Facts & Figures

ENERGY STORAGE

ISSUES, TECHNICAL SOLUTIONS AND DEVELOPMENT OPPORTUNITIES

March 2012

89, rue Réaumur 75002 Paris France I +33 (0) 1 82 83 83 83 I www.enea-consulting.com

This work is licensed under the Creative Commons Attribution - Pas d'Utilisation Commerciale - Partage à l'Identique 2.0 France License. To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-sa/2.0/fr/ or send a letter to Creative Commons, 444 Castro Street, Suite 900, Mountain View, California, 94041, USA.

ENERGY STORAGE: INCREASINGLY IN DEMAND

Background : why store electricity ?

The balance between the supply and demand of electricity, necessary for the proper functioning of electrical grids, is becoming increasingly fragile. The grid is designed to withstand a certain number of hazards, for example the effect of climate on consumption (in France a 1°C drop in the temperature in the winter causes an increase in power demand by 2.3 GW), loss of work hours on production, etc.

The increased use of intermittent renewable energy sources, mainly wind, is an additional source of fragility. Weather hazards cause fluctuations in production, which are independent of consumption. New types of situations have to be handled: overproduction of electricity during off-peak hours, and means of production which cannot be relied upon during peak periods.

The increased volatility in the price of electricity is one indicator of these tensions. In France, on the 8th of February 2012, a peak of 102 GW in consumption brought the market price up to 2000€/MWh. In contrast, in 2010 Germany experienced periods of negative pricing as low as -500 €/MWh, caused by a surplus in wind turbine production.

Faced with these tensions, different solutions known as mitigation measures, can be implemented.

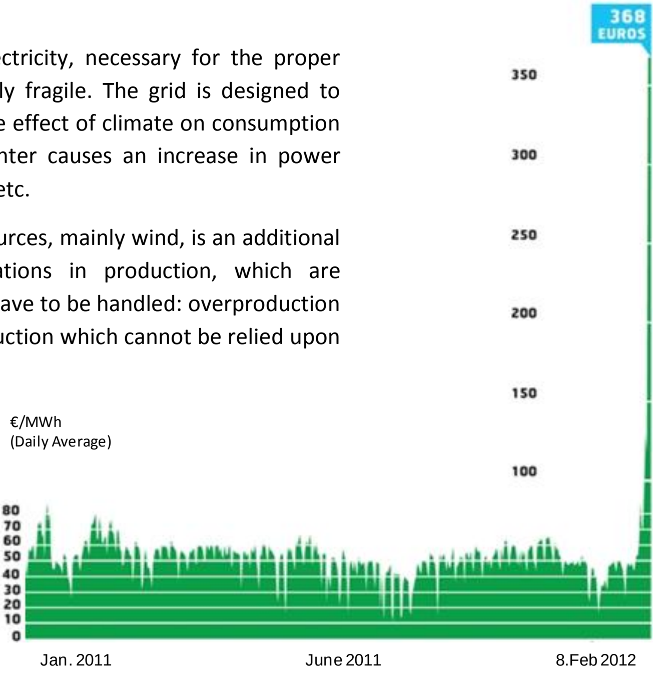


Figure 1: Epex Spot's electricity prices for next day delivery on the Stock Exchange (source: Les Echos, 02/09/12)

The use of **peaking power plants** such as gas or diesel turbines is an option widely used today. However, the penetration of intermittent energies, with their *zero marginal costs of production*, affects the profitability of these flexible means of production by lowering their duration of operation because of an alteration of the *merit order*[1].

The **interconnections** of the electricity grid reduce local fluctuations through inherent load balancing. However, projects for new lines are very costly and often face problems with social acceptance. This is exemplified by the 14 years of negotiations undertaken for the French-Spanish line, incurring a final cost 7 times higher than expected.

Demand side management (DSM) aims to adapt consumer demand in line with fluctuations in production, thanks to demand reduction contracts used at peak times and communication solutions existing between points of production and points of consumption (*smartgrids*). While it is efficient with large consumers, DSM requires massive deployment and costly equipment (for communication and accounting) in order to reach individuals.

Energy storage is one solution, which is cross-functional and complimentary. Although the sector still has to reach maturity, it is clear there are many advantages:

- The environmental gain of unlocking the widespread use of low-carbon energy, and the replacement of fossil-fired plants (see p.15).
- The ability to respond in a centralised and decentralised manner to local and global constraints.
- An independence from fossil fuels, which is a long term economic advantage given the predictable increase in cost of fuel and cost associated with CO_2 emissions.

[1] *Merit order : ways of ranking power plants in order of increasing marginal costs of production.*

ENERGY STORAGE: INCREASINGLY IN DEMAND

Energy storage: both a technical solution and an economic opportunity

Energy storage has the ability to fill **a technical gap**: in the long-term, it is an indispensable asset contributing to a low-carbon electricity mix preferred by public policy, particularly European.

Energy storage is also **an economic lever**: it is a way to capitalize on the volatility of the electricity market, generate profits or reduce costs associated with the consumption of electricity. All actors with the ability to store energy (industrial, communities or individuals) can take advantage of this opportunity.

This technical and economic duality creates a favourable context for the development of energy storage.

