IEAGHG Information Paper: 2015-IP22; Energy Storage

Background

Developments in energy storage technologies have significant implications for future energy systems and the optimum mix of low carbon energy technologies, including CCS. IEAGHG considered producing a detailed review of energy storage technologies but various detailed reviews have been published, as described later, so instead this IP has been produced to provide a brief summary of energy storage technologies and the interaction with flexible CCS plants.

The need for energy storage

Electricity demand and generation need to be in balance at all times. This can be achieved by:

1. Varying the output of power plants
2. Demand side management, i.e. deliberately curtailing or delaying some electricity demand
3. Energy storage

The technique that is currently used most is to vary the output of power plants, mainly fossil fuel-fired plants that have relatively good operating flexibility. The increasing use of variable renewable electricity generators such as wind and solar is increasing the variability of power generation and hence the need for the three balancing techniques listed above. Fossil fuel power plant manufacturers are already responding to the needs of the market by improving the operating flexibility of the plants they offer.

Energy storage technologies will compete with flexible fossil fuel plants to provide grid stability and supply-demand management in electricity systems. The development and costs of energy storage technologies is therefore of interest to the CCS community as it will affect the need for and the economic revenues of power plants with CCS.

Power plants with CCS are expected to be able to operate flexibly, although this needs to be demonstrated in commercial plants. The ability to operate flexibly and complement renewable energy sources in electricity systems is one of the key advantages of CCS. There are options for enhancing the operating flexibility of CCS plants by incorporating energy storage and internal energy demand management within the plants, as assessed in an IEAGHG report (IEAGHG, 2012) and elsewhere. Examples of this are:

- Producing and storing surplus oxygen or liquid air in oxy-combustion and IGCC plants at times of low power demand to enable oxygen production to be reduced and net power output increased during times of high power demand.
- Storing CO_2-laden solvent in post combustion capture plants or allowing the CO_2 loading of recirculating solvent to increase during times of high power demand and increasing the solvent regeneration rate during times of low power demand.
- By-passing the CO_2 capture unit to increase net power output at times of high power demand.
- Using gasification plants with CCS to produce hydrogen at a constant rate, storing the hydrogen during times of low power demand then using it for electricity generation at times of high power demand, as discussed in an earlier IEAGHG information paper (IEAGHG, 2015).

Energy storage technologies

A wide range of technologies can be used for grid-scale energy storage. Several technology reviews and roadmaps for energy storage technologies have been published, e.g. ENEA, 2012; EPRI, 2010; IEA, 2014; Sandia, 2013; Strbac, 2012; Taylor, 2012; Ter-Gazarian, 2011; USDOE, 2013. Storage technologies are characterised by power output and discharge time, as shown in Figure 1. The short duration technologies are mainly used to provide grid support (voltage and frequency regulation, reserve capacity and black start capability) and the longer duration technologies are mainly used to smooth out longer term variations in supply and demand. Note that some of the technologies have the capability to operate beyond the indicative ranges shown in Figure 1, for example underground hydrogen storage can extend the capacity of hydrogen storage to the GW scale. While some energy storage technologies are mature or near maturity, many others are still in the early stages of development, as shown in Figure 2, and costs are currently high.

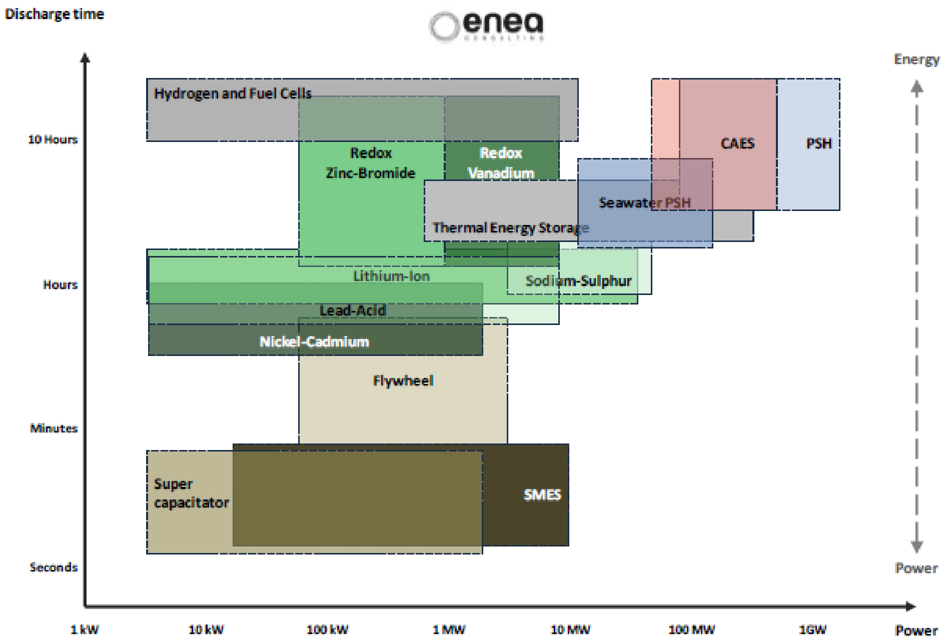

Figure 1 Energy storage according to discharge time and typical power (ENEA, 2012)
(PSH: Pumped storage hydro, CAES: Compressed air energy storage, SMES: Superconducting magnetic energy storage)

