Energy Community Workshop

Energy Storage Technologies

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EASE Members

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European Association for Storage of Energy

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2. Energy Storage Overview

What is Energy Storage?

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We follow the energy storage definition established in the Clean Energy Package, Article 2(59) of Directive (EU) 2019/944 of the European Parliament and of the Council.

Clean Energy Package definition of 'Energy Storage' in the electricity system is defined as:

Deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier.

Power-to-X-to-Power

- Batteries
- V2G
- Flywheels
- PHS
- CAES
- LAES
- Supercapacitors
- Gravity storage
- Electrolysers (P2G2P)
- Thermal energy storage (P2H2P)
- Superconducting magnetic energy storage (SMES)
- ……

Power-to-X

- Electrolysers (P2G)
- Thermal energy storage (P2H)
- V1G
- ……

All solutions provide System Flexibility

bi-directional Energy Shifting

one-directional flexibility

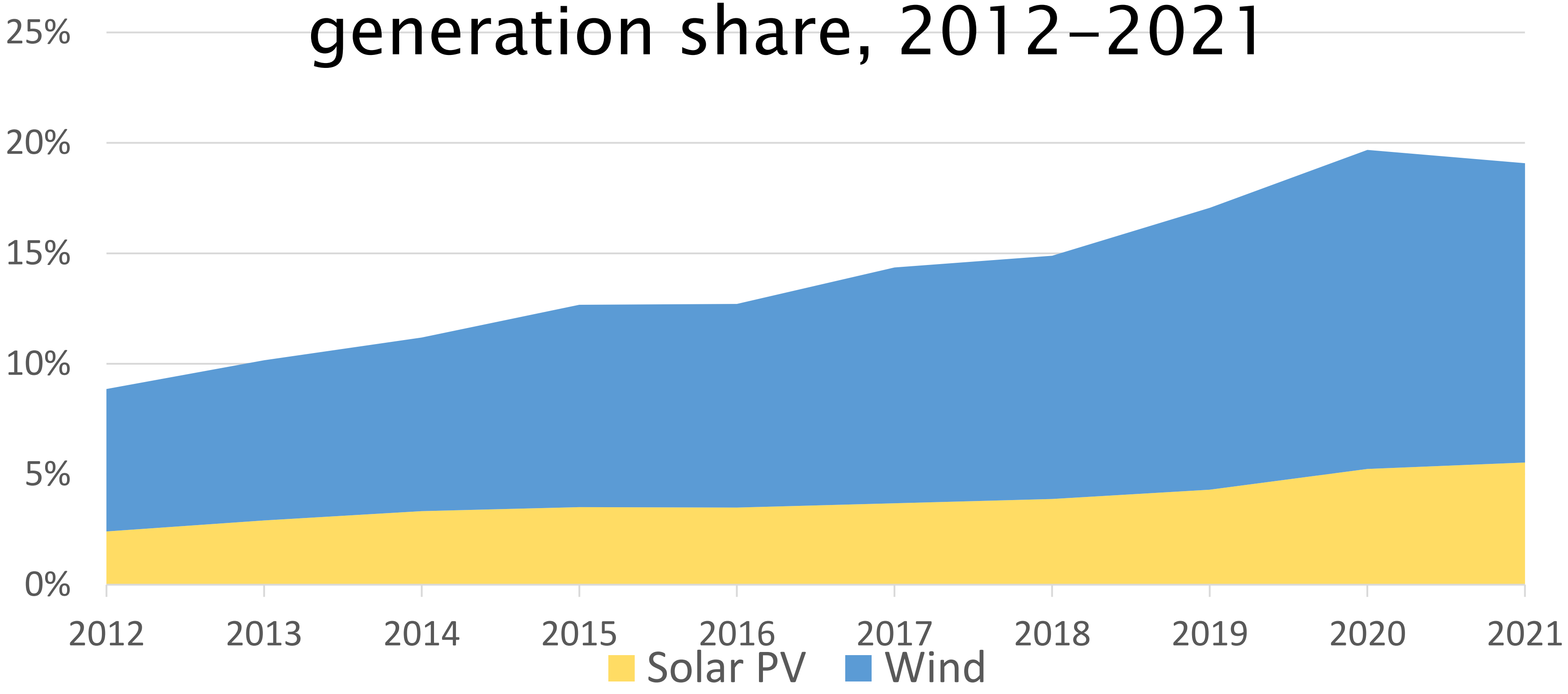
Where: V2G: vehicle-to-grid, V1G: smart charging, P2G2P: Power-to-gas-to-power, P2H2P: Power-to-heat-to-power, P2G: Power-to-gas, PHS: pumped-hydro storage, CAES: Compressed air energy storage, LAES: Liquid air energy storage

