Valuing dedicated storage in electricity grids

European Academies easac Science Advisory Council

Summary

The focus of this report is on dedicated storage in electrical power systems: that is, 'electricity in – electricity out' of storage systems connected to electricity grids in the period 2017–2030. Longer-term options and non-dedicated energy storage (including heat, battery electric vehicles and power-to-gas) are also briefly discussed.

The report is intended for European Union (EU) policy-makers, investors, and other stakeholders (including system operators, generators, and electricity users) who are engaged in policy debates on the future of EU electricity grids, notably those involved in discussions on the 'Clean Energy for All Europeans' package, which was proposed by the European Commission (EC) on 30 November 2016.

The report summarises the latest independent scientific evidence on the use of dedicated electricity storage in electricity grids, explains potential impacts on electricity markets of recent and expected developments in storage technologies, and highlights what could be done through electricity market design, energy policy and investment support to ensure that grid-connected storage is used effectively in the future. EASAC did not specifically address EU research policy or industry policy in its work for this report.

Current and future deployment of dedicated electricity storage

The current (2016) deployment of dedicated electricity storage on the grid in the EU is dominated by pumped hydroelectric storage (PHS) (see Figure S1), but the deployment of lithium-ion batteries is growing fast and growth is also expected in the deployment of other energy storage technologies.

At least two EU Member States (Germany and the UK) have recently started to procure more dedicated storage for deployment on their electricity grids, and more can be expected in the period to 2030 and beyond. Against this background, two key technology developments justify the attention of EU policy-makers.

(1) As the penetration of variable renewable generation (wind and photovoltaics (PV)) increases, more storage systems may be connected to transmission and distribution grids to provide short-term flexibility in competition with other flexibility options (flexible generation, interconnections, demand response and curtailment).

(2) Small storage systems will be installed on distribution grids as consumers (mainly householders) invest in PV plus battery systems for increased self-consumption.

Market readiness of electricity storage technologies

Many different electricity storage technologies have been studied, developed and piloted over the past several decades, and research is continuing on several potentially competing options. Pumped hydroelectric storage (PHS) and possibly lithium-ion batteries appear to be ready for large-scale deployment over the next few years in grid-connected applications in the EU.

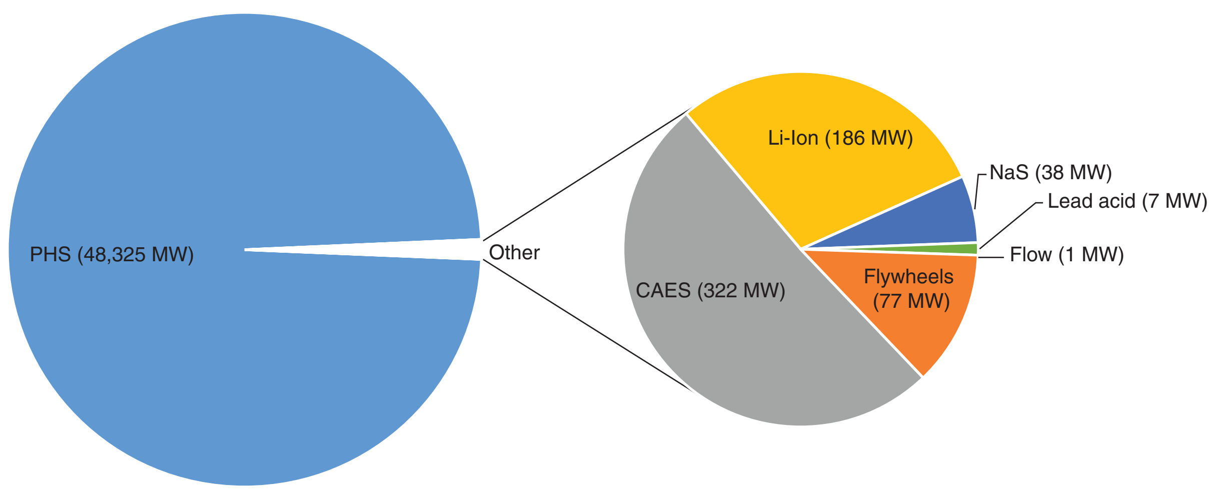

Figure S1 Operational grid-connected electricity storage capacity in the 28 Member States of the EU (EU28) plus Norway and Switzerland. Note: data were exported from the US Department of Energy (DOE) database in September 2016. Specialised applications of high-power flywheels in the UK and German fusion research laboratories and the RWE Adele Compressed Air Energy Storage (CAES) plant (which is not operational) were excluded.

Pumped hydroelectric storage (PHS) is the most widely used and proven electricity storage technology today, with more than 48 gigawatts (GW) currently in operation in the EU28 plus Norway and +Switzerland, and approximately three times that worldwide. There is scope for increasing the output from many existing PHS plants, and several new sites could be used in the EU, so it is estimated that up to about 75 GW of PHS could be working in the EU by 2030, and more could be built after that.

