European Association
for Storage of Energy

EASE Study on Energy Storage Demand

Contents

Definition of Energy Storage

In this study, EASE seeks to analyse the demand for energy storage systems. EASE defines energy storage as follows: "'energy storage' means, in the electricity system, deferring an amount of the electricity that was produced to the moment of use, either as final energy or converted into another energy carrier."[1] This definition encompasses Power-to-Gas, Power-to-Heat/Cold, and Power-to-Liquid technologies, recognising that they can support the dynamic operation of the electricity grid with thermal, fuel or gas as flexibility for downward regulation.

Definition of Storage Demand

The demand for energy storage is assessed in many studies on the basis of targets for renewable energy supply. These studies give evidence of storage demand on different time scales that are required in order to achieve a certain degree of renewable generation for the electricity supply. **Storage demand studies differ from market outlook studies since they seek to quantify the *technical need* for energy storage, rather than estimating the future market for energy storage systems.**

This kind of assessment of energy storage demand on the basis of technical necessity, however, does not answer the crucial question of whether the needed energy storage capacity can economically be built in the existing market design environment.

Critical Assumptions to Assess Storage Demand

Energy storage is one of several flexibility options that can help integrate increasing shares of variable renewable electricity supply[2]. In order to derive storage demand, assumptions need to be made with respect to the alternative flexibility options like grid extension, demand-side management (DSM), and flexible conventional generation.

Grid extension allows for improved regional exchange of power flows, thereby improving hosting capacities of electricity grids.

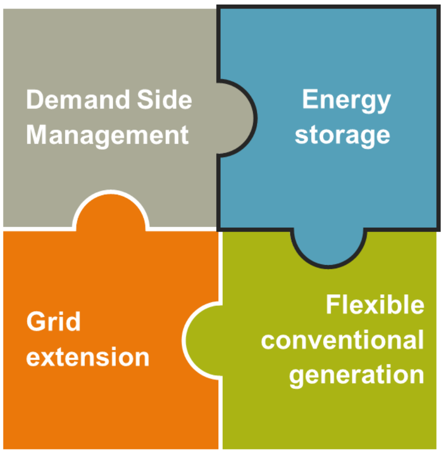

Figure 1: Flexibility options to improve the management of electricity grids

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[1] This is similar to the definition proposed in European Commission: *Directive on common rules for the internal market in electricity*, November 2016.

[2] David Sanders, Alex Hart, Manu Ravishankar and Joshua Brunert: *An analysis of electricity system flexibility for Great Britain.* Carbon Trust and Imperial College London, November 2016.

DSM – programmes encouraging end-consumers to modify their energy demand – allows for the reduction in electricity demand in times of undersupply, and increase in demand in times of oversupply. The line between energy storage and DSM can be blurry, since some forms of storage – such as PV combined with batteries in households – are considered by some as DSM. The studies analysed in this paper mainly consider storage technologies deployed at grid scale, which is clearly separate from DSM.

Flexible generation refers to the ability of thermal dispatchable generation capacities (e.g. fossil, biomass, etc) to vary the electricity output in correspondence to volatile feed-in that needs to be balanced. The degree of flexibility of these facilities can be measured through factors such as cold-start time, ramp rates, and minimum load capabilities. Energy storage systems can be considered as an important measure to increase the flexibility of any thermal generation unit.

The derived storage demand is only valid in combination with assumptions on the alternative flexibility measures. The costs of each flexibility option will have an effect on the deployment of the other flexibility options. For the sake of transparency, the concrete assumptions for the alternative flexibility measures should be clearly stated in reports on storage demand.

As a general rule, the more alternative flexibility options are allowed (e.g. better grid interconnection, more demand-side management, a highly flexible thermal fleet), the smaller the derived energy storage demand will be for a targeted degree of variable renewable generation[3]. When analysing published energy storage studies for EU Member States, one can therefore find a wide range in storage demand estimates, which are strongly influenced by the boundary conditions.

