Notes de l'Ifri

Storage Integration in Energy Systems : A New Perspective

Aurélie FAURE-SCHUYER

June 2016

ifri Center for Energy

The Institut français des relations internationales (Ifri) is a research center and a forum for debate on major international political and economic issues. Headed by Thierry de Montbrial since its founding in 1979, Ifri is a non-governmental and a non-profit organization.

As an independent think tank, Ifri sets its own research agenda, publishing its findings regularly for a global audience. Using an interdisciplinary approach, Ifri brings together political and economic decision-makers, researchers and internationally renowned experts to animate its debate and research activities.

With offices in Paris and Brussels, Ifri stands out as one of the rare French think tanks to have positioned itself at the very heart of European debate.

ISBN: 978-2-36567-584-0

How to quote this document:
Aurélie Faure-Schuyer, "Storage Integration in Energy Systems: A New Perspective", *Notes de l'Ifri*, June 2016.

Ifri

27 rue de la Procession 75740 Paris Cedex 15 – FRANCE

Tel.: +33 (0)1 40 61 60 00 – Fax: +33 (0)1 40 61 60 60

Email: accueil@ifri.org

Ifri-Bruxelles

Rue Marie-Thérèse, 21 1000 – Bruxelles – BELGIQUE

Tel.: +32 (0)2 238 51 10 – Fax: +32 (0)2 238 51 15

Email: bruxelles@ifri.org

Website: Ifri.org

Author

Before joining Ifri Center for energy as a Research Fellow in 2014, Aurélie Faure-Schuyer worked 15 years in investment banks BNP-Paribas, HSBC and Dexia Asset Management, as a financial analyst covering the energy and commodity sectors (oil companies, oil services, mining companies, electricity, gas and water utilities).

She graduated from Paris-Dauphine University (Master's Degree in Management) and the École Nationale Supérieure du Pétrole et des Moteurs (ENSPM). Aurélie Faure is a certified financial analyst from the Société Française des Analystes Financiers - 2000. Recently, she pursued an Executive Master's in Communication and European Politics in IHECS – Brussels.

Abstract

Energy storage is partly an “old story” and a new one. Energy storage is an essential stabilizing factor in existing electrical systems. Looking forward, energy storage is being considered as a key element of the transformation of energy systems, given the higher shares of renewable generation integrating the systems and demand-side management offered to end-customers. Today, the cost of electricity produced from battery storage is approaching parity with electricity bought from the grid. For this trend to gain strength and energy storage to be part of new business models, energy policies and regulatory frameworks need to be adapted.

Table of contents

Introduction

Storage is already a component of existing energy systems, situated in specific locations in the form of primary energy supplies. In primary modes, energy can be stored as water or as fuel, notably for electricity generation (hydro, coal, fuel oil or natural gas). Energy can also be stored for final usages in the form of cold in industries, or hot water for residential uses (hot boilers). With hydro storages, energy storage has been traditionally used for balancing off-peak power, partly to complement nuclear base-load generation.

The renewed attention to energy storage stems from the transformation of our energy systems, with the growth of renewables in electricity generation and the progressive development of electric mobility. In particular, the integration of renewable electricity is tied up with the question of energy storage as a response to fluctuations in electricity output from wind and solar power generation.

Storage may also act as a "newcomer" in the system, in areas where the development of self-consumption from photovoltaic panels associated with battery systems induces new load flow patterns.

From an economic perspective, there is potentially a tipping point related to the fast decline in battery investment costs, allowing self-consumed electricity to equal the price of electricity conveyed by the grid. This is the principle of "cost parity" between self-consumed electricity and retail electricity prices. In some countries such as Germany and Italy, it is becoming economically feasible to install a battery behind the meter of a residential/commercial premise, and recover the investment costs through saving the variable cost of unconsumed electricity. With batteries, energy storage has the potential to generate savings on the final customer bill; a potential that Tesla is already promoting for residential uses, through the roll out of its Power Wall.[1]

The purpose of this paper is to go through the transformations that new modes of energy storage – mostly batteries – are expected to bring to the energy systems. It addresses some of their impacts on the electricity

1. Power Wall refers to a Tesla battery. It is installed on premises using a DC current network, and requires the installation of an inverter to convert DC into AC. There are currently two product-sizes on the market: 10 kWh and 7 kWh.

sector and provides an overview of recent policy developments related generally to storage. The paper also offers some considerations about the wider implications for EU policy making.

The Energy Storage Landscape

Storage technology overview

Energy storage has traditionally been associated with different forms of primary or final energy modes. But given its technical characteristics allowing the intermittency and seasonality of renewable energy to be offset, it is now seen as having a potential strategic role to play in electricity systems, in view of the growing share of renewables in power generation. As a result, energy storage is now closely related to wider energy system transformations.

