

Power Storage options to integrate renewables:



the case of large-scale applications

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<http://www.jrc.ec.europa.eu/>

- ✓ **NREAPs - Harnessing EU's renewable resource**
 - Offshore wind (~ 33% CAGR)
- ✓ **Cost of wind power**
 - New record (?): contract price of < 100 BRL/MWh (< 41€/MWh) , Aug 2011 Brazil
- ✓ **Cost of intermittency is lower than the monthly volatility in fossil fuels prices**
- ✓ **Technologies enable competition not only in generation and distribution but also for voltage regulation, back-up power, management of intermittency, efficiency improvements etc.**
- ✓ **Integration of large volumes of RES generation - whilst dealing with decreasing capacity margins (retirement & post-Fukushima rethinking)**
- ✓ **How much variable generation is possible at what cost?**

✖ EU activities on storage development

EU Initiatives, RD&D projects, Political agenda

✖ Large-scale applications in support to RES

Services, Potential, Developments, Challenges

✖ Market and regulatory drivers

Tools for Supply push and Demand pull effects

✖ Ending remarks

GENERATION -Supply

- RES integration
- Peak shaving
- Price arbitrage
- Ancillary services
- Frequency regulation
- Spinning reserve
- Cycling costs management



T&D - Delivery

- T&D Network investment deferral
- Increase T&D load factor
- T&D component life extension
- Reliability
- Black-start
- Power Quality
- Voltage support
- Congestion management



END-USER

- Commercial and Industrial energy management
- Avoided outages (UPS)
- Reduce energy cost
- Cost-savings
- Home energy management
- Home back-up



EU activities on energy storage technology development & deployment

The European Association of Energy Storage (EASE)

- European platform for sharing information - for advancing RD&D on storage.

The Association of European Automotive and Ind. Battery Manufacturers

- Joins R&D efforts of 85% of European industrial actors in the field (EV, RES).

SET-PLAN

The European Energy Research Alliance (EERA)

Aims to offer solutions which can be embedded in industry driven research

The SET-Plan Material Initiative

Proposal for RD&D activities for materials for energy storage (2020/ 30/ 50)

The European Fuel Cells and Hydrogen Joint Technology Initiative

Aims to accelerate RD&D of hydrogen-based technologies in a cost effective way.

The European Industrial Initiative Smart Grids

Proposes a 10-year European RD&D programme to accelerate network innovation.

The European Joint Programme on Smart Cities

Further integration of storage in support to sustainable, low-carbon cities concepts

The European Industrial Initiative on Concentrated Solar Power (*Heat Storage*)

Identifies CSP development objectives to maintain the European leadership

Framework Programme (6 & 7) Projects

- **FP6 ALISTORE** gathers 23 European research organisations structuring R&D activities on **lithium systems** and promoting nano-materials.
- **FP6 DEMO-RESTORE** tests the robustness of **lead-acid batteries** in support to PV systems.
- **FP6 NIGHT WIND** demonstrates the **storage of electrical energy**, produced by wind turbines, in refrigerated warehouses (Cold Stores).
- **FP7 MESSIB** focuses among others on advancing the research on materials, on phase change slurries, **flywheels** and **VRB batteries**.
- **FP7 HESCAP** aims to develop a new generation of high energy **super-capacitor** based system.
- **FP7 POWAIR** aims to create a low cost modular electricity storage system based on **Zinc-Air Flow Batteries** for electrical power distribution networks.

Intelligent Energy Europe

- **stoRE**: Facilitating Energy Storage to Allow High Penetration of Intermittent Renewable Energy- examines **non-technical barriers** to developing energy storage across Europe.

Recommendations to consider energy storage in energy innovation:

SET-Plan Council Conclusions (February, 2008): *“Further Industrial Initiatives may be necessary[...] the Council encourages the Commission to continue to examine areas with great potential such as marine energy, **energy storage** and energy efficiency for this purpose...”*

SET-Plan EP Conclusions (June, 2008): *“Asks the Commission to investigate the possibility of extending EII to other sectors[...] **better energy storage**[...].”*

Push to create or reinforce the industry leadership on storage:

COM (2010) “Energy 2020. A Strategy for competitive, sustainable and secure energy”: *Aims at “re-establishing **Europe’s leadership on electricity storage**...”*

