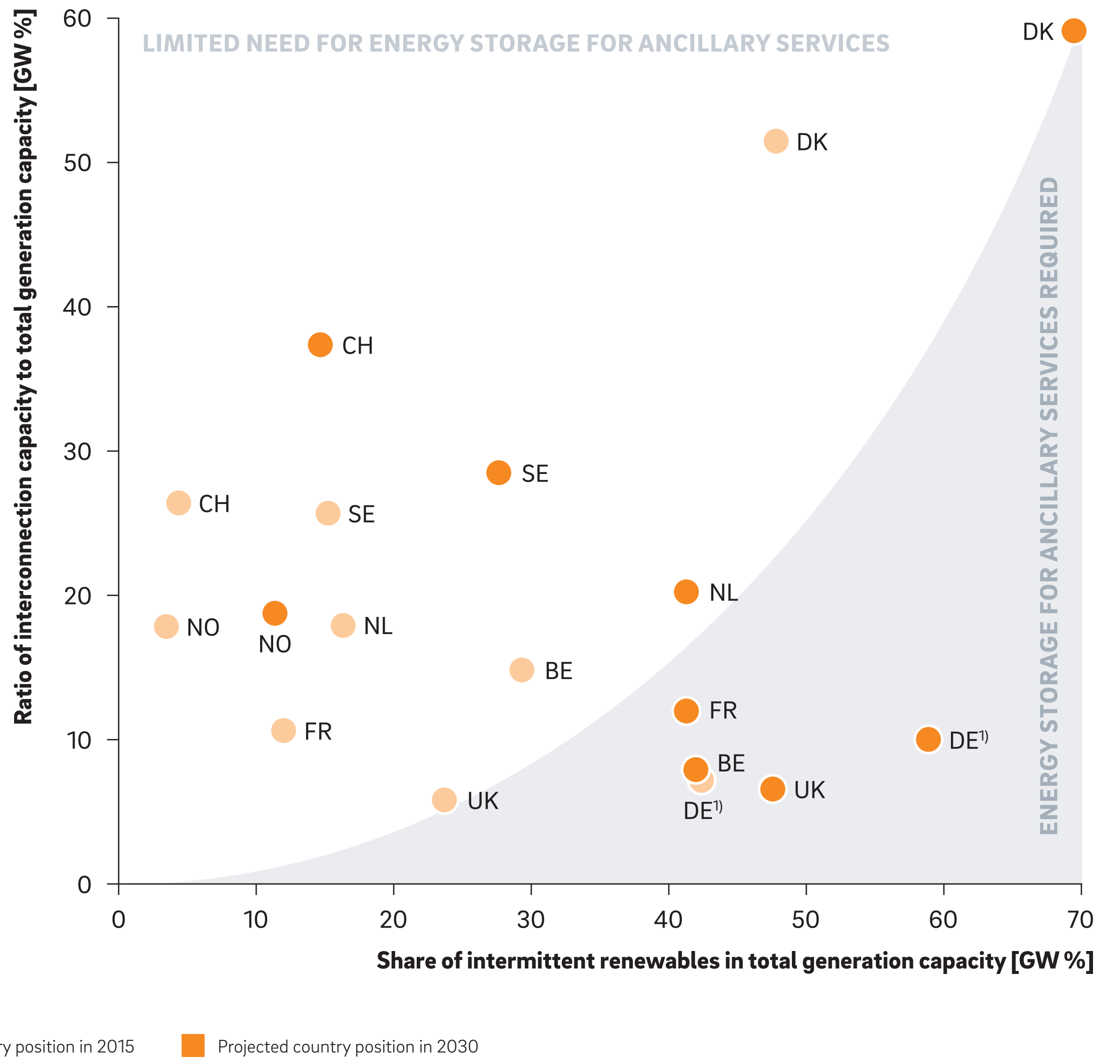
The provision of ancillary services also adds an attractive revenue stream for operators of storage technology. These operators should design models that enable the often short-term deployment of the storage assets for the provision of these services, while continuing the reliable delivery of the storage services to other users. Ancillary services could be a separate business line for utilities.