Regulatory constraints and opportunities

To avoid grid constraints becoming a barrier for renewable energy, some states are changing the regulatory framework to support storage solutions. In California, for example, the specifications for intermittent energy production projects includes an obligation for energy storage. In France, the latest tender for wind turbines in Corsica and overseas territories explicitly mentioned a constraint on energy storage in order to improve grid integration.

These new laws provide a necessary framework for the development of this sector. Although it is still under development, it has two immediate consequences:

- **The arrival of a new constraint** for intermittent energy producers,
- **The birth of a new opportunity**, in France, for instance, the NOME[2] Act gives a competitive value to the power capacity made available to the grid (see below).

A regulation opportunity in France: NOME Act and Capacity Mechanism

Article 6 of the NOME Act puts in place a capacity obligation for electricity producers who must now justify that their physical capacity of production is equal to the power needed to supply their customers. This requirement will come with the first appearance of a capacity market, expected in 2017.

By providing them with a certificate of capacity, to be capitalised on the market, a new value will then be granted to the power made available by energy storage. The exact terms are not yet known, but the source of earnings will increase the income generated by the sale of energy. In addition, a scenario of double capitalisation on storage capacity (for both charge and discharge) would also serve as a competitive catalyst for the energy storage sector.

[2] *NOME : New Organisation of Electricity Markets*

TECHNICAL SOLUTIONS

How to store energy?

Except for special cases, it is difficult to directly store electricity. It therefore needs to be transformed into a different form, which can be stored with greater ease:

Mechanical: This category includes some of the best known large-scale storage systems: PSH[3] (see page 6 for details) and CAES[4] (see page 13 for details). It also includes flywheels, hydraulic accumulators, and more generally, any type of potential or kinetic energy storage system.

Electrochemical: Batteries. This is the most familiar option for the general public, given their daily usage (in vehicles, mobile phones ...). This category also includes flow batteries (and in particularly redox batteries), based on the same principle except the active solution is contained in a separate tank, thus allowing for flexible energy capacity sizing, independent from the battery power capacity. There are, in fact, many battery technologies, which have a wide variety of characteristics.

Thermal: Many thermal storage solutions exist, from cold (ice, cryogenic liquids) to heat (molten salts, steam accumulators, phases changing materials...), and are used to store energy as heat (latent heat, sensible heat) before it is recovered, usually directly for heating or cooling, but sometimes for generating electricity.

Electrostatic / Magnetic: Some systems can store electric energy directly, like capacitors, which store electrons. Likewise, an SMES[5] system can convert and store electrical energy into magnetic energy.

Chemical: That is the use of electricity to form a chemical compound, a molecule, which then has the ability by burning or using a fuel cell for example, to release energy. Hydrogen and methanol are two examples.

Utility: Utility energy storage is the process which concentrates off-peak electricity consumption, by binding its production into an intermediate product like that of oxygen or liquid nitrogen, for example, which can then be stored at low cost for later use (see page 12 for details).

Choosing the form of energy

The type of storage best suited for each particular case will depend on its final use (sometimes it is electricity, but often heat, chemical, utility ...).

Indeed, converting stored energy into electricity only to reconvert into another form of energy is rarely the most efficient solution.

It is, for example, possible to avoid the losses associated with power conversions, by using direct heat storage to meet the needs of this type.

---

[3]*PSH: Pumped Storage Hydroelectricity*

[4]*CAES : Compressed Air Energy Storage.*

[5]*SMES : Superconducting Magnetic Energy Storage. At very low temperature, superconducting materials can store electricity in loops: given that it is subject to no loss, the current can run indefinitely.*

.

TECHNICAL SOLUTIONS

Technology Focus: Pumped- Storage Hydroelectricity (PSH)

Theory: Water from a low reservoir is pumped to an elevated reservoir during off-peak periods, storing energy in water's gravitational potential energy. During periods of high electrical demand the stored water is released through turbines to produce electricity.

Benefits: PSH is able to store energy on a large scale, given that it can transfer massive quantities of energy. It is also cost effective, with a life-span of about 40 years.

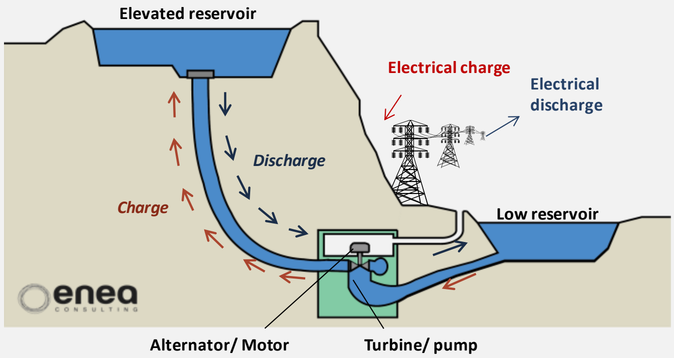


Figure 2 : A diagram of PSH

Disadvantages: This type of storage requires two closely located basins, one more elevated than the other, which hugely limits the suitable geographical locations. In addition, the best sites are used first, which further limits availability and increases construction costs. Furthermore, there is a persisting problems of social acceptance with new water reservoirs. As a result, the remaining 7 GW potential in France is unlikely to ever be fully exploited.