Power storage in support of de-carbonisation policies:

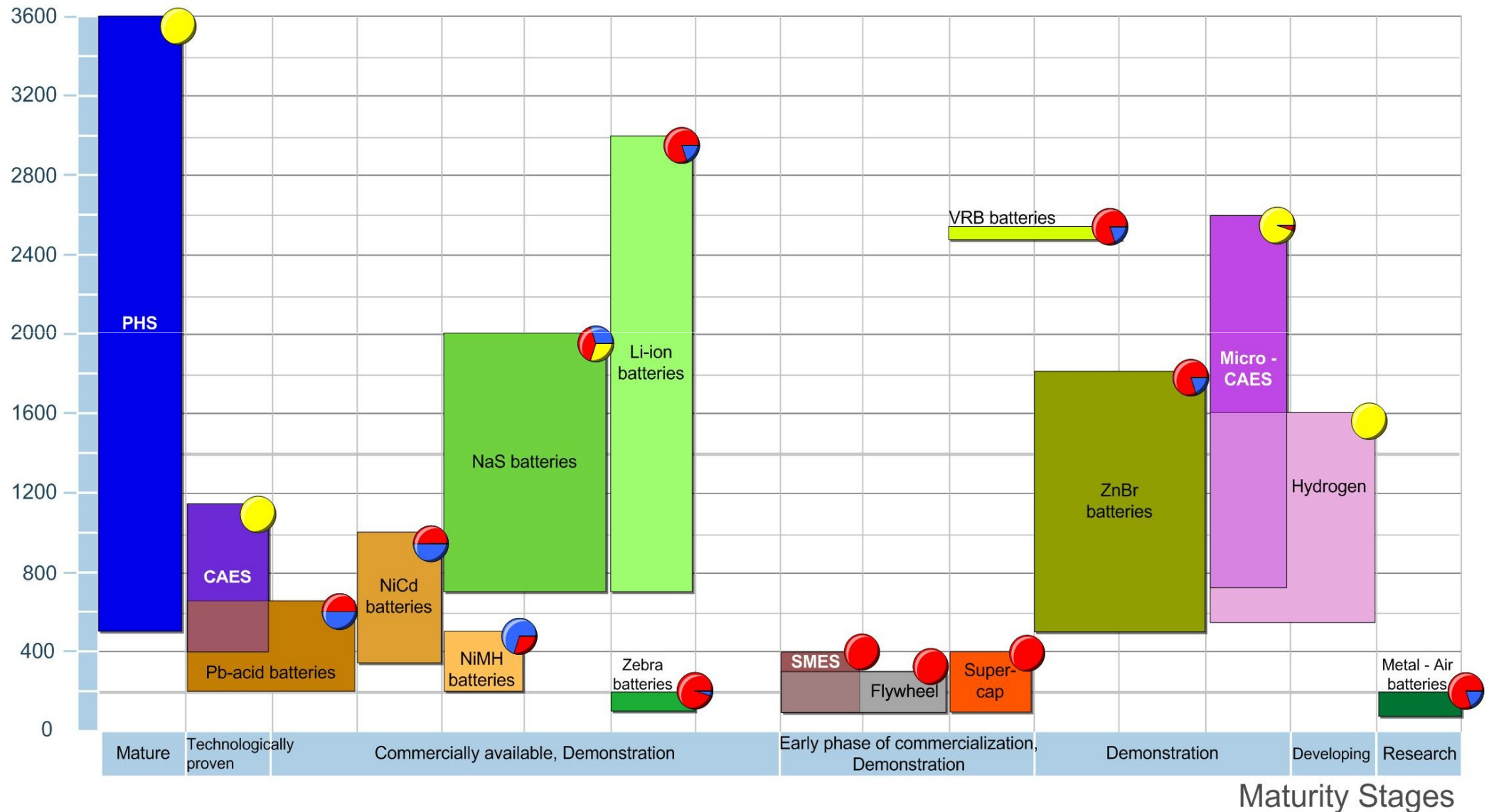
RES Directive (2009) *“stipulates that MS should develop transmission and distribution grid infrastructure, intelligent networks, **storage facilities** and the electricity system generally...”*

COM (2010) “Energy infrastructure priorities for 2020 and beyond” : *“electricity grids will have to evolve more fundamentally to enable the shift to a decarbonised electricity system in the 2050 horizon, supported by new high-voltage long distance and **new electricity storage technologies** ...”*

Large scale application in support to RES

Services, Potential, Developments, Challenges

Power Cost (€/kW)



Source: EC, JRC- SETIS, Technology Map (2011).