## BATTERIES BECOMING THE LINKING PIN IN ENABLING SALES OF POWER BETWEEN PRO-SUMERS

**Utilities and system operators need to offer battery capacity so that they too play a role in the future decentralized energy system**

In the retail market, the adoption of batteries depends to a great extent on rules and regulations. The reimburse-

**F: Need for energy storage in provision of ancillary services.**
Large shares of intermittent renewables and low interconnection capacity require the adoption of energy storage.




1 Interconnection capacity between Germany and Austria not included, as it concerns a single market zone

Source: ENTSO-E, Roland Berger

ment of non-self-consumed solar PV and the access fee to the grid determine whether investing in a battery represents an optimal investment or not. In Germany, where there is a large difference between the feed-in tariff and high retail prices, promotion of self-consumption raises the value of the solar PV system. In countries with net metering, or smaller differences between retail prices and feed-in tariffs, energy storage delivers little value as batteries still represent a substantial cost.

In the future, pure domestic solar PV + battery systems will not be a hardware-only solution. New services will add value to the system. Remotely operating a network of batteries can provide ancillary services to the grid. The network of batteries also opens up the opportunity to store electricity in the batteries of others and to share and trade electricity between solar PV owners. Current network fees dependent on volume rather than capacity could still impede this trade between consumers. However, a switch towards a capacity tariff could enable battery sharing on a larger scale. It is conceivable that batteries could one day be placed at central locations and their capacity rented out to consumers.

The advent of these services is also an indication that an autarkic future or grid defection is not likely. A grid connection is needed to profit from these services. Furthermore, an over-dimensioned solar PV array and battery system is needed to maintain sufficient security of supply and also have electricity after several cloudy days in winter. However, such a large system will yield much more electricity during the year than needed. It would be costly not to sell the excess electricity via the grid.

Batteries in electric vehicles will also greatly expand the future business models in solar PV + batteries. Electric vehicles can be charged when production of solar PV is highest. However, charging of electric vehicles depends on the network and tariff structure as to whether your own solar panels can charge the car parked at your workplace. Furthermore, the required driving range would limit the use of car batteries to some extent. Still, car batteries can be connected in a virtual network and deliver ancillary services to the grid.

### Implications

Future business models for solar PV and battery systems are characterized by uncertainty. The revenue models are dependent on regulation of the energy sector, the prices and pricing models for grid access and retail energy, and the evolution of the technology, such as electric vehicles, and digital tools like demand-side management. Nevertheless, more and more solar panels will be installed and the needs of traditional energy clients will shift from buying electricity to procuring energy services.

Batteries will become a commodity, even more so than solar panels. To become a successful battery manufacturer, a company needs to have scale to optimize the production processes and produce at the lowest cost. Differentiation will come from the provision of energy services and digital solutions.

Utilities losing revenue from power generation as consumers produce more and more of their own electricity can find new business opportunities in the provision of energy services. Batteries will become the linking pin in offering services for decentralized energy supply. Batteries enable the trading and sharing of energy between pro-sumers, demand-side management and the provision of ancillary services. Access to consumers' batteries can even be used for personal portfolio management and trading operations. Utilities can also experiment with the provision of virtual batteries to clients, or batteries in the cloud, partially backed by more central batteries in distribution grids. To open up the opportunities of these future business models, utilities need to maintain access to customers in the face of many service providers and digital companies entering the market already. Integrated offers with solar PV, battery and

e-vehicle charging and power supply could be compelling to end users. Furthermore, utilities must ensure that the rules for grid access and grid-fee models are favorable to the provision of these energy services.
Distribution service operators (DSOs) could also play a role in the pro-sumer landscape by providing services. DSOs could offer virtual batteries to end users, or manage a network of batteries to provide ancillary services. DSOs should anticipate the future power flows in a battery-networked world, where solar PV panels and e-vehicle charging could lead to different flows than in the current central model. New connection capacity and batteries at crucial locations would enable these shifts in flows.