Energy storage refers to a range of non-standardized technologies or Electrical Energy Storage technologies, divided into four main families: electrical storage, mechanical storage, chemical or hydrogen-based storage and electrochemical types of storages.

These various forms of storage meet different needs, providing either energy applications i.e. delivering a constant energy flow daily or hourly, or providing capacity for instantaneous needs, in power applications. Each storage application can be differentiated according to its reaction time (from milliseconds to hours), its size or capacity (from 1 kW to 1 GW), its duration of storage discharge (seconds to days) and the costs of electricity generated.[2]

Overall, the difference between injection and withdrawal (or production and consumption) yields an efficiency factor that ranges between 20% for chemical/hydrogen storage to above 90% for high power kinetic energy-based systems (flywheels).[3]

Traditional large scale forms of storage (pumped hydro storage and compressed air energy systems) need to be integrated into specific fields or locations (water reservoirs, caverns). At the end of the spectrum, electrochemical storage (batteries) offer smaller scales and more modular forms of energy storage, as they can be designed for different locations on

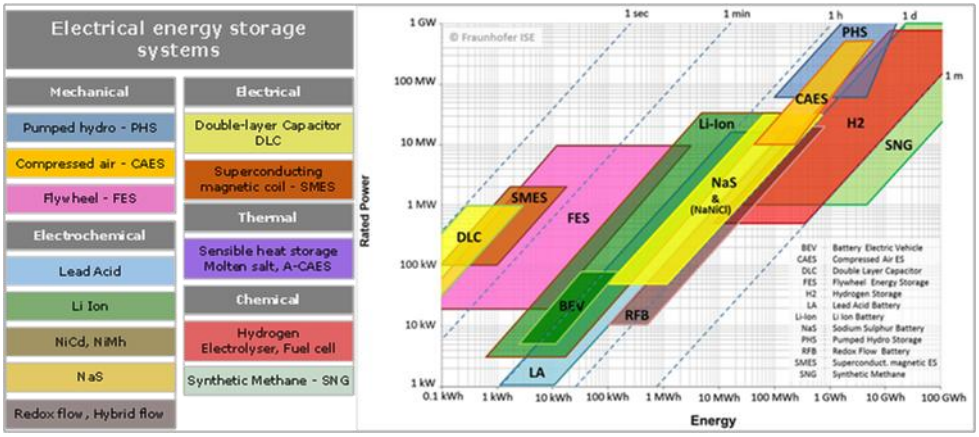
2. *Electricity Storage, Technology Brief*, IEA, ETSAP, Irena, April 2012.
3. *Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs and Benefits*, Electric Power Research Institute, December 2010.

the grid, from the mid-scale (50mW) to the smaller scale (10kW) location. The location of storage is therefore an essential element to be taken into account when assessing storage integration into the system.

Storage multi-functionalities

Based on the performances of the different families of technologies, initial considerations can be given in terms of applications and functionalities of energy storage in future energy systems.

Figure 1: Electrical Energy Storage Classification and Performances



Note: Classification of electrical energy storage systems according to: (a) rated power, energy content and discharge time, and (b) own representation based on (International Electrotechnical Commission (IEC), 2011).

Source: International Electrotechnical Commission

The comparison of the amount of energy released from the storage (Energy) with the ability of sustaining power without recharging (Rated Power) reflects the duration of the storage at rated capacity. Figure 1 also shows the distinction between large-scale and small-scale storage.

Technologies situated in the top right-hand corner of Figure 1, like pumped hydro storage (PHS), compressed air storage (CAES), and hydrogen-based storage, constitute the most suitable forms of storage for the integration of renewables over periods from days to months. Technologies situated in the bottom left-hand corner of Figure 1, like flywheels, compose the most suitable answers to grid-related reliability issues. While batteries can answer different needs from residential/commercial peak shaving, to grid stabilization or electric mobility, they can be located at decentralized residential (5-20 kW) and centralized residential levels (100 kW). Hydrogen and methane are not desirable from an efficiency perspective (efficiency from 20-50%), but can

be used in the transportation sector and the chemical sector.[4] Diabatic[5] and advanced adiabatic CAES (A-CAES) can be considered as alternatives to pumped hydro storage units.

The European Association for Storage of Energy (EASE) provides different definitions of storage, throughout the distinction of three main energy storage functionalities:

- the ability to time-shift electrical energy considers storing cheap off-peak electricity and reselling it at a more expensive peak-time period (energy arbitrage) or storing excess renewable electricity, mainly for purposes of system stability;
- the ability to inject energy to the electrical grid, similarly to a generator;
- the ability to extract energy from the electrical grid, similarly to demand response.

