ENERGY STORAGE – BACKGROUND BRIEFING

Introduction

The present paper is intended to be a short briefing on the subject of energy (electricity) storage, accompanying the Webinar Panel on investment projects organised by the Energy Community Secretariat in May 2020. This is based on the Secretariat's staff desk research of the current literature on storage.

Building upon the recent years' developments of energy storage in EU and worldwide, and acknowledging its key role in supporting large scale introduction of variable renewable energy such as solar and wind, the Energy Community Secretariat embarked on the path of supporting information sharing and capacity building of its Contracting Parties, on both technology, and regulatory issues of energy storage.

Energy system storage technologies

Energy storage systems are becoming ever more an essential part of the renewable power generation, given the fluctuating and uncertain nature of renewable energy sources like solar and wind, and to a less extent hydro. As costs of renewable power generation technologies decline sharply and EU decarbonisation policy becomes more ambitious, energy storage systems become an important component of the future power system that improves the reliability of networks, but also helps to de-carbonise the end use sectors, such as industry, buildings and transport.

There are various types of energy storages, including (a more detail presentation is shown in figure 1):

a) *Pumped hydro storage*: Potential energy stored in reservoir above a turbine.
These facilities are able to provide both baseload power and balancing services, supporting grid reliability. However, due to complex planning procedures, high capital expenditures and increasing public resistance, there are few new facilities under development.

b) *Hydrogen fuel cells (HFCs)*: Chemical energy released and converted to electrical energy as hydrogen binds with oxygen.
A Hydrogen fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. The products of the reaction in the cell are water, electricity, and heat. Since O_2 is readily available in the atmosphere, the fuel cell has to be supplied with H_2 which can come from an electrolysis process. The Secretariat endeavours to go into further detail about the potentials of the hydrogen economy separately.

c) *Compressed air energy storage (CAES):* High-pressure air stored most often in underground caverns.
CAES is an energy storage technology based on gas turbine technology. It uses electricity to compress air and store it in a storage reservoir during the energy storage period and release the compressed air to drive a turbine to generate electricity during the stage of power supply. Storage reservoir can be underground salt cavern, underground mine, expired well or gas chamber.

d) *Battery banks:* Conventional lead-acid battery storage, sodium sulphide battery, Li-ion battery, flow battery, solid state battery or other electrode battery storage.
There are in principle two different use cases for battery storage systems. Firstly, residential solutions, mostly in combination with photovoltaic (PV) systems, and secondly, large scale or industrial systems, which either secure electricity supply for large consumers, provide reserve control or ancillary services, or a combination thereof.

e) *Thermal (including Molten Salt):* Thermal energy storage facilities use temperature to store energy.

Thermal energy storage (TES) is a technology that preserves thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for heating and cooling applications, as well as for power generation.

f) *Superconductors:* Magnetic field energy storage in a super-cooled environment.
Superconducting magnetic energy storage systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature.

g) *Super-capacitors:* Porous carbon-electrode capacitors offer high-density storage.
Current research and development on energy-storage devices have been mainly focused on super-capacitors, lithium-ion batteries and other related batteries. Compared with batteries, super-capacitors possess higher power density, longer cyclic stability, higher Coulombic efficiency and shorter period for full charge–discharge cycles. Thus, super-capacitors, particularly those based on carbon nanotubes (CNTs), graphene and mesoporous carbon electrodes may become one of the most important energy-storage devices in the near future.

h) *Flywheel storage:* Rotating disc stores mechanical energy within a vacuum.
Flywheel energy storage uses electric motors to drive the flywheel to rotate at high speeds so that the electrical power is transformed into mechanical power and stored; when necessary, flywheels drive generators to generate power.