1. Renewable energy generation and energy storage

1. RES Generation and Energy Storage

Current trends

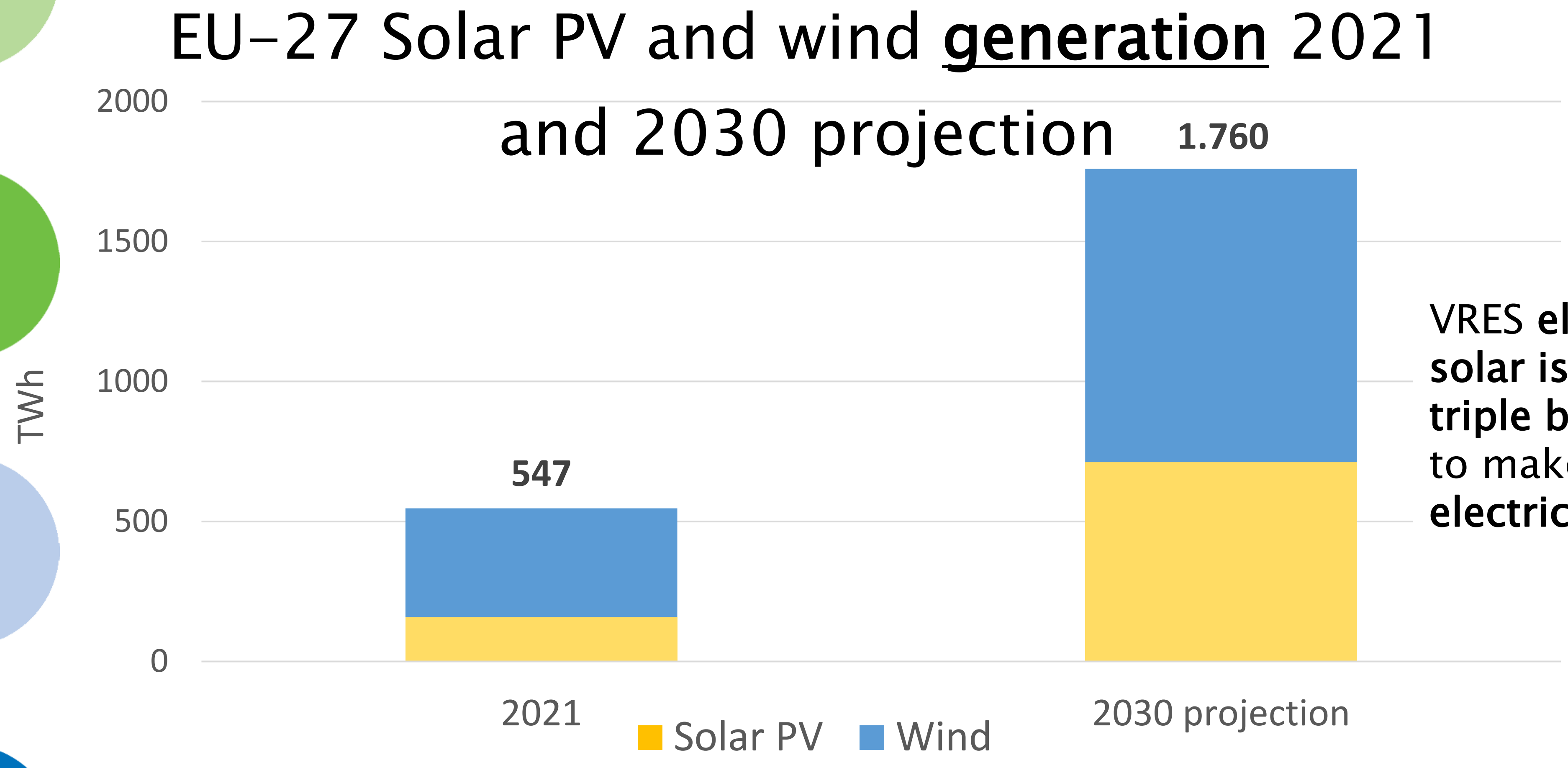
EU-27 solar PV and wind electricity generation share, 2012-2021



Source: WindEurope, 2023

1. RES Generation and Energy Storage

Future trends

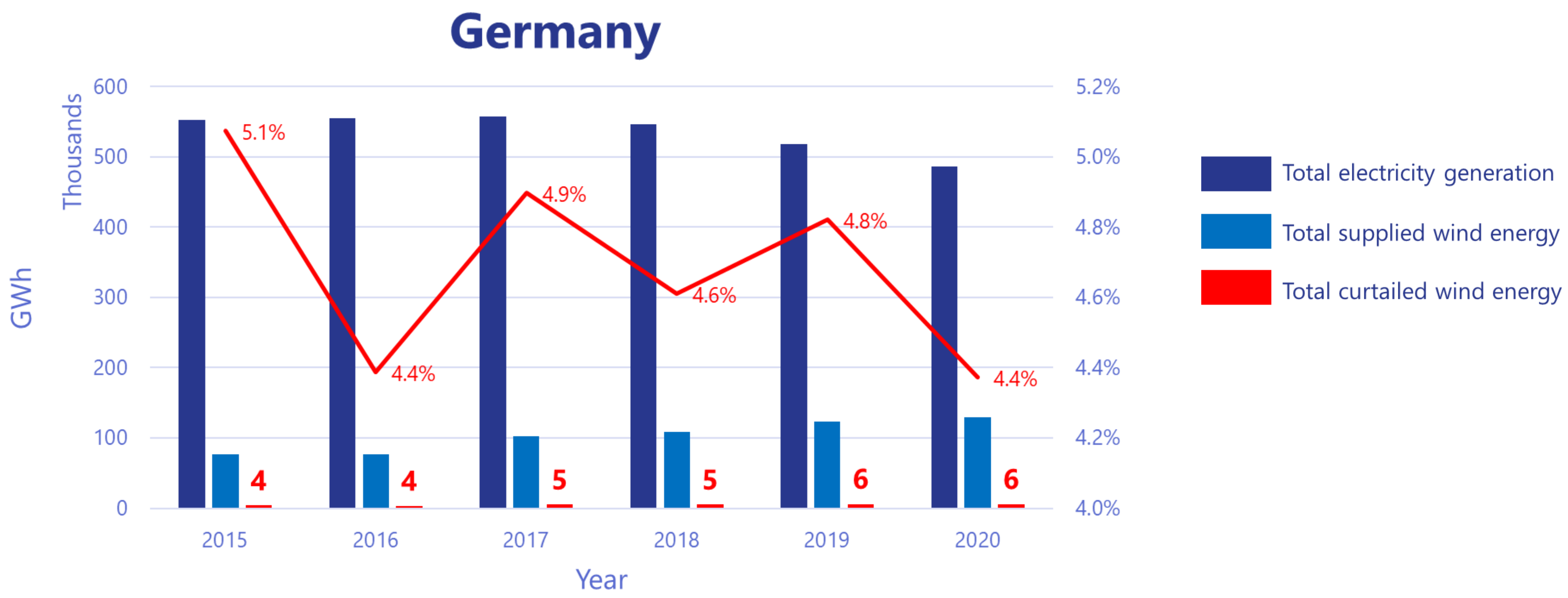


VRES **electricity from wind and solar is expected to more than triple by 2030.** RES are expected to make up **64-67% of EU electricity generation**

Source: SolarPower Europe, 2023

1. RES Generation and Energy Storage

Renewables curtailment

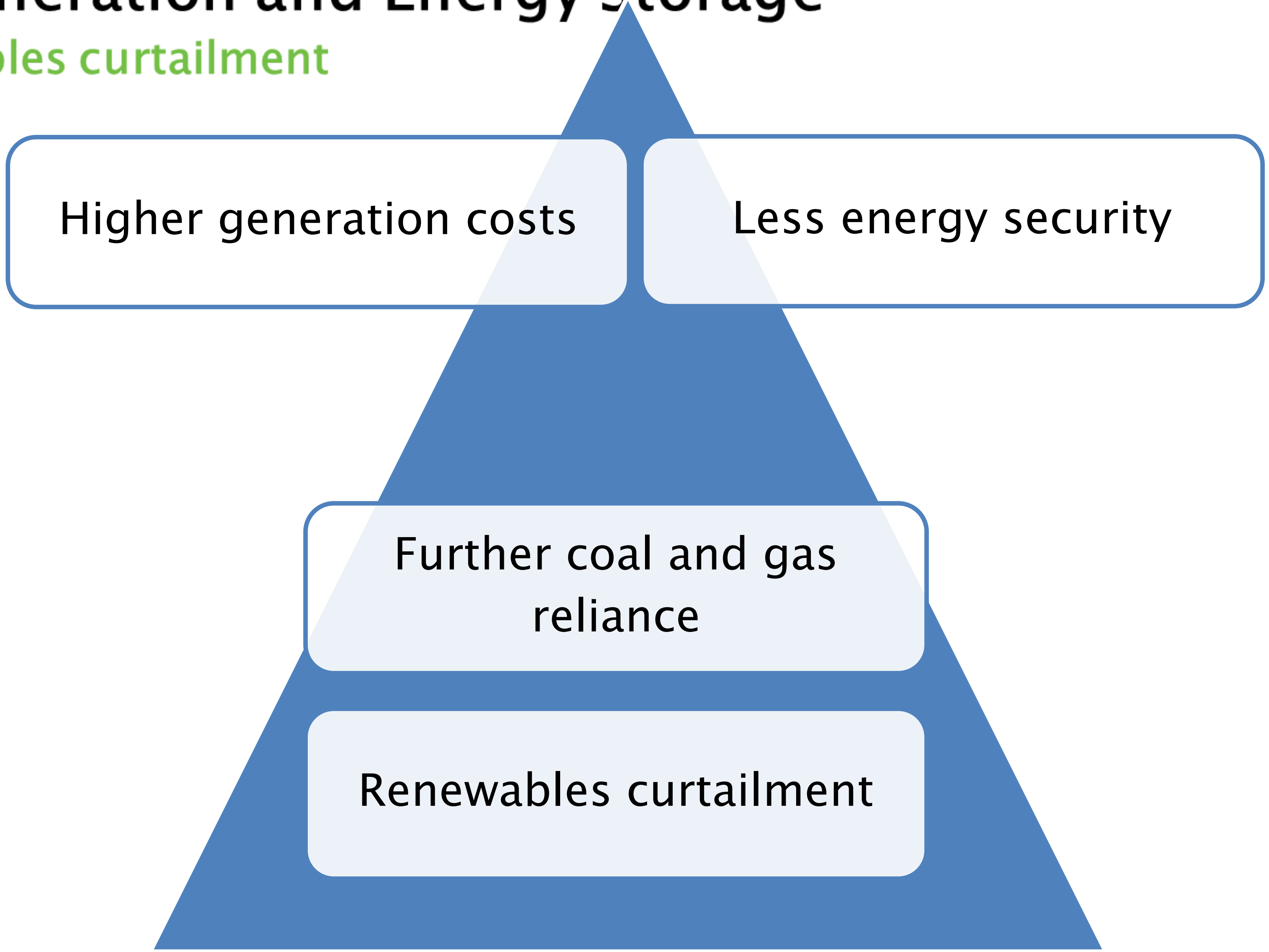


Congestion Management Costs: €1.3bn (2019) and €1.4bn (2020)

Source: Bundesnetzagentur, WindEurope, 2022

1. RES Generation and Energy Storage

Renewables curtailment



1. RES Generation and Energy Storage

Renewables curtailment

The solution: scale up flexible assets compatible with net-zero:

- to channel surplus or shift it to shortage hours
- to cover up for renewables' shortage

2. Energy Storage Overview

What is energy storage?

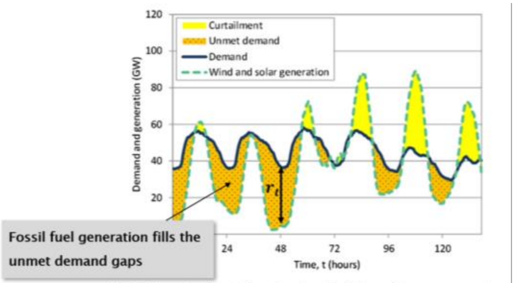
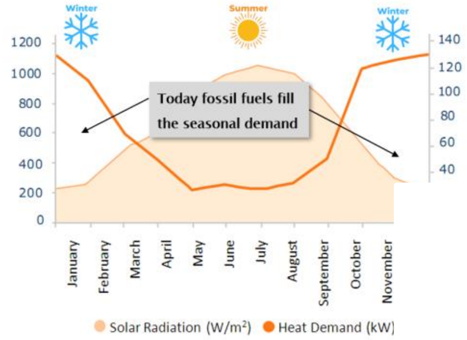


Fig. 2. Example of curtailment and residual demand in a power system.



Source: https://www.icax.co.uk/Heat_Recycling.html

✔ Solution ✔ Partial solution

Flexibility duration	System Challange	Dispatchable generation	Grid reinforcement	Curtailment or feed-in management	Energy Storage – bidirectional flexibility (energy shifting)	Demand-side response/Energy Storage – unidirection flexibility
Intraday	Intermittent daily generation	Solution		Solution	Solution	Solution
	Reduced grid stability	Solution			Solution	Partial solution
Multiday, multiweek	Multi-day imbalances	Solution	Partial solution	Partial solution	Solution	
	Grid congestion	Partial solution	Solution	Solution	Solution	
Seasonal duration	Seasonal unbalances	Solution	Solution		Solution	
	Extreme weather events	Solution			Solution	

What Solutions at our Disposal?

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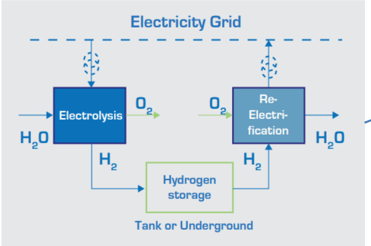
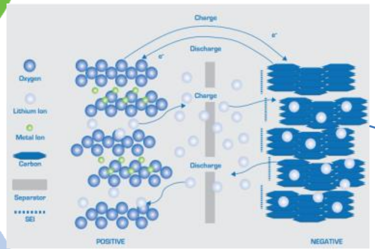


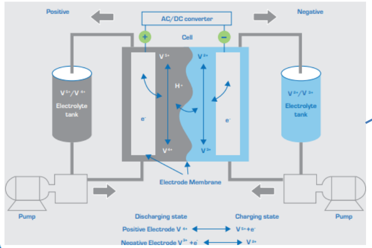
Chemical

- Ammonia
- Drop-in Fuels
- Hydrogen
- Methanol
- Synthetic Fuels
- Synthetic Natural Gas



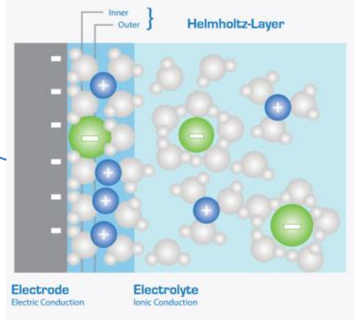
Electrochemical

- Classic Batteries
- Flow Batteries
- Lead Acid
- Li-Ion
- Vanadium Red-Ox
- Zn-Br
- Li-Polymer
- Li-S
- Zn-Fe
- Metal Air
- Na-Ion
- Hybrid Supercapacitors
- $Na-NiCl_2$
- Na-S
- Electrochemical Recuperator
- Ni-Cd
- Ni-MH



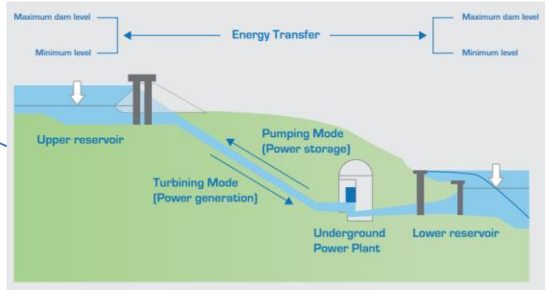
Electrical

- Supercapacitors
- Superconducting Magnetic Energy Storage (SMES)



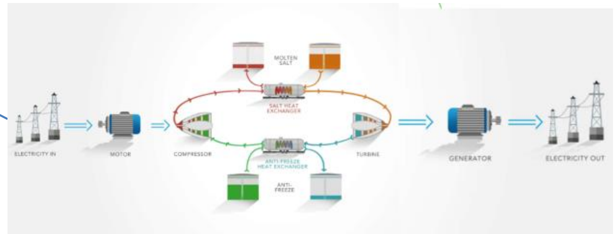
Mechanical

- Adiabatic Compressed Air
- Diabatic Compressed Air
- Liquid Air Energy Storage
- Flywheels
- Pumped Hydro



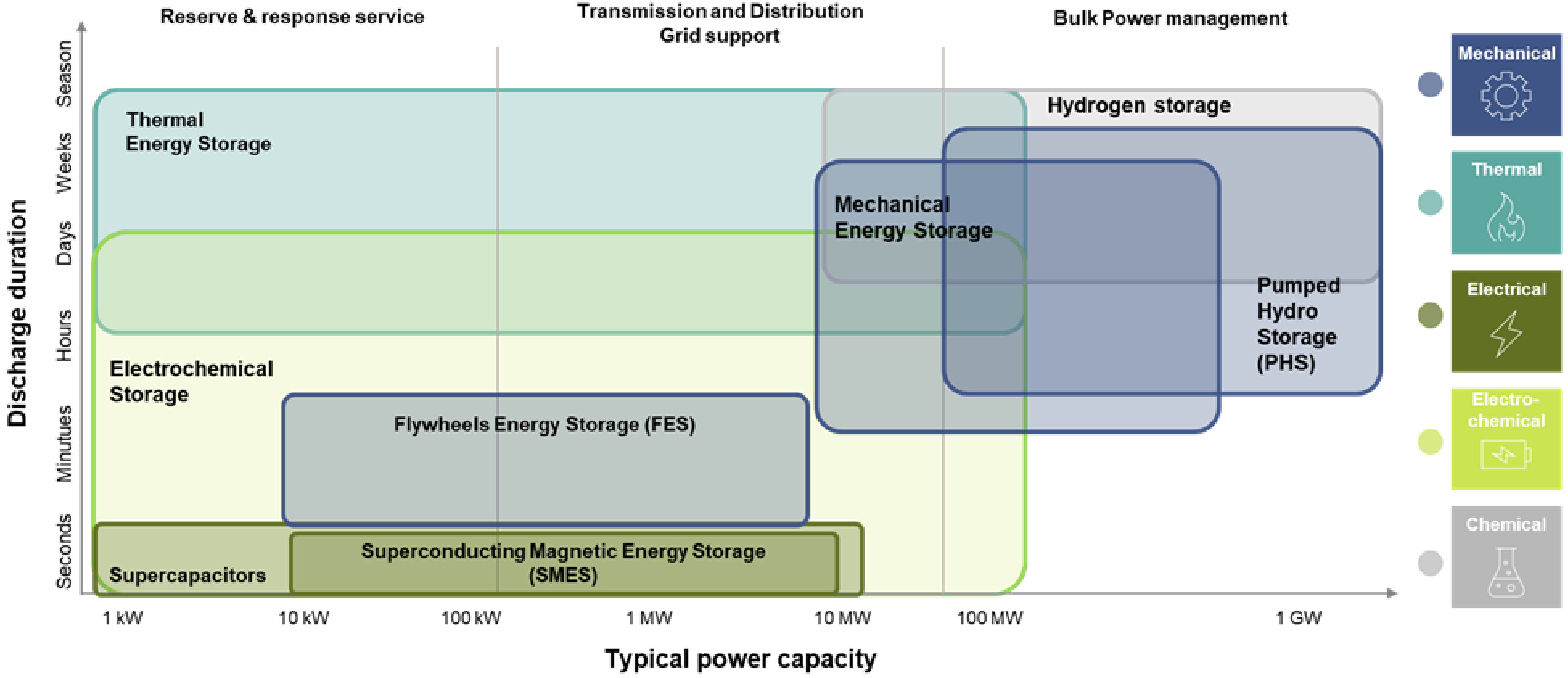
Thermal

- Latent Heat Storage
- Sensible Heat Storage
- Thermochemical Storage
- Ice Storage



Source: https://ease-storage.eu/energy-storage/technologies/

What Solutions at our Disposal?



Source: Global Data (2019), IRENA (2020), WEC (2020), BNEF (2020), EU (2020), HEATSTORE project (2021)

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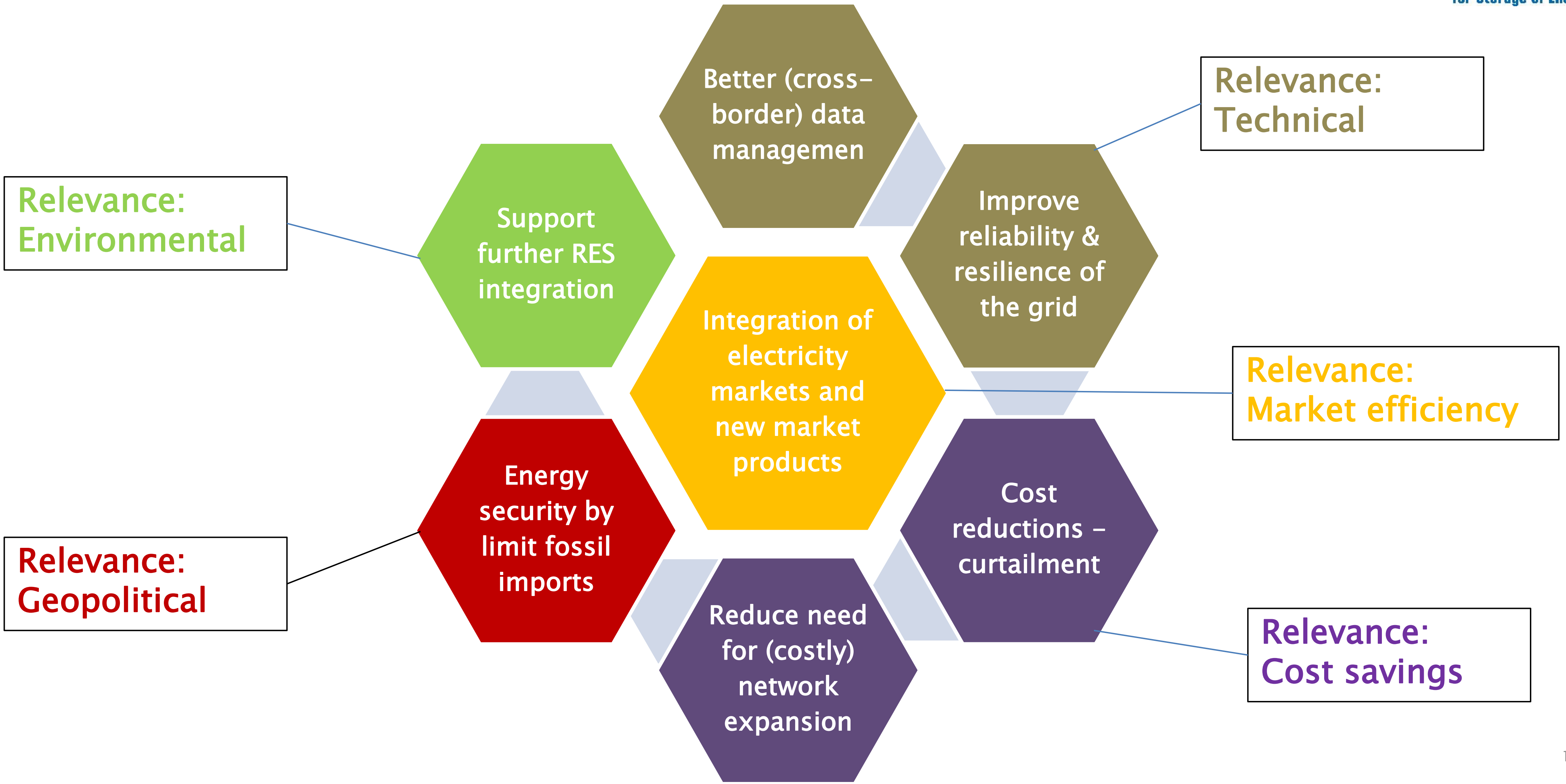
What Solutions at our Disposal?

Shorter storage duration (seconds) ↕ Longer storage duration (season)

Energy storage form	Technology	Market readiness	Sector integration	Deployment
Electrical	Supercapasitors	Commercial	/	approx. 1%
Electrochemical	Classic batteries	Commercial	Electricity + Mobility	approx. 10%
	Aqueous electrolyte flow batteries	Pilot/commercial		
	Metal anode batteries	R&D/pilot		
	Hybrid flow battery, with liquid electrolyte and metal anode	Commercial		
Mechanical	Novel pumped hydro (PSH)	Commercial	Electricity + Gas	approx. 85%
	Gravity-based	Pilot/commercial		
	Compressed air (CAES)	Commercial		
	Liquid air (LAES)	Pilot (commercial announced)		
	Liquid CO_2	Pilot		
	Flywheel	Commercial		
Thermal	Novel pumped hydro (PSH)	Commercial	Electricity + Heating and Cooling	approx. 1%
	Sensible heat (eg, molten salts, rock material, concrete)	R&D/pilot		
	Latent heat (eg, aluminum alloy)	Commercial		
	Thermochemical heat (eg, zeolites, silica gel)	R&D		
	Ice storage	Commercial		
Chemical	Power-to-gas-(incl. hydrogen, syngas) -to-power	Commercial/pilot	Electricity + Gas	approx. 1%

Why Energy Storage Projects for P(E)CI are Key



3. European Union PCI Projects: Which Technologies?

3. PCI Projects: Which Technology?

a. Mechanical Storage – Pumped Hydro Storage (PHS)

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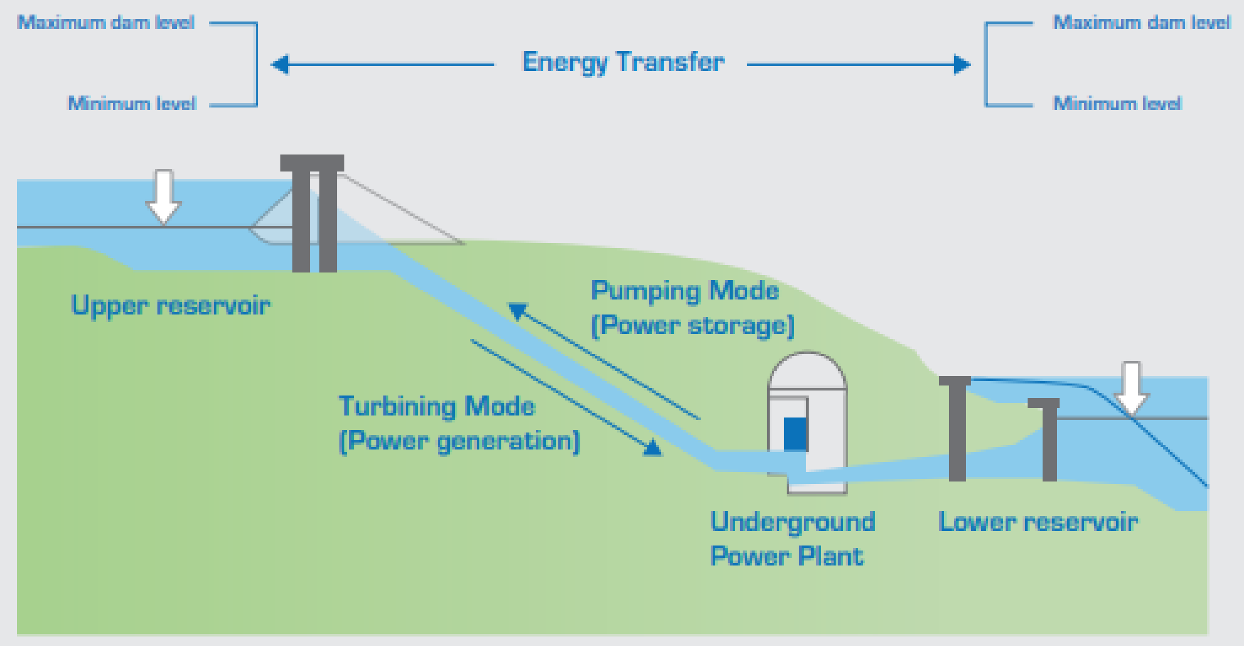
Description	Generally, this involves pumping water into a large reservoir at a high elevation—usually located on the top of a mountain or hill. When energy is required, the water in the reservoir is guided through a hydroelectric turbine, which converts the energy of flowing water to electricity.



Power range [1]	10 MW – 3.0 GW
Energy range	up to some 100 GWh
Discharge time	min – some 10h
Cycle life	technically unlimited
Life duration	> 80 years
Reaction time	some sec – few min
Efficiency [2]	70 - 85 %
Energy (power) density	0.5 - 3 Wh/kg
CAPEX: energy	40 - 150 €/kWh
CAPEX: power	400 - 1,500 €/kW

3. PCI Projects: Which Technology?

a. Mechanical Storage – Pumped Hydro Storage (PHS)

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State of the art	Generally speaking, PHS is the most mature storage concept in respect of installed capacity and storage volume. There are over 170 GW of pumped storage capacity in operation worldwide, with Europe accounting for approximately 33% of the market. PHS PCI projects are numerous.

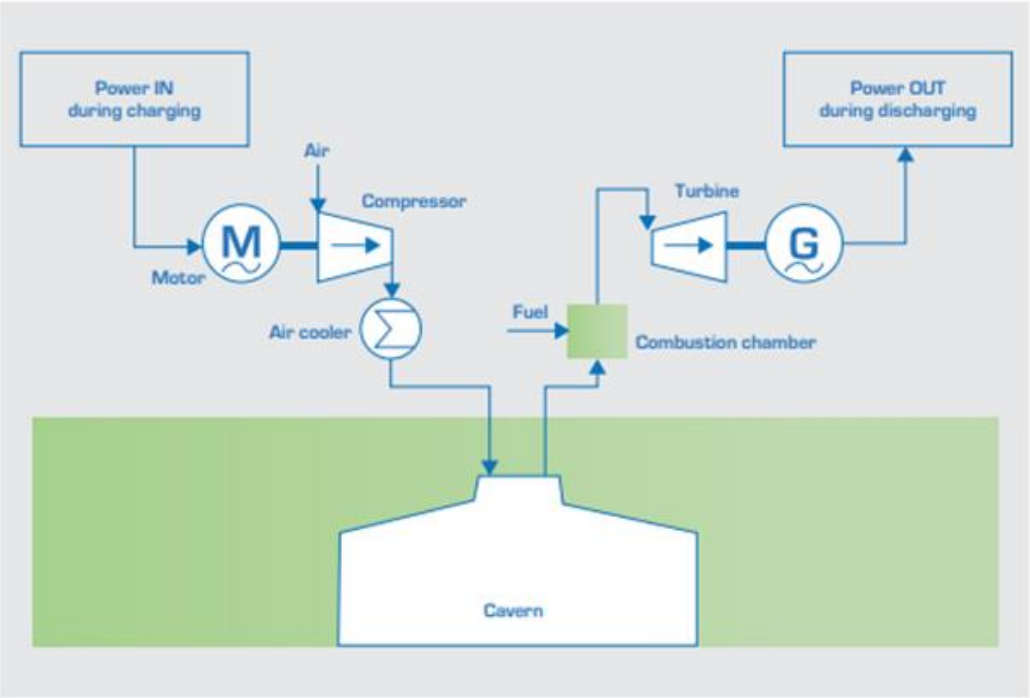
Applications

Due to their flexibility, large-scale storage possibilities and grid operations benefits, PHS systems will enable utilities to efficiently balance the grid and to develop their renewable energy portfolios. In fact the installation of intermittent renewable generation has added a new degree of uncertainty to the dispatch of interconnected power system. Pumped storage is therefore set to play a key role in enabling renewables' grid integration while helping countries meet their ambitious targets of cutting GHG emissions and of building additional clean renewable energy capacity.

3. PCI Projects: Which Technology?

a. Mechanical Storage – Compressed Air Energy Storage (CAES)

Description	CAES uses excess electrical energy to compress air using an electrically driven pump. When excess or low-cost electricity is available from the grid, it is used to run an electric compressor, which compresses air and stores it under high pressure. When energy is required, the compressed air is directed towards a modified gas turbine, which converts the stored energy to electricity.



Power range	Some 100 MWs
Energy range	100 MWh – 10 GWh
Discharge time	Some h – some 10h
Life duration	> 30 years
Reaction time	Some min
Efficiency	≈ 55 %
CAPEX: energy	50 - 150 €/kWh
CAPEX: power	400 – 1,200 €/kW

3. PCI Projects: Which Technology?

a. Mechanical Storage – Compressed Air Energy Storage (CAES)

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State of art	Although there are few CAES plants worldwide, CAES systems are becoming commercially available. CAES PCI projects presence is on the rise.

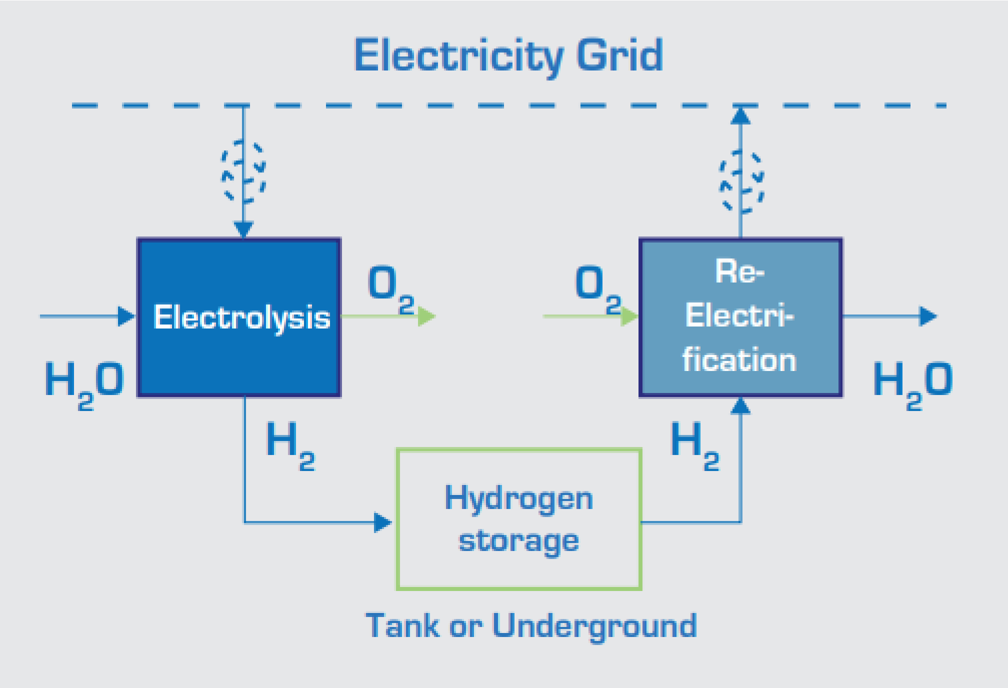
Applications

- Daily/weekly balancing
- Arbitrage
- Reserve
- Demand Services & other standard Ancillary Services

3. PCI Projects: Which Technology?

b. Chemical Storage – Hydrogen

Description	Chemical energy storage systems store electricity through the creation of chemical bonds. Defined as the utilisation of chemical species or materials from which energy can be extracted immediately or latently through different processes. For example: using power to create syngases, which can subsequently be used to generate power.



