# Long Duration Energy Storage (LDES) Council

March 2023 – K.EY conference Rimini – Alexander Schoenfeldt

The storage for the flexibility of the electric system

# About the LDES Council

# The LDES Council is formed by ~60 companies, from start-ups to large corporates in over 20 countries

**TECHNOLOGY PROVIDERS**

**ANCHOR MEMBERS**

- Industry & services customers
- Capital providers
- Equipment manufacturers
- Low-carbon energy system integrators & developers

Membership overview as of March 2023

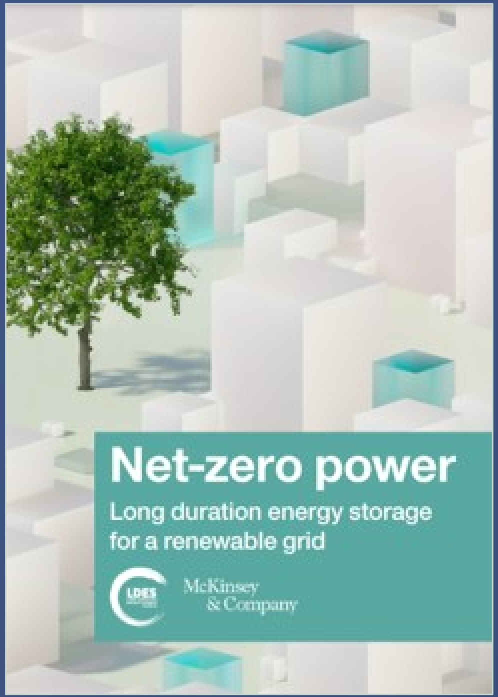
## Key principles of the LDES Council

- Executive-led
- Global
- Fact-based
- For societal benefit
- All types of energy storage (Chemical, Thermal Electrochemical, Mechanical)

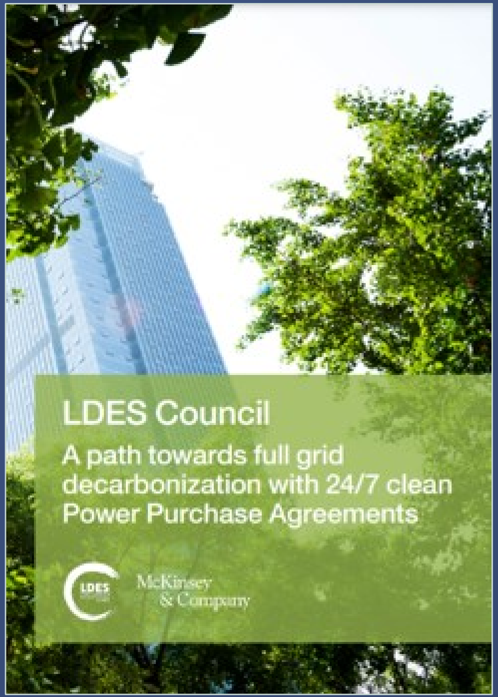
The LDES Council is an independent body with its own governance structure, with the mission to accelerate energy decarbonization through the scale-up of LDES

# The LDES Council Reports

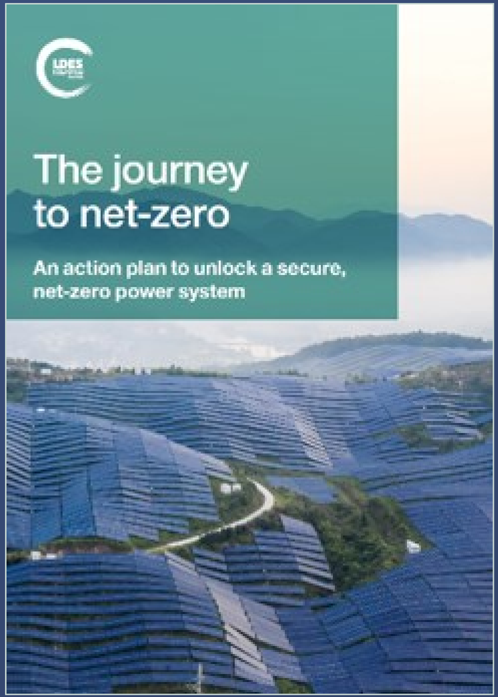
## Net-zero power



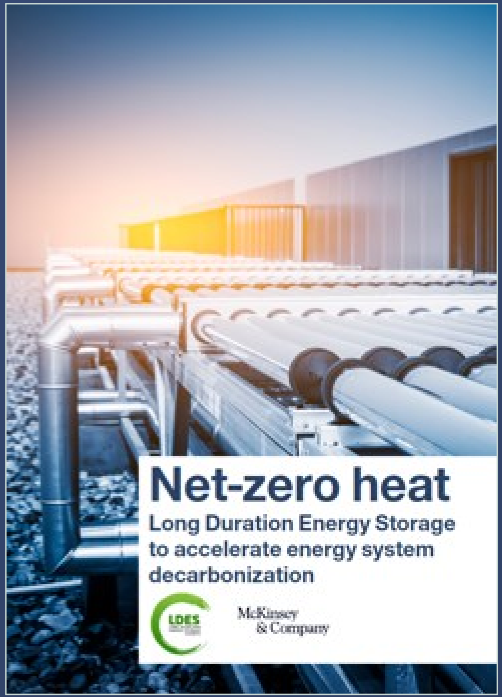

## 24/7 clean PPAs




## Policy Toolbox




## Net-zero heat




November 2021

May 2022

June 2022

November 2022

# LDES Council technology providers by technology type

## Thermal

| Member | Sub-Archetype |
|---|---|
| Azelio, 1414 Degrees, TORC, MGA Thermal | Latent heat (solid-liquid) |
| Brenmiller, Echogen power systems, EnergyNest, Kraftblock, Magaldi, Storworks, Electrified Thermal Solutions, Antora, Rondo | Sensible heat (solids) |
| Kyoto, Malta | Sensible heat (solids / liquids) |
| SaltX | Thermochemical (salt) |