Battery technologies have been successfully demonstrated in both transmission and distribution grid-connected applications. Research is continuing in particular to reduce the costs and to improve the performance of batteries, and major investments are being made worldwide in new mass production plants for producing lithium-ion batteries in particular.

Future storage options research is continuing on a wide range of storage technology options, including power-to-gas-to-power, but no new storage technologies are expected to be commercially deployed on a large-scale in grid-connected applications before 2030. Similarly, the charging and discharging of electric vehicles as a (non-dedicated electricity storage) service to support the grid are being studied by researchers, but it is unlikely that such options will have a commercial role before 2030. In contrast, non-dedicated storage using power-to-heat and power to gas are less expensive and could be deployed earlier, notably as an alternative to curtailment.

Further research EASAC recognises the importance of continuing research on dedicated electricity storage technologies to reduce costs and increase performance, as well as a need for further work on the integration and modelling of electricity systems, to assess the multiple values of dedicated grid-connected electricity storage.

Policy options affecting future markets for electricity storage

Future policy options for the EU electricity sector must ensure efficient and stable power system operation with the lowest possible cost to consumers, while the fraction of variable renewable electricity continues to grow in response to a continuing drive to reduce carbon emissions. Against this background, the future deployment of dedicated electricity storage in the EU will be strongly influenced by future EU policies for the following:

(1) electricity market design (including tariff structures and the regulation of system operators);

(2) electricity system operating rules (regulations, directives and network codes);

(3) technology investments (transparent planning to build investor confidence);

(4) involvement of consumers and prosumers (including self-consumption).

Conclusions and advice for policy-makers

The conclusions and policy advice, which are presented below, have been compiled by EASAC, on the basis of the peer-reviewed information and independent analyses that are presented in this report.

What is the value of dedicated storage?

1. **The value of dedicated storage on an electricity grid is system dependent.** The roles and opportunities for electricity storage and its competitors grow as the electricity systems grow, in particular as the penetrations of variable renewable generation increase. The same storage technology can offer several different services to the grid, and have different values in different situations. The business case for investing in storage becomes more attractive when one specific storage system can viably compete in more than one role/market at the same location (multiple use with value stacking).

2. **Storage is widely acknowledged today as an expensive option, but its costs are falling and its value is improving.** There are many conflicting claims and projections for current and future costs of the different storage technologies, and many ongoing research projects aiming at cost reductions. Among the different storage technologies, it is clear that batteries have the highest cost reduction potential and their costs are falling fast, partly as a result of the economies of scale that accompany their growing use, especially in transport applications. In contrast, the costs of other storage technologies are coming down more slowly but, for future large-scale applications, PHS in particular may offer good value for money in suitable locations.

3. **Storage adds value to electricity grids by contributing to the growing demand for flexibility (including congestion management), which is resulting from increasing levels of variable renewable generation (notably wind and PV) on electricity grids.** However, the demand for flexibility will be met in future by combinations of five competing options**,** namely flexible generation, curtailment, grid reinforcement/interconnections, demand response and storage. Flexible generation has been a major source of flexibility historically, but as capacity factors for peaking plants fall, investments become less favourable (particularly in the absence of capacity markets). Where they are feasible, curtailment, grid reinforcements/interconnections and demand response are typically cheaper than dedicated storage, but (a) the scope for *curtailment* is limited, the market is not yet ready in many parts

of the EU for power to heat, and power to gas is not yet commercially available, (b) it can take many years to build new grid reinforcements/*interconnections* because of public resistance, and (c) in many areas, systems may not yet be in place to manage dispatchable load programmes and end-use constraints may limit the potential for *demand response*. Consequently, it is reasonable to expect a growing penetration of dedicated electricity storage in future markets for flexibility on the grid.

4. **Storage adds value to electricity grids by contributing to balancing, reserves, network capacity and generation adequacy.** PHS has been used for many years to provide balancing, and other storage technologies could contribute similarly to balancing and, in addition, to other key components of EU electricity markets in future. The use of storage to provide peaking capacity as well as reserves, permits the most cost-effective (high merit order) generators to operate with higher utilisation levels, thereby increasing their efficiency and potentially leading to lower electricity prices for consumers.

5. **Battery storage systems are valued by consumers, who are installing them increasingly at household level together with PV systems for self-consumption (prosumers).** This growing trend, which is being driven largely by consumer preferences as well as by incentives/tariff structures, falling PV and battery prices, and technology push by suppliers can bring financial benefits to PV and storage system owners, but may add to the costs of other electricity consumers and bring new management challenges for distribution system operators. It is attracting a new source of investment capital (householders) in distributed storage systems, but is an emerging challenge from an overall system perspective.

6. **Storage is particularly valuable in isolated systems.** In islands, remote locations and micro-grids, storage is needed to balance supply and demand because isolated systems cannot benefit from the regional diversity and smoothing that takes place across large interconnected systems, such as those in continental Europe. Some of the challenges faced by small isolated systems are also faced by relatively large but isolated systems, and in areas of the EU with poor interconnections.

