Renewable Energy Storage Benefits and Economic Impact

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Abstract

Algeria as other oil and gas producing countries, is facing for the last six months the downward trends of the oil and gas prices. In addition, the alarming global climate changes are calling for a wise use of the remaining natural resources and thoughtful measures to reduce the environmental footprint of human activity. The positive consequence is the push on getting renewable energy technologies to accelerate their potential to substitute conventional processes in the production of electricity. Solar and wind resources and technologies are well positioned to increasingly replace fossil fuel as the main source of energy. Advances in the field brought these energy generation technologies to a level of becoming an alternative source that is economically viable and technically reliable.

The benefits and the economic potential of energy storage as well as the different energy storage technologies are presented in this contribution. The global market insights and trends reveal that electrical energy storage will in the coming five years win the economic argument and catalyze large PV generation deployment worldwide.

Algeria is gifted with worldwide most significant solar insulation resources, which constitutes a great potential for energy production through PV and CPS plants. The energetic potential overpasses by far the country's needs, thus rendering the deployment and exploitation of storage capabilities key to exploit to its fullest the resources at both ends and throughout the new electrical energy value chain, including generation, distribution/transport and consumption.

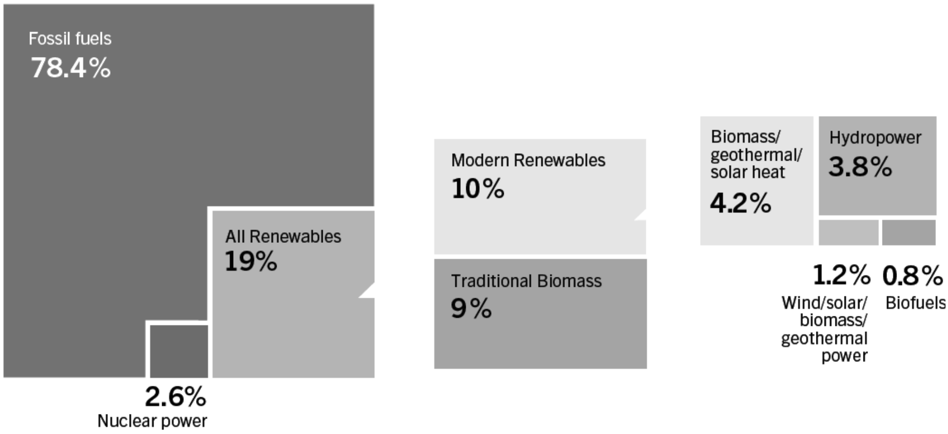
I- INTRODUCTION:

According to the 2014 report of the Renewable Energy Policy Network for the 21st Century (REN21), renewable energy represented 19% of the energy consumed globally in 2012. This level is in constant growth with the increasing penetration rate of renewable energy supply sources and the deployment of electricity storage capabilities at the renewable energy production sites. Energy storage offers more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy. Locally, it can improve the management of distribution networks, by reducing costs and improving efficiency. In this way, it can both stimulate the market penetration of renewables and improve the security and efficiency of electricity transmission and distribution.

Renewable energy applications present several unique challenges to energy accumulators including electrochemical devices, which are particularly interesting for storage applications in Algeria. Energy generation sources are often intermittent by nature and energy storage means can provide a constant supply of power to electrical loads, regardless of weather conditions, time of the day and charging conditions. Several energy storage technologies are being implemented and closely monitored for further development and field applications, including, chemical, electrochemical, mechanical and hydraulic storage methods. Among other storage technologies, lead-acid batteries are considered to be technically and economically a well suited storage mean for a large array of production capacity of electricity from renewable energy sources. We consider in the present contribution the industry trends, the different technologies, their cost as well as the technical and economic aspects of renewable energy storage, regardless of the generation source, wind or solar. We will however focus on photovoltaic generation source, considering the Algerian high potential resources.

II- Renewable energy production and trends

According to global statistics reported by REN21 in their 2014 report [1], the most significant growth in the power sector occurred in 2013, with global capacity exceeding 1,560 gig watts (GW), up more than 8% over 2012. The industry is back on track after the 2008 global financial crisis, driving back by the end of 2013, many solar photovoltaic (PV) and wind turbine manufacturers to profitability path. In addition, the data clearly shows that the world still strongly relies on fossil fuel as a primary source of energy, this transpires when comparing worldwide energy production with the consumption.



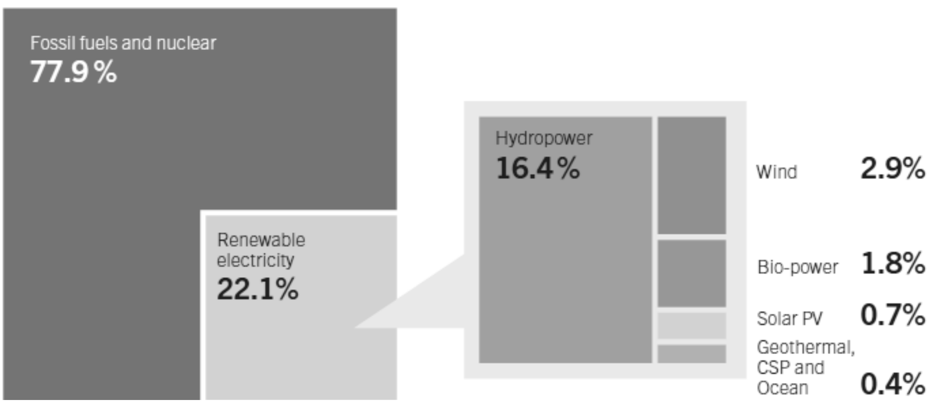


Figure 1: Estimated Renewable Energy Share of Global Final Energy Consumption in 2012 (upper graph), vs its share of Global Electricity Production by the end of 2013 (lower graph) [1].

Renewable energy constituted 19% of the worldwide energy consumption in the year 2012, when 22.1% of the global energy produced in 2013 was from renewable source. Despite an increase of 7.7 % of renewable power capacity (YoY), the consumption is not following the trend with still a 3.1% difference between production and consumption of energy from renewable sources. It is worthwhile noting that wind and solar constitute 3.6% of the reduction capacity and 1.2% of the consumption. A possible interpretation of the data is that at least 2.4% of the energy production capacity by wind and solar are lost and that represents about 11GW (figure 2). This is a significant production capacity that can be exploited for production and storage.

		START 2004[1]	END 2012	END 2013
INVESTMENT				
New investment (annual) in renewable power and fuels[2]	billion USD	39.5	249.5	**214.4** (249.4)
POWER				
Renewable power capacity (total, not including hydro)	GW	85	480	**560**
Renewable power capacity (total, including hydro)	GW	800	1,440	**1,560**
Hydropower capacity (total)[3]	GW	715	960	**1,000**
Bio-power capacity	GW	<36	83	**88**
Bio-power generation	TWh	227	350	**405**
Geothermal power capacity	GW	8.9	11.5	**12**
Solar PV capacity (total)	GW	2.6	100	**139**
Concentrating solar thermal power (total)	GW	0.4	2.5	**3.4**
Wind power capacity (total)	GW	48	283	**318**

Figure 2: Renewable energy indicators as per end 2012 and 2013 [1].