## Electrochemical

| Member | Sub-Archetype |
|---|---|
| redflow | Hybrid flow battery (ZnBr) |
| eos | Aqueous Zinc Halide |
| cellcube, Invinity | Aqueous (VRFB) |
| Enlighten | Aqueous (NaSICON membrane) |
| Ambri | Metal anode (Calcium) |
| EnerVenue | Metal anode (Nickel Hydrogen) |
| ESS Inc | Metal anode (iron flow battery) |
| e-zinc | Metal anode (Zn) |
| Form energy | Metal anode (iron air battery) |
| VoltStorage | Metal anode (Iron salt) |

## Mechanical

| Member | Sub-Archetype |
|---|---|
| Breeze, Hydrostor, Siemens energy | CAES |
| RheEnergise, Mine Storage | Gravity-based PS |
| Energy Vault | Gravity-based |
| Energy Dome | Liquified $CO_2$ |
| Rye Development | Closed loop PHS and run of river |
| Pumped Hydro Storage SENS, Quidnet Energy | PHS |

## Chemical

| Member | Sub-Archetype |
|---|---|
| ceres | Solid oxide fuel cell |



Membership overview as of March 2023

# CellCube is leading VRFB provider of MW-scale BESS installations with 3-10 hours both in grid and industrial applications

### Electric power equipment – Resilient Microgrid in Illinois, US

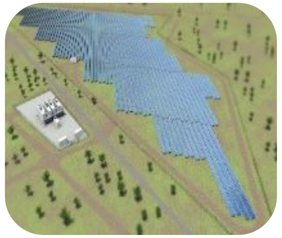
G&W Electric

| | |
|---|---|
| Market sector | Industrial Microgrid |
| Location | Bolingbrook, USA (2023) |
| CellCube Product | 4 x FB 500-2000 |
| Key Applications | Energy shifting, peak shaving, UPS, PJM |
| Rated power / capacity | 2MW / 8MWh |

### Medical Equipment - Resilient Microgrid in California, US

Applied Medical

| | |
|---|---|
| Market sector | Industrial Microgrid |
| Location | Santa Margarita, California, US (2022) |
| CellCube Product | 1 x FB500 – 2000, 1x FB250 - 1000 |
| Key Applications | Energy shifting, offgrid, backup |
| Rated power / capacity | 0.75MW / 3MWh |



### Mining Plant - moving towards net-zero, South Africa

BUSHVELD ENERGY

| | |
|---|---|
| Market sector | Remote Microgrid |
| Location | Brits, South Africa (2023) |
| CellCube Product | 2 x CellCube FB 500-2000 |
| Key Applications | Energy shifting, renewable integration |
| Rated power / capacity | 1MW / 4MWh |

### Lighthouse Project, Australia

NORTH HARBOUR CLEAN ENERGY

| | |
|---|---|
| Market sector | Industrial Microgrid |
| Location | Sydney Area, Australia (2024) |
| CellCube Product | 12 x CellCube FB333 - 2666 |
| Key Applications | Energy shifting, FFR, arbitrage |
| Rated power / capacity | 4 MW / 16MWh |

### Grid Company – Renewable Integration, Austria
### >10 years in continuous operation (COD in 2010)

EVN

| | |
|---|---|
| Market sector | Critical Infrastructure |
| Location | Lichtenegg, Austria (2010) |
| CellCube Product | 1 x CellCube FB 10-100 |
| Key Applications | renewable integration, DSM |
| Rated power / capacity | 10 kW / 100kWh |

### Grid Company - Resilience for energy community, Sweden

e.on

| | |
|---|---|
| Market sector | Critical Infrastructure |
| Location | Simris, Sweden (2019) |
| CellCube Product | 1 x CellCube FB 250-1000 |
| Key Applications | Renewable baseload, Islanding |
| Rated power / capacity | 0,25MW / 1MWh |

### Grid Company – Congestion Mgmt - Brazil

WEG

| | |
|---|---|
| Market sector | Critical Infrastructure |
| Location | Ipiranga, Brazil (2022) |
| CellCube Product | 1 x CellCube FB 250-1000 |
| Key Applications | Peak Mgmt, Frequency / Voltage Regulation |
| Rated power / capacity | 250kW / 1000 kWh |