## PHS AND CAES WILL BECOME IMPORTANT ASSETS IN THE FUTURE ENERGY SYSTEM

### Obtaining access to prime locations will enable energy players to make optimal use of these assets and support their trading activities

PHS and CAES are the most mature technologies. Their main stream of revenue comes from selling power when prices are high and thereby contributing to meeting peak demand or compensating for the absence of wind or solar power. In addition, they provide ancillary services. Nevertheless, at current power prices, new PHS and CAES cannot operate without subsidies in the EU.
Increasing the shares of renewables in the fuel mix in the next decade will lead to larger price differences, creating more incentives for large-scale energy storage. While the current share of renewables in the EU equates to 23%, it is expected to almost double by 2030 (to more than 40%). In certain countries, wind and solar PV can then generate more power than is consumed, driving prices to zero for longer time periods. Being one of the largest cost items, lower electricity prices will enhance the value of storage and enable more price arbitrages both during days/weeks and seasons.

**Implications**
Since traditional utilities are losing production volumes to owners of renewable energy assets, obtaining storage assets can return some of the lost revenue base. With decreasing costs of storage technology and large price differences, operators of energy storage technology can obtain a positive return from price arbitrage by essentially delivering power when demand is high (or wind and/or solar power generation is absent). These assets will also enable the owners to compete with carbon-intensive generation capacity. As PHS and CAES are location specific, utilities can already begin trying to obtain access to prime sites (i.e. featuring good caverns or lakes) now, and prepare for larger price fluctuation in the future.
In addition, owners of a renewable energy portfolio may benefit from operating storage assets, as it will support the management of their production portfolio and trading on wholesale markets. The operators can better predict and determine the production volume at specific hours and better balance their demand and supply portfolio. Renewable energy asset owners should obtain access to storage locations, either by renting capacity or by owning and operating the plant.

## POWER-TO-GAS WILL BE A FUTURE ROUTE TO DECARBONIZING THE ECONOMY

### Participation in current pilot projects will weld together the partnerships required to optimally valorize the various value streams

So far power-to-x installations exist only as pilot projects. Yet it is clear from these projects that a wide range of value streams are available to the operators of power-to-gas installations. In such projects, chemical companies see the opportunity to produce hydrogen and other fuels; utility companies see the potential to use excess power; car companies see the benefits of producing fuels for automotive applications; and even gas TSOs may earn from

storing gas in their system. The German gas network has storage capacity for three months of demand.
When the costs of power-to-x decrease, more applications will become available. First applications would initially be in the form of fuel production to generate positive returns, when the electricity prices are low enough during certain time periods. Operators of these installations must carefully design the outlets of their fuels to optimize the value of the business. Only later, when the price of the produced gas or ammonia is lower or equal to current fossil fuels, will it be possible to use power-to-x installations to generate power and close the storage cycle. This is, however, not a necessity.

### Implications

Given the scale of the disruption that synthetic fuels could create for the chemical industry, chemical companies need to monitor the developments carefully. Though these synthetic fuels are currently more expensive than fossil fuels, declining costs and changing regulations and stricter $CO_2$ emissions policies could lead to the adoption of these synthetic fuels in the coming decades. Besides focusing on production technology, these companies should reinforce their capabilities to deal with power market trading. The value of power-to-gas comes from sourcing electricity at times when prices are low. Partnerships with utility companies could enable these capabilities to grow.
As a large part of the value of power-to-x comes from the use and sale of the fuels, utilities need to develop new competencies to operate these installations. Partnerships with chemical companies may add value as well. Utilities can benefit from operating the power-to-gas installation to smooth out (unexpected) intermittency of the renewable energy portfolio.
In the long term, energy traders may use power-to-x installations for their arbitrage trades on wholesale markets. And it may well suffice to have access to these installations, rather than owning them.

## Section 5:

# Recommendations

## Energy stakeholders need to prepare today to capture the business opportunities in energy storage and develop their own business models.

In the energy transition, new players offering intermittent power supply have disrupted the old business models of utilities. The rise of storage technology will again lead to a shift in the industry. New business models are being designed and their ultimate form will depend on many technological, market and financial factors. Players need to prepare now to stay in the game in the future. We have depicted a few of the key success factors for market leaders in energy storage. Various players can already take steps to start building up a competitive edge in this new market segment of the energy industry.

**Key success factors for market leaders in energy storage.**
Activities to put in place the key success factors in energy storage.

| | Key success factors of market leaders | What to do in the next five years |
|---|---|---|
| OEMs | > Low costs of production<br>> Access to appropriate technologies | > Obtain scale for production<br>> Invest in R&D<br>> Monitor developments and manage portfolio of technologies |
| DSOs and TSOs | > Provision of infrastructure for power and data flows (IT, power lines and storage capacity)<br>> Use storage technology to optimize operations and lower costs | > Roll out smart grid technology<br>> Prepare grid for role of storage in network<br>> Define ownership models for storage and/or procurement of services<br>> Set up technology watch function to systematically identify and assess business potential and impacts of new storage solutions |
| Energy service companies | > Integration of heat/power technologies to offer lowest energy costs<br>> Optimization of equipment to serve internal needs and external (on-grid) needs, like ancillary services | > Design integrated solar PV, batteries, heat pumps and demand-side management solutions<br>> Develop networks of ESCOs to develop additional services |
| Energy traders | > Provision of appropriate quantities of power at the right time<br>> Optimal integration of storage in complete supply portfolio to deliver the lowest costs | > Invest in access to storage capacity<br>> Include storage technology characteristics in trading algorithms<br>> Develop business models to link energy storage with capacity and flexibility in wholesale markets |
| Energy suppliers/ utilities | > Optimization of energy trade between pro-sumers<br>> Ability to provide large-scale capacity on demand<br>> Absorption of excess power in markets or from clients (last resort)<br>> Access to batteries | > Build up a portfolio of storage technologies<br>> Design new energy services/offer tailored solutions to pro-sumers<br>> Partnerships with large energy users of power-to-x facilities |
| Chemical companies | > Low-cost fuel production with flexibility<br>> New materials for energy storage technology | > Develop partnerships with utilities for power-to-x facilities<br>> Partner with OEMs for technology and supply of materials<br>> Conduct R&D and pilot new technologies |
| Automotive companies | > Low lifetime costs of storage technology in vehicles<br>> Ability to harvest synergies between stationary batteries and energy storage (V2G) | > Develop service models to integrate car batteries, fuel cells or engine with the grid<br>> Develop innovative business models to integrate EV with decentralized energy production at home and at work (buildings) |

Source: Roland Berger

## Section 6:

# Conclusions

Energy storage will become a new business line in the energy world.

The energy transition is changing the energy landscape. New players have entered the industry, operating renewable energy generation capacity, while taking away sales from traditional utilities. Consumers have started to produce energy themselves, leading to lower demand. System operators have to incorporate intermittent supplies in their grid and major shifts in power flows have occurred.
Energy storage technology will become indispensable to increase the share of renewable energy in the system. It enables the balance between demand and supply to be struck by absorbing and releasing power when needed. Energy storage technology will become the linking pin in the energy system. By balancing supply and demand it will create the platform for many new services. Traditionally, utility companies have experience in balancing demand and supply. Operating energy storage technologies and providing the associated services gives them a unique position in the industry once more. To succeed, however, they need to own, operate and experiment with energy storage assets and design the business models of the future. Utilities need to start operating these assets now to preempt the competition in order to stay in the game, because energy storage will become a new business line.
New entrants designing energy services solutions around storage and digital offerings are knocking on the door. For these players energy storage is a mode to enter the market. Some players may only offer storage capacity and will act as independent storage operators, as opposed to the independent power producers we know today. Other players may offer new energy services and trading concepts and have no storage themselves. And anything in-between could also arise.
The new business models in energy storage have not yet crystallized. But the first outlines are becoming clear. Now is the time to experiment, gain experience and build partnerships. To be ready for the future and be a part of the future.

**It is time to experiment, gain experience and build partnerships in energy storage. Future business models are being designed now.**

# Imprint

## WE WELCOME YOUR QUESTIONS, COMMENTS AND SUGGESTIONS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