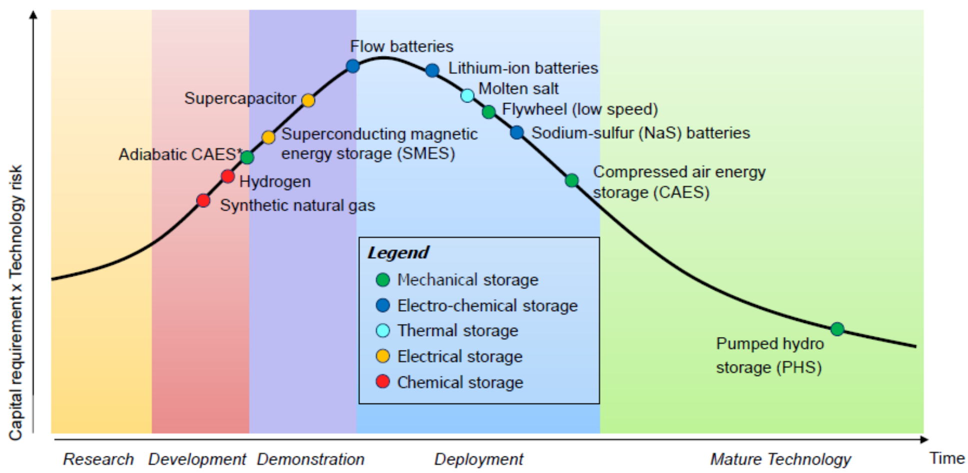

Figure 2 Energy storage technology maturity curve (©SBC Energy Institute, 2013)

Over 99% of the installed grid-connected storage capacity is currently pumped storage hydro, as shown in Figure 3, but the limited availability of suitable sites is a constraint on future capacity additions in many areas.

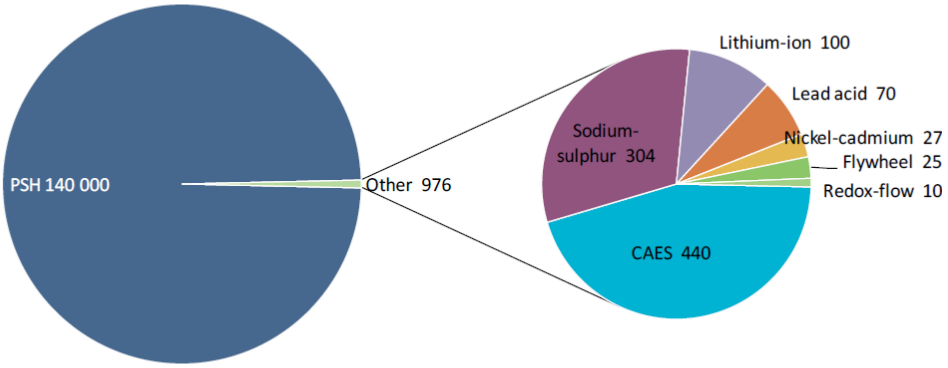

Figure 3 Current global installed grid-connected electricity storage capacity (MW), (IEA, 2014)
(PSH: Pumped storage hydro, CAES: Compressed air energy storage)

In addition to grid-connected applications, there is increasing interest in electricity storage for end-use consumers, who would have the additional benefit of back-up power in the event of grid outages.

Efficiencies and costs of electricity storage technologies are summarised in Table 1.

Table 1 Efficiencies and costs of electricity storage technologies (IEA, 2014)

Technology	Efficiency (%)	Initial investment (US$/kW)
Pumped storage hydro	50-85	500-4600
Compressed air energy storage	27-75	500-1500
Batteries	75-95	300-3500
Chemical hydrogen storage	22-50	500-750
Flywheels	90-95	130-500
Supercapacitors	90-95	130-515
Superconducting magnetic energy storage	90-95	130-515

On-going work by IEAGHG

IEAGHG is currently undertaking a study to assess the value of flexible CCS power plants in an overall electricity system. The study will initially exclude energy storage technologies for the electricity system to simplify the analysis and because storage is not widely used at present but the intention is to include it in a second phase of the study. The study could take into account opportunities to integrate electricity storage technologies with CCS plants, for example using oxygen by-product from electrolysis plants in oxy-combustion or gasification plants with CCS.

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