Also, current models cannot always capture the full value of storage. For instance, storage demand studies cannot quantify storage demand for intra-hour needs (with a time scale below 1 hour), as the existing input time series is mostly on an hourly basis. Therefore, the storage demand required to increase the grid's hosting capacity and to mitigate intra-hour variations – which will grow with the increasing penetration of wind and solar – is generally not assessed. Similarly, the demand and benefit of storage for various ancillary services (e.g. frequency regulation) has yet to be fully understood and modelled, even though some studies provide preliminary insights on that topic[4]. It should also be noted that in some studies, storage need is not always

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[3] See Goran Strbac, Ioannis Konstantelos, Marko Aunedi, Michael Pollitt, Richard Green: *Delivering Future-Proof Energy Infrastructure,* Cambridge University and Imperial College London, February 2016.

[4] For example, Strbac, Goran: *Strategic Assessment of the Role and Value of Energy Storage in the UK Low Carbon Energy Future*. Imperial College London June 2012 and Artelys Consulting, Enea Consulting, G2Elab: *France – study on energy potential storage*, November 2013.

assessed through economic indicators; other quantitative indicators (such as the spilled energy) can be used instead.

Range of Estimates for Storage Demand in EU Member States

Currently, EU Member States have a combined electricity storage capacity in pumped hydro schemes of 42 roughly GW power and 300 GWh capacity[5]. A number of studies for individual EU Member States (mainly published within the framework of the Horizon 2020-funded StoRE project[6]) predict expected storage demand until 2030/2050[7]. From a total of 20 analysed studies, only six gave concrete numbers for individual Member States in GW and GWh. Based on these studies and the defined renewable energy targets of individual countries and the EU as a whole, future storage demand for the EU can be roughly extrapolated.

In figure 2, a summary of the analysed studies is depicted. First of all, the figure shows a large variety in storage demand for individual countries, which is mainly due to country sizes but also relates, as discussed previously, to different assumptions on the alternative flexibility options and on how they are modelled. Generally, it can be said that with an increasing share of renewables (in most countries, this growth will mainly be achieved by variable renewables such as wind and solar PV) there is initially a demand for power capacity (GW). Up to a certain level, the existing pumped hydro schemes can cope with the increasing volatilities in many countries. Above ~25 – 40% of volatile feed-in, however, additional flexibilities in GW terms are required. The situation will likely be most pressing for individual Member States with limited interconnection capacity (e.g. Spain, UK, Ireland, and other small European islands). At a later stage, demand for storage capacity (GWh) will emerge to effectively shift temporary oversupply into time periods with little infeed from renewables (in the figure, this is indicated by the increased bubble size towards higher volatile feed-in).

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[5] EASE analysis on pumped hydro schemes.

[6] https://ec.europa.eu/energy/intelligent/projects/en/projects/store

[7] Please find the list of the analysed studies in the below Annex.

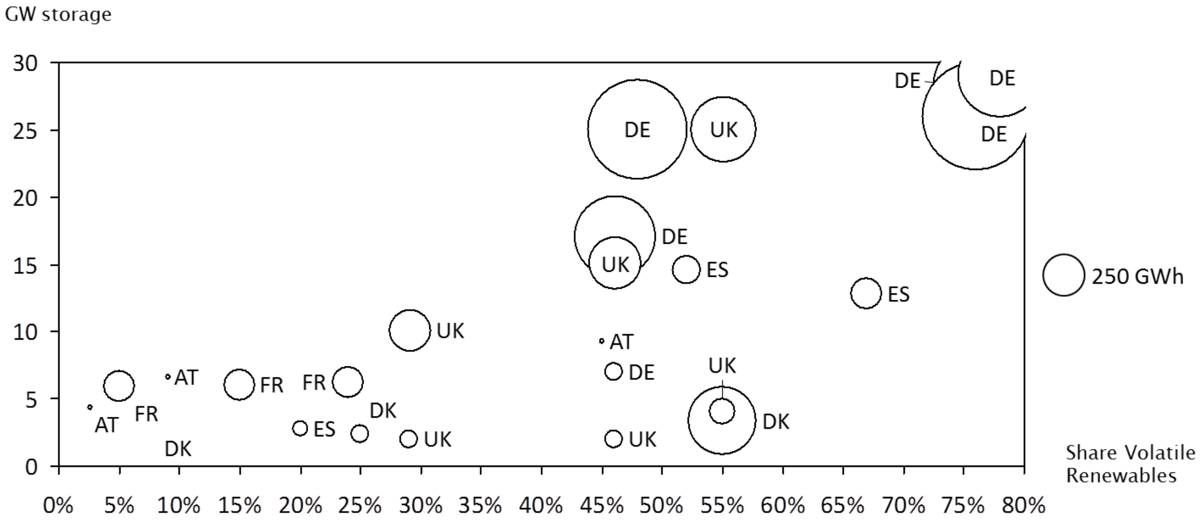

Figure 2: Storage demand of EU member countries in GW and GWh (bubble size) as a function of the share of volatile power generation