For large-scale storage units, the economic benefit of storage will depend on the timescale where these functionalities will be activated. Energy storage could theoretically be considered as a generation element, a grid asset being subject to regulatory oversight or a home-based component. There is no clear definition of energy storage in European energy legislation. In grid-fee regulations, storage is either considered as bearing single or double grid fees.[6]

In the following sections, the reference to energy storage should be understood as the storage of electrical energy in stationary modes (i.e. excluding electric mobility).

From technologies to deployment

The integration of storage in energy systems is not straightforward, as storage encompasses multiple technologies. Energy policy decision-makers together with private actors need to make an assessment of the degree of technical maturity of energy storage technologies.

Pumped hydro storage is the only large-scale technology available in the world accounting for 142 GW of installed capacity.[7] The development of

4. *Energy Storage Technologies and their Role in Renewable Integration*, GENI July 2012.
5. In a diabatic CAES, air is cooled before compression and reheated before expansion in a gas turbine. In an adiabatic CAES, the air's heat energy is stored separately and recovered before expansion (Swider, 2007).
6. B. Normark, and A. Faure, "How can batteries support the EU electricity network", Insight_E, 2015.
7. D. Mooney, "Large-Scale Energy Storage", *GCEP Tutorial Series*, National Renewable Energy Laboratory, October 14, 2015.

large-scale utility battery storage has been limited over the last years, because of low energy densities and relatively small power capacities, leading to a high land footprint. Average density of lithium-ion batteries stands at between 80-150 Wh / kg,[8] far lower than their competing fuel cell technologies (1,000 Wh / kg)[9] or superconducting magnetic energy storage capacitors. In the Joint Fuel Cell Undertaking, the European roadmap contemplates a progressive integration of hydrogen in the systems between 2020 and 2050.[10]

Except "new generation batteries", where research and development is still ongoing, in particular in relation to new electrochemistries, energy storage technologies can be considered as advanced technologies, i.e. standing between demonstration and deployment.[11] For more elements to assess stand-alone technical functionalities and applications (system uses), the US Department of Energy differentiates between demonstration, deployment and early stage technologies.[12]

If technological maturity is generally advanced for energy storage, its uptake does not seem pronounced in all regions of the world. Meanwhile, renewable-based energy policies are accompanying technology diversification strategies. This is the case for Japan which has selected hydrogen storage,[13] as a key pillar of its energy policy, but, is also considering battery storage, while operating pumped hydro storage (see Figure 2).

All energy storage systems described above lead to concerns about safety and to their effect on the environment. In relation to batteries, there are concerns related to the environmental impact of advanced chemicals like metal oxides.[14] Alternative forms of metal to liquid or water-based chemicals are under research and development.[15]

8. Overview of current development in electrical energy storage technologies and the application potential in power system operation, Xing Luo, Jihong Wang, Mark Dooner, Jonathan Clarke, January 2015.
9. *Ibid.*
10. *Study on hydrogen, from renewable resources in the EU*, Ludwig-Bölkow-SystemtechnikGmbH (LBST) and Hinicio S.A., July 2015.
11. Asset life also needs to be considered a parameter. When PHS has an asset life of 50-60 years, batteries have a 15-years life use, before they need to be recycled, possibly for re-use.
12. Grid Energy Storage, US Department of Energy, December 2013.
13. C. Mathieu and S. Cornot-Gandolphe, "Japan's Energy and Climate Policy: Towards Dispelling the Uncertainties", *Notes de l'Ifri*, May 2015.
14. Available at: www.environmentalresearchweb.org.
15. "Storage Technologies: Status and Perspectives", RES Gmbh Germany, January 2016.

Energy storage policy choices

Japan and Korea are considered as the most ambitious countries in the field of energy storage. Their strategies have been built on the large industrial progress made by these countries in semiconductor and power cell manufacturing. They were initiated after the Fukushima disaster, which provided a new impetus to energy security in Japan. Korea has a 2 GW target for storage by 2020.[16] These strategies are aimed at consolidating the positions of these two countries in export markets.

Except from Japan and Korea, and despite the optimism in market developments globally, an overview of storage developments in the world's largest regions (China, Europe and the United States) does not show any clear evidence that storage developments in these regions are driven by policies on renewables.

In China, the government is targeting 70 GW of pumped hydro storage capacity by 2020; while existing dominant players have limited sites to new pumped storage installations (Europe, Japan and North America account for 142 GW of installed capacity).[17] China's growth in energy storage stems from a combination of planned projects of pumped hydro, together with growth in end-user battery applications (at residential premises and industrial sites).[18] China's forecasts of having 10 million Electric Vehicles on the road by 2020 should be carefully watched, as this could also lead to an uptake of energy applications, with car batteries providing electric grid services.