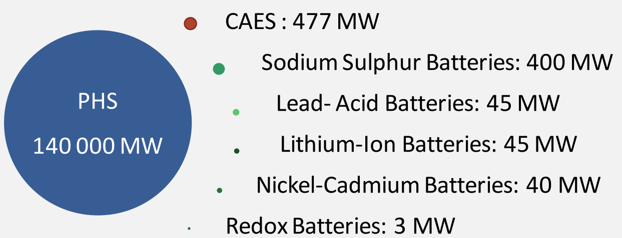


Figure 3 : Energy storage capacities worldwide (Source: EDF R&D)

Worldwide: Across the world over 100 GW are installed, spread over about 380 plants, and accounting for over 99% of the stationary storage power capacity worldwide. It is estimated that this figure is set to decline as storage diversification takes hold. The installed capacity of stationary batteries is expected to reach 40 GW by 2030 (including Japan and the USA).

Future developments: Worldwide, 60 GW are planned for 2013, mostly in Asia. In Europe a further 27 GW are planned for 2020.

The technologies of variable speed pumps are becoming the norm, increasing the flexibility of PSH to provide new services (frequency control, voltage control, etc.).

To overcome the site constraints, discussions for new types of PSH are underway. The concept of a seawater PSH could prove interesting, especially if combined with off-shore wind turbines: the sea is used as the lower reservoir, and the upper reservoir is placed near the coast, with an acceptable elevation. A 30 MW seawater PSH is already in operation in Okinawa, Japan.

TECHNICAL SOLUTIONS

Numerous solutions in development

The maturity levels for various storage technologies are presented below (figure 4). Many of them are still in the R&D stage. At present PSH is primarily the only technology in use, responsible for over 99% of the bulk-storage capacity installed in the world.

The choice of technology depends on a variety of conditions, which means that a thorough analysis of each situation is essential. In fact, each of these technologies can be suitable for a particular purpose, which explains why many R&D tracks are being explored with the support of major government programs like the U.S. DoE[6] or the Japanese NEDO[7].

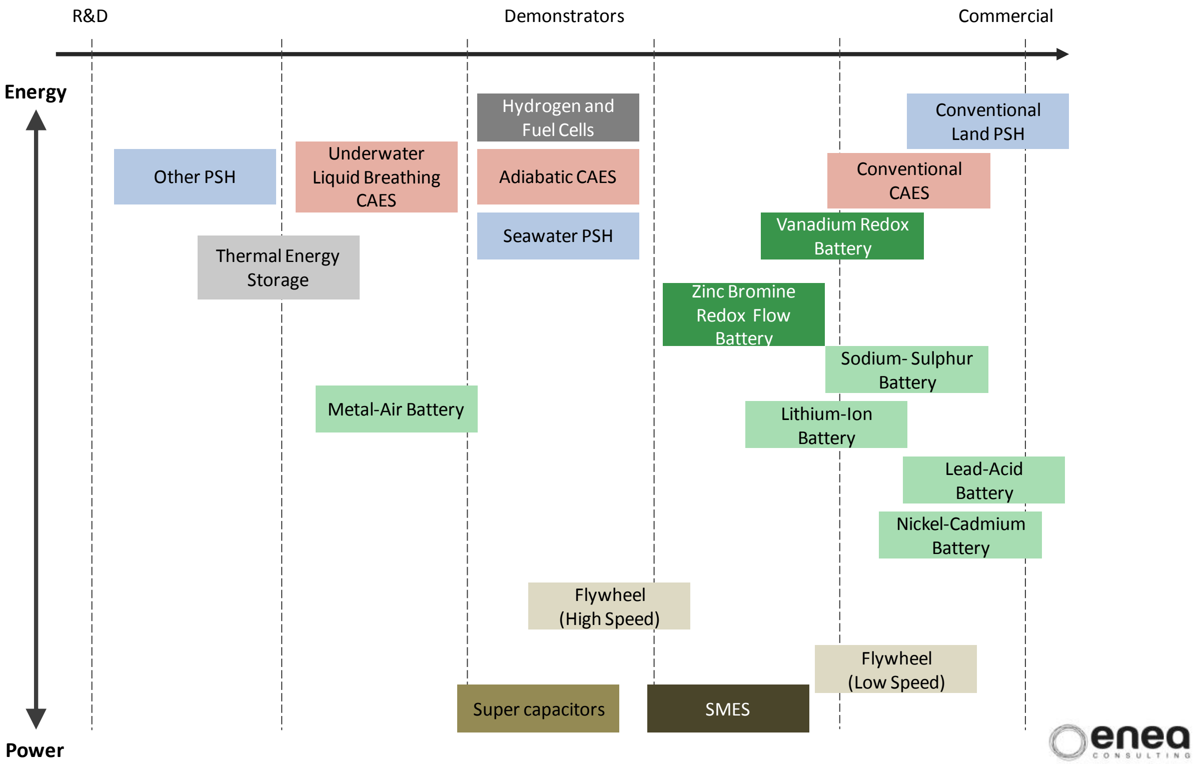


Figure 4 : Level of technological maturity for energy storage technologies

Typology of Energy Storage

- Gravity storage
- Compressed air storage
- Thermal storage
- Chemical storage
- Electrochemical storage
- Electrochemical flow storage
- Inertial storage
- Electrostatic storage
- Electromagnetic storage

[6] *DoE : Department of Energy*

[7] *NEDO : New Energy and Industrial Technology Development Organization*

TECHNICAL SOLUTIONS

The choice of storage technologies

In order to compare storage technologies, and determine the most relevant for a particular purpose, several technical factors must be considered. Take the case of stationary electricity storage, for example:

- The **available power** (in MW) and the **energy capacity** (MWh). The combination of these two criteria can be used to define the ratio of energy/power corresponding to the discharge time, often a characteristic of a particular application.
- The **reaction time** is an indicator of the responsiveness of the storage technology. Sometimes it is preferable to consider the charge and discharge rates, as they more acutely characterise the reactivity of the system.
- The **efficiency**, defined as the ratio of recovered energy to stored energy (MWh_{OUT}/MWh_{IN}).
- The **lifespan**, which is sometimes better defined in terms of the **number of charge/discharge cycles** for technologies such as batteries.