### Grid Company - ESS Test Facility, Italy

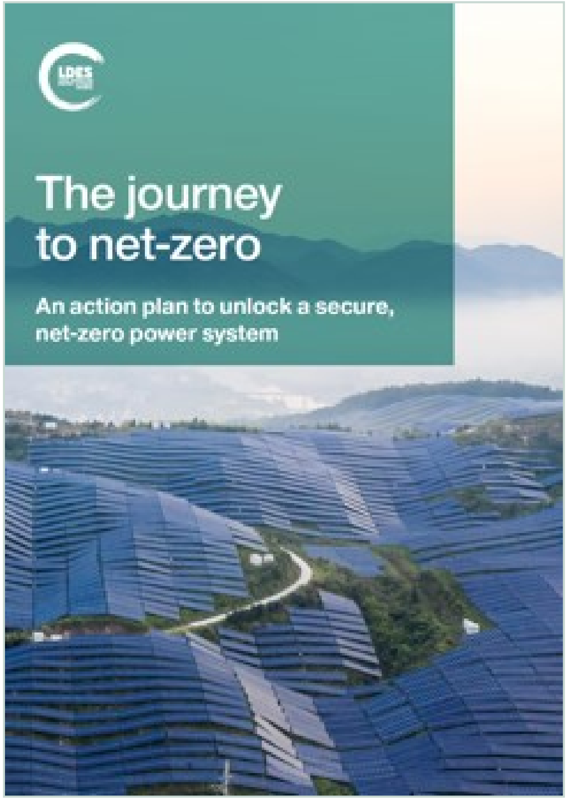
Terna Driving Energy

| | |
|---|---|
| Market sector | Critical Infrastructure |
| Location | Sardinia, Italy (2016) |
| CellCube Product | 2x CellCube FB 200-800 |
| Key Applications | FCR, VAR, Trading, Test of Degradation |
| Rated power / capacity | 400 kW / 1200 kWh |

# The storage for the flexibility of the electric system

# Policy & Regulatory Tools Report

Key Takeaway: There are a wide range of well-tested tools available to policymakers looking to accelerate the role of LDES in power systems




## The Council developed a "toolbox" of different options for consideration

### Long-term market signals

Inform the trajectory of the energy system

- Carbon pricing and greenhouse gas reduction targets
- Procurement targets
- Grid planning
- Renewable energy targets
- Phase-out of fossil fuel subsidies
- Storage capacity targets

### Revenue mechanisms

Enhance the viability of projects

- Cap and floor
- Long term bilateral contract for balancing / ancillary services
- Capacity market
- Nodal & locational pricing
- Contract for Difference
- Regulated asset base
- Hourly energy attribute certificates
- 24/7 clean PPA

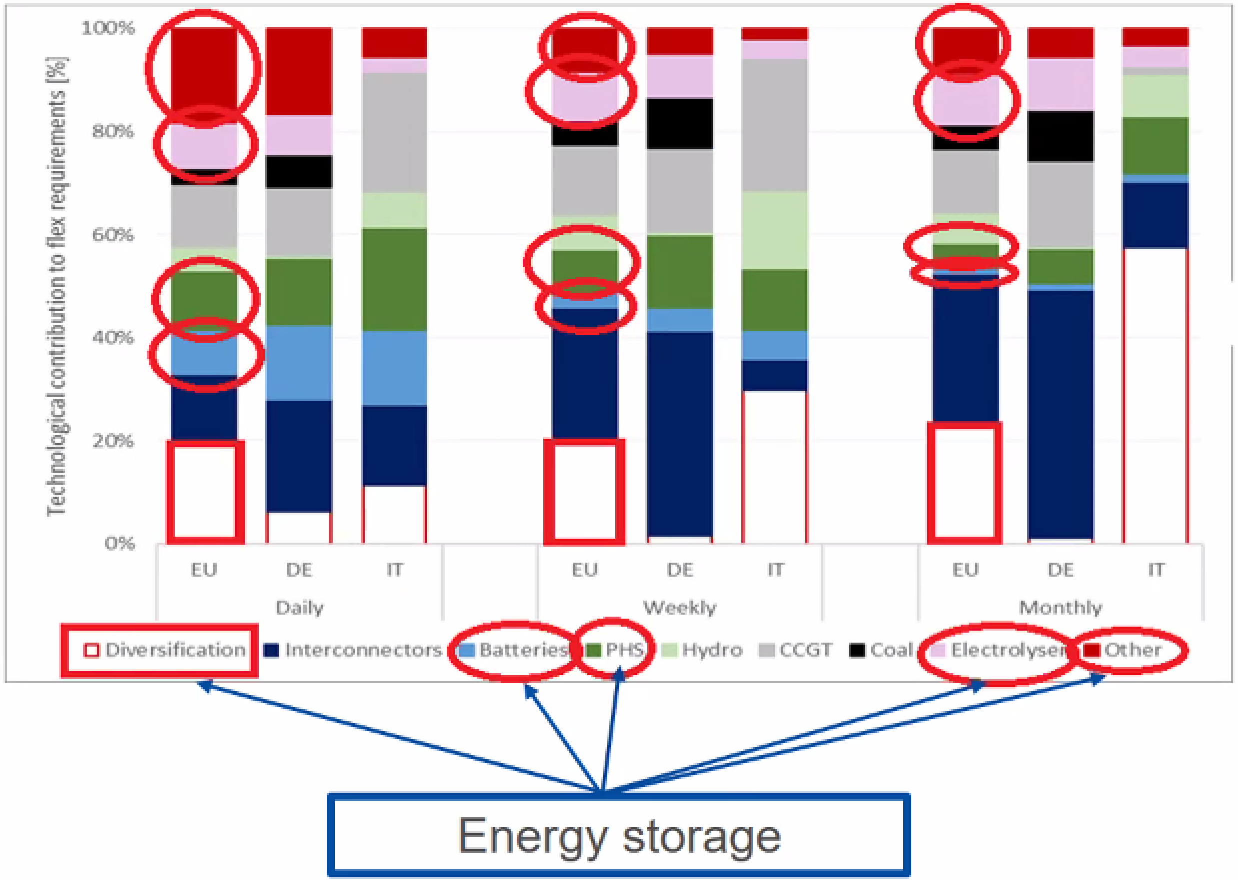
### Direct technology support and enabling measures