In the field of pumped hydro, Europe can rely on large turbine manufacturers (Alstom-General Electric in France, Andritz in Switzerland) providing a strong manufacturing know-how. Attractive options could be considered in retrofitting existing turbines with variable speed turbines that allow operation in the ancillary services market. However, pumped hydro is constrained by water availability at specific sites, and more recently by local opposition related to environmental protection.[19] To this extent, Europe needs to clarify its industrial strategy in the field of energy storage. Policy adaptation is also required in Europe. The unbundling of generation and grid assets left storage in a position in which it cannot serve explicitly both the purpose of energy arbitrage (generation) and grid

16. *Battery storage for renewables: Market Status and Technology Outlook*, Irena, January 2015.
17. 12th Five Year Plan.
18. S. Blom, *Global Energy Storage Market Overview & Regional Summary Report*, Energy Storage Council, December 2015.
19. M. Baumann, "Analysis of a Controversial Decision Process: the Case of the Pumped Hydro Storage Power Plant Atdorf in Germany", *IET Working Papers Series*, WPS04/2015, 17/11/2015.

stability services to system operators, as it may create market interferences, anti-competitive forms of behaviour and risks of dominant positions.[20]

In the United States, California[21] has a prominent policy as part of a mandated strategy to diversify storage into battery technologies. A mandate of 1,325 MW has been given to three utilities,[22] with pumped hydro storage above 50 MW not being eligible for the mandate. California has the ambition of replicating its model in other regions of the world, making this experience a benchmark for technology clustering and economic development, in particular in the field of US-China climate cooperation. Initiatives in other regions are also taking a wider approach to storage technologies. In its new energy vision ("Reforming the Energy Vision"),[23] the state of New York is targeting a share of 50% of the city's electricity mix coming from renewables, and is adopting a diversified approach to storage technologies: i.e. it is considering the possibility of selecting technologies according to specific needs and circumstances. Part of the Department of Energy smart grid analysis (the Gridwise alliance)[24] is also integrating storage as part of its future energy system vision.

Figure 2: Comparison between Pumped Hydro Energy Storage (PHS) and Solar Photovoltaic (PV) Current Deployment and Targets (in GW)

	PV capacity – 2015	Target PV capacity 2020	Pumped Hydro Storage 2014	Target Pumped Hydro Storage 2020
Europe	98	139.5	44*	-
China	43	70 (2017)	22 **	70
Japan	33	64 GW	35*	-

*Source: * Data from Ease; ** International HydroPower Associations and estimates from PV Market Alliance; PV capacity 2015 from GTM Research.*

Although growth in solar capacities globally is buoyant, large scale storage capacities appear limited. Market estimates in decentralised energy storage indicate an 841 MW global installed based in 2020, according to

20. Directive 2009/72/EC, Article 9.
21. California Storage Law – AB 2514 ; FERC Ruling 755 on frequency regulation, available at: www.ferc.gov.
22. Southern California Edison (580 MW), Pacific Gas and Electric (580 MW) and San Diego Gas and Electric (165 MW).
23. Available at: ww3.dps.ny.gov.
24. Available at: www.smartgrid.gov.

GTM Research. Meanwhile, storage in the form of centralised/bulk storage would be multiplied by 4, rising from 538 MW to 2100 MW in 2024 – according to Navigant Research. However, recent policy developments in Europe, China and Japan point to large installed PV capacities, with varying deployment strategies being adopted in the field of energy storage. As such, there is no uniform trend in relation to storage development.

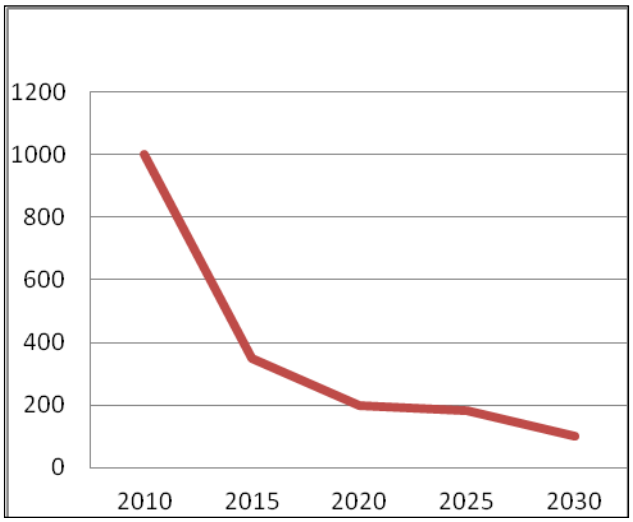
Energy Storage in a Decarbonised System

Experiences from Denmark and Spain are often used to recall that when renewables rise above 20-25% penetration of the electricity mix, new challenges related to networks appear in terms of frequency stability and flow congestions. In this context, energy storage should be considered more carefully. Projecting the future of energy storage in decarbonised systems relies on the mapping of performances (reaction time, energy conversion, power/energy ratio) that energy storage will be able to feature in future energy systems.