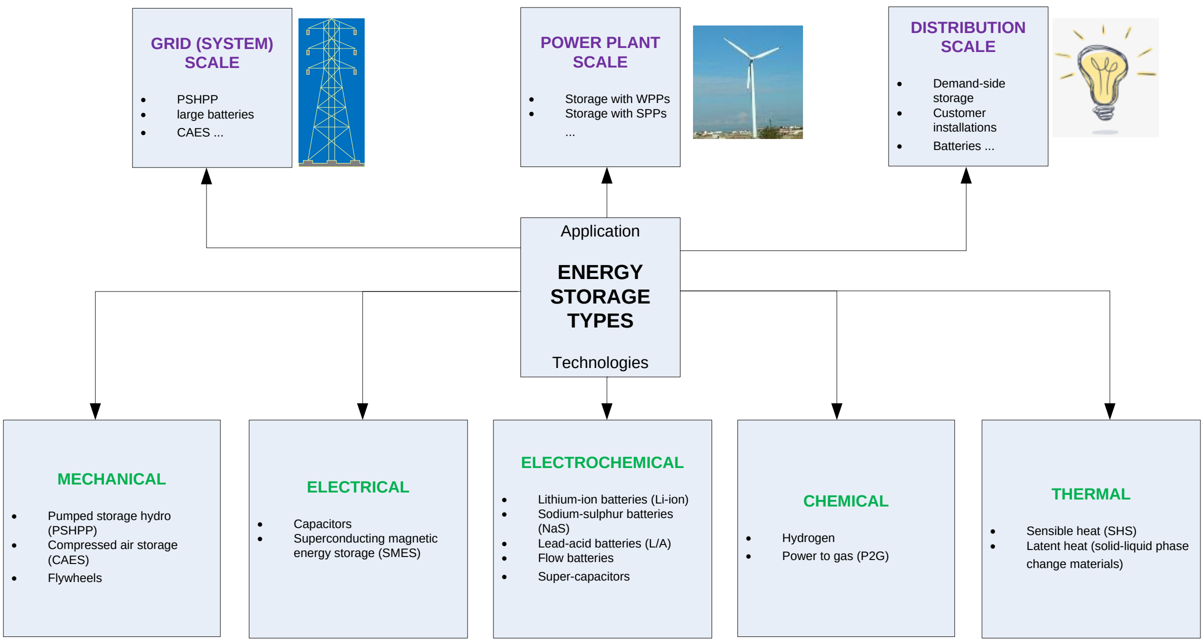

FIGURE 1: ENERGY STORAGE TECHNOLOGIES AND APPLICATIONS IN A POWER SYSTEM

Energy system storage services

Energy storage systems may provide different types of system services like:

1. Energy services (generation time-shift/adjustments, generation capacity);

2. Transmission services (infrastructure development postponement/suspension, congestion relief, stability/resonance damping);
3. Distribution services (infrastructure development postponement/suspension, voltage support);
4. Ancillary services (frequency control, voltage control, black start, load following and ramping, spinning/non-spinning reserve, renewable production support);
5. Customer energy management services (power quality and reliability, demand charge management, supply time-shift, uninterruptible supply, smart/micro-grid formation).

All of these services provide additional benefits for system users (producers, suppliers, consumers), TSOs and DSOs, also bringing large-scale benefits for the society by increasing the security of supply and having positive environmental impact, while supporting larger scale renewable integration, thus decreasing CO_2 emissions from the power sector. Power system operations may be optimized by using storage systems in both directions during off-peak (energy conservation), and in peak demand hours (energy generation), avoiding additional investments in peak load generation capacities.

Energy system storage Regulatory & Policy framework - legislation related to energy storage

Energy/electricity storage is critical for the future of the European power system. However, in order to realize its full potential, a robust regulatory framework is needed. In the European Union, the role that energy storage plays in EU power markets was formally recognized in the Directive (EU) 2019/944 on common rules for the internal market for electricity, as well as in the Regulation (EU) 2019/943 on the internal market for electricity. The new Directive must be transposed by EU Member states by the end of 2020 and is applicable from the beginning of 2021, while the Regulation is directly applicable from the beginning of 2020.

The Electricity Market Design, part of the EU's Clean Energy for All Europeans legislative package includes measures designed to adapt the EU electricity policy framework to clean energy transition, with measures to enhance flexibility and enable consumer participation in the energy markets. The directive aims to reduce barriers to energy storage, and mandates non-discriminatory and competitive procurement of balancing services and fair rules in relation to network access and charging. Interestingly, the directive has adopted a wide definition of 'energy storage', encompassing both reconversion to electricity or conversion into another energy carrier. Very important, energy storage is for the first time recognized as a distinct asset class, separate from generation.

These measures are expected to facilitate the development of energy storage facilities, but it remains to be seen how individual countries will implement measures to enable consumers to shift their demand, to allow self-consumption and storage, and to enable dynamic time-of-use tariffs. The same applies to the role of aggregators and local energy communities introduced by the directive.

The Energy Community Contracting Parties are expected to adopt the EU's Clean Energy for All Europeans legislative package in 2021.

There are also other EU initiatives/legislation relevant to and with the direct impact on the implementation of the energy system storage, as the following:

- Energy Taxation Directive

- Guidelines on Environmental Protection and Energy State Aid
- Trans-European Energy Infrastructure (TEN-E) Regulation and the Connecting Europe Facility (CEF) Regulation
- Water Framework Directive
- Hydropower rights granting procedures
- R&I Framework Programmes: Horizon 2020 and Horizon Europe
- Critical raw materials
- Financing

Drivers and barriers to the energy system storage implementation

The key driver for the development of energy storage is the Energy Transition and the ambitious national targets to increase the share of renewable energy sources in the generation market by 2030. As the EU overall grid expansion is still under development, the current shift from centralized to decentralized energy generation requires measures to ensure greater grid stability, reliability and flexibility.

Following the political decision to decarbonize the energy and transport sector, e-mobility and charging infrastructure increasingly drives the progress of energy storage solutions. The growing electric vehicles (EV) charging network includes both residential and commercial charging stations, and requires greater grid capacities, as well as flexible solutions for electricity demand and supply.

However, energy storage projects face several legal and commercial challenges. For example, storage facilities are treated as consumers when drawing electricity and as generators when providing electricity. The regulatory framework is still highly complex and requires case-by case consideration, especially when a device is supposed to be operated in multi-use scenarios.

A key challenge with regard to large-scale battery storage facilities is the uncertainty regarding price forecasts on the balancing market. On the one hand, the increasing installation of variable renewable generation is a factor supporting future demand for balancing services, while on the other hand, enhanced interconnection, grid expansion and the growing number of balancing service providers are factors influencing future price expectations.

Other relevant potential barriers for the implementation of the energy system storage are clustered in the following categories:

- public support,
- permitting,
- energy markets and capacity mechanisms,
- ancillary and grid management services,
- grid capacity and connection aspects,
- taxes & other levies,
- involvement of network operators,
- storage definition and other policy aspects.

Energy storage – what incentives may be provided

In 2015 the European Parliament published the paper "*Energy Storage: Which Market Designs and Regulatory Incentives are Needed?*"[1], identifying the most important policy recommendations aimed to promote wider use of the energy storage systems. These recommendations include among others:

1. Stimulate *R&D to achieve competitiveness of the most promising and cost competitive storage technologies. Smart-grid developments should also be promoted, together with smart cities concepts.*

2. Storage for renewable energy producers: define different incentives to stimulate more balanced production of renewable energy sources, for example, RE producers may adhere to standard balancing requirements, pumped storage hydro may be financially supported, price signals may be reinforced through scarcity pricing etc.

3. Flexibility markets: Energy storage technologies should receive equal access to markets for flexibility and these markets, together with ancillary services markets and/or potential capacity markets should be designed to be technologically neutral, allowing energy storage systems to compete against other flexible generation. Multiple services that energy storage can provide should be also acknowledged.

4. Ownership and control of storage by grid operators: allow transmission and distribution system operators to invest, use and exploit energy storage services to strengthen flexibility, reliability and resilience of the grids, since under present regulations this possibility is very limited.

5. Storage and end-users: The European Commission provide guidance to Member States on how to adapt support schemes for renewables in such a way that energy storage at the end-user level is stimulated in a harmonised way across the EU. Possible good examples are to establish simplified authorization procedures, promoting distributed energy storage acceptance and demand side flexibility, introduce dynamic pricing, variable tariffs etc.

Lessons learned from a number of implemented storage projects, indicated some pre-requisites, that would enable the competitive development of storage, before any kind of economic support is considered, such as:

- ✓ adequate grid tariffs and levies;
- ✓ non-discriminatory access to all electricity markets and eventual capacity mechanisms;
- ✓ a stable regulatory framework that reflects the long-term lifetime of storage assets.

Integrated or indirect support schemes can be considered as the preferred option to stimulate investments in energy storage; such an approach is in general less distortive than direct support. National support schemes for small scale PV can indirectly incentivize behind-the-meter small scale storage units, if the support scheme is properly designed and implemented.

Several EU Member States (e.g. AT, DE, GR) have implemented renewable energy support schemes which de facto stimulate local storage and can be considered as best practices.

[1] https://www.europarl.europa.eu/RegData/etudes/STUD/2015/563469/IPOL_STU(2015)563469_EN.pdf

Some countries, like Ireland, have launched a specific pilot micro-generation scheme to support PV installations coupled with home battery storage for self-generation.

In their National Energy and Climate Plans (NECPs), some Member States such as Belgium, Finland, France, the Netherlands, Poland, Portugal and Spain have dedicated R&I budgets for energy storage.

Storage has been addressed in a more holistic way in the NECPs of Austria, France, Greece and Spain. In these plans, the concerned authorities do not only recognise the need for storage, but they also address the different technologies and applications they intend to focus on. Some plans are more detailed and also contain specific storage objectives, a set of concrete policies and measures, a clear R&I agenda and proposed regulatory changes to address barriers and/or incentivize the deployment of storage at scale.

Economic support, especially in countries with low level of cross-border interconnection and immature electricity markets, is recommended, and would also depend on the expected technologies, applications and market penetration.

When choosing to implement a storage support scheme, attention should be paid to minimising market distortions and the discrimination of other flexibility sources as much as possible.