E-storage: Shifting from cost to value

Wind and solar applications 2016

WORLD ENERGY COUNCIL
CONSEIL MONDIAL DE L'ÉNERGIE
For sustainable energy.

World Energy Resources

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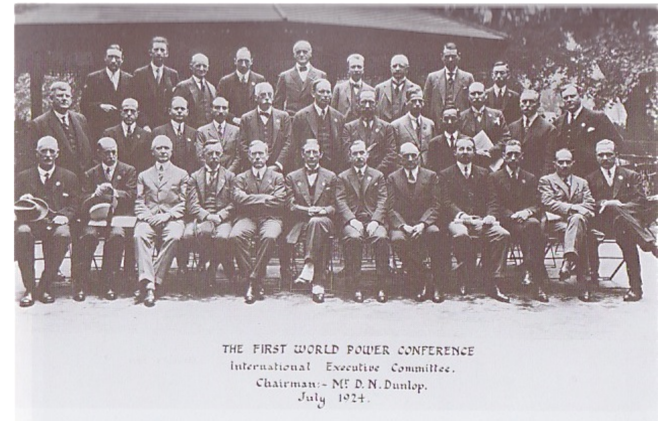
World Energy Council – who we are

“The world energy leaders’ network”

- Truly global
- Inclusive and impartial
- Committed to our sustainable energy future since 1923
  - 95 national committees chaired by energy ministers, leading CEOs and practitioners
  - Represents over 3000 government, private sector and experts organisations
  - Flagship event: World Energy Congress, every three years, 2013 in Daegu, South Korea. Next Congress, 2016 in Istanbul, Turkey

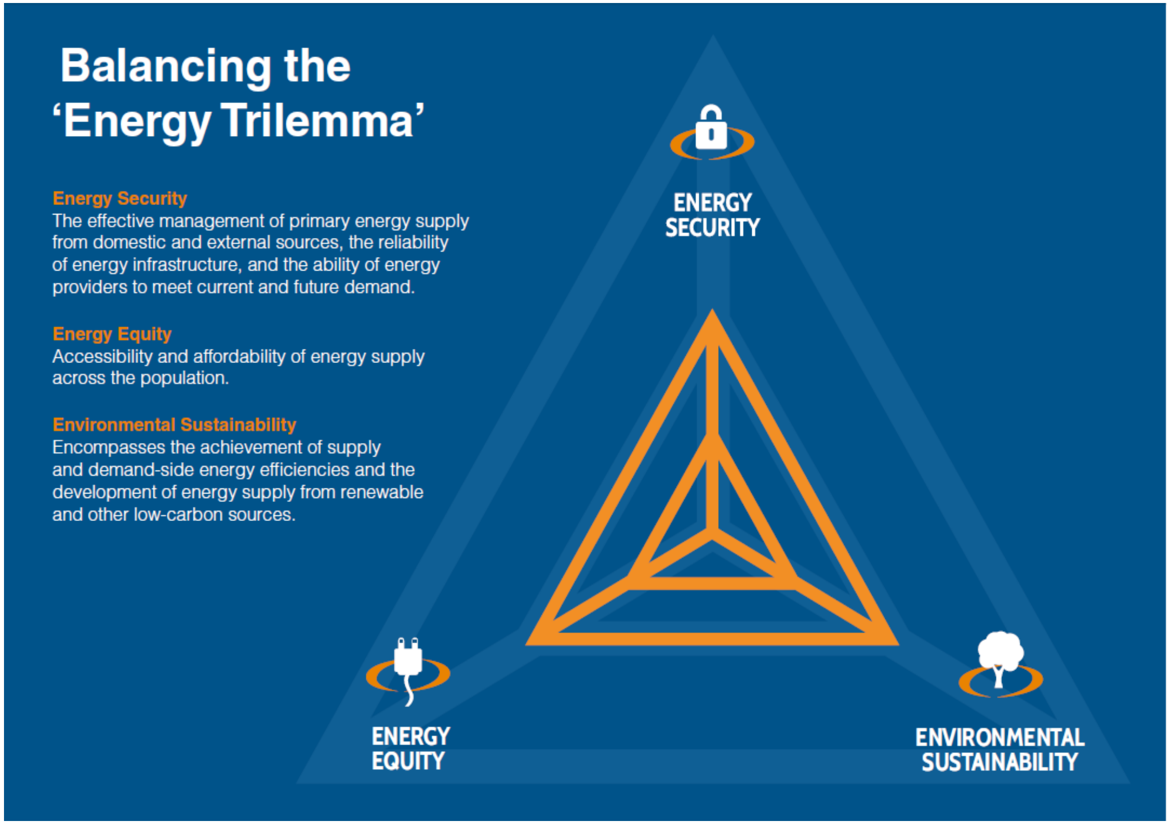


Our mission and vision

- The energy leaders' network promoting the sustainable supply and use of energy for the greatest benefit of all

  – All resources and technologies are needed

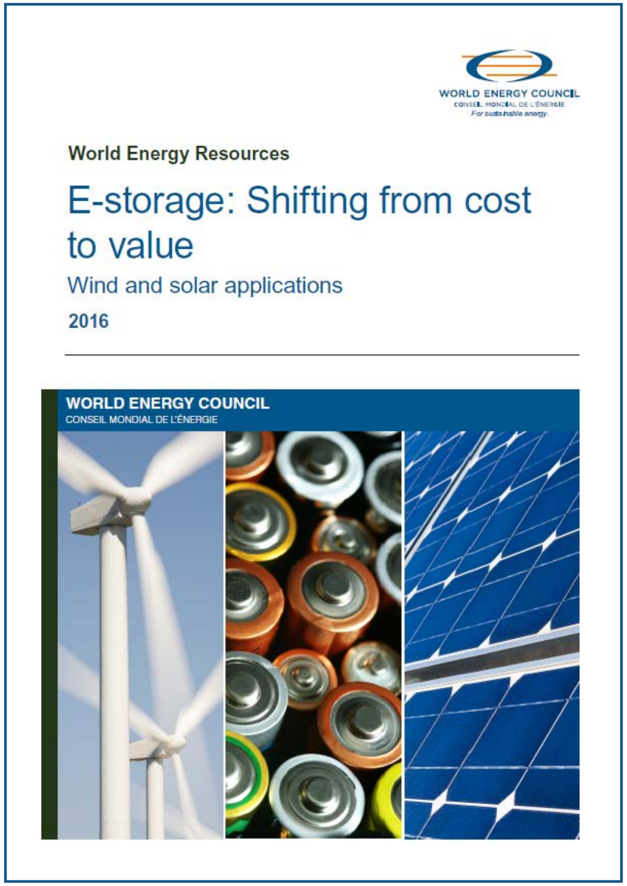
  – The concept of the 'energy trilemma' guides policymakers and industry leaders to make sustainable choices.

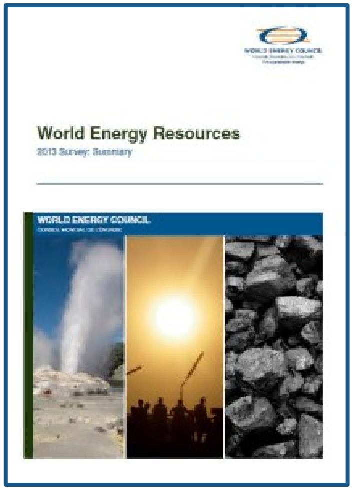


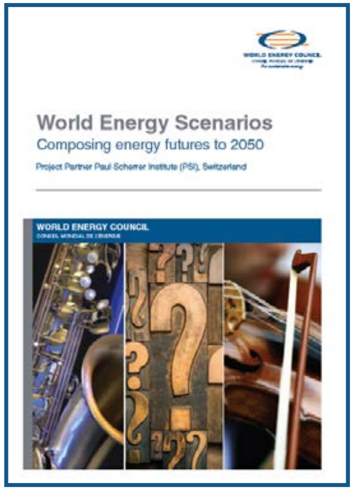
World Energy Council Studies

- **World Energy Scenarios** – exploratory assessments providing a realistic vision of alternative future energy landscapes
- **World Energy Resources** – surveys the global availability and production of all major energy sources, with national and regional assessments
- **World Energy Trilemma** – assesses how well countries are addressing the energy trilemma
- **World Energy Issues Monitor** – assesses the issues on top of the global and regional energy agenda
- **World Energy Perspectives** – specific issues and technologies

This report will form part of the E-storage Chapter in the World Energy Resources Report 2016







Purpose

- This work has been prompted by the combination of:
  - Falling costs of renewables, especially PV
  - Falling costs of storage, especially batteries
  - Increasing penetration levels of volatile renewables (wind and solar), prompting concerns about electricity system stability, and effect on system costs

- How can we understand the ***costs*** of storage with PV and wind?
- How can we establish the ***value*** of storage with PV and wind?

Key messages

- The costs of energy storage technologies are forecasted to reduce by as much as 70% by 2030

- Levelised Cost of Energy (LCOE) is useful as a metric
  but its limitations need to be clearly understood

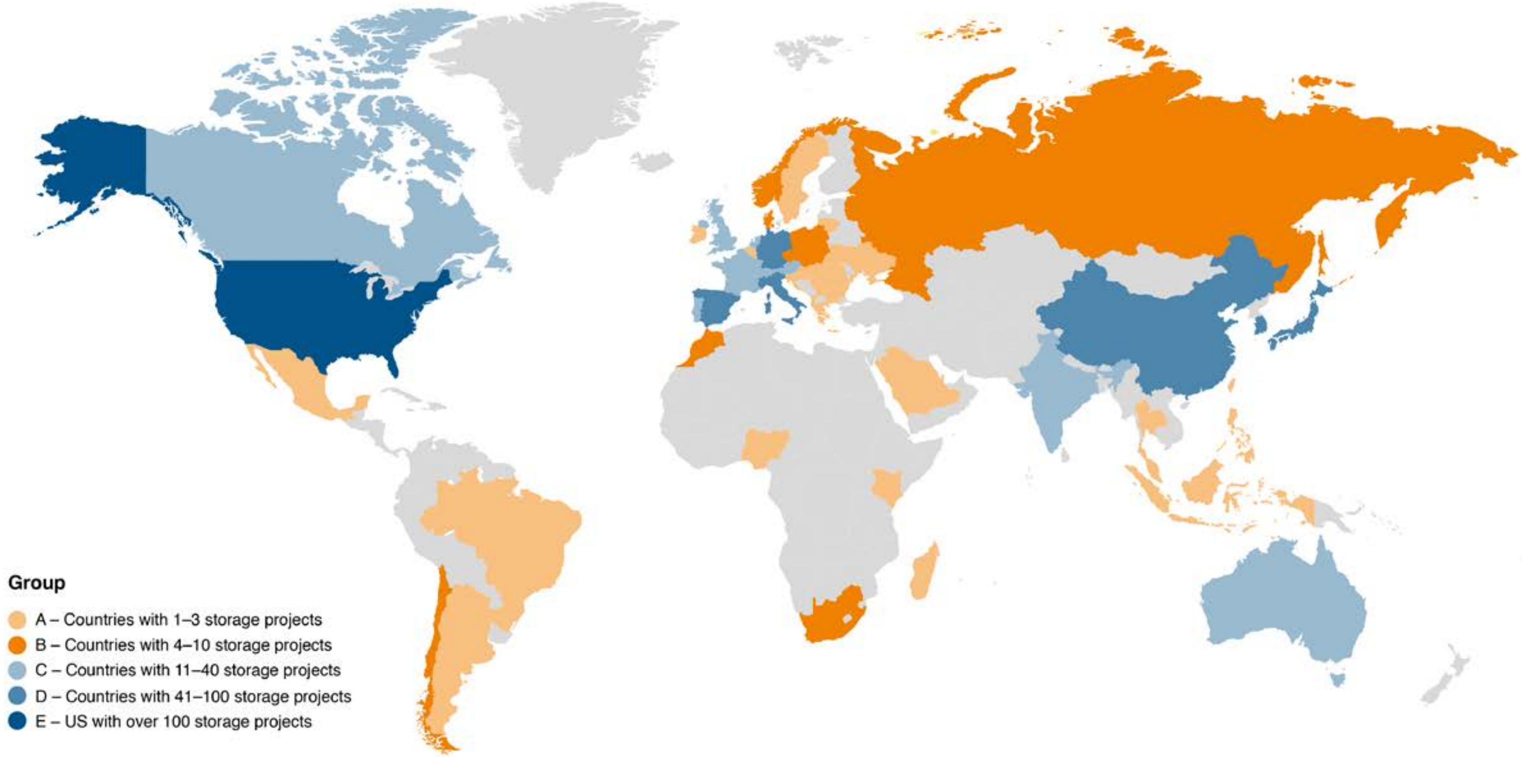
- The value of storage lies in the ability to provide power reliability and improve power quality

- Storage creates additional value through its function to:
  - Level the load,
  - Enable deferral of grid investment and
  - Creates the possibility of price arbitrage for operators

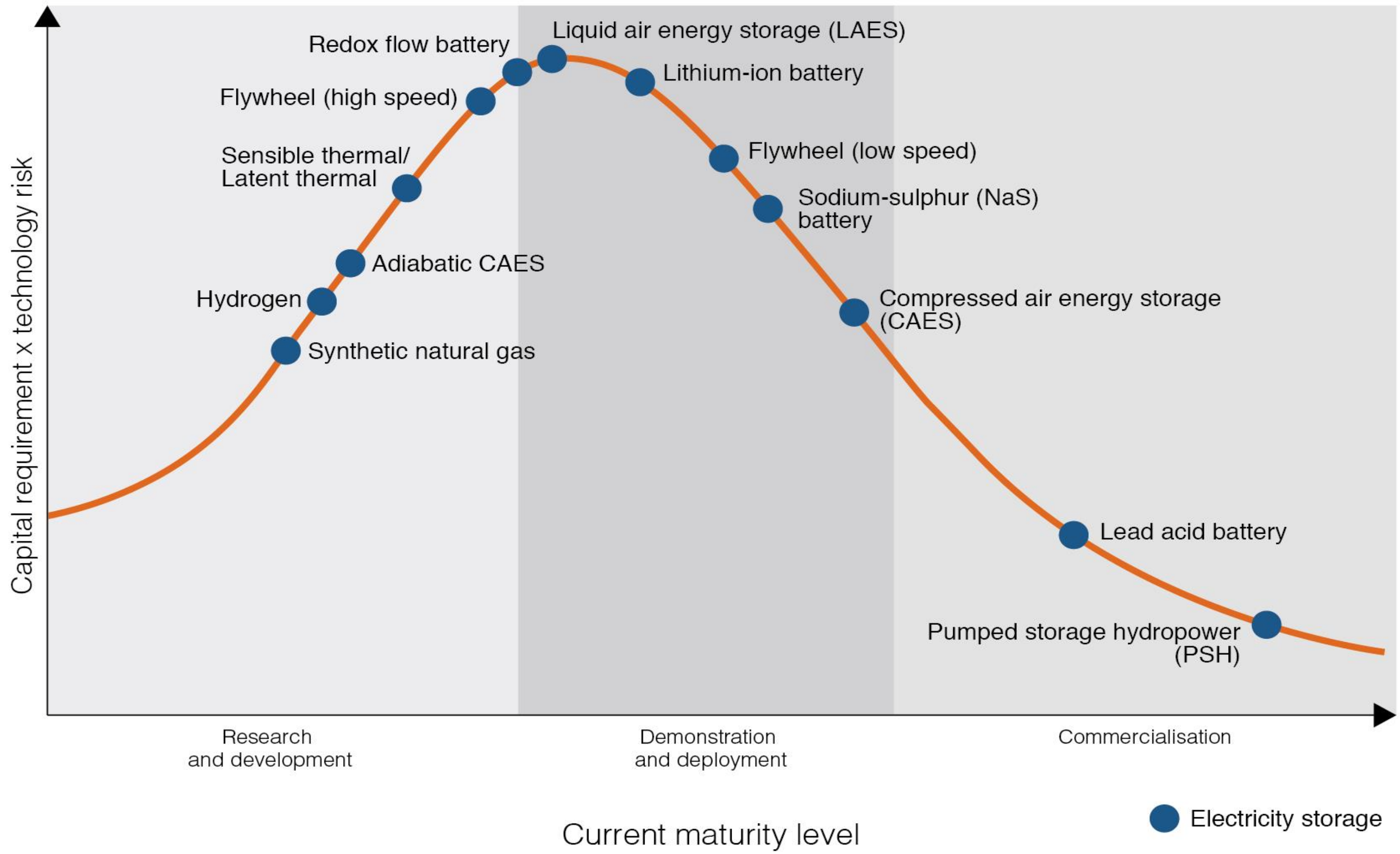
Key messages

- Pumped hydropower storage plants constitute over 90% of all installed storage capacity