Batteries' inexorable cost decline

Compared to wind or solar turbines, batteries have gone through a massive decline in manufacturing cell costs. These are being projected to be divided by 10 between 2010 ($1000/kWh) and 2030 ($150-180 /kWh).[25]

Figure 3: Costs for Lithium ion Battery Packs ($/KWh)



Source: Bloomberg New Energy Finance

This trend highlights the competitive advantage of storage relative to alternative options of grid connection. However, for a reliable assessment

25. According to data compiled by Bloomberg New Energy Finance.

of the costs of battery storage, the whole integrated PV-battery systems should be take into account. Total system costs (expressed as levelised costs of energy storage) include inverter costs, system balancing costs, maintenance and recycling, over the life of the storage unit. A recent study[26] shows that residential electricity self-consumption could gain ground based on the decline in equipment costs in relation to a certain level of grid-derived electricity costs. This is why battery costs (which still represent the core element of investments in self-consumption above 50%) are central to this dynamic.

Industry structure helps understanding this trend and projecting it further.

The battery market is largely dominated by Sodium Sulphur (NaS) and lithium-ion batteries (Li) manufacturers. Japanese NGK Insulators and NEC Energy Solutions (formerly A123 Systems) control 75% of the market related to cell manufacturing. In 2014, NGK Insulators, the only provider of Sodium Sulphur technologies, controlled 350 MW of battery capacity, of which 200 MW were used for stationary energy applications. The sharp cost decline illustrated in Figure 3 can be explained by two main factors:

- Battery manufacturing is an assembly industry, whereby costs decline with the mass production of products. This trend, which characterises many other mass products in the electronic industry (semiconductors, laptops, cell phones etc.) is particularly relevant to the manufacturing of cells, in which electro material components (cathodes, anodes and electrolyte) have been experiencing a trend of cost reduction in past years. This is also strongly related to government-sponsored export strategies (i.e. public stimulus to exports).
- The rise in the oil prices between 2000 and mid-2014 stimulated the development of batteries for Electric Vehicles or Plug-in Hybrid Vehicles. Large amounts of overcapacity have been built up in the battery industry, leading to downward pressure on battery cell prices. This evolution is taking place not only for batteries, but also for other types of equipment like inverters used in combination with photovoltaic panels.
- In 2015, Bloomberg New Energy Finance estimated levelised costs of Li-ion batteries below $400/kwh, representing a 33% decline rate in only two year time. At the end of2014, German car manufacturers

26. J. Hoppmann, J. Volland, T. S. Schmidt, V. H. Hoffmann, "The Economic Viability of Battery Storage for Residential Solar Photovoltaic Systems – A Review and a Simulation Model", *Renewable and Sustainable Energy Reviews,* vol.39 November 2014, pp.1101-1118.

indicated that the cell price per kWh would decrease to less than $100 /kWh by 2025, which would lead to cost parity with Internal Combustion Engine (ICE) cars.[27] In the United States, Tesla aims at achieving the $ 100/kWh level by 2020, once the Nevada based Gigafactory is running. Lithium-ion batteries used for distributed energy storage applications of various capacities and power output ranged around $0.5-2/kWh (EPRI and DOE, 2013).

The decline in oil prices to $40 per barrel since 2014 has two indirect impacts on battery manufacturing costs. In electricity generation, it may improve the competitive advantage of fossil-fuel based generation, compared to wind and solar renewable energy costs, which are driven mainly by fixed capital costs. If any delays in the PV installation roll out were to occur, they will not however offset the long-term trend largely supported by public policies globally. In case of a significant slowdown in PV installation, and given the current situation of overcapacity on the electricity market, additional pressure will be put on equipment delivery prices.