Storage needs to be matched to application

	PHS	CAES	AA-CAES	Hydrogen	NaS
Energy density, Wh/kg	0.5-1.5	30-60	30-60	800-10 ⁴	150-240
Round-trip efficiency, %	75-85	42-54	70	20-50	85-90
Technical Life-time, yrs	50-100	25-40	30-40	5-15	10-15
Power cost, €/kW	500-3600	400-1150	1300	550-1600	700-2000
Maturity Stage	+++	++	-	-	+
Response time	s-min	min	min	min	s-min
Power rating, MW	100-5000	100-300	300	0.001-50	0.1-50

Source EC, JRC- SETIS, Technology Map (2011).

Best Storage Technology Candidate for:



PHS	seasonal storage, secondary reserve
CAES	wind-remote areas, seasonal storage, tertiary reserve
Hydrogen	very large-scale storage in isolated systems with expensive grid extension
NaS	medium-scale storage, long daily cycles

Basic principle: to store energy by means of two reservoirs located at different elevations

Installed Capacity in Europe: ~ 40 GW

Developments in Europe:

- **Planned/ ongoing projects** by 2020 ~ 7 GW (CH, PT, AT, ES, DE, SI);
- **Upgrading old plants** + optimizing turbine/ pump system (CH, AT, ES);
- **Transformation of standalone reservoirs into PHS**
- **Norway potential 10-25 GW** (driven by large deployment of wind power in the North Sea)



Aguayo PHS (ES), courtesy of E.ON

Research fields:

- **on the location of the technology:** improved civil engineering and construction techniques
- **underground reservoirs** (Netherlands), **former opencast mines:** from granite mining (Estonia), from coal mining (Germany)
- **demonstration of open coast sea concept** (Japan)
- **variable speed**

- The **potential for new conventional hydropower is rather limited** (~ 19GW – Eurelectric 2011) in Europe because of environmental considerations, lack of adequate sites and public acceptance issues
- Transformation of standalone reservoirs to PHS likely to offer:
 - Lower environmental impact – caused years ago!
 - Grid already there (if transforming from a hydropower scheme)
 - Lower cost
- *But... what is the potential?*

A JRC - SETIS study on this potential is ongoing

Basic principle: to store energy mechanically by compressing the air from the atmosphere, in e.g. underground caverns.

Worldwide capacities: 320 MW (Germany), 110 MW (USA).

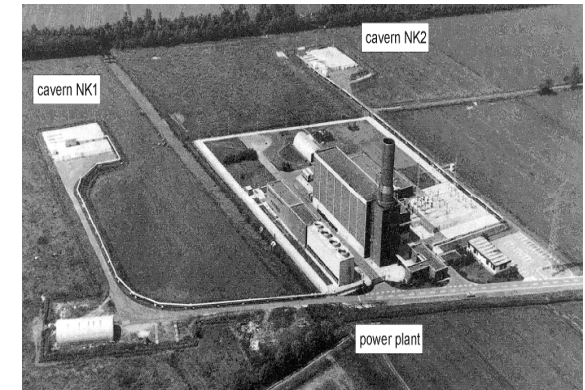
Projects: USA, Italy, Japan, South Africa, Israel, Morocco, Korea.

Developments in Europe

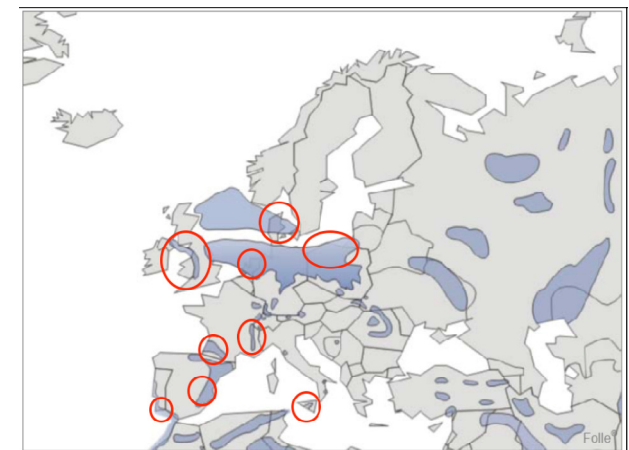
- Underground caverns potential: DE, DK, ES, FR, NL, PT, UK
- R&D Adiabatic CAES: ADELE project (DE).