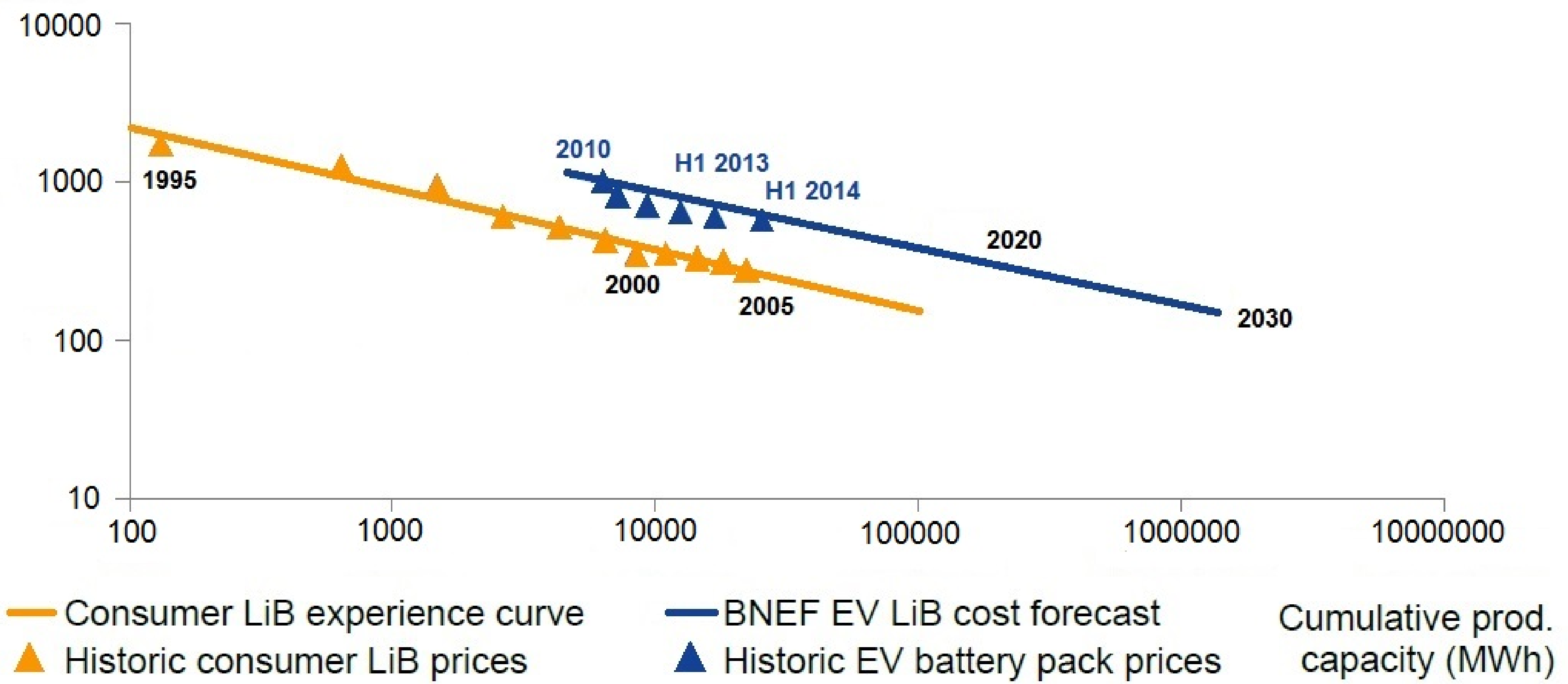
- Lithium-ion batteries constitute about one third of all installations in the world