This graph shows the storage demand estimates made in the studies analysed by EASE. Each bubble represents a different estimate for the storage capacity a particular country would require to balance a given share of variable renewables. Where there were multiple different estimates in the studies for one country, this is shown by multiple bubbles for that country in the graph. The position of the bubbles with regards to the left axis shows the power storage demand (in GW) while the bubble size shows the energy storage demand (GWh). There is a large variety in predicted storage demand for individual countries, which is mainly due to differences in country sizes but is also influenced by the different assumptions on the alternative flexibility options and on how they are modelled in each study.

In order to calibrate this analysis with respect to the different country sizes, storage demand in GW was divided by the peak load and storage demand in GWh was divided by the country specific annual consumption. In figure 3 depicting the estimated normalised storage demand (figure 3), a corridor with upper and lower boundaries is defined. Most Member States fit into this corridor. These upper and lower boundaries[8] reflect the diversity of assumptions used with regards to competing flexibility providers as well as strong differences in modelling approaches (ranging from rather normative and simplified models to extensive system models). These boundaries are therefore taken to give a first very broad estimate to the storage demand of all 28 EU countries as a function of their renewable energy (RE) targets.

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[8] The boundaries were calculated as follows:

Normalised GW demand = min 0.3…max 0.9 * volatile share

Normalised GWh demand = min 0.001…max 0.004 * volatile share

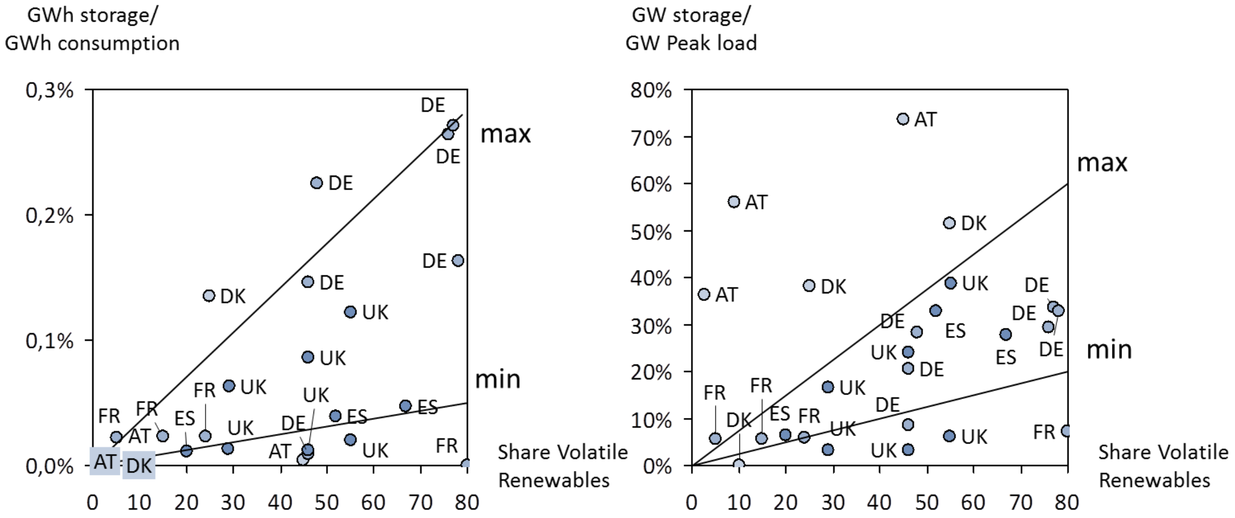
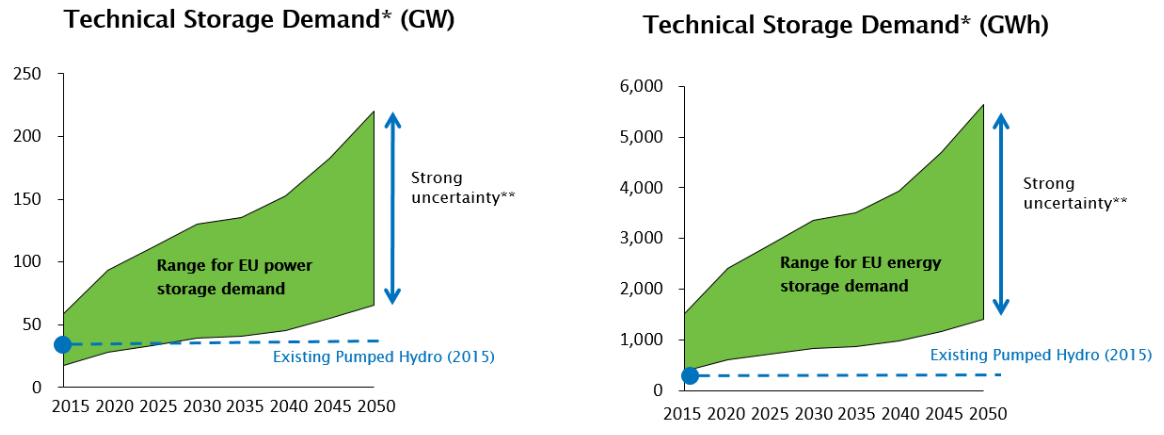