For other uses, different criteria must be taken into account. For example energy density (MWh/kg or MWh/m³) is important to consider for mobility applications.

The chart below sets out the technologies according to their typical power and discharge time.

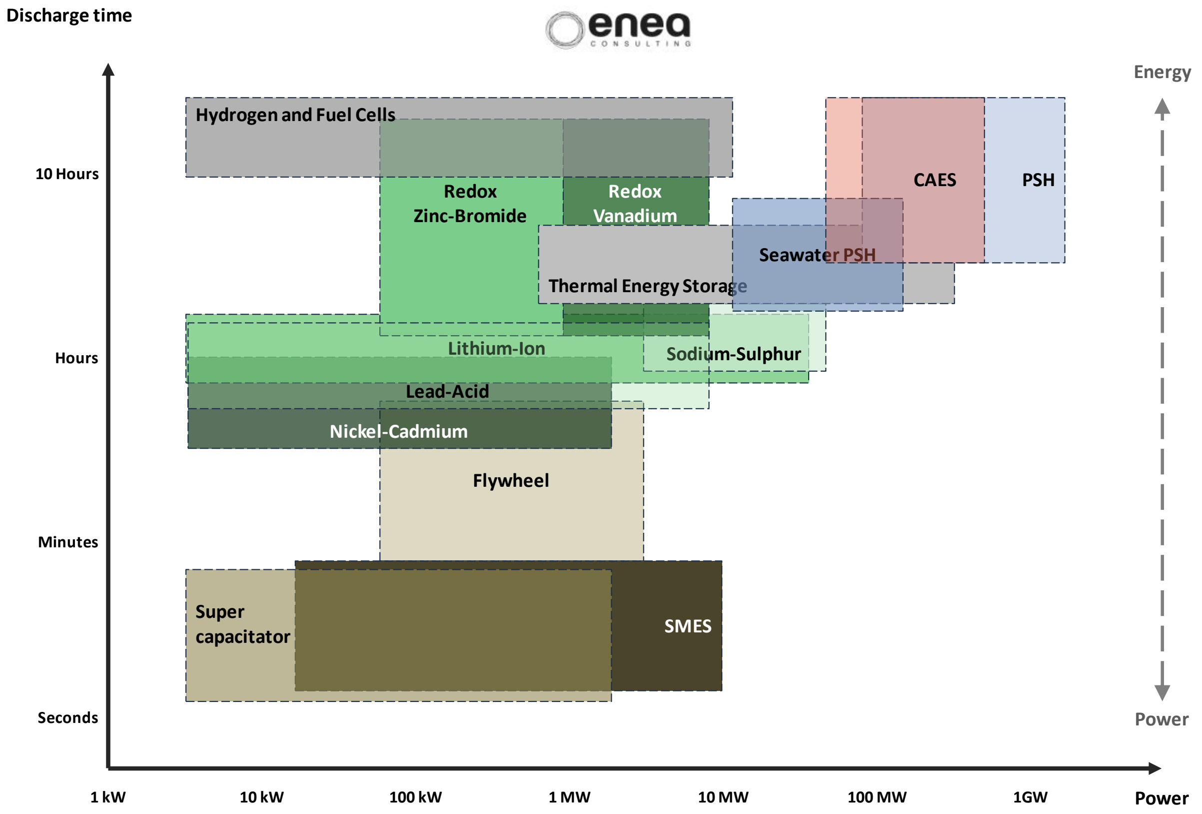


Figure 5: Mapping stationary electrical storage according to discharge time and typical power

TECHNICAL SOLUTIONS

Which technologies at what cost?

A comparative study of the different storage solutions cannot be done without carefully studying the economic data. For each technology, the investment costs (CAPEX), which may be described in terms of per unit of power/energy, and operating costs (OPEX), are taken into account. Furthermore, one should also consider the replacement costs (as well as the frequency of replacement) for technologies such as batteries.

The technological diversity multiplies the associated cost structures. PSH, for example, is capital intensive, while batteries have high replacement costs. For some systems the power is expensive (flow batteries, for example), while for others it is the energy capacity (supercapacitors, for example).

In order to appropriately compare the actual cost of storage solutions, it is essential to include usage constraints (lifespan, frequency of use, etc.). The emerging nature of the industry and lack of feedback means that the analysis retains significant uncertainties.