E-storage technologies improving their maturity level



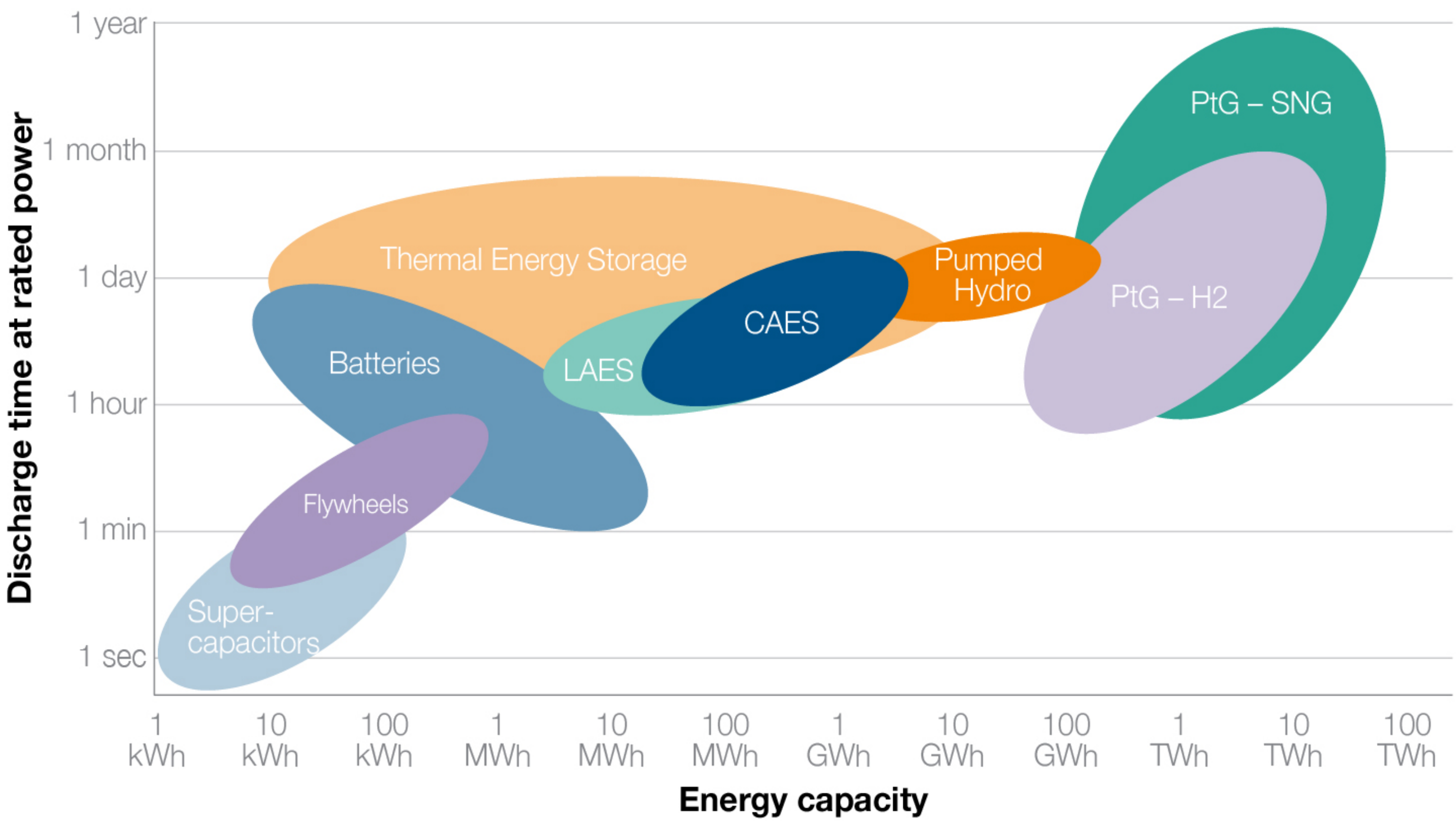
Cost reduction is forecasted!



Source: Bloomberg New Energy Finance, Maycock, Battery University, MIIT

Cost are important to consider, but even more important is to take in account the application for each technology

E-storage has a wide range of technologies and applications



Source: PwC, 2015, following Sterner et al. 2014

E-storage is ready to use

Duration and frequency of power supply

„seconds to minutes“ short term energy storage systems E2P ratio: 0,25h	Batteries Supercapacitors Flywheels	• Grid services • Compensation for day-night load imbalance • Peak shaving, valley filling, load shifting • Correction of forecast errors of renewable producers • Prevention of redispatch • Opportunity of spot market price fluctuations
„daily storage“ medium term energy storage systems E2P ratio: 1 - 10h	Batteries Pumped Hydro CAES / LAES Thermochemical Redox Flow	
„weekly to monthly“ long term energy storage E2P ratio: 50 - 500h	Sensible / Latent thermal PtG	• Future application to bridge periods of low wind and photovoltaic generation • Seasonal storage for thermal energy

Source: PwC, 2015, following ISEA Aachen, 2012 ; E2P stands for Energy to Power Ratio

Cost modelling

- The cost analysis is based on a literature review, cost modelling and review by World Energy Council Knowledge Network Energy storage

- The two key metrics considered in the analysis are:
  - Specific investment cost **(SIC)** and
  - Levelised cost of storage **(LCOS)**

- Results are estimated for both current 2015 and 2030 conditions

- LCOS in particular raises methodological difficulties: see Discussion

Levelised Cost of Storage (LCOS)

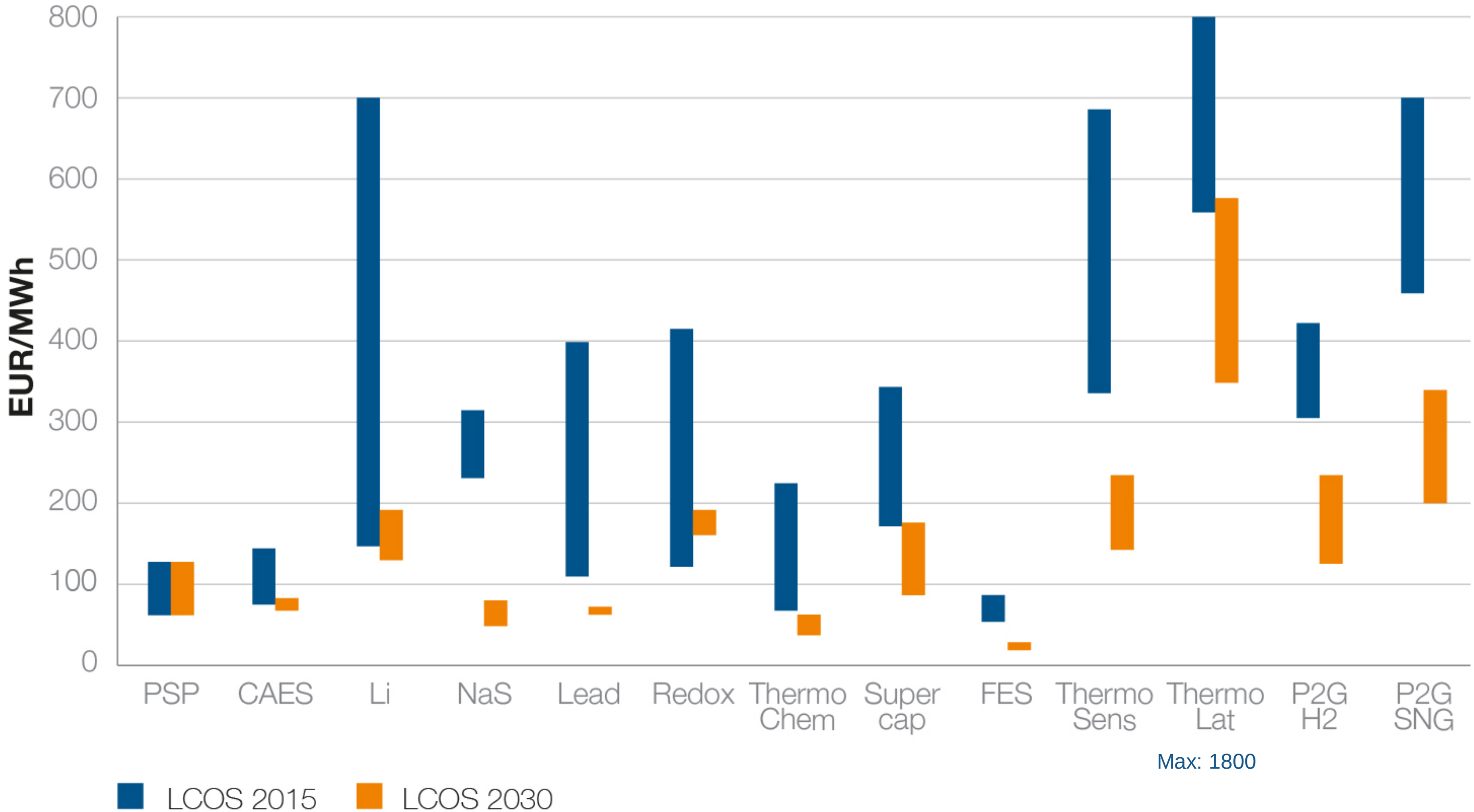
- LCOE is typically used to assess the cost of electricity from different power plant types. In this analysis it has been transferred to storage technologies and therefore the term LCOS is used
- LCOS enables comparison between different types of storage technologies in terms of average cost per produced / stored kWh

$$LCOS = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{el}}{(1+i)^t}}$$

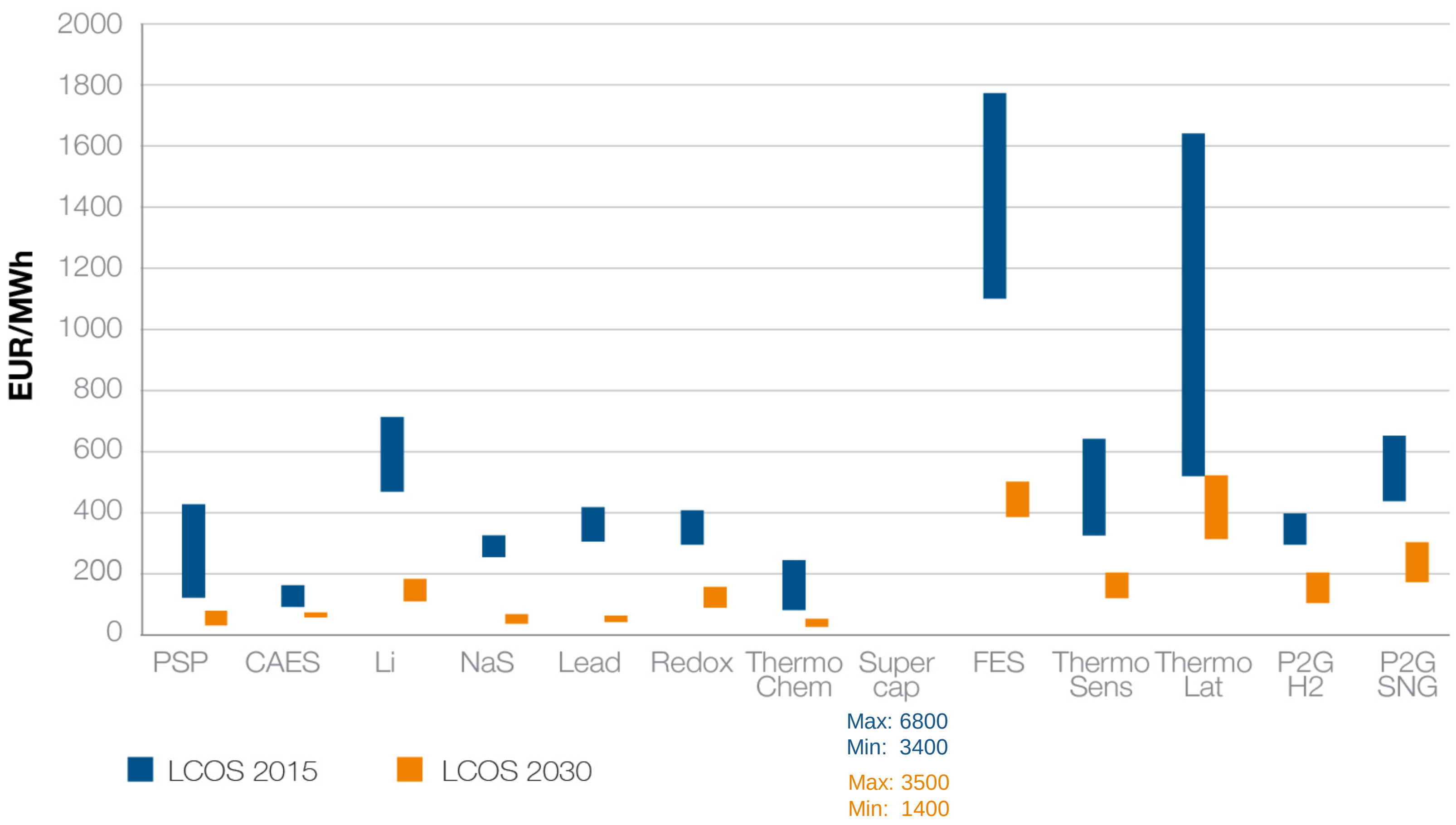
LCOS	Levelized cost of energy [€/kWh]
I_o	Investment costs [€]
A_t	Annual total costs in year t [€]
M_{el}	Produced electricity in each year* [kWh]
n	Technical lifetime [years]
t	Year of technical lifetime (1, ..., n)
i	Interest rate (WACC) [%]