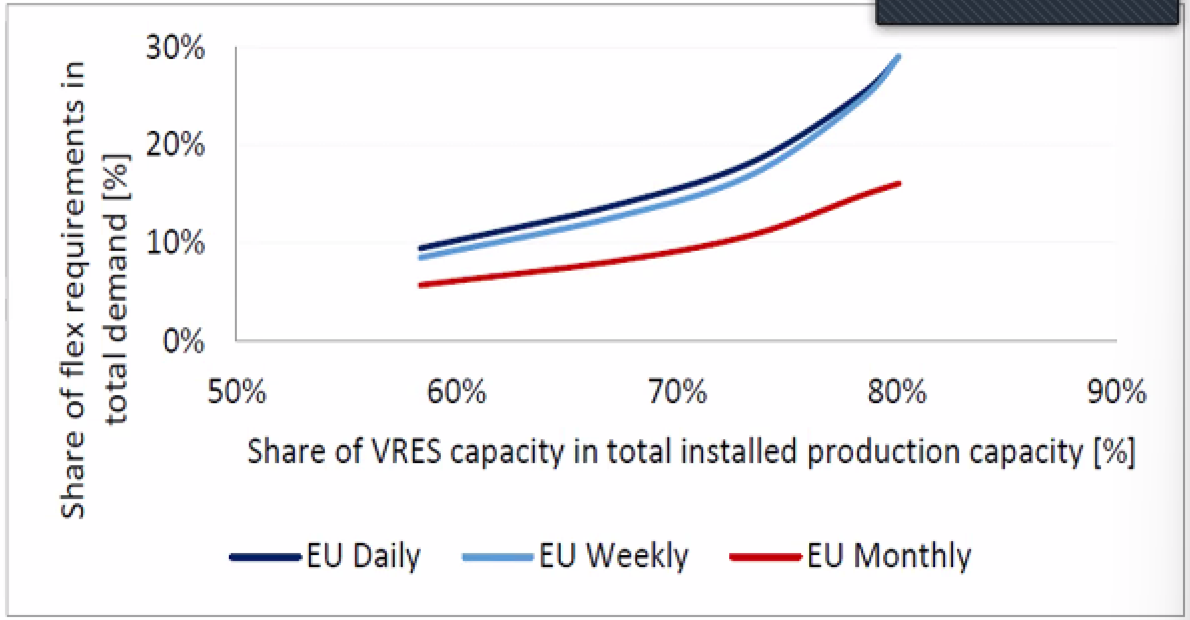
Create pathways for access and uptake

- Grants and incentives
- Investment de-risk mechanisms
- Sandboxes
- Market rules
- Targeted tenders
- Technology standards

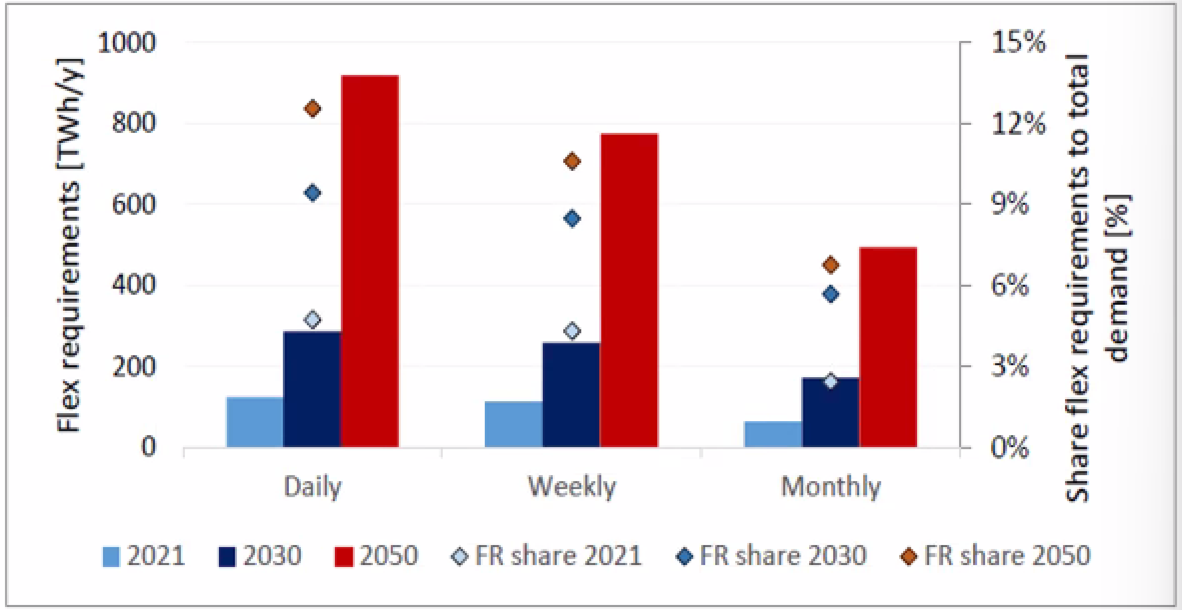
# Role of energy storage

Technological contribution to flexibility requirements
in the EU, Germany and Italy, 2030




Flexibility requirements and their share to total demand (FR share) in the EU




*Source*: JRC analysis.



Source: March 2023 Beatriz Sinobas, DG ENER Unit B4

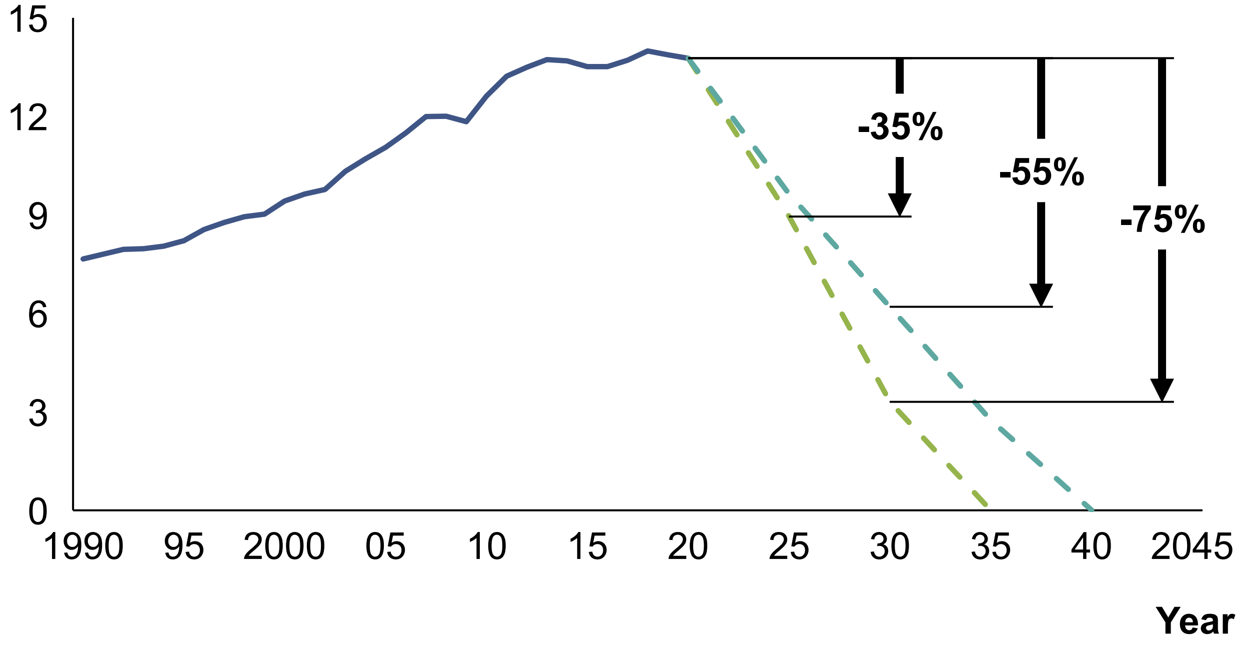
# Energy transition increasingly about more than decarbonization – energy security and affordability are key imperatives

Historical emissions — Net-zero 2035 (MEDCs reference case)[1] — Net-zero 2040 (Global reference case)[2]

## Deep and early decarbonization of power sector is key to achieving 1.5 C targets

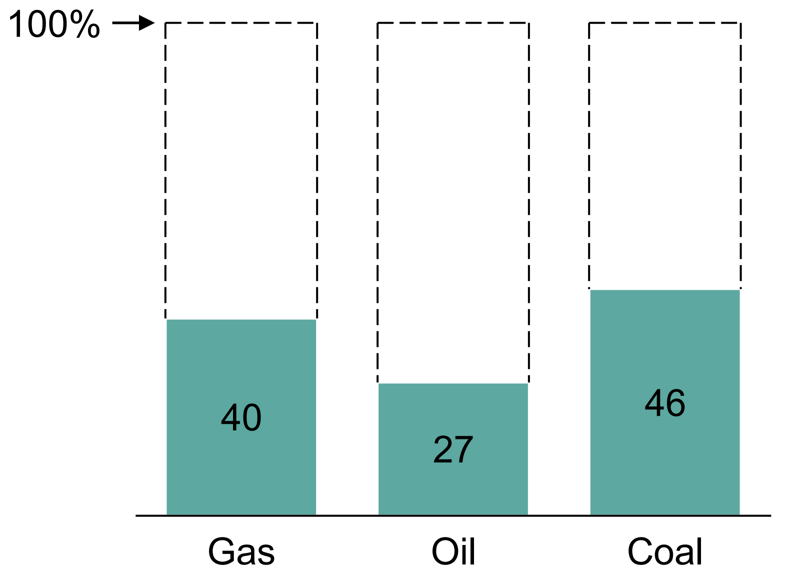
Global historical emissions of the power sector and assumed reduction pathways

**Gt $CO_2e$**




## Energy transition also seen as means to reduce dependence on imports

European Union imports from Russia, %, 2021



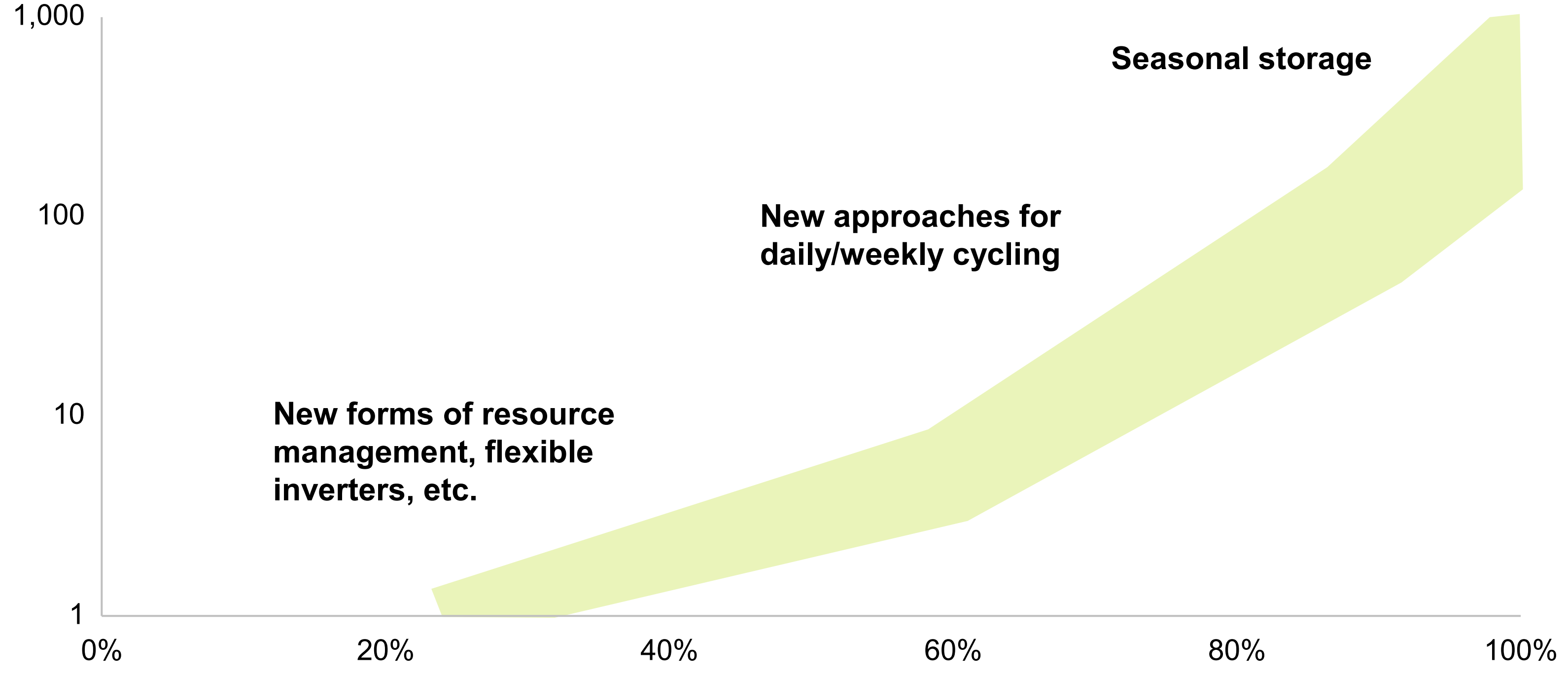

1. Informed by IEA Net Zero 2050 report on more economically developed countries (MEDCs) needs to get to net zero power by 2035. Consistent with US President Biden climate ambition.
2. Informed by IEA Net Zero 2050 report on the world's power sector needs to get to net zero by 2040.

Source: Net-zero power: Long duration energy storage for a renewable grid (November 2021), IEA, European Commission

# Long Duration Energy Storage (LDES) will be required to get to net-zero power systems

## Adoption curve of longer flexibility durations accelerates at 60-70% RE penetration

**Storage duration,** hours at rated power




**Percentage of annual energy from wind and solar in a large grid**

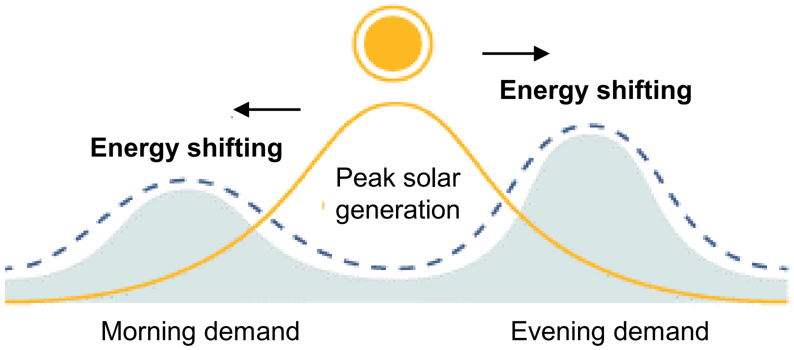
### RES integration leads to new system challenges

- Power supply and demand not always in balance
- Transmission flow changes potentially require costly and lengthy transmission upgrades
- Retirement of conventional, synchronous generators creates need for new sources of grid support services, e.g., reactive power, inertia

Source: Advanced Research Projects Agency–Energy

# Long Duration Energy Storage deployed in different contexts

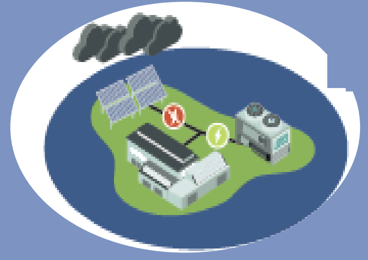
## LDES unlocks many different use cases




**Energy shifting**

+

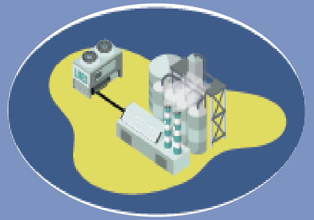
**Grid services**



Optimizing transmission & distribution investment

Firming renewable PPAs for heat and power

Supporting island grids



Supporting industries with remote and unreliable grids for heat and power

# LDES typically offers two major value propositions

## Energy shifting

| Time horizon | Role of storage | Typical solution |
|---|---|---|
| **Intraday** | Balance variable daily generation with load | **8-24 hours LDES** |
| **Multiday, multiweek** | Support multi-day imbalances<br>Absorb surplus generation to avoid grid congestion | **24+ hours LDES** |
| **Seasonal duration** | Support during seasonal imbalances<br>Mitigate extreme weather events | **Pumped hydro, compressed air, Hydrogen** |

+

## Grid services

**Grid services offered by LDES**

- **Inertia**
- **Fast frequency response (FFR)**
- **Primary/secondary/tertiary reserve**
- **Reactive power/voltage control**
- **Short circuit level improvement**
- **System restoration/ black start**

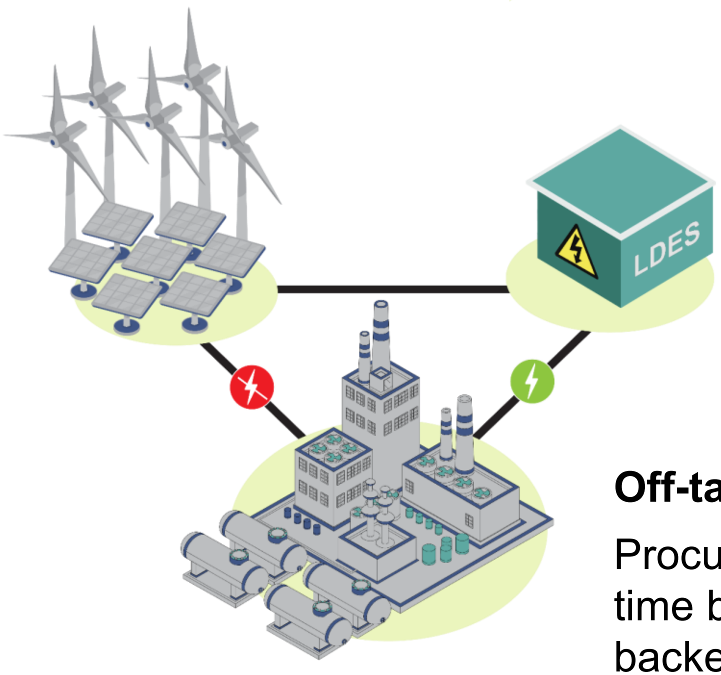
*Note: services are technology-specific*

# Already today, 24/7 clean PPAs can enable investments in time-matched clean power supply – typically the solution includes storage

## Hybrid system as technical solution for 24/7 clean PPA

### Renewables generation

Often Solar and Wind, i.e., non-dispatchable generation




### Energy storage

Dispatchable energy storage enables supply when there is no direct renewable generation

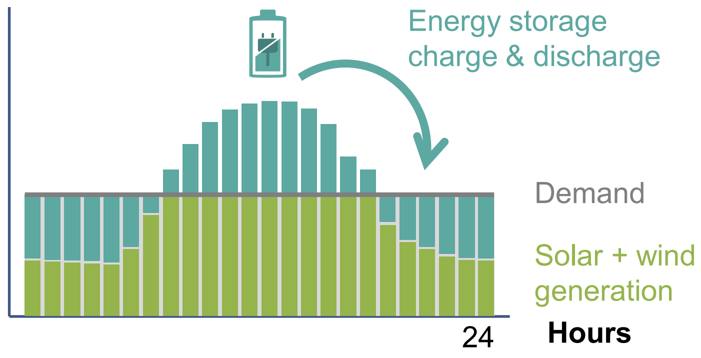
### Off-taker

Procuring clean power on a granular time basis through 24/7 clean PPA backed by renewables and storage

## Time-matched clean supply

### Storage enables matching of clean power supply and demand

Clean power that is supplied for each unit of demand, measured at granular time intervals (e.g., 1 hour or less)

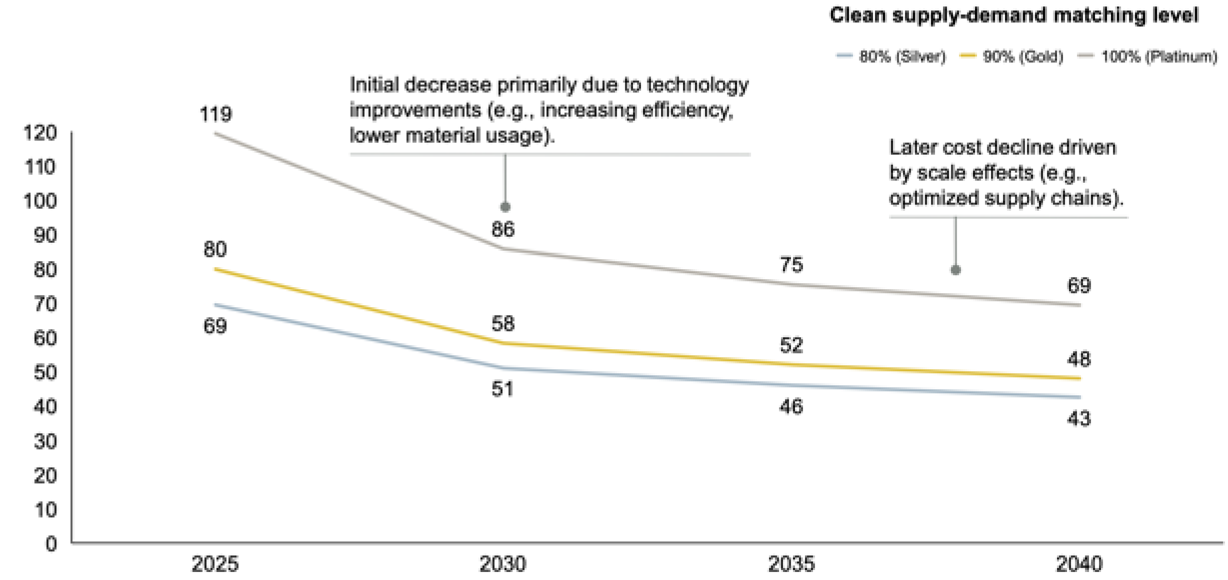



Source: Report "A path towards full grid decarbonization with 24/7 clean Power Purchase Agreements" (LDES Council, McKinsey)

# LDES and Renewables: paired symmetry

## RES + Storage LCOE to decrease as LDES technologies mature

**RES + Storage LCOE[1] for 100 MW baseload 24/7 supply in California over years**
USD / MWh

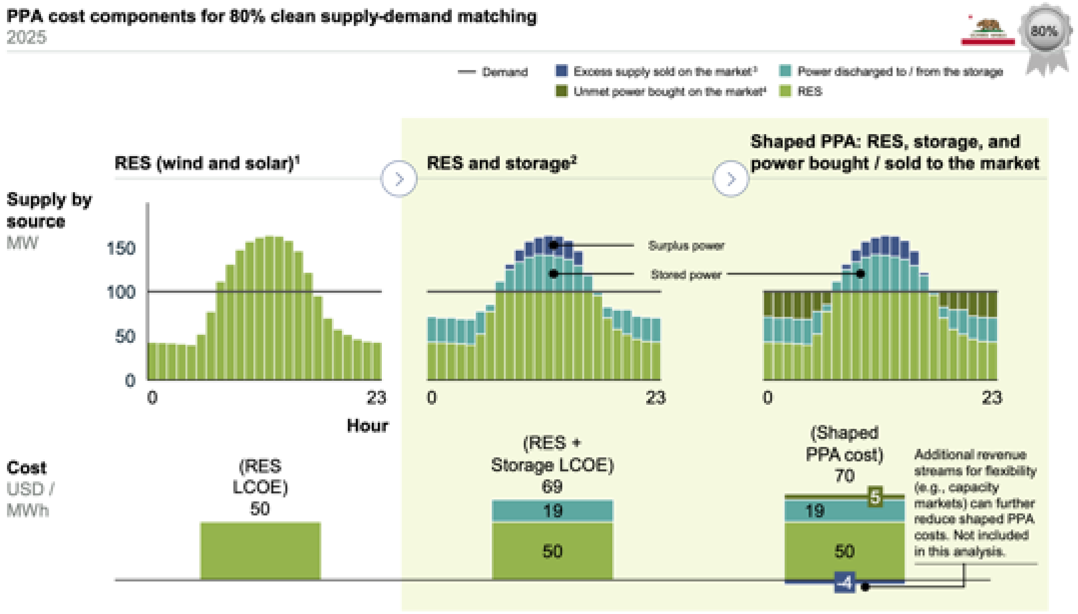



1. RES + Storage LCOE is calculated as: (annualized cost of renewable generation + storage capacity) / clean energy delivered to the off-taker. This excludes additional costs / revenues that would impact final PPA price.

Source: LDES Council 2021 technology benchmark and report, McKinsey Power Model.

## The Shaped PPA Cost consists of renewables and storage LCOE, and cost balance of buying and selling power to the grid

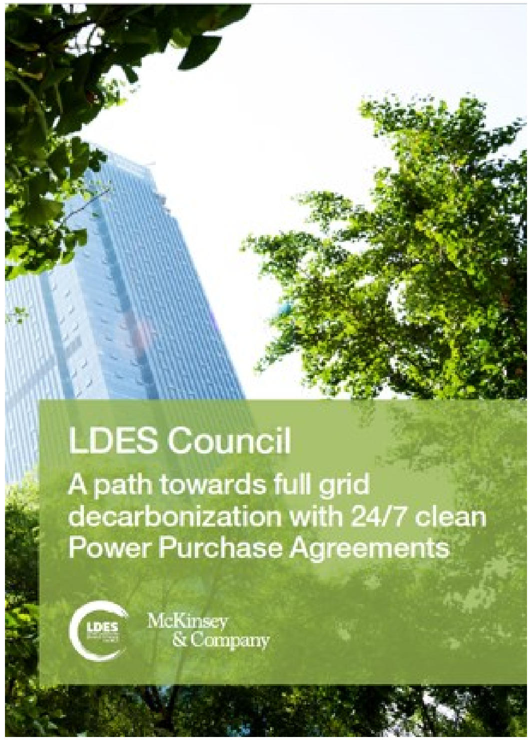
**PPA cost components for 80% clean supply-demand matching**
2025




1. Calculated as total costs over energy delivered by solar and wind.
2. Calculated as the total cost of the capacity mix divided by the energy delivered by the renewables and the storage.
3. Surplus power from PPA RES assets sold to the day-ahead market. That excess is assumed to be sold during the average price for cheapest % of hours (where % of hour is equal to the % of time that there is excess generation).
4. Power bought 20% of the hours when supply from low-carbon sources is unable to meet demand. The price at those hours is assumed to be the price of the 20% most expensive hours (as met by peaking assets).

# 24/7 Clean PPA Report

## Findings: 24/7 clean PPAs boost flexibility to fully decarbonize power




### Today's clean power PPAs…

**100% RES**

Today's 100% RES power procurement typically only achieves 40-70% emission reduction due to variable generation

**>$200/MWh with Li-Ion**

LCOE of renewables plus Lithium-Ion battery hybrid solutions in most regions

### Future 24/7 clean PPAs…

**0 gCO2/kWh possible**

Full decarbonization through temporal and geographic matching of supply and demand

**<$100/MWh with LDES**

LCOE of renewables plus LDES may decline to <$100/MWh before ~2030 for 100% demand matching

### Carbon optimized 24/7 clean PPAs…

**+100%**