What are the limits of storage?

7. **Storage will not substantially reduce EU needs for back-up generating capacity** in the short to medium term. Storage has traditionally been used to smooth out peaks in demand, and it can similarly be used to smooth out peaks in supply. However, where over-capacity exists, it is difficult to justify significant additional investments in storage. As new capacity is required, storage can play a valuable role in contributing to generation adequacy and reducing system operating costs. However, none of the dedicated storage systems, which are commercially available for grid applications in 2016, is typically able to deliver its nominal power for more than about 10 hours, so they could not fill the gap when there is little or no supply from wind and solar generation during periods of several days with low wind speeds and limited sunshine. As a result, it seems likely that the most cost-effective solutions for providing generation adequacy in the coming decades will involve combinations of hydro and thermal generators along with dedicated storage.

8. **New technologies are not yet ready to deliver competitive seasonal storage of electricity for the grid.** Seasonal storage of grid electricity will not be needed until much higher levels of variable renewable generation are on line than is the case today. Nevertheless, several power to gas options are being studied with the initial aim of producing synthetic gas for transport and industry, and these could be used within a few years to avoid curtailment of variable renewable generation. In contrast, the costs of power to gas to power systems are far too high and their round-trip efficiencies too low to be deployed commercially for seasonal grid electricity storage applications within the foreseeable future, but they could perhaps be deployed within the 2050 timeframe.

What should be done to ensure that storage is used effectively?

9. **Electricity market design should deliver price signals (locational and temporal) that will encourage investments in the most cost-efficient flexibility options on both transmission and distribution grids.**

   (a) A redefinition of bidding zones (reflecting the physical constraints of the system) would help to deliver a cost-efficient mix of flexibility options and to avoid unnecessarily expensive systems being built.

   (b) Increasingly important for investors will be transparency about plans and rules for the future management of flexibility, because the marginal value of providing additional flexibility decreases as more is deployed on the grid. Particularly important for independent investors will be the planned split between (i) flexibility management within the regulated market by the network operators using interconnectors, international agreements and possibly storage and (ii) flexibility management within competitive markets by means of flexible generation, demand response and storage.

(c) Authorities in several parts of the world have put in place short-term incentives, targets or demonstration programmes to promote the deployment of storage on electricity grids. However, it is too early to assess the extent to which these will lead to the large-scale deployment of cost-effective mixes of flexibility options on a long-term basis.

10. **Electricity market design should address the emerging challenge of more PV plus battery systems being installed by householders on distribution grids.** Most existing tariff structures focus largely on energy used (costs per kilowatt hour) and therefore produce a lack of price signals or in some cases counter-productive price signals regarding network costs (costs per kilowatt). While consumer wishes for self-production should be respected, it will be important that the costs of grid infrastructure be shared fairly across all users, and that any additional costs, which result from new clusters of PV systems being added to the grid, should also be attributed transparently to those who create them. Similarly, any benefits to distribution system management, which result from the use of (aggregated) household storage systems, should be fairly shared between those who provide them. Time-varying tariff structures with more intelligent metering are expected to contribute to the management of these issues.

11. **Electricity market design should be technology neutral, which means that it should not create barriers to the deployment of potentially valuable systems and technologies (including storage).**

(a) Provision should be made to define and accommodate the specific features of all system assets and technologies for providing flexibility to the grid (including storage), so that they are not excluded or discouraged without good reasons. For example, without objective justifications, minimum bid sizes, lack of provision for aggregator involvement and double payments for use of grid infrastructure (payment when energy comes into and out of storage) currently limit the participation of storage in some markets.

(b) Independent flexibility providers, such as storage system owners or aggregators of many small storage systems, should be allowed to participate in multiple markets provided it is physically possible to provide the multiple services simultaneously. In addition, independent owners of storage systems should be allowed to use them for regulated functions when contracted by system operators, but also free to use the same systems in competitive markets at other times. This would improve the business case for providing flexibility (for example by using dedicated storage) and improve the management of regulated networks at the same time.

(c) Public support at EU level for investments in systems to provide flexibility to the grid (for example via the Connecting Europe Facility or the European Investment Bank) should continue to give equal treatment to potential investments in all options for providing flexibility, including dedicated electricity storage.

12. **Policy for science.** More research and development is warranted with a focus on the following issues.

(a) Continuing to reduce costs, for those dedicated storage technologies with significant potential for cost reductions, as well as pursuing continued technological advances for those storage systems. Key storage characteristics are application specific and those for dedicated grid-connected (stationary) applications are not necessarily well matched to those used for transportation (for example energy density and cycle life requirements can differ significantly).

(b) Studies and analysis (including modelling) of transmission and distribution systems and markets, including socio-economic monitoring of demonstrations and innovation programmes, and of prosumer markets, as the market design evolves to meet increases in the demand for flexibility and as storage costs fall and its deployment increases.

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