Input Variables	Elements	Example values
Investment costs [€]	Specific cumulative investment cost * rated power	700 - 1500 €/kW * rated power
Annual total costs in year t [€]	Operational costs (in %) * Investment costs	2% * Investment costs
Produced electricity in each year [kWh]	Rated power * Equivalent full-load hours * Efficiency	Rated power *1,460 h/a * 80%
Technical lifetime [years]	Technical lifetime	50 years
Interest rate (WACC)	Interest rate	8%

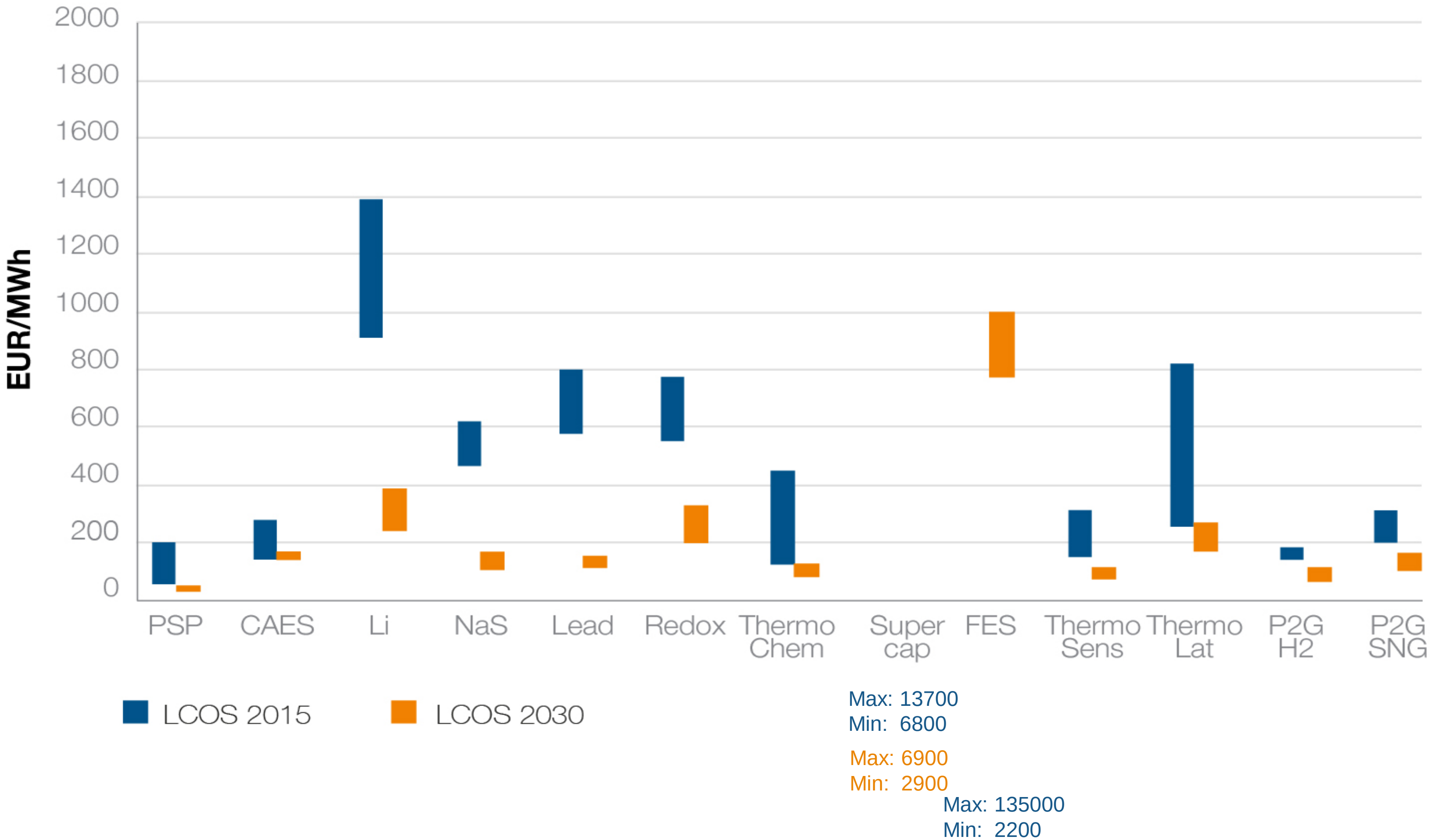
Comparing general levelised cost of storage for 2015 and 2030 (€_2014)