Power range	1 kW - 1 GW
Energy range	Some 10 kWh – several GWh
Discharge time	Some h – some weeks
Cycle life	n.a.
Life duration	5-30 years
Reaction time	<sec - <min
Efficiency	20-40 %*
Energy (power) density	30 - 2,550 kWh/m³ (H_2 tank storage)
CAPEX: energy	1-10 €/kWh
CAPEX: power	2,000 - 5,000 €/kW

3. PCI Projects: Which Technology?

b. Chemical Storage – Hydrogen

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State of the art	One chemical energy storage solution is hydrogen. Currently, there are many power-to-gas projects emerging in different European countries. Only a few of the demo projects have large scale storage and re-electrification in its scope.

Applications

Balancing demand & supply: seasonal & weekly fluctuations, ancillary services

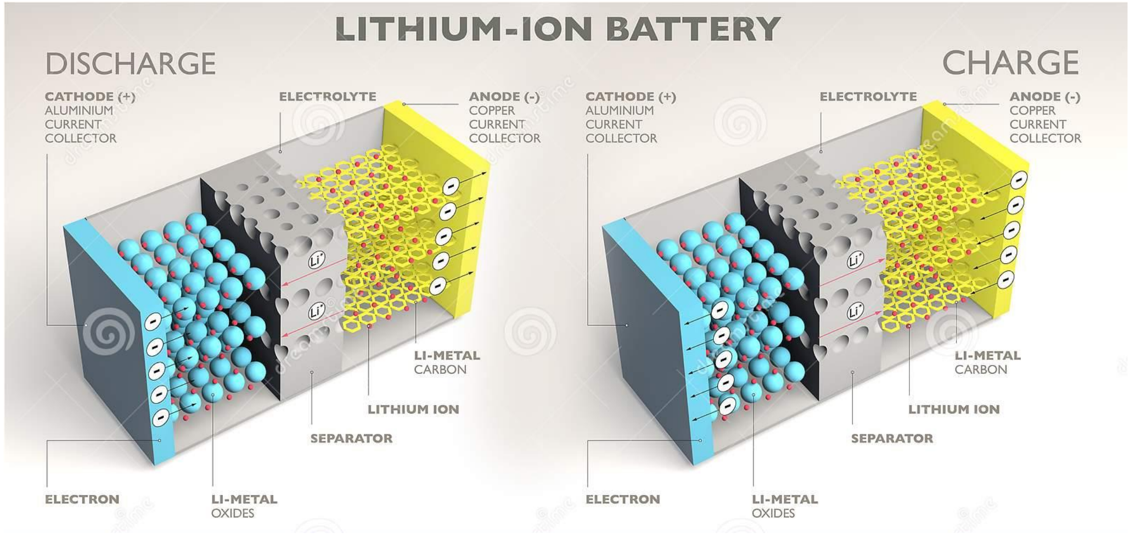
Grid management: grid extension alternative, grid reinforcements...

Hydrogen refuelling stations
Hydrogen production as raw material

3. Technologies

c. Electrochemical Storage – Classic Batteries

Description	Batteries are an energy storage technology that uses chemicals to absorb and release energy on demand. Unlike many other forms of energy storage, batteries can provide great flexibility. They can respond faster and help maintain grid stability by turning on and off in fractions of a second.



Power range	1kW to 50 MW
Energy range	Up to 10 MWh
Discharge time	10min to 4h
Cycle life	2,000 - 10,000 cycles
Life duration	15 – 20 years
Reaction time	Some millisec
Efficiency	90 - 98 % (*)
Energy (power) density	120 - 180 Wh/kg
CAPEX: energy	700 – 1,300 €/kWh
CAPEX: power	150 – 1,000 €/kW

3. Technologies

c. Electrochemical Storage – Classic Batteries

State of the art	Lithium-ion is the most common battery chemistry used to store electricity. Batteries PCI projects are on the rise.

Applications

Residential and commercial buildings: time shifting and self-consumption of locally produced PV energy

Distribution grids: voltage, capacity and contingency support of smart grids

Transmission grids: Ancillary services, namely frequency regulation

Renewable generation: smoothing and shaping functions associated with voltage and frequency support to ensure better integration of large renewable plants into the electricity system

PCI projects are not only about adding new capacity – they are also about smarter grids, better provision of different system services

4. Applications

Energy Storage Applications – Summary

- EASE divides the applications into **five main categories**:

Generation Support Services and Bulk Storage Services

Services to Support Transmission Infrastructure

Services to Support Distribution Infrastructure

Services to Support Behind the Meter Customer Energy Management

Ancillary Services

Conclusions

The importance of energy storage

- Renewable generation and energy storage go hand-in-hand with renewables deployment
- Energy storage itself embraces very different solutions that provide different services at different timeframes
  - Unsurprisingly, PCI projects rely on several technologies
- Focusing on energy storage projects (from an countries interconnection-perspective or not) has several benefits related to several aspects:
  - Technical
  - Cost savings
  - Market efficiency
  - Environment
  - Energy security / Geopolitical