Figure 3: Normalised storage demand in GW (left) and GWh (right) as a function of the volatile Renewable Electricity Share as analysed in the reported storage studies.

For the country specific shares of renewable electricity and the respective contribution of variable power generation until 2050, we used data from the EU reference scenario published by the European Commission in 2016. This scenario envisages the combined share of wind and solar in power generation reaching 35% by 2050 (compared to a share of 12% today). By multiplying the hereby derived normalised storage demand by the expected peak load (w.r.t. GW storage demand) and expected future consumption values (w.r.t. GWh storage demand), the absolute values for estimated future country specific storage demand can be derived.

Following this logic, extrapolating storage demand at EU level in 2050 with the RE targets from the Reference Scenario gives a total power storage demand in the range of 70-220 GW (compared to 45 GW existing today) and an energy storage capacity of 1500-5500 GWh (see Figure 4). The latter number compares to ~300 GWh existing capacity in pumped hydro schemes plus other existing storage systems, such as thermal storage, further contributing to available storage capacity. While electricity storage was dominated by pumped hydro in the past years, a large variety of energy storage technologies is now readily available to realise this steep increase in terms of power and energy.



** The graphs show a **simplified extrapolation of existing studies on energy storage demand.** They assess only the technical need for storage, rather than estimating the future market for energy storage systems.*
*** The large gap between the upper and lower boundaries reflects the diversity of estimates found in existing studies on storage demand: their assumptions about competing flexibility providers (e.g. deployment of demand-side management, grid extension) and their modelling approaches differ significantly.*

Figure 4: EU Energy storage demand in GW (left) and GWh (right) for the EC Reference Scenario

If the more progressive decarbonisation scenarios with variable RE shares of 65% by 2050 were taken, the technical storage demand would roughly double compared to the reference scenario.

As noted above, this analysis solely describes the estimated technical need for storage systems with increasing volatilities but does not address the economic question of whether these storage systems should be built and at which cost, nor does it explore the viability of such storage projects under the current and future market designs. The current analysis indicating a potentially significant need for storage in a high RES power system must be complemented with extensive cost-benefit analysis at the European scale, with modelling characteristics that are thoroughly discussed and approved by the scientific community.

System modelling is thus a key aspect to assess the relevance and value of storage for future systems. EASE is committed to contributing to this research effort – in particular, EASE and ENTSO-E are currently discussing how to better assess storage in ENTSO-E's cost-benefit analyses for the Ten-Year Network Development Plan and Projects of Common Interest. Among the aspects discussed, measuring the avoided generation costs and the contribution of storage to flexibility are two challenging items. In addition to the improvements of the ENTSO-E method, EASE remains convinced that further discussions and strong modelling improvements are needed to fully measure the systemic interest of the various storage technologies.