In terms of optimizing the battery system industrial chain, the push by battery manufacturers for cheaper materials remains, however, ultimately negative for the whole industry, as it reduces the incentive for recycling.[28]

Storage contribution in an environment of high feed-in tariffs for renewables

Failure to operate the high-voltage[29] transmission systems at their required frequency can disrupt the functioning of equipment, disconnect power plants and lead to blackouts.[30] In this context, storage is being considered with increasing interest, as an element of reliability in the system among other elements like interconnections, demand-side management and dispatchable generation plants. Electrochemical storage could be activated in areas of low-system inertia (islands). In reserve requirements, in primary and secondary control (up to 30 seconds for primary control and to 15 minutes for secondary control), electrochemical batteries could also

27. P. Hummel, *Will Solar, Batteries and Electric Cars Re-shape the Electricity System?* , UBS Study, August 2014.
28. M. Leuthold, "How can batteries support the EU electricity network", Insight_E, Expert Webinar, 28th October 2014.
29. CENELEC (European Committee for Electrotechnical Standardization)'s definition of HV-MV-LV is usually used: LV is under 1kv, MV is 1kv to <35kv, HV is above 35kv.
30. Eto *et al.*, *Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation*, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, 2010

be appropriately activated by transmission system operators. Solutions based on Lithium-ion to Sodium Sulphur batteries, with duration up to 7 hours, can approach the functionalities of large scale models like pumped hydro storage or compressed air storage. This experience has been carried out by Terna in Italy. A study published by the European Parliament provides estimates of the minimum required level of energy storage ranging from 20% to over 60% for the renewable energy share in electricity production.[31] This is of a particular interest for the EU, given its policy objectives for 2030 (45% of renewables in electricity generation and increased interconnection to 15% of existing installed capacities).

With 90% of renewables being connected at low-voltage distribution level (as part of distributed generation), different challenges arise on the low-voltage distribution grid, compared to those occurring on the high-voltage transmission grid. It is shown in particular that more than 50% of low-voltage distribution reinforcement is caused by voltage problems,[32] therefore limiting grid hosting capacity (i.e. the amount of electricity production that can be connected to the distribution network without endangering the voltage quality and reliability for other grid users).[33] Furthermore, according to a study realised in Sweden on grid security limits and grid configuration (traditionally based on spatial network configuration and population density), there is room for a high amount of distributed PV-based generation.[34] Local energy storage is an alternative solution that needs to be assessed compared to more traditional grid reinforcements, inverter installation, or a possibility with the integration of electrical vehicles.[35]

As a result, developing successful policies in relation to storage requires a sound technico-economic analysis of the benefits of storage compared to market or grid related transformations and costs induced by renewables' feed-in.

31. *Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?*, European Parliament, Study for the ITRE Committee, December 2015, p.19.
32. *Integration of renewable energy in Europe*, Final Report, Imperial College, NERA, DNV GL, June 2014.
33. CEER definition: Ref: C13-EQS-57-04 CEER Status Review of regulatory approaches to smart grids.
34. Available at: www.diva-portal.org.
35. *Renewable Energy Integration in Power Grids – Technology Brief*, Irena, April 2015, p.8.

Energy Storage: Value Versus Strategy

Over the long term, the value of electricity storage should converge with the cost of building new power generating capacity. As the situation of the European electricity market is characterised today by large overcapacity of installed conventional generation, it may be asked how energy storage can still achieve value under current market conditions.

Storage requirements and the electricity market design

In Europe, the utilisation rate of generation capacity achieved a low point in 2015 at less than 50%,[36] meaning that at the aggregate EU level half of generator plants were idle, if we do not consider peak demand situations. In an oversupplied electricity market, it is difficult to anticipate any economic value creation from storage, unless storage can bundle revenues from the wholesale market and operate in reserves management (i.e. by participating in frequency reserves).

A study by Imperial College London shows that in the absence of markets for ancillary services, profitability of energy arbitrage is realised over short duration timescales of 4 to 6 hours.[37] It also details to what extent the decline in capital expenditures relative to new combined-cycle gas turbines, together with lower electricity and CO_2 prices have led to a reduction in the value of storage for the electricity system as a whole. Another indication given by the Brattle group is that the value of storage could be considered as mainly being derived from a generation capacity component, which results from the lack of a differential in time shifting.[38]

Positioning energy storage's strategic value in energy systems is a challenge for the European electricity market design reform. Given the

36. S. Savvantidou, *How to Survive on Less Than Seven Billion*, Exane BNPParibas Equity Research, April 2016.
37. *Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future*, Energy Futures Lab, Imperial College London, June 2012.
38. J. Chang, J. Karkatsouli, *et al.*, "The Value of Distributed Electricity Storage in Texas", November 2014, available at: www.brattle.com.

poor prospects for storage value creation in generation, one should ask if storage value lies in retail consumer data management.