The techno-economic figures for the main stationary energy storage technologies are summarized in the table below. The investment costs are subject to evolve given the rapid technological evolution, and thus should be used with care.

enea CONSULTING	Energy Range	Power Range	Reaction Time	Efficiency	Lifetime	CAPEX Power (€/kW)	CAPEX Energy (€/kWh)
PSH	1 – 100 GWh	100 MW – 1 GW	s - min	70 – 85 %	> 40 years	500 – 1 500	70 – 150
CAES	10 MWh – 10 GWh	10 – 300 MW	min	50 % (1st Gen.) 70 % (AA-CAES)	> 30 years	400 – 1 200	50 – 150
Hydrogen and Fuel Cell	10 kWh – 10 GWh	1 kW – 10 MW	s - min	25 – 35 %	5 – 10 years	6 000	< 500
Sodium Sulphur Batteries	< 100 MWh	< 10 MW	ms	75 – 85 %	2 000 – 5 000 cycles	5 00 – 1 500	150 – 500
Lithium-Ion Batteries	< 10 MWh	< 10 MW	ms	85 – 95 %	2 000 – 10 000 cycles	1 000 – 3 000	300 – 1 200
Redox *Flow* *Batteries*	< 100 MWh	< 10 MW	ms	65 – 80 %	2 000 – 12 000 cycles	500 – 2 300	100 – 400
Flywheel	5 – 10 kWh	1 – 20 MW	ms	> 90 %	100 000 cycles	500 – 2 000	2 000 – 8 000
SMES	1 – 10 kWh	10 kW – 5 MW	ms	> 90 %	20 – 30 years	300	> 10 000
Supercapacitor	1 – 5 kWh	10 kW – 5 MW	ms	90 – 95 %	500 000 years	100 – 500	10 000 – 20 000

Figure 6 : Comparison of different storage technologies (the list is not exhaustive). The values are for informational purpose only.

DEVELOPMENT OPPORTUNITIES

The necessity to think in terms of services

Beyond the cost of technology, the current focus is on reaching economic profitability, which is a prerequisite for the development of the sector. This requires a certain level of thought on the services available: the development opportunities are numerous and specific to each type of actor. A precise assessment of the constraints and valorization opportunities will dictate technological choices and design considerations (ratio of energy/power, the necessary reactivity, frequency of use…).

Which economic benefits for which actors?

Different actors will discover different benefits from storing energy (see page 11 for details). Electricity producers, for example, will see the beneficial pricing shifts in wholesale markets (see opposite). Industrial consumers can in turn minimize the electric power they need to purchase from the supplier. For system operators, most of their services (control of frequency, voltage ...) can be provided through storage of electricity.

Combine economic benefits to solve the business case

New openings for economic opportunities appear alongside the introduction of intermittent energies. The coupling of energy storage with the generation of intermittent electricity allows for the consolidation of the installed capacity, and the smoothing of short term fluctuations from weather hazards.

Generally, the range of potential economic opportunities provided by energy storage is still only partially exploited, mainly because of the remaining regulatory gap (see page 4).

Looking for multiple economic opportunities is the key to achieving profitability.

A primary economic opportunity: energy transfer

The imbalances between the supply and demand of electricity are reflected on the wholesale market through price difference, occurring between peak and off peak periods.

Energy storage provides the opportunity to inject electricity into the grid when the price is high, and draw from it when the price is low. This practice is currently the principal way to give value to energy storage.

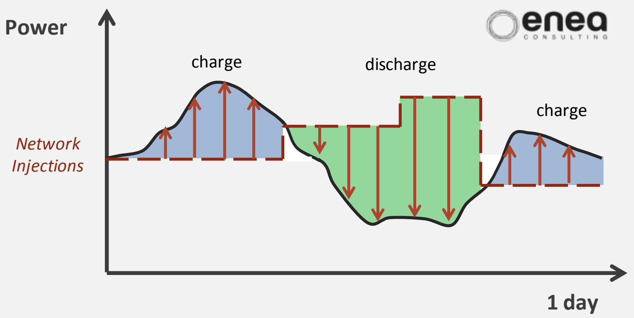


Figure 7 : Illustration of the process: a daily energy transfer

PSH, CAES, H_2 or thermal storage are adapted to such energy transfers, on a daily or weekly scale.

However, the high uncertainty about developments in the electricity market negatively impacts investment decisions based on the valuation of this economic opportunity: this is the case today for two PSH in the Netherlands, which would total 1.3 GW of installed capacity (16 GWh); the economic profitability remains too uncertain for the construction to be fully confirmed.

DEVELOPMENT OPPORTUNITIES

Territories

- Integrate energy storage as part of a development strategy for intermittent energy
- Secure the energy supply in the territory and reduce its dependence on fossil fuels
- Generate consensus on a coherent energy policy for the environment
- Create an industrial base for an innovative and emerging sector

Grid Operators

- Economically optimize the infrastructure investments by deferring the investments required for grid enhancements
- Integrate intermittent energy production by ensuring a stable supply of electricity
- Secure the supply/demand balance forecast by optimizing peak capacity and load shedding
- Optimise ancillary services by building on the performance of energy storage

Dispatchable[8] Producers

- Leverage storage as an arbitrage tool on energy markets
- Optimize the design of its facilities by linking production and storage
- Anticipate future capacity obligations and make the most of the capacity market
- Take protective measures against mid-long term economic risks (increase in the price of fossil fuels and CO_2)

Intermittent Producers

- Anticipate regulatory constraints on storage obligations for intermittent producers
- Consolidate installed capacity in order to be able to participate in future market capacity
- Develop technological synergies between intermittent assets and energy storage in order to improve competitiveness

Consumers

- Find an economic optimum in energy consumption by integrating storage at the heart of its processes
- Generate revenue through curtailment and anticipate the development of capacity markets
- Secure its energy supply and ensure the quality of power

Figure 8 : The value and challenges of storing energy for the key energy players

[8]*Dispatchable : refers to sources of electricity which can flexibly adapt to the grid demands*

DEVELOPMENT OPPORTUNITIES

Integrating energy storage with processes - utility storage

The electrical storage technologies available today are still often too expensive or not yet mature enough. Other innovative solutions can sometimes be found, which combine profitability and technical feasibility.