Research fields:

- **Identification of new locations:** in vessels or above ground (SSCAES)
- **Adiabatic CAES (AA-CAES):** demo; lower the cost.
- **Isothermal compression** (thermo-dynamically reversible cycle, theoretical efficiency of 100%): demo; lower the cost.



Huntorf, Germany, KBB, E.ON



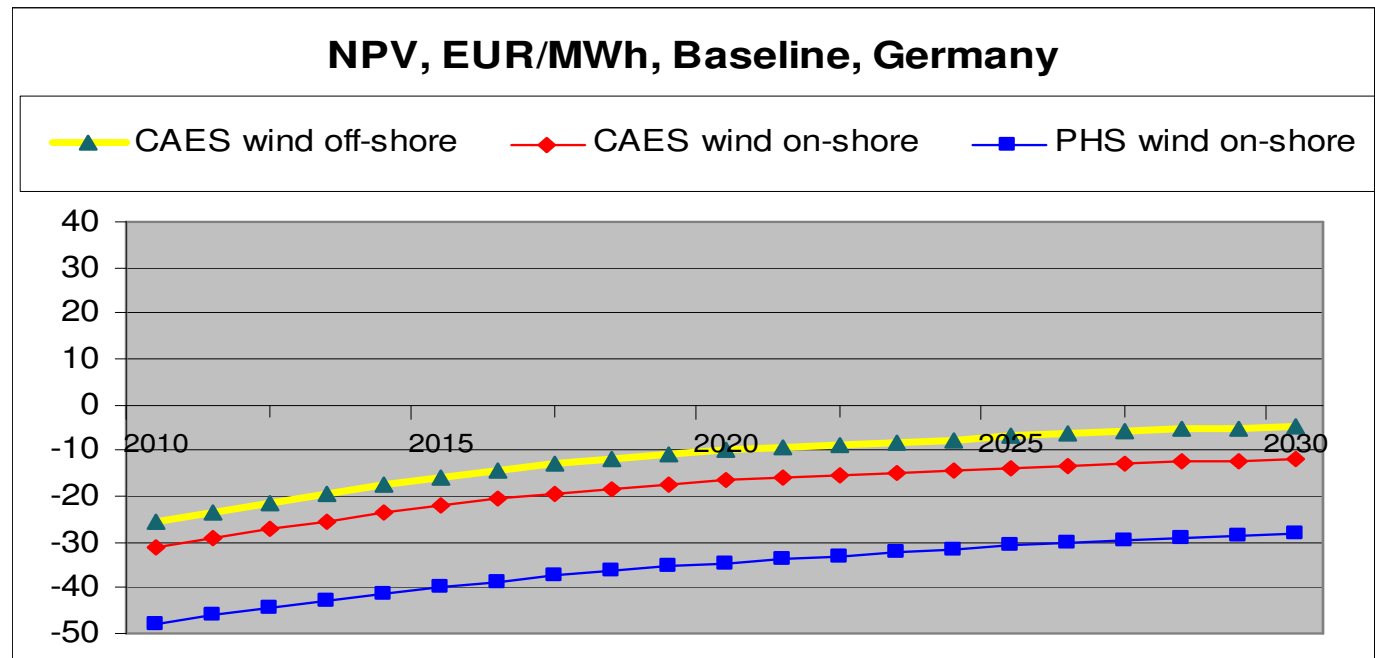
CAES potential, Calaminus (2007)

NPV < 0

PHS & CAES fail to recover their investment costs, due to **high capital costs**.

NPV_{CAES} > NPV_{PHS}

When the choice is possible, CAES is more profitable than PHS, due to **lower** investment costs and **learning effects** expected in the future.



Storage provides benefits to the power system through **avoided wind curtailment** and **grid bottleneck**, **wholesale price arbitrage** and provision of **reserves**.