Such analyses should also take into account future storage cost developments and potentially anticipated technology breakthroughs that would strongly increase the level of storage that can be built economically. Lastly, some viable business cases for storage may be hampered by overly restrictive market design rules. EASE is also committed to discussing these issues with European policymakers and the broader energy industry.

Conclusion

As an increasing share of renewable energies is being integrated into European electricity grids and as storage system prices are continuously decreasing, the first economically viable storage application areas are just emerging. Promising examples are battery storage systems participating in electricity markets or, potentially, PV+storage combinations for self-consumption in residential areas or in off-grid situations. The anticipated electric vehicle ramp-up in the coming years, along with the industrialisation of battery, electrolysis, and fuel-cell manufacturing, will solidify these first commercial storage applications.

Storage demand is thus undoubtedly picking up. Although the exact storage capacity that would be needed from a technical point of view to integrate variable renewables is difficult to pinpoint, our review of various storage demand studies revealed valuable insights into the factors that affect storage demand.

EASE believes that the future need for storage depends heavily on the deployment of the other flexibility options. From today's perspective, storage may appear costly compared to the other options. However, these other flexibility options also face strong challenges:

- Social acceptance for grid extension is becoming increasingly limited, rendering some needed reinforcements impossible.
- DSM has yet to demonstrate its full potential and uncertainties remain on the role it will be able to play in the future.
- There are concerns about the environmental impacts and sustainability of flexible thermal generation.

Given these elements, **EASE strongly believes that an efficient mix of the flexibility options is needed to mitigate the various risks, and that energy storage should be a priority for EU policy makers seeking to support the transition to a decarbonised energy system.**

In order for storage deployments to continue increasing to meet demand, we must further improve our understanding of the added value of storage and build innovative business models, whilst preventing delays due to ill-equipped regulations.

One of the key issues for the development of energy storage is the energy market design. It should aim to create long-term investment security, clarity on the position of storage in the energy system, and a level playing-field for energy storage so that storage can compete on a fair and equal basis with alternative flexibility options. If storage brings additional value to the system, adequate remuneration should be feasible and available. Particularly important aspects of the regulatory framework for storage include the price of CO_2 (a high CO_2 price allows large price spread and therefore better revenues for storage), remuneration of capacity (either through capacity mechanisms or enhanced energy only markets), balancing markets organisation, etc.

A further issue is the recognition that Power-to-Gas, Power-to-Heat/Cold, and Power-to-Liquids may, in the long term and given continuous improvements in efficiency, become valuable flexibility elements. These technologies could then enable the transfer of larger amounts of electricity into various sectors (sectoral integration), and reduce RES curtailment, fossil fuel use, and CO_2 emissions for the overall energy supply. Energy storage will be a key component to effectively achieve sectoral integration. Additionally Power-to-Gas and Power-to-Liquids could allow seasonal energy storage using today's national gas and fuel storage systems and infrastructure, i.e. to allow shifting the use of TWh of energy over several months[9]. Until these technologies are economically viable, electrification – supported by a range of storage technologies – can in the short term speed up the decarbonisation of the economy.

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[9] For more information, see EASE: *Recommendations on Sectoral Integration Through Power-to-Gas/Power-to-Liquid*, May 2017, available at http://ease-storage.eu/ease-recommendations-on-sectoral-integration-through-power-to-gaspower-to-liquid/

Annex I – Literature

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The European Association for Storage of Energy (EASE) is the voice of the energy storage community, actively promoting the use of energy storage in Europe and worldwide to support low-carbon energy and climate policy. EASE supports the deployment of energy storage as an indispensable instrument to improve the flexibility of and deliver valuable services to the energy system. EASE seeks to build a European platform for sharing and disseminating energy storage-related information. EASE ultimately aims to support the transition towards a sustainable, flexible and stable energy system in Europe.

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This response was elaborated by EASE and reflects a consolidated view of its members from an energy storage point of view. Individual EASE members may adopt different positions on certain topics from their corporate standpoint.