Integrating Energy Storage into Industrial Processes

Many industrial processes contain stages of energy consumption, which could be suitable for utility storage. In the past, interest was relatively low, even nonexistent, due to only small variations in energy costs. Today however, it is possible to use this potential as a lever of economic efficiency and operational flexibility. The process which is the most symbolic is the storage of compressed air at the heart of the operation of a gas turbine, namely the CAES. (See page 13 for details). This is a principle that can be applied to many processes involving electricity.

Although these storage solutions do not directly correspond to the storage of electricity, it is nonetheless energy storage which can influence the consumption patterns of electricity and help to manage demand.

Example: Capturing CO_2 from coal plants is an electricity intensive process: up to one third of the electricity produced can be self-consumed for the purification of the gases. Some methods use chemical compounds, amines, to capture CO_2; heating can then regenerate the molecules, releasing pure CO_2, which is a very energy-intensive part of the process. A proposed solution is to store amines containing CO_2 during peak hours, when the need for electricity is at its highest, then regenerate during off-peak hours, when energy is cheaper. Although this solution is still considered too expensive today, it has opened the door to a whole new way of addressing the subject.

Key points of integration for storage in an industrial process

Identifying solutions requires knowledge of the industrial processes involved and the technical principles which underlie storage technologies. In this case one should be creative, while keeping economic and technical pragmatism necessary in all industrial application.

The key to the success of such integration is:

- Select preferentially intermittent processes
- Identify the storable vector
- Minimize the addition of stages within the process
- Use energy which is the most suitable in form and quality, as well as having the lowest cost
- Identify counterparties (loss of operational flexibility, limits to the predicted capacity needed for the storage, new losses associated with the storage process)
- Optimize the modes of operation for the storage units
- Identify all the technical and economic uses of the storage so that when combined it will provide sufficient returns to trigger the investment:
  - Take advantage of changes in electricity prices
  - Possibly be paid for providing ancillary services.

DEVELOPMENT OPPORTUNITIES

Technology focus: CAES – Compressed Air Energy Storage

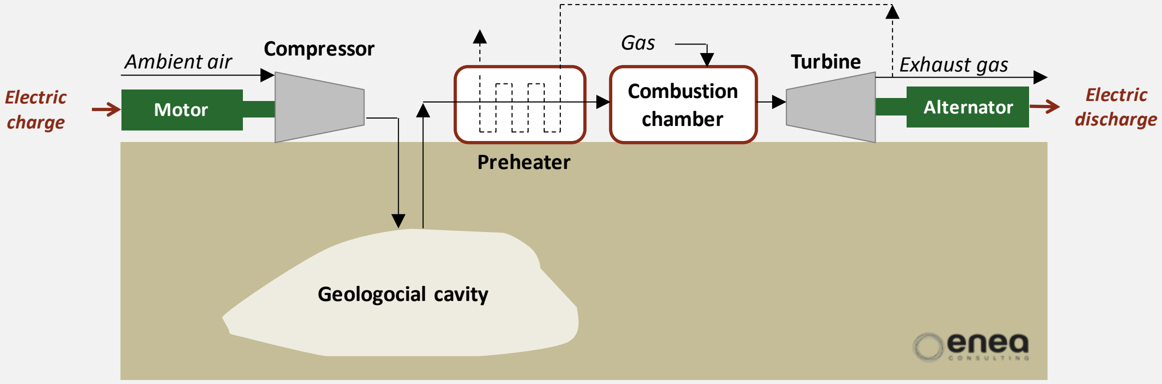


Figure 9 : Diagram of an underground CAES plant

Theory: Store compressed air during off-peak times in order to deliver it at peak times.

The idea: A gas turbine uses about a third of its power to compress air as it enters the system, and therefore represents unsold power. Choosing to lose this power during off-peak rather than peak hours can create substantial savings: it is a good example of how, by taking advantage of an inevitably costly compression step, energy storage can be integrated into an industrial process. Storage allows for the decorrelation of energy consumption and usage. Here compressed air is stored in an underground cave (for small installations or surface reservoirs). There are fewer site limitations in terms of the dug out cavities, than for storage of natural gas or CO_2, which are for example, stored in porous rocks. It is therefore possible to build CAES almost anywhere, at costs ranging from 0.5 to 25 €/kWh.

Investment costs of CAES are competitive with the costs of PSH, varying between 400 and 1200 €/kW. Today, two CAES units are in operation, one in Huntorf (Germany) producing 290 MW and a second in Alabama (USA), producing 110 MW; other units are under consideration.

Main drawback: Unlike the case of the gas turbine, gas heat is lost post-compression, making the overall efficiency of the system less than 50%.

Solutions: The AA-CAES (Advanced Adiabatic CAES) includes a thermal storage system to retrieve the heat released during the compression phase. The AA-CAES still requires further research to reduce costs of thermal storage. A first pilot of 2.7 GW is planned for 2013 in Ohio (USA).