The answer lies at the level of residential customers

With the fast decline in energy storage costs, self-consumption (referring to the consumption of distributed electricity produced by a photovoltaic panel and which is not metered) is now achieving cost parity with the electricity conveyed on the electric grid (at retail prices). In Germany and Italy,[39] electricity produced from solar panels combined with a residential battery is cheaper than electricity bought on the grid, standing at €288/mWh and €245/mWh respectively (Eurostat). As a result, storage constitutes a potential means of leverage for creating savings on the final customer's bill, a potential that Tesla has already identified.[40]

At the residential level, the "grid parity" effect is relatively independent from oil and gas price movements, unless governments decide to limit their solar PV subsidies. These steadier prospects in stationary applications both at residential and low-voltage grid levels both ensure that battery storage will continue to grow, compared to other traditional storage modes.

Towards a coordinated EU policy answer

As explained above, energy storage is not structured as one homogeneous industry, but refers to a range of multiple technologies sold by equipment manufacturers. These technologies provide local and temporal system "adjustments". At Member State level, storage remains relatively absent from energy debates, as it does not provide a single picture of future energy systems. Therefore, it is necessary to build an EU vision defining the role of energy storage in systems transformation.

The EU should clarify the role of energy storage in servicing energy markets and system components.[41] In the European electricity market design proposal, two different levels can be considered. The first one should allow storage to operate as an ancillary service provider both for

39. *Report on Self-consumption and Autogeneration of Renewable Electricity*, France Energy-Ecology-Sustainable Development Ministry, December 2014.
40. A. Faure-Schuyer, "Le défi posé par Tesla", *Édito Énergie*, Ifri, 22 May 2015, available at: www.ifri.org.
41. *Energy Storage: Which Market Designs and Regulatory Incentives are Needed?*, European Parliament, ITRE Committee, 2015.

large and small scale level (on the low voltage distribution grid). In this field, new proposals are required to clarify the neutral position of energy storage in relation to the frontier between generation and networks. Secondly, the European electricity market should ultimately allow for a wider penetration of storage at residential customer level. Through subsidy schemes for solar power and battery storage, Germany has taken the lead, in recognising the long-term benefits of storage for residential customers, which bear relatively high end-user prices. It remains to be seen if the Commission will take these experiments as an example for further development.

Thus, contrary to other regions in the world, there is no clear European-wide vision and policy on energy storage. The Energy Union has an opportunity to consider energy storage as a differentiating policy leverage that also supports the renewal of energy infrastructure or highway transmission projects (e.g., North Sea Grid).

Coordination with the utilities and the storage industry (battery manufacturers and assemblers) is the most important, in order to avoid EU battery prices relying on the fluctuations of manufacturing abroad, leading to new types of external dependence. A strategy for recycling should also be designed.

Conclusion

Although the prospects of decarbonising the energy sector are facing large uncertainties in terms of technological breakthroughs, stationary energy storage has already gained a competitive advantage, partly driven by cost reductions in battery manufacturing.

Since 2014, the decline in oil prices has improved the fossil-based cost advantage relative to wind and solar energies' high unit costs. However, any delays in the PV installation roll out will not offset the long-term trends.

The specifications of the internal combustion engine will be becoming more stringent independently from gasoline prices, and, prospects for electric vehicles recharging infrastructures development and market growth will remain strong, even though the price of gasoline has retreated.

In the transition to a decarbonised energy system, the integration of storage will lead to closer interactions of supply and demand. As a result, value to the system will not rely on the volume and the scale of the technology deployed, as is the case for the existing modes of storage (hydro or fossil fuel based). Storage could therefore be recognised as an alternative form of investment in grids (copper grid lines), an element of demand service response, and an electricity grid stabilization factor.

The energy storage industry is progressively moving from an equipment-based industry to a service-based industry, whereby different actors of the system (generators, grid operators, aggregators, final customers) will be allowed to access storage-related services. This energy storage overview illustrates the potential roles of new services in the transformation of energy systems.

The upcoming legislation on the electricity market design under the implementation of the Energy Union is an opportunity to raise the ambition further in the promotion of energy storage, compared to other regions like the United States, China or Japan.

Finally, in developing countries, energy storage could revamp some projects like Desertec[42] or Helios,[43] by providing an alternative to the cost

42. Available at: www.desertec.org.

of laying high-voltage transmission cables in certain areas. Storage is also contemplated for shorter project lead times and feasible developments facilitating the access to energy.

43. "The Helios project and the role of energy for Greek and European growth", Speech by Günter Oettinger, Commissioner for Energy, April 2012.