Comparing levelised cost of storage co-located with Solar for 2015 and 2030 (€_2014)



Comparing levelised cost of storage co-located with Wind plant for 2015 and 2030 (€_2014)



Sample case studies

Case study - Enel Green Power PV storage project, Catania 1, Italy

This project was built in 2014-15, entirely funded by Enel Green Power. It consists of a 10 MW PV plant (limited to 8 MW due to grid constraints) and a sodium-nickel chloride battery ($NaNiCl_2$) of 1 MW/ 2 MWh .This technology was selected due to the energy intensive application.

The energy is sold to the market, with the stored energy classifying as green energy, under existing incentives for the PV plant. The roles performed by the storage plant are as follows:

- Active energy management
- Improved predictability of generation
- Less volatile generation profile
- Provision of ancillary services to the grid.

There were challenges in integrating the new system with the existing system, and with the Enel Green Power system for real time remote control and energy management. Installing the storage system involved several upgrades on the power plant itself. Also, defining a new framework for authorization required the involvement of several authorities.

Sample case studies

Case study - Enel Green Power off-grid hybrid storage project, Ollagüe, Chile

This project was built in 2014, and was entirely funded by Enel Green Power and partner company. It consists of PV (200 kW), wind (30 kW), a sodium-nickel chloride battery (NaNiCl2) of 520 kWh net for users, and a diesel generator.

The aim was for this off-grid power plant to provide energy 24 hours a day to the local mining community, and in particular to:

- **Reduce diesel consumption; and**
- **Provide energy throughout the night.**

The project is located in an extremely harsh environment, with extreme daily temperature ranges and dust conditions. Robust technologies were needed for both the PV system (3Sun double glass PV modules) and for the storage unit (BESS sodium nickel chloride by Fiamm, and redundant inverters by Nidec-ASI).

Sample case studies

Case study - InovCity grid-connected energy storage in Évora, Portugal

This project was built in 2015, funded by the European Union. It consists of a battery storage system of 393kW / 196kWh by Siemens SA. It is connected to the MV distribution grid.

The purpose of the project is to demonstrate how an Energy Storage System can contribute to EDP Distribuição's main technical challenges

- Increase in grid reliability
- Improvement of grid power quality
- Reduction of grid losses

The main function is to provide backup to the main load/client. Nevertheless, there are other auxiliary functions under investigation, such as fault-ride-through (for grid support), peak-shaving (for grid loss reduction) and voltage control.

There were challenges in developing a priority management plan, to achieve system optimization. Also, grid simulation studies were necessary in order to obtain authorization for connection of the storage system to the distribution network.

Methodological challenges

Challenge one – Arbitrariness

Challenge two – Incompleteness

Implications

The key implication of these challenges is that ***context matters***

- Wide variation in energy storage costs
- The important metric is value, where value is a function of both cost and revenue
- Cost reduction of storage is important, yet insufficient
- The industry's focus on cost seems to stem from two areas:
  - From a country and societal perspective, the value of storage is the ability to provide power quality and reliability, and security of supply
  - Storage creates additional value through its function to level the load
- **Understanding the revenue side of storage has urgency due to its complexity**

Discussion of results: PV application case

- Solar-storage results: Assuming daily cycles and six hours discharge time at rated power, the most competitive technologies have LCOS of 50-200 €/MWh, though these are technologies which are not necessarily suited to all PV projects. Battery technologies are next, around 200-400 €/MWh. By 2030, a much wider range of technologies offer LCOS below 100 €/MWh. Looking to 2030, it is particularly striking that battery technology becomes especially more competitive, with sodium sulfur (NaS), lead acid and lithium-ion technologies leading the way
- It is important to stress that the cost ranges are specific to the application cases and assumptions defined in this report

Discussion of results: wind application case

- Wind storage results: This application assumes two-day cycle structure, and 24 hours discharge time at rated power. Levelised costs are much higher for the wind-storage case than the solar-storage case because of the high sensitivity of the LCOS to the number of discharge cycles, and the suboptimal energy-to-power ratios required for the wind-storage case as defined
- It is important to stress that the cost ranges are specific to the application cases and assumptions defined in this report

Recommendations

- ► Go beyond a narrow levelised cost approach to storage technology assessment
  - The lowest LCOS is not always the best option
- ► Examine storage technologies through holistic case studies in context
- ► Accelerate the development of flexible markets
  - working with transmission and distribution system operators and regulators
- ► The main value of storage is the ability to provide power quality and reliability, and security of supply
- ► Storage is a key component when planning for grid expansion or extension

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For the full report, please go to:
http://www.worldenergy.org/publications/