DEVELOPMENT OPPORTUNITIES

A particular case of utility storage: thermal storage

Thermal storage is a special type of utility energy storage, which is both mature and able to meet the needs of industry, commercial buildings, and even individuals. An obvious example is the decentralised hot water tanks found in homes; Storing hot water during off-peak periods helps to avoid excessive consumption of electricity during peak periods. Similarly, there are storage solutions for efficient cold air conditioning for the needs of residential buildings, and for the production of industrial refrigeration (see below).

Thermal storage can also be used to regulate the production of certain renewable energy sources. Solar thermal concentrators can be combined with thermal storage in order to stabilize their electricity production.

Improvements and innovations are of course expected, but mature economic solutions already exist. These solutions, both for cold and heat, are based on the storage of ice, hot water, molten salts or phase-change materials, which are available today and increasingly popular.

Cold Storage With the Phase-Change Materials

Phase-change materials, from solid to liquid, like water, provide cold storage at night during off-peak hours, and then restore it during peak hours.

Used for industrial refrigeration or collective air conditioning, as a supplement to refrigeration units, this system optimizes energy bills to avoid additional consumption at peak hours. It is also a way to limit investments as a result of the decreased nominal power of the cooling equipment. Finally, the environmental impact can be reduced in cases where peak-power has higher carbon levels than its base level counterpart.

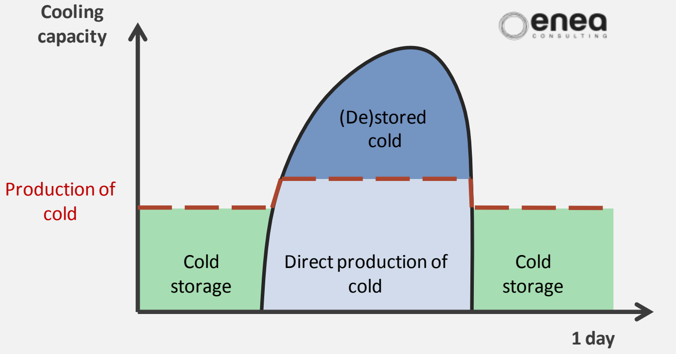


Figure 10 : Illustration of the impact of cold storage on refrigeration during peak periods

The cold storage systems are affordable, at 1500 €/kW and 250 €/kWh, and their efficiency is high (around 90% or more).

BEYOND THE ECONOMY: A GLOBAL IMPACT

Energy storage, a key component for low carbon electricity

Beyond technical and economic interests, energy storage is part of an overall strategy to achieve a low-carbon energy mix.

The large-scale deployment of intermittent energy cannot be achieved without the development of compensatory solutions. Current peaking plants, which emit CO_2, may ease the production hazards of renewable energy but are not, in the long term, compatible with the intended goal. The coupling of intermittent renewable energies with storage, however, achieves real benefits, particularly within coherent environmental energy policies.

In the short term, these two types of compensatory solutions will prove to be complementary. The flexible thermal power station would benefit from being coupled with storage solutions: the operation of turbines at partial load affects their performance and increases the emission factors of greenhouse gases; in addition, the all too frequent starts and stops end up impacting their lifetime. Therefore, combining fossil generation and energy storage represents an improvement both at the operational and environmental level.

More generally, the CO_2 content of electricity depends on the power plants in operation to meet the demand. In the case that the peaking power plants emit more CO_2 than their baseload counterparts (as in France for instance), electricity storage can lower the mean CO_2 emissions from electricity production: low carbon electricity is stored off-peak and released at peak period, as a substitute of higher emitting production plants. The existence and quantitative value of this environmental gain will be determined by the energy mix within each territory.

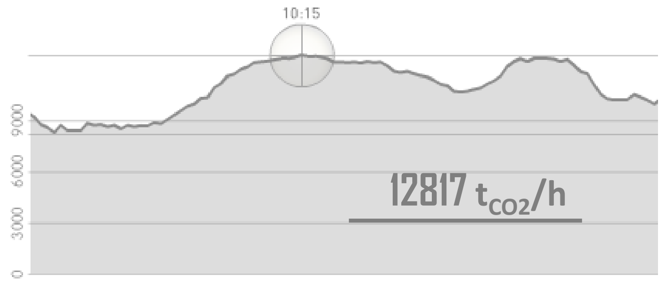


Figure 10 : French electricity carbon content during the 8th of February, 2012 (Source: RTE)

BEYOND THE ECONOMY: A GLOBAL IMPACT

Social impact: the role of electricity storage in energy access in developing countries

In the field, limitations of electricity storage solutions have long been a barrier to energy access.

Indeed, the majority of systems in use couple intermittent renewable energy with electricity storage (solar home systems for instance). In this case, the storage system is one of the major bottlenecks.

Figure 11 : A school from project "Lighting at School" led by Electricians Without Borders in northern Senegal, and evaluated by ENEA Consulting.

Figure 12 : Batteries used for the battery swap in Tanzania by EGG-Energy, a social business sponsored by ENEA Consulting.

Lead-acid batteries are commonly used, but their need for frequent replacement presents a complex economic problem for low-income populations. Their lifetime is also strongly reduced by hot climates. Improved systems would make renewable energies truly accessible in decentralized areas.