Investment data from Bloomberg New Energy Finance (BNEF) [2] estimate that, including the unreported investments in hydropower projects >50 MW, total new investment in renewable power and fuels was at least USD 249.4 billion in 2013. This includes all generation projects with biomass, geothermal, wind (>1 MW), hydro projects (1 - 50 MW), solar (>1 MW), ocean energy and biofuel (annual production capacity> 1 million liters).

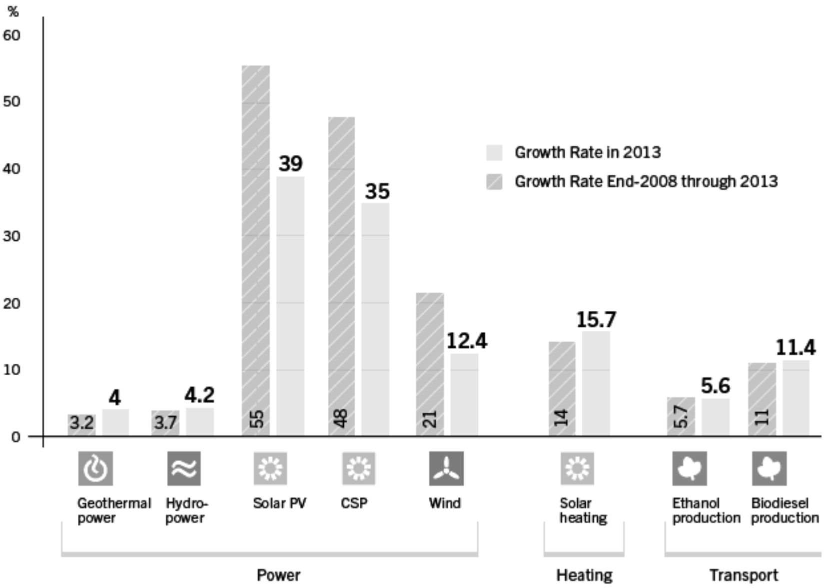


Figure 3: Average annual growth rates of renewable energy production capacity in 2013 and end 2008 through 2013 [1].

The annual growth rate of renewable energy including all sources of generation boomed in 2013. Figure 3 shows significant development of renewable energy production capacity in particular PV, CSP and Wind in 2013 compared to the 4 years period of 2009 – 2013. Indeed, during the years 2009 through 2013, installed capacity as well as output of most renewable energy technologies grew at rapid rates, particularly in the power sector. Over this period and of all renewable technology, solar photovoltaics (PV) experienced the fastest capacity growth rates and wind the most power capacity added.

The role of renewable sources in the global power mix continues to increase [3]. As global renewable electricity generation expands in absolute terms, it is expected to surpass that from natural gas and double that from nuclear power by 2016, becoming the second most important global electricity source, after coal. Globally, renewable generation is estimated to rise to 25% of gross power generation in 2018, up from 20% in 2011. Driven by fast-growing generation from wind and solar photovoltaics (PV), the share of non-hydro renewable power expected to double, to 8% of gross generation in 2018, up from 4% in 2011.

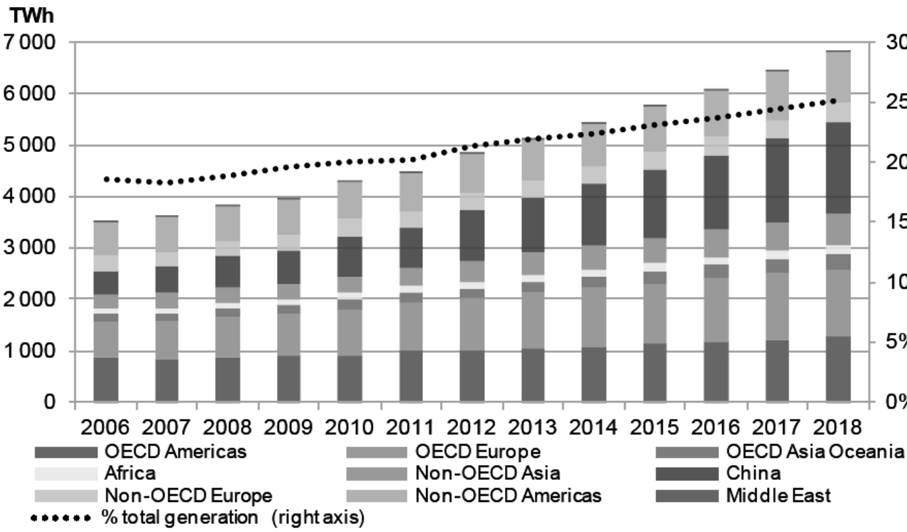


Figure 4: Global renewable electricity production by region [3] derived from International Energy Agency (IEA) data and analysis.

Renewable electricity growth is expected to accelerate over the medium term. From 2012-18 renewable electricity generation should rise by 40%, 1,990 TWh (6% per year), from 4,860 TWh to 6,850 TWh. Total renewable capacity is expected to grow to 2,350 GW in 2018.

II- renewable energy Storage

Energy storage systems breakthroughs will dramatically reduce the costs of electricity storage systems and drive revolutionary changes in the design and operation of the electric power system. This will reduce peak load problems, improve electrical stability and eliminate power quality disturbances. Indeed, energy storage plays a flexible and multifunctional role in the grid of electric power supply, assuring more efficient management of available power. The

Energy Storage System (ESS) combines different power generation systems and provide, in real time, the balance between production and consumption and improve the management and the reliability of the grid. In addition, ESS facilitates the penetration of renewable energy and the quality of the supplied energy through a better control of the frequency and the voltage. Storage can be applied at the power plant, in support of the transmission system, at various points in the distribution system and on particular appliances and equipment's on the customer's side of the meter.

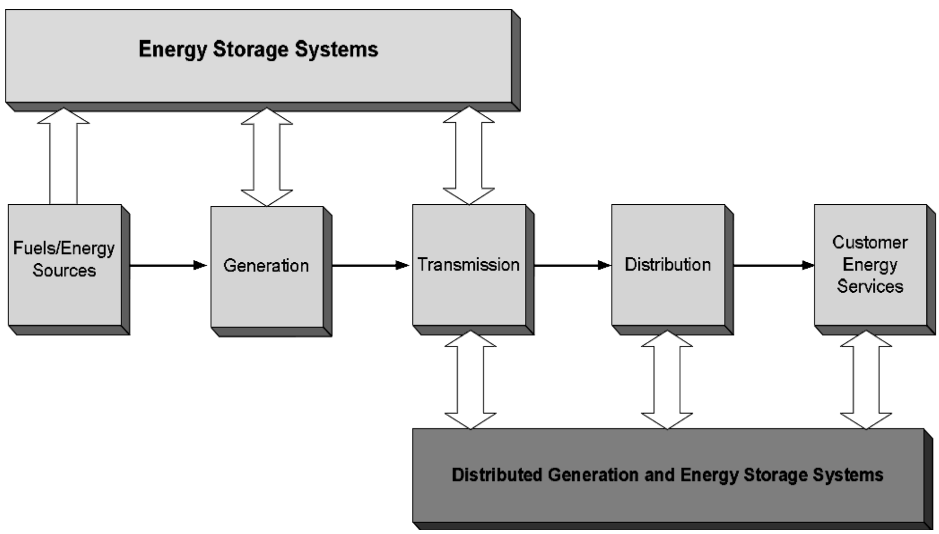


Figure 5: New electricity value chain with energy storage as the sixth dimension [4, 5].