Hydrogen

Basic principle: to produce hydrogen using electricity via reversible water electrolysis. H_2 is stored and transformed back into electricity by means of a fuel cell or a combustion turbine.

Demo Projects: Norway (Utsira Island), UK (Unst, Shetland Islands), Denmark (Nakskov), Greece (Keratea); Spain (Galicia; Aragón), etc.

Research fields: lower the cost; increase the efficiency; scale-up electrolyzers; increase the fuel cell durability and lifetime.

Synergies: transport

Advanced batteries: NaS

Basic principle: molten sulphur (anode) + molten sodium at the cathode, and a solid beta-alumina electrolyte membrane which allows the battery to function without self-discharge.

Worldwide: market is expected to grow from the current 440 MW (mainly Japan) to more than 1 GW by 2020; single manufacturer

Demo Projects: Germany (Berlin-Adlershof), Spain (Gran Canaria), France (Reunion Islands)

Research fields: beta-alumina membrane; new electrolytes; reduce corrosion risks of container materials.

Market & Regulatory Barriers

Drivers

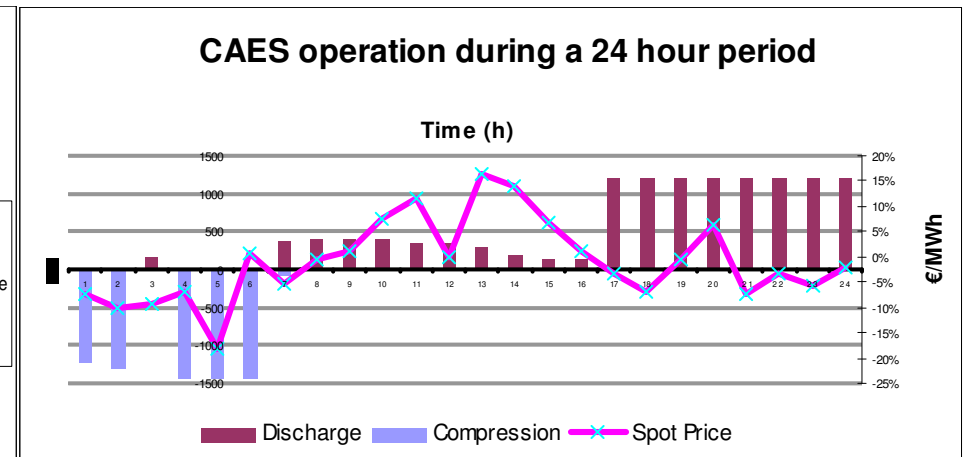
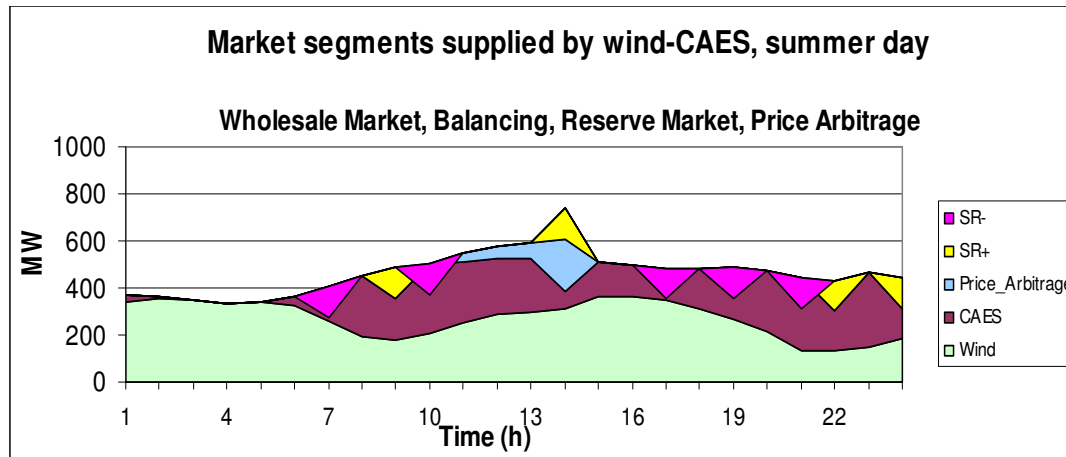
Factors that **improve** the opportunities for storage:

- **Geological potential:** suitable sites for PHS, CAES, H2.
- **Technological innovation:** CAES
- **Energy mix:**
 - Non-flexible power systems (e.g. nuclear-based).
 - Non-dispatchable RES increase market volatility ~ frequent price fluctuations.
- **Regulation:** hybrid system designs (e.g. PV- batteries in French islands)

Barriers

Factors that **reduce** the opportunities for storage :

- **Geographical constraints, geology:**
 - Few PHS additional sites possible in Europe, further exploration and permeability tests for CAES locations.
- **Energy mix:**
 - High share of flexible technologies, good network, import/export capacities.
- **Regulation:** withdrawal authorization (e.g. Livorno, IT) ; conflicts of interests with utilities due to e.g. local subsidies, market shares (e.g. Graciosa, PT).



The storage facility supports the balancing needs of the system and makes additional profits on the other segments of the market, like price arbitrage and ancillary services provision.

The storage facility is optimally charged with wind-based electricity and grid-supplied power. The storage is here **discharged continuously**, even during base-load periods due to insufficient wind power. A higher rate of discharge power during peak times is due to higher spot prices.

Market evaluation of hybrid wind-storage power systems in case of balancing responsibilities

Rodica Loisel et al, *Renewable & Sustainable Energy Reviews*, Forthcoming 2011.

Market and regulatory issues:

- Uncertainties related to the future energy supply and demand:

- On the power sector evolution, RES level, CO₂ price, base-load (e.g. nuclear)
- Effectiveness of demand-side management in curbing and peak-shaving energy consumption

- The difficulty to evaluate the storage profitability due to:

- The overlap of multiple services brought by storage at different system levels (generation, T&D, end-user)
- The difficulty to assess a common framework of regulation and market evaluation in EU given the heterogeneity of power systems and markets among Member States

Needs for storage operators:

- To be able to accumulate all multiple value streams to become profitable
- To establish a framework to assess the economic potential of storage
- To build scenarios on the future needs for storage
- To synchronize storage planning with the investment in electricity generation, transmission and distribution (T&D)

- **Energy storage** is a necessary **option** for future decarbonised systems, complementary to other **flexibility** and **energy security** solutions
- Advanced storage technologies still require **long term** (research phase) and **high risk investment** (demonstration)
- The level of innovation in storage technologies is rather low – **underdeveloped & underinvested**
- There needs to be mechanisms that **reward the benefits** that storage technologies provide
- SET-Plan offers the opportunity for re-addressing European **innovation in energy storage** and ultimately to create an integrated EU strategy on storage



The screenshot shows the SETIS website homepage. At the top, there is a navigation bar with links for FAQ, A-Z, Site Map, Accessibility, Contact, Legal Notice, and LOGIN. Below this is a header section with the European Commission logo and the SETIS title. A search bar is located on the right. The main content area features a welcome message, a 'LATEST NEWS' section with a headline about smart electricity grids, and a 'TOOLKIT' section with a diagram of energy technologies. A large green banner is overlaid on the page with the text 'Thank you ...Visit the SETIS Website'.

European Commission
SETIS Strategic energy technologies information system

European Commission > SETIS >

SETIS SET-Plan Activities Strategic Energy Technologies Newsroom

Welcome to SETIS - Towards a low-carbon future
The Information System for the European Strategic Energy Technology Plan (SET-Plan)

LATEST NEWS

White paper says consumers and retailers are key to the success of smart electricity grids 08/04/2011

As the energy value chain becomes increasingly two-way, for example with the introduction of micro-generation and energy efficiency focused technologies, the customer becomes an active element in the operation of the electricity grid, with the retailer as an essential link with electricity grid infrastructure

TOOLKIT

Fission CCS Energy Efficiency in Industry Hydropower Wind Cogeneration

**Thank you
...Visit the SETIS Website**

More research and development (R&D) expenditure across the EU- on the priority low-carbon energy technologies.

SETIS is... Building a community

Managed by the Joint Research Centre (JRC), SETIS works in close collaboration with the European Technology Platforms, European Energy Research Alliance and European Industrial Initiatives (EII).

MORE NEWS

More information at

<http://www.jrc.ec.europa.eu/>

<http://setis.ec.europa.eu/>

http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm