



Electric energy storage as an element of low-carbon energy supply

Energy storage is one option to provide the electricity grid with flexibility. Short-term storage can provide system services for power quality, whereas medium-term storage allows to shift significant amounts of energy over some hours up to days. Seasonal or long-term storage can, for example, be provided by the power-to-gas technology. Significant amounts of storage will be necessary, especially when a fully renewable supply is approached. New mechanisms are needed to ensure anticipatorily that sufficient flexibility is in the system at any time.

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Introduction

Energy demand and supply have to be in balance at all times. That is crucial especially for the electricity system: A mismatch endangers the stability of the supply grid. In a conventional energy system, the balance is ensured by the in-time production of energy from fossil fuels. When moving towards a low-carbon energy supply, the energy from those fossil power plants needs to be replaced by feed-in from renewable energy sources. However, renewable feed-in is less flexible than fossil generation, since electricity is generated when the wind blows or when the sun shines, not when it is needed. This means a loss of flexibility in electricity generation. To compensate for that loss, new forms of flexibility are needed. There are several options to achieve that: apart from energy storage,

grid extension, demand side management or over-installation of renewables can also contribute. None of this options is going to be the only solution, but a concerted use of all of these will most probably turn out to be the best answer to the challenge of balancing renewable energy supply. It is therefore important to keep in mind that storage is one among several balancing options.

Storage technologies

There are several electric storage technologies that differ in size, response time, capacity, power and in the kind of energy used to store electricity. Figure 1 gives an overview over those technologies.

Short-term storage does not allow to shift larger amounts of energy, but can respond within milliseconds and has a high output power. That qualifies it to provide system services, such as inertia control or reactive power, which are important for voltage quality in transmission grids.

The term **medium-term storage** identifies storage

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technologies that are able to store and provide energy for minutes up to some days, such as pumped hydro-storage or large batteries.

Long-term storage is also referred to as “seasonal storage”. It is a kind of storage that provides energy over long periods, ranging from several days up to months. It is an alternative to having fossil backup capacities and becomes important in systems with high shares of renewables. Technologies suited to those tasks are either pumped hydro-storage with very large reservoirs or the use of the so called power-to-gas technology, i.e. the conversion of electricity to hydrogen via electrolysis and the optional further processing with carbon-dioxide, which results in methane. Both forms of gas can be used in different gas-appliances.

Cross-sectoral storage is another kind of storage that uses links between the electricity and other sectors. For example, heat pumps and combined heat and power plants (CHP) are links between electricity and heating. When these are equipped with thermal storage, they give extra flexibility on the electrical side: their electricity consumption or production can be shifted

to proper times, thereby providing a “virtual electricity storage”. In the transport sector, electric vehicles are likely to be a widely spread technology in the future. Their batteries can be charged in suited times, providing a virtual storage compared to uncontrolled charging.

Also, there is a huge potential in electrifying appliances that have so far been fuelled by other forms of energy. In a renewable energy system, this has a double use: on the one hand, decarbonising electricity is easier than other forms of energy. On the other hand, if the consumption of those appliances can be timed, this gives additional flexibility to the electricity system.

When will storage be needed?

This is not a question aiming at a certain point in time, but at the share of renewables. Figure 2 gives an overview over different phases of storage demand. In a system with low to medium renewable shares, storage rather promotes fossil base-load power plants: By providing an additional load in times of high renewable feed-in (going along with low energy prices), storage raises energy prices to a level suited to conventional power generation.

Above a share of about 40%, physical excess feed-in from renewables will occur. At that point, storage becomes necessary to promote the integration of renewables into the electricity system by shifting energy from times of excess to times of demand.

Without storage, a fully renewable electricity supply, based on fluctuating renewables such as wind and solar, can't be achieved as there will always be times without sufficient feed-in, which needs to be covered either by storage or by conventional power plants.