The figure above shows how the new electricity value chain is changing supported by the ESS. Indeed, ESS applications can be integrated at different levels of the electrical system [6, 7]:

1- Generation level: Arbitrage, capacity firming, curtailment reduction.

2- Transmission level: frequency and voltage control, investment deferral, curtailment reduction, black starting.

3- Distribution level: voltage control, capacity support, curtailment reduction.

4- Customer level: peak shaving, time of use cost management, off-grid supply.

These different locations in the power system will involve different stakeholders and will have an impact on the associations of services to be provided. Each location may provide a specific share of deregulated and regulated income streams. The integration of storage applications will be further detailed in the following sections.

A- Timing and planning of energy storage:

According to the research firm HIS [8], the energy storage market is set to explode to an annual size of 6 gig watts (GW) in 2017 and over 40 GW by 2022, from an initial base of 0.34 GW installed in 2012 and 2013.

As mentioned earlier EES is a process of converting electrical energy from a power network into a form that can be stored to be converted back to electrical energy when needed [4]. Such a process enables electricity to be produced at times of either low demand, low generation cost or from intermittent energy sources and to be used at times of high demand, high generation cost or when no other generation means is available. Figure 6 illustrates how electricity storage can be fitted to the daily fluctuating load demand.

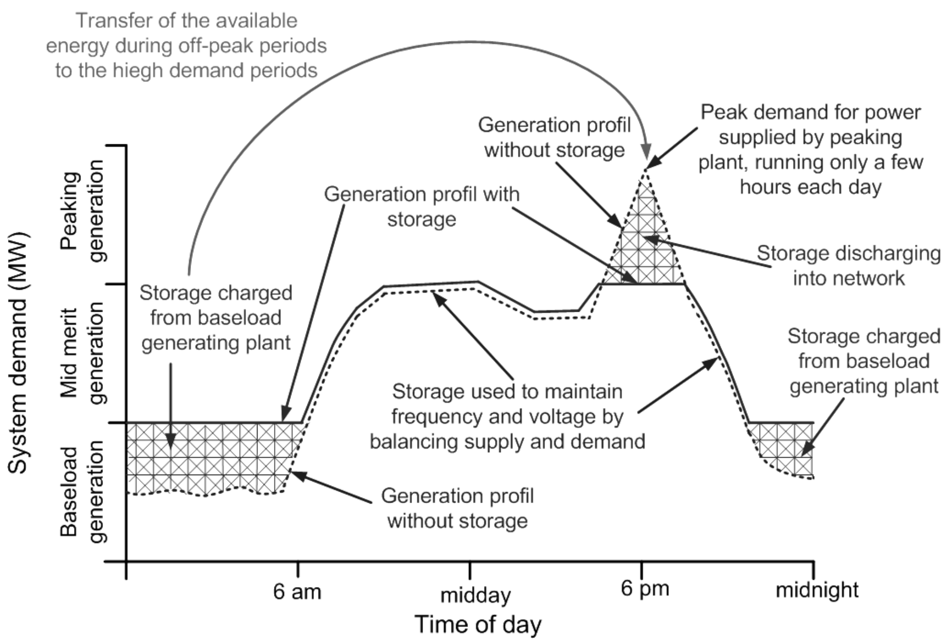


Figure 6: Fundamental schema of energy storage [4].

During low demand, while base load generating plants deliver electricity to the grid, storage capabilities (devices or stations) will accumulate energy to restitute it back to the electrical network during peak demand. Storage planning depends on the application and the size of the network of generation sources. On the other hand, it is driven by the demand profile, the storage capability cost, the tariff of the kWh as well as the storage cost savings/financial benefits.

B- Integration of energy storage in the electrical network:

Storage serves several purposes in today's power system [4, 7, 9], regardless of the nature of the generation source (conventional or renewable), it contributes to support the following three main components of the electrical network:

1- Generation:

– *Commodity Storage:* Bulk energy generated during low demand will be stored to serve arbitrating the production price and allow uniform load factor for the generation, transmission and distribution systems. Storage optimally selects the production / consumption timing based either on energy market prices or technical choices for specific aims such as leveling the load, curtailment minimization and replacement of sources.

- *Contingency reserve:* Power capacity capable of providing power to fulfill customer demand should a power facility fall off-line. Spinning reserve is the amount of generation capacity that can be used to produce active power over a given period of time which has not yet been committed to the production of energy during this period.

- *Capacity firming:* Increase the dispatch ability of variable Distributed Generation (DG) just like conventional generation assets. When it is not possible to inject in networks all the energy produced, storage can replace fossil-fuels generation sources at a later time-period.

- *Area Control:* Prevents unplanned transfer of power between one utility and another. This is called Generator Bridging and consists in the ability of electrical energy storage (EES) to firm a generator's load while the generator is stopping and until a new generator starts up or the same generator is restarted. Generator ramping occurs when EES picks up fast load variations allowing a given generator to ramp-up/-down production level according to technical limits.

- *Grid Frequency Support:* Real power provided to the electrical distribution grid to reduce any sudden large load/generation imbalance and maintain a state of frequency equilibrium of the system during regular and irregular grid conditions.

- *Black-Start:* Units with the capability to start-up on their own in order to energize the transmission system and assist other facilities to start-up and synchronize to the grid.

2- Transmission and Distribution:

- *System Stability:* Prevent a system collapse by maintaining all system components on a transmission line in synchronous operation with each other.

- *Grid Angular Stability:* Reducing power oscillations (due to rapid events) by injection and absorption of real power. For instance, when an accident occurs, some storage technologies can charge and discharge high levels of energy in short periods, reduce the acceleration of the groups to stop synchronism perturbations.

- *Frequency stability:* in island systems, the very prompt response of Decentralized Energy Storage Systems (DESS) can be used to stabilize the frequency by helping to avoid load shedding. This application requires a very short response time (<1s) and a discharge duration of a few seconds. Three other control levels can be served by DESS:

* Primary: DESS and bulk storage systems can help maintaining the instantaneous balance between generation and demand. Primary control limits and stops frequency excursions.

* Secondary: Support adjusting the active power production of the generating units to restore the frequency and the interchanges with other systems to their target values following an imbalance, bringing the frequency back to its target value.

* Tertiary: Manual changes in the dispatching and commitment of generating units and loads. This control is used to restore the primary and secondary frequency control reserves, manage congestions in the transmission network and bring the frequency and the interchanges back to their target value when the secondary control fails doing so.

- *Grid Voltage Support:* Power provided to the electrical distribution grid to maintain voltages within the acceptable range between each end of all power lines. This involves a trade-off between the amount of “real” energy produced by generators and the amount of “reactive” power produced. (DESS) may help to maintain the voltage profile within admissible contractual/regulatory limits.

- *Asset Deferral:* Defers the need for additional transmission facilities by extending existing transmission facilities, saving capital that otherwise goes underutilized for years.

- *Curtailment Reduction and Congestion Management:* Energy intensive storage solutions such as NaS batteries or hydro, when strategically placed within the grid, can help defer energy production, thus reducing the load on critical lines and balancing the intermittency of renewable energy generation units, concentrated in specific and circumscribed areas.

3- Energy service:

- *Energy Management (Load Leveling / Peak Shaving):* Load leveling is rescheduling certain loads to cut electrical power demand, or the production of energy during off-peak periods for storage and use during peak demand periods. Peak Shaving is reducing electric usage during peak periods or moving usage from the time of peak demand to off-peak periods. This strategy allows customers to peak shave by shifting energy demand from one time of the day to another, reducing their charges.

- *Unbalanced Load Compensation:* Performed combining four-wire inverters and by injecting and absorbing power individually at each phase to supply unbalanced loads.

- *Power Quality improvement:* Due to changes in magnitude and shape of voltage and current, causing: harmonics, transients, flickers, sag and swell, spikes, etc. DESS can mitigate these problems and provide electrical service to the customer without any secondary oscillations or disruptions to the electricity waveform.

- *Power Reliability:* Interruption in delivery of electric power, including exceeding the threshold, not only complete loss of power. DESS can help provide reliable electric service to consumers (UPS) to 'ride-through' a power disruption. Coupled with energy management storage, this allows remote power operation.

- *End-user peak shaving***:** Allows minimizing the part of their invoice that varies according to their highest power demand. Such a service might be profitable if the peaks are sufficiently predictable and relatively of short duration.

- *Limitation of upstream disturbances:* storage can help a given DSO to comply with its contractual commitment to the customers in terms of limitation of disturbances.

- *Compensation of the reactive power:* DESS can with power electronics converter, compensate locally the reactive power.

Storage applications and benefits are summarized in the following table [9], including conventional and renewable sources of generation.

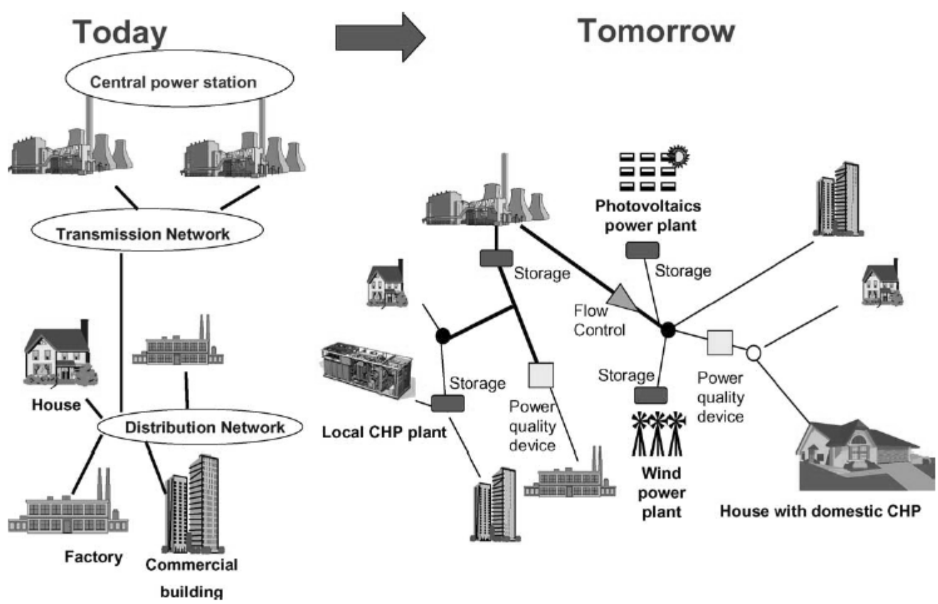
Conventional Ceneration	Transmission	Distribution	Customers Services
Black start	Participation to the primary frequency control	Capacity support	End-user peak shaving
Arbitrage	Participation to the secondary Frequency control	Dynamic, local voltage control	Time-of-use energy cost management
Support to conventional generation	Participation to the tertiary frequency control	Contingency Grid Support	Particular requirements in power quality
Renewable Generation	Improvement of the frequency stability of weak grids	Intentional islanding	Continuity of energy supply
DG Flexibility	Investment deferral	Reactive power compensation	Limitation of upstream disturbances
Capacity firming	Participation to angular stability	Distribution power quality	Compensation of the reactive power
Limitation of upstream perturbations		Limitation of upstream perturbations	
Curtailment minimisation			

*DG: Distributed Generation

Table 1: Energy Storage segmentation [9].

IV- energy Storage technologies:

As described in earlier sections, electrical energy storage is increasingly becoming a reality and is applied at different levels of the electrical network, to such an extent that is becoming an important component of the renewable energy value chain.



*CHP: Combined Heat and Power

Figure 7: Schematic representation of present and future electricity networks [10].

Energy storage used in electric grids worldwide is dominated by pumped-storage hydropower (PSH), with about 20 GW deployed in the United States and more than 127 GW deployed worldwide (EIA 2008; Ingram 2010). In addition to PSH, other technologies are proving to be technically viable and economically acceptable depending on the scale of deployment and location in the electrical energy network. Interest in energy storage technologies, which has reemerged over the past decade, has been motivated by at least five factors[11]:

- Advances in storage technologies.

- Volatility of fossil fuel prices.

- Development of deregulated energy markets.

- Challenges to siting new transmission and distribution facilities.

- Need and opportunities for storage of renewable and ecological contribution.

A- Assessment criteria:

Numerous studies summarized in the EASE/EERA 2013 [9] report, identified current and promising storage technologies for the next decades on the basis of their technical capabilities and implementation mechanisms including market and social status. In general, when identifying the technologies of interest, technical properties and their future potential are key:

- Energy density (volume and weight).

- Energy capacity potential (scale of storage facility).

- Power density.

- Response / discharge time at rated power.

- Power potential.

- Efficiency (round-trip).

- Calendar lifetime.

- Cycle lifetime.

- Cost (including to lifetime).

- Environmental issues (sourcing, building devices and recycling potential).

- System power ratings.

- Safety.

Along with the inherent technical characteristics of the different technologies, field implementation and large scale deployment of a specific technology is depend among others on market mechanisms and its status, including:

- Level of maturity.
- Industrial technology status.
- Development potential.
- Research status and potential.
- Possible applications.
- Market potential.
- Social acceptability.

Based on both technical and implement ability aspects, the following table summarizes the 2013 state of the art repartition of storage technologies and current as well as perspective fields of application.

Technologies aggregate in focus	Conventional generation	Renewable Generation	Transmission	Distribution	Customers services
Pumped hydro energy storage	Suitable	Possible	Suitable	Possible	Unsuitable
Compresses air energy storage	Suitable	Possible	Suitable	Possible	Unsuitable
Electrochemical	Possible	Possible	Suitable	Suitable	Suitable
Chemical	Possible	Possible	Possible	Unsuitable	Possible
Electro-magnetic Energy Storage, Flywheels	Unsuitable	Possible	Suitable	Suitable	Unsuitable
Thermal energy storage	Suitable	Possible	Possible	Possible	Suitable

Table 2: Summary actual state-of-the art repartition [9].

One of the main R&D challenges for the next decade will be to transform "possible" or "unsuitable" applications to "suitable" and increase the range of services each storage technology can deliver in order to diversify applications for a given storage solution, fostering hybrid technologies solutions, using complementary technologies in one single storage site.

Technological options:

The field closest approach to assess the suitability and performance of different storage technologies for electrical energy storage applications, is to classify the options according to:

- Technology type; mechanical, electrical, electrochemical, etc.

- Power and energy rating; large scale or small scale.

- Application; power quality and reliability or power network applications.

Depending on the assessment criteria discussed earlier and the classification method above, different studies have proposed a graphical representation of the different options to facilitate comparing relative suitability of technologies for the given applications, regardless of the economic implications that will be discussed later in this paper.

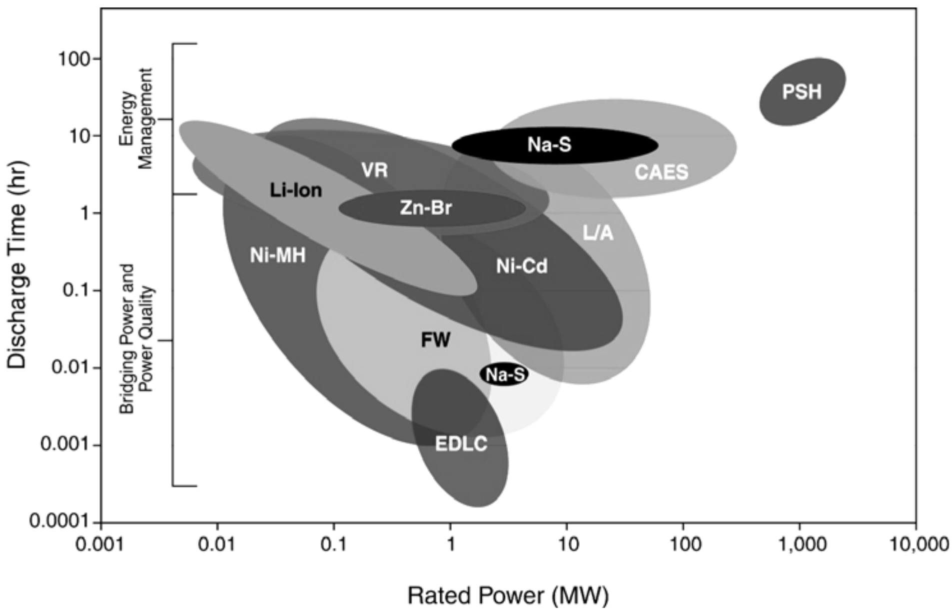


Figure 8: Energy storage applications and technologies [11].

CAES: Compressed air

EDLC: Double-layer capacitors

FW: Flywheels

L/A: Lead-acid

Li-Ion: Lithium-ion

Na-S: Sodium-sulfur

Ni-Cd: Nickel-cadmium

Ni-MH: Nickel-metal hydride

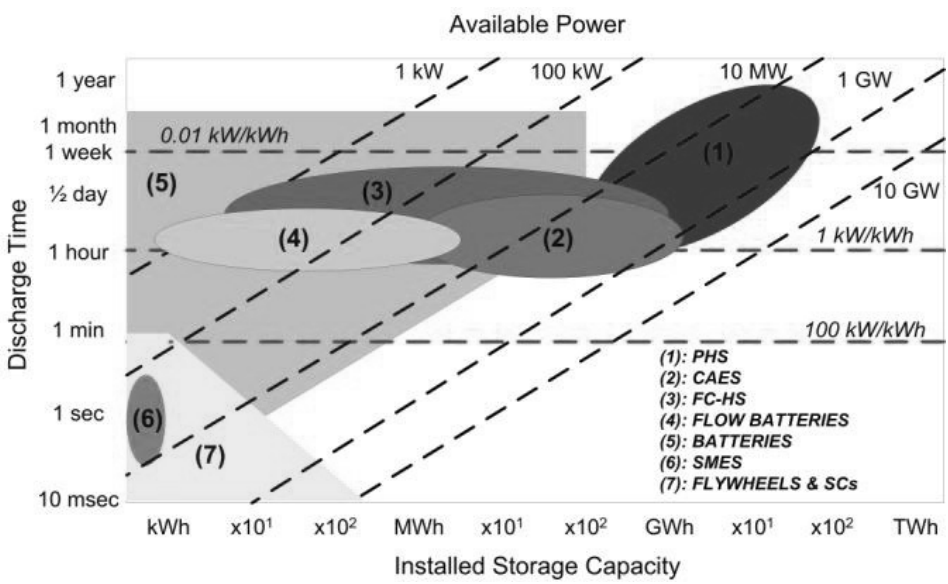
PSH: Pumped-storage hydropower

VR: Vanadium redox

Zn-Br: Zinc-bromine

The figure above allows to compare commonly used technologies based on storage capacity expressed as a rated power of up to 10 GW versus their capacity to maintain the charge and restitute it back when required, expressed as discharge time in hours. In addition, the graph shows that some technologies such as EDLC is mostly suited for power bridging and quality control, whereas other technologies including Li-ions and Lead Acid batteries can also serve in energy management, for rated powers of respectively 10 kw – 1 MW and 1 MW – 100 MW. The discharge times shown in figure 9 represents the continuous discharge capability as opposed to the response time.

Figure 9 (a and b) enables an even better depiction of storage technologies' performance for different applications, revealing not only storage capacity ranges technologies can cover but also their discharge time, i.e. their capacity to serve in a specific application and the power they can deliver when solicited.



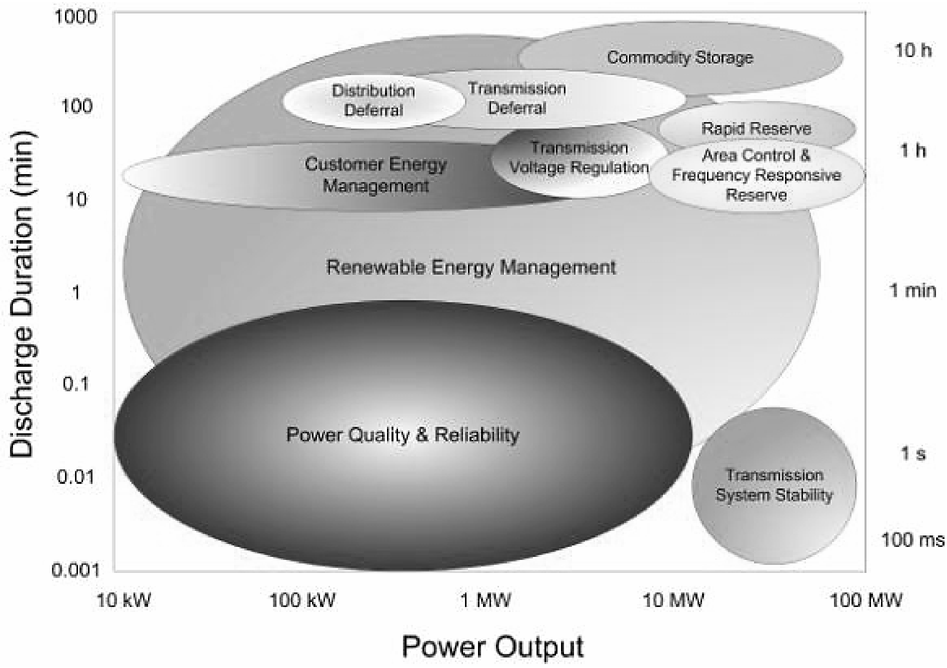


Figure 9: (a) Mapping of contemporary energy storage technologies and; (b) application fields [12].

The figure above provides a mean of assessing cotemporary storage technologies including capacity and application fields. If we exclude for now the economic and social impact, it is widespread that the different technologies are primarily selected based on three parameters: the power storage capacity, discharge duration and energetic potential. In addition, figure 9 (a) gives a picture of the installed storage capacity as of 2012 and the type of technologies as well as their adoption over different power and energy capacity ranges. Figure 9 (b) identifies filed applications to correlate suitability of the different technologies. Renewable Energy Management occupies a large domain of power output and discharge duration, that includes most of the technologies sorted in figure 9 (a) in the power output range of 1 kW - 100 MW.

B- Storage technologies:

As of 2013 worldwide energy storage capacity [9] installed in electricity grids is estimated to 127,000 MW, of which 99% is pumped-hydro systems. Electrochemical storage amounts to about 446 MW, with Na-S (365), lead-acid (35), Ni-Cd (27), Li-ion (16) and redox flow (3). The remaining capacity is covered by other technologies. The main contemporain storage technologies [9, 11-13] installed or in advanced maturation status are:

1- Chemical Storage:

Energy is stored principally through hydrogen and technical focus in the late decade is oriented towards the production (electrolysis), storage and conversion (fuel cell) of hydrogen.

2- Electrochemical Storage:

Electrochemistry is the core technology in batteries. The European position is strong in the Lead-Acid and Ni-Cd storage batteries, while the Li-ion technology is currently dominated by Asian actors (Japan, Korea, China). In addition, the weakness of the Japanese grid contributes to the fact that there is only one NaS supplier located in Japan. However, the joint development of the European battery market for transport and stationary applications represents a significant opportunity for strong industrial suppliers and European R & D networks to compete against Asian and that explains the rapidly increasing European competences in the field.

3- Mechanical Storage:

Compressed Air Energy Storage CAES has an enormous potential and one plant, out of two in the world (the other in Alabama, USA), is located in Germany. It is a 290 MW plant operating since 1978. The European competences in the field are of extremely high class within crucial areas like compressor and turbine technology as well as solution mining, which is of central importance also for storing gases (hydrogen or synthetic methane) prepared by electrolysis via electricity from renewable sources.

4- Pumped Hydro Energy Storage:

PHES constitutes the largest storage technology worldwide. In 2009 the European Union had 41.3 GW net pumped hydro storage capacity (34% of world capacity) out of a total of 103 GW, representing 5% of total net electrical capacity in the EU zone. This technology has a significant quantitative and qualitative potential for development and deployment.

5- Kinetic Energy Storage – Flywheels:

It is a fast energy storage technology, with the main characteristics of high power and energy densities and the possibility to decouple power and energy in the design stage. Particular characteristics of this technology is the large number of life-cycles and the flexibility to be installed in any location. It provides high power but usually low energy compared with other technologies.

6- Thermal Storage:

This is a fast developing technology in Europe with the emergence of new materials and systems. Examples of new successfully commercialized thermal storage systems are Underground Thermal Energy Storage (UTES) being deployed particularly in the Netherlands, Sweden and Germany and the 1000 MWh molten salt storage technology which makes dispatch able power generation by CSP plants feasible.

7- Electrical Storage:

Energy storage based on superconducting coils has been developed for small to medium size systems. The top performances is high short-term power at high overall efficiency (>95%), high robustness and long lifetime with an almost unlimited number of cycles. The use of High Temperature Superconductors combined with long-term energy supply based on liquefied hydrogen is an example of a competitive multi-functionality hybrid solutions.

C- Field applications:

Most studies and field reports [4, 7]converge towards a classification approach based on the power capacity size for electrical energy storage. Indeed, depending on the application, storage can be large-scale (GW), medium-sized (MW) or micro, local systems (kW).Some of the key technologies, not all of which are at the stage of commercial application are:

1- Large bulk energy (GW):

- Thermal storage, pumped hydro;
- Compressed Air Energy Storage (CAES);
- Chemical storage (hydrogen - large scale >100MW for up to weeks and months).

2- Grid storage systems (MW) able to provide:

- Power: super-capacitors, Superconducting Magnetic Energy Storage (SMES) and flywheels ;
- Energy : batteries such as Lead Acid, Li-ion, NaS and Flow batteries ;
- Energy & Power: Lead Acid and Li-ion batteries ;
- Hydrogen Energy Storage / CAES / Pumped Hydro Energy Storage (PHES) (small scale 10 – 100 MW for hours to days).

3- End-user storage systems (kW):

- Power: super-capacitors, flywheels ;
- Energy: batteries such as Lead acid and Li-ion ;
- Energy and Power: Li-ion batteries.

In the same line of thoughts, highly efficient storage systems need to be tightly adapted to the application (low to mid power in isolated areas, network connection, etc) and to the type of production (permanent, portable, renewable, etc).

V- Financial benefits of energy storage systems:

Numerous technical and economic analysis [4, 7, 9, 10, 12, 13-17] have tackled the topic of energy storage benefits and converged to the following highlights:

- *Cost reduction or revenue increase of bulk energy arbitrage* :Arbitrage involves purchase of inexpensive electricity available during low demand periods to charge the storage plant, so that the low priced energy can be used or sold at a later time when the price of electricity is high.

- Cost avoidance or revenue increase of central generation capacity: In areas where electricity generation capacity is tight, energy storage could be used to offset the need to purchase and install or rent generation capacity in the wholesale electricity marketplace.

- Cost avoidance or revenue increase of ancillary services: Energy storage can provide several types of ancillary services called support services and used to keep the regional grid operating, through spinning reserves and load following.

- Cost avoidance or revenue increase for transmission access/congestion: Energy storage can improve the performance of the transmission and distribution system by enabling utilities to increase energy transfer, stabilize voltage levels and avoid congestion charges.

- Reduced demand charges: Energy storage is used to reduce an electricity end-user's consumption drawn from the electric grid, during peak electric demand periods).

- Reduced reliability-related financial losses: Associated with power outages. This benefit is very end-user-specific and applies to commercial and industrial customers, primarily those for which power outages cause moderate to significant losses.

- Reduced power quality-related financial losses: Associated with power quality anomalies. Power quality anomalies of interest are those that cause loads to go off-line and/or that damage electricity-using equipment and which negative effects can be avoided if storage is used.

- Increased revenue from renewable energy sources: Renewable energy is stored when demand and price for power are low. This energy can be used when demand and price for power is high and output from the intermittent renewable generation is low.

VI- Energy Storage cost:

The cost of storage technologies requires to consider that storage devices in electric applications have both a power component (kW of discharge capacity) and an energy component (kWh of discharge capacity, which may also be expressed as hours of discharge at rated output). The total cost of a storage application must account for the ratings of both components[15], and it may be expressed differently depending on the application or audience. Utilities universally define the cost of power plants only in terms of rated power ($/kW), they would expect to see costs in these terms, with the hours of storage (kWh capacity) expressed separately. A grid storage plant therefore might be expressed as costing $2,000/kW for a device with eight hours of discharge capacity. On the other hand, the battery community typically expresses costs in terms of rated energy ($/kWh), and it may or may not include the power component in the cost. So the cost of a battery might be stated as $500/kWh with the power capacity of the battery established separately. To compare different options, when evaluating the economics of storage technologies, it is important to consider the costs for meeting both kW and kWh specifications and ascertain that both components are "sized" properly for any specific application.

When developing the estimates for electricity storage capacity, there are also two components, namely the cost of the storage devices (depending on the technology) and the cost of setting the storage facility, which becomes a major component to count for in the calculation of the Level zed Cost Of Electricity (LCOE). Building the storage infrastructures includes "Overnight Costs" which consist of [16]: civil and structural costs, mechanical equipment supply and installation, electrical and instrumentation and control, project indirect costs and owner's costs (feasibility, engineering and environmental studies, legal fees, insurance, taxes, etc).

The power and energy costs of various storage technologies as well as the application suitability are depicted in figure 10. This represents a quite practical method to compare on the same basis, the cost of the different technologies. However, these technologies are rapidly evolving and the costs are an estimation that maybe subject to variations due to the size and location of the application and not only the cost of the technology itself.

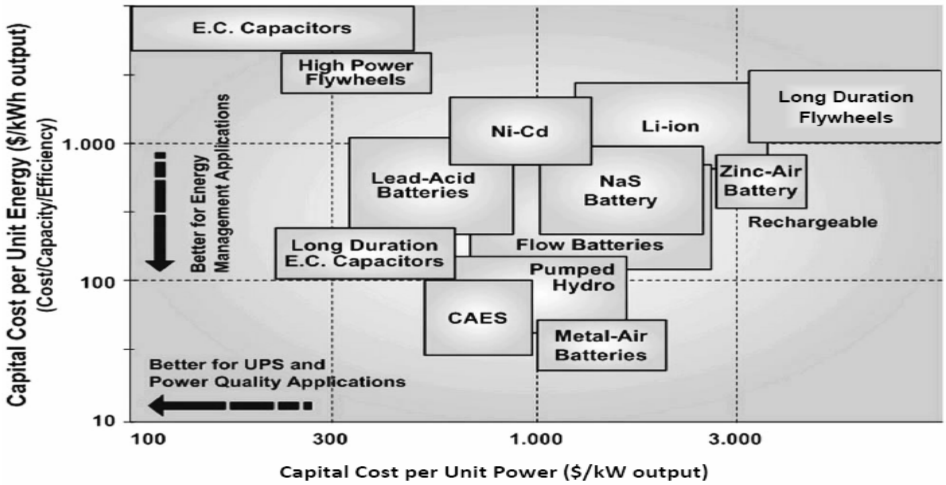


Figure 10: Per unit energy and power capital costs by technology [18].

Figure 10 also reflects the industry reality, namely that energy technologies have lower energy capacity costs and high power capacity costs, as well as slower response times Conversely, batteries often considered power technologies, have lower power capacity costs and higher energy capacity costs as well as faster response times. Figure 11 presents the system costs and benefits as a function of the applications [19].

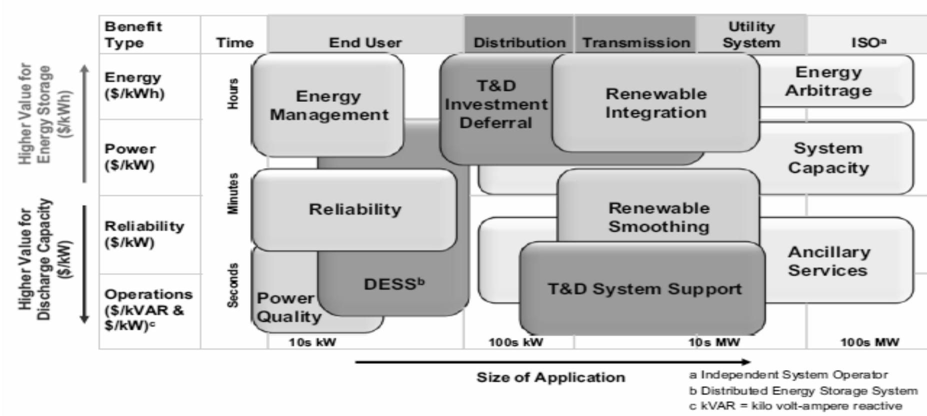


Figure 11: Overview of electricity storage applications.

The conventional way to valuate storage cost is drawn from the concept of Level zed Cost Of Energy (LCOE), used by bankers (borrowers), developers (utility and generation capacity) and purchasers and distributors of energy. In general, the LCOE concept determines the total costs incurred during the lifetime of a technology divided by the lifetime energy production and thus accounts for the differences in lifetimes across technologies. This method is used as a benchmarking or ranking tool to calculate the cost-effectiveness of different energy generation technologies and is based on the following formula:

$$LCOE = \frac{\sum_{n}^{N}(CAPEX + OPEX/(1+i)x^{n}}{\sum_{n=0}^{N}(kWh_{initial.net}/(1+i)^{\quad n}}$$

The same formula has been expanded to reflect the costs related to the degradation of the storage capacity.

$$LCOE = \frac{\sum_{n}^{N}(CAPEX + OPEX/(1+i)x^{n}}{\sum_{n=0}^{N}(kWh_{initial.net} * (1 - Degrade)^{n}/(1+i)x^{n}}$$

Where CAPEX: Investment costs [€]; OPEX: Operation and maintenance costs [€]; $kWh_{initial.net}$: Initial net electricity production [kWh]; i: Discount rate [%]; N: Plant lifetime [years].

The "Level zed Cost of Electricity for Storage Applications" ($LCOE_{SA}$) adapts the LCOE concept to storage technologies. The $LCOE_{SA}$ is defined as the total annualized cost of the energy storage system divided by the annual energy output and may vary strongly depending on the application. For instance, because the annual energy output enters the $LCOE_{SA}$ formula in the denominator, an application with a high energy throughput (utility energy time-shift) is likely to have lower $LCOE_{SA}$ than an application with very little energy throughput (area and frequency regulation). Taken together, the $LCOE_{SA}$ concept provides a useful metric to compare on a fair basis, the costs of technologies across applications.

The commonly accepted method to account for a cost of storage is to include it in the calculation of the LCOE for a specific energy generation capacity, with among other assumptions, the cost evolution of battery, O&M and replacement.

Today	
Cost per KwH	$1,500
Battery Size (kwh)	10
Total Battery Cost	$15,000
System Size (w)	6400
Battery Cost/W	$2.34
System Cost/W	$2.90
Total System Cost	$5.24
LCOE in the US (no battery)	$0.17
With Battery	$0.31

Figure 12: Illustrative Solar + Battery LCOE [20].

The figures provided by the Deutsche Bank study is an illustrative example for a solar installation with battery storage capacity, showing the improvement of the system cost and a saving of about 40% of the LCOE, if we consider a yearly decline of battery cost of 15% over 10 years. The decline of the generation and storage system cost may be much higher over the coming 10 years. In addition, the system size may induce further savings with increasing system capacities.

Deutsche Bank believes that ultimate solar and renewable energy goal might not be far out of reach and that economically competitive batteries will be the catalyze of solar penetration.

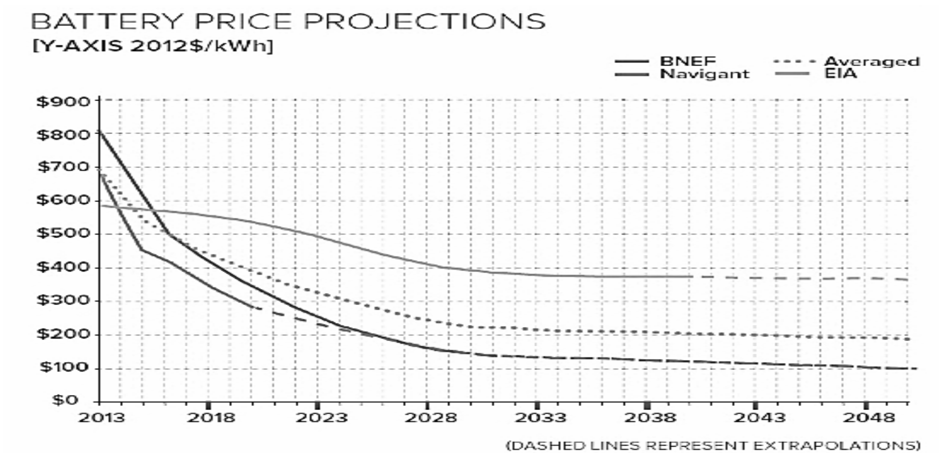


Figure 13: Blended battery price projections [20].

Studies conducted by BNF, Navigant and EIA (figure 13) support the Deutsche Bank analysis, forecasting that the incremental cost of storage will decrease from ~14c/kWh today to ~2c/kWh within the coming five years.

The following figure provides the cost of different energy storage technologies [21], a state of the art in the USA as of 2011. This is a valuable tool to compare different technologies and account for the cost contribution of storage in the perspective of increasing integration of renewable energies.

Storage Option	Application	Level of Maturity	Energy Duration hrs (cycles)	Efficiency ac/ac %	Total Installed Capital Cost $ / kW	Total Installed Cost $/kW-h
Pumped Hydro	ISO Services Wind Integration	Mature	10-20 (>13000)	80-82	$1500-$4300	250-430
Compressed Air	ISO services Wind Integration	Demo	10-20 (>13000)	4000 Btu/kWh 0.7 ER	$960-$1250	60-125
NAS	Grid Support Wind Integration	Mature	6 (4500)	80	$3200-$4200	445-555
Lead Acid Battery Adv. Lead Acid Battery	Grid Support ISO Services Wind / PV	Mature Demo	4 (2200-4500)	85-90	$2020-$3040	505-760
Flow Battery (Various Types)	Grid Support Wind / PV Integration	Demo	4 (>10000)	60-70	2350-4500	470-1125
Li-ion Battery	ISO Services Grid Support C&I Energy Mgt PV Integration	Demo	0.25 (>10000)	90	1200-1500	4800-6000
			2 (5000)		2100-4650	1050-1550
Fly Wheels	ISO Services	Demo	0.25 (>>20,000)	90	1900-2250	7800-7900

Figure 14: Capital costs of energy storage options [21].

The energy and power costs listed in the table are examples only. As mentioned in earlier sections the real costs depend on the application, location and size of the generation and storage capacity.

VII- conclusion :

Algeria as other oil and gas producing countries, is facing for the last six months the downward trends of the conventional resources prices. Alarming global climate changes are calling for a wise use of the remaining natural resources and thoughtful measures to reduce the environmental footprint of human activity. The positive consequence is the push on getting renewable energy technologies to accelerate their potential to substitute conventional processes in the production of electricity. Solar and wind resources and technologies are well positioned to increasingly replace fossil fuel as the main source of energy. Advances in the field brought these energy generation technologies to a level of becoming an alternative source that is economically viable and technically reliable.

The benefits and the economic potential of energy storage as well as the different energy storage technologies have been presented in this contribution. The global market insights and trends reveal that electrical energy storage will in the coming five years win the economic argument and catalyze large PV generation deployment worldwide.

Algeria is gifted with worldwide most significant solar insulation resources, which constitutes a great potential for energy production through PV and CPS plants. The energetic potential overpasses by far the country's needs, thus rendering the deployment and exploitation of storage capabilities key to exploit to its fullest the resources at both ends and throughout the new electrical energy value chain, including generation, distribution/transport and consumption.

The Algerian government has during the last decade embarked in the renewable energy global wave with an ambitious program [1, 23] to scale up renewable energy generation capacity from 25 MW Solar PV in 2013; to 241 MW by 2015; 946 MW by 2020 and 2.8 GW by 2030. Concerning CSP 25 MW in 2013 Algeria counts increasing its capacity to 325 MW by 2015; 1,500 MW by 2020 to end up with 7,200 MW by 2030. Wind energy has also gotten its share in the mix with 10 MW in 2013 growing to 50 MW by 2015; 270 MW by 2020 and 2,000 MW by 2030. The Algerian renewable energy deployment program aims to raising renewable energy penetration rate from 0.8% in 2012 to 5% by 2017 with the objective of reaching 40% by 2030.

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