ENEA Consulting, for example, studied the opportunities of the hybridization of renewable energies and hydrogen production from electrolysis, in rural decentralized areas, as a way of improving access to electricity, or securing grids for essential services like hospitals. In compensation for the high costs found today, the high reliability, lifespan and independence from the weak grids of these solutions, are strong enough to attract interest from industries and actors in civil society.

ENERGY STORAGE TODAY

Key points

Increased volatility of energy markets, growing technological constraints to connect intermittent energies to the grid, and the pressure for a carbon-free mix all advocate for the development of energy storage. Energy storage has significant benefits and will find its logical place complementing other mitigating measures (interconnections, flexible production and demand management).

This issue concerns, in different ways, all stakeholders (producers and consumers of electricity, grid operators). For each of them, the technological choices differ depending on their specific constraints and valorization opportunities. In particular, it is important to think about energy storage, and not only electricity storage: utility energy storage, particularly thermal, represents a real opportunity for electricity consumers.

The current environment is particularly favourable for the consideration of storage based on a service-based approach rather than by technologies. It is now the time to seize the opportunities already proving to be profitable, as a way of anticipating the technological, economic and regulatory future. For these developments to emerge, obstacles of various kinds must be overcome:

- Legislative work should be conducted in order to create the favourable regulatory environment, which is still missing. Future French capacity mechanism is a step in the right direction
- Some technologies will come up against problems of social acceptance, which should be anticipated
- R&D effort is still required for most technologies to achieve economic viability

Energy storage is a technical lever which is difficult to ignore when it comes to the integration of intermittent energies into a low-carbon energy mix. It also represents an economic opportunity for many players. The first solutions are technically available, and the changing economic context makes them more and more profitable. Many innovations and technological breakthroughs are expected in this emerging sector.

FOR MORE INFOMATION:

Electricity Storage Association : *http://www.electricitystorage.org/*

Sandia National Laboratories : *Energy storage for the electricity grid : benefits and market potential assessment guide*

ENEA Consulting : *Application des systèmes hydrogène pour les besoins du développement à horizon 2020-2025*

Authors : Louis-Marie JACQUELIN, Olivier LACROIX, Mathieu BORDELEAU
contact@enea-consulting.com

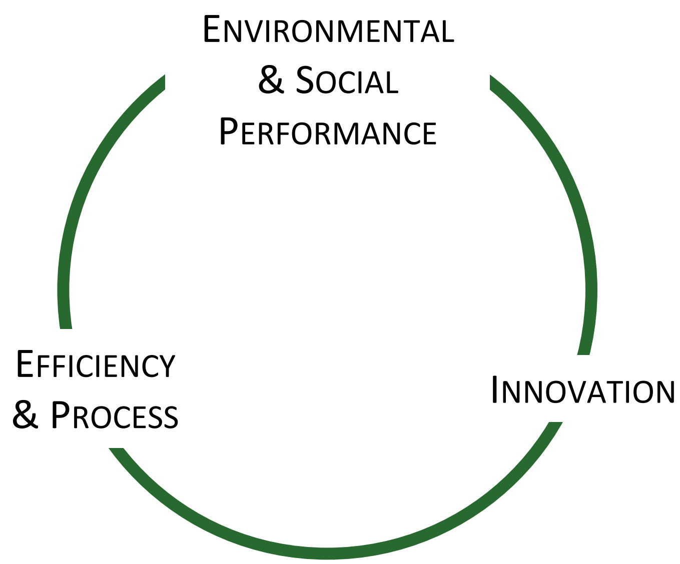
ENERGY • PURPOSE • PERFORMANCE

Energy Consulting for the Industry

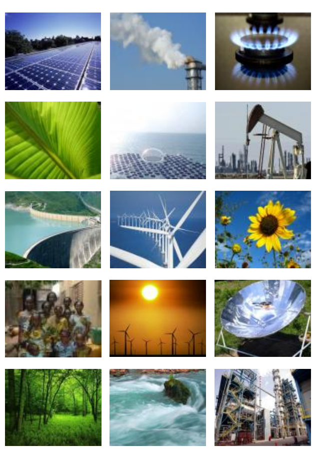
Our commitment: conciliate performance and purpose in who we are and what we do

From strategy to technical expertise, we support our clients through the energy transition and implementation of sustainable development within their core businesses and projects:

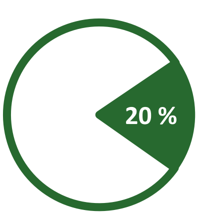
- Energy producers
- Energy consumers
- Technology providers
- Investors
- Engineering companies
- Equipment manufacturers
- Institutions
- Social stakeholders



We favor a **sustainable and global approach to energy issues**, working on all energy-related challenges, according to their maturity and context of application :



- Energy efficiency
- Industrial ecology & Waste valorization
- Biogas & Bio-energies
- Renewable energies
- Carbon capture, transport and storage
- Hydrogen & Fuel cells
- Energy storage
- Environmental performance
- Social acceptance of projects
- Business and project indicators



Concerned about our own impact and convinced that building a meaningful organization generates performance, ***we dedicate 20% of our time to energy access issues, particularly through pro bono work.***

ENEA Consulting | 89 rue Reaumur Paris 75002 | LLC with a 40 000 € capital stock| RCS 499 590 123
Tel : 01 82 83 83 83 | Mail : contact@enea-consulting.com