Annexes

Annexe 1: Energy storage: technology overview

There are three forms of mechanical storage:

- Flywheel technology (FES) uses spinning discs, retaining kinetic energy or rotational energy. Flywheels are already deployed for frequency regulation in order to ensure steady power on the grid.
- Compressed Air Energy Storage (CAES). Air is used as storage vehicle, and, electricity is used to compress air and store it in either underground structures or in vessels or pipes. When needed, the compressed air is mixed with natural gas, burned and expanded in a modified gas turbine. Typical underground storage options are caverns, aquifers or abandoned mines.
- Pumped hydro storage (PHS) store energy in the form of water circulating between two water reservoirs at different levels of elevation, operating along the mode of turbining (electricity production) or pumping (electricity consumption). Pumped hydro storage was first developed in 1890 and rolled out as of the 1970s, in order to allow time shift through day-night arbitrage. They were often designed as a complement to nuclear generation. PHS has a rapid reaction time and features an average efficiency of 70-80% due to losses between the two reservoirs.[44]

Electrochemical storage (battery storage) refers to a more recent approach to conserving electrical energy in chemical form. This form of storage takes advantage of the fact that electrical energy and chemical energy share the same vector, the electron. This advantage allows losses related to the conversion of energy from one form to another to be limited.[45] Electrochemical storage refers to battery storage, a unit of one or more cells, in which chemical energy is converted into electricity. This allows different chemistries to be deployed depending on the requested functional properties (from lead-acid to lithium-ion, sulphur dioxide) and different capacities. Current systems are proposed below 10 MW, while

44. "PHS Economic model", WG PHS UFE, January 2013.
45. Réseau sur le stockage électrochimique de l'énergie ; www.energie-rs2e.com

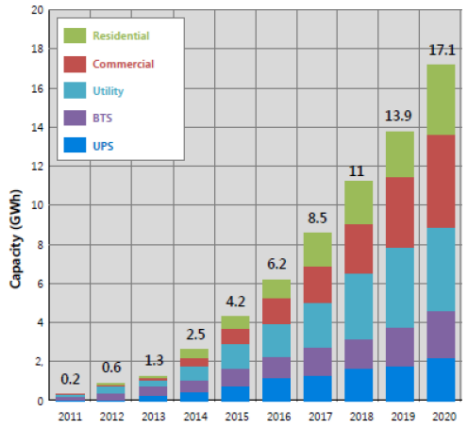
50 MW projects are being tested. In the case of electric vehicles (where mostly lead acid or lithium ion batteries are used), electricity is subsequently converted into mechanical energy.

Pure electrical storage in supermagnetic conductive fields stores energy in the form of an electromagnetic field surrounding a coil, which is made of a superconductor. These systems have fast response and are capable of deep discharge.[46]

46. *Energy Storage Technologies and their Role in Renewable Integration*, Global Energy Network Institute, July 2012.

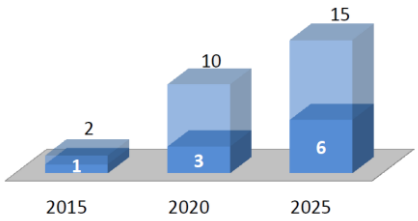
Annexe 2: Battery market

Total Li-ion battery market (exc. vehicles/consumer)



Source: SAFT

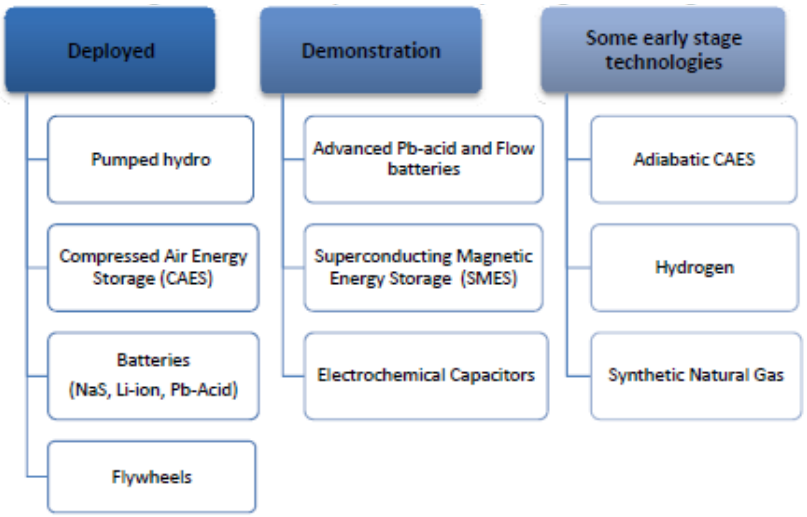
Global home Li-ion storage market, GWh



Source: SAFT

Source: Raymond James Research – Saft.

Annexe 3 : Maturity of Electricity Storage Technologies



Source: US Department of Energy.

institut français
des relations
internationales