The higher the share of

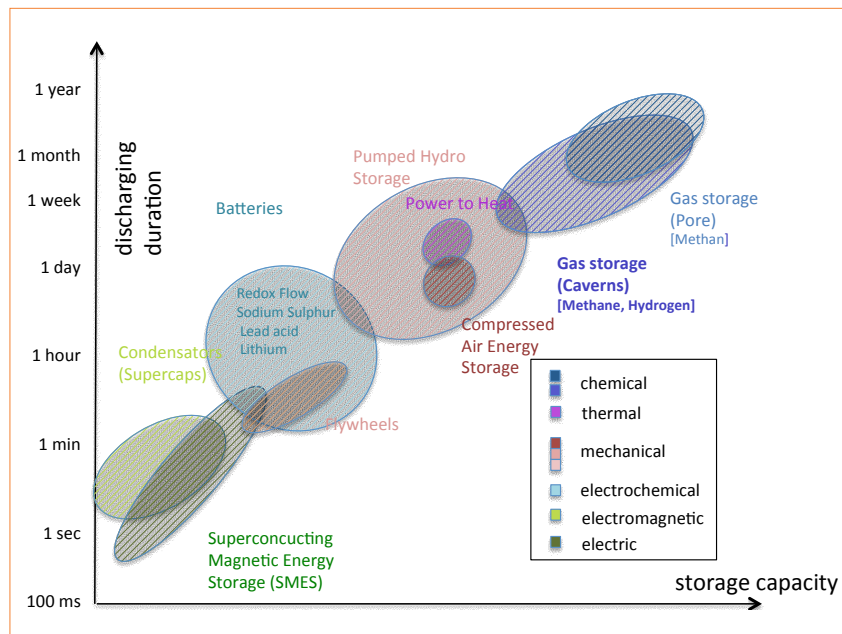


FIGURE 1 Overview over electric storage technologies
Source: own figure based on [1]

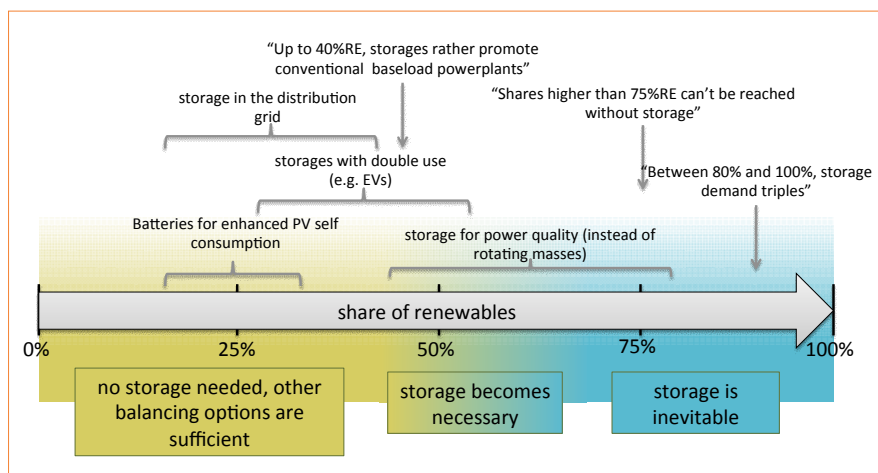


FIGURE 2 Development of flexibility demand over share of renewables
 Source: own figure based on [2, 3, 4]

renewables, the larger the storage needed. Storage demand rises particularly fast when approaching 100%, as large amounts of energy need to be stored to ensure sufficient energy supply at all times.

Locally, short-term storage can already be necessary at an earlier stage. Conventional power plants do not only provide energy, but also system services such as reactive power control. Short-term storage is one option to compensate the loss of conventional plants' system services.

Apart from the task of balancing energy, storage also comes into the grid for other purposes. For example, the batteries for electric vehicles' or for solar home systems have different primary functions, but can also be used for grid balancing.

Recommendations regarding energy storage

Along with the rising share of renewables, new forms of flexibility are needed in the electricity grid. In the short to medium term, measures such as flexible power generation, demand side management and grid extension might be sufficient but, in the long-term, storage will be necessary to balance the electricity supply.

Therefore, new mechanisms are required, which ensure

that sufficient flexibility already exists when it is needed. Such mechanisms can be, e.g., capacity markets or regulatory instruments. These mechanisms have to be designed in a way that they escort the transformation of the energy system towards renewable supply. This means anticipating the needs of different stages of transformation and thereby providing a framework for storage when it becomes necessary.

To determine the future demand for storage technologies, additional research is necessary. Studies have been conducted and have given first ideas, but

deeper insights are necessary since the energy supply is a highly complex system.

Even though the amount of future storage demand is uncertain, conceivably rather large storage capacities will be needed. Therefore it is important to prepare storage for the future: research is needed to decrease storage costs across technologies. New business models for storage have to be developed and demonstrational projects need to be funded in order to gain experience, especially regarding new promising technologies.

Since the installation of large storage units has a high impact on nature and landscape, public acceptance is likely to become crucial to storage. Therefore concepts are needed to involve stakeholders in participatory processes from early planning stages.

Conclusions

With rising share of renewables, new flexibilities are needed to match energy demand and supply. Energy storage is one among other balancing options which are able to provide this flexibility. In a near system near 100% renewable share, storage will be indispensable. By now, there is only a low demand for electricity storage from the electricity grid perspective, but there

are other reasons for implementing storage systems, such as PV self supply or electric vehicles. A significant demand for storage will presumably not occur before the next two to three decades. But to enable a purposeful and system compliant integration of storage, in-depth,

multidisciplinary research needs to be conducted to provide a profound base for creating suited regulatory frameworks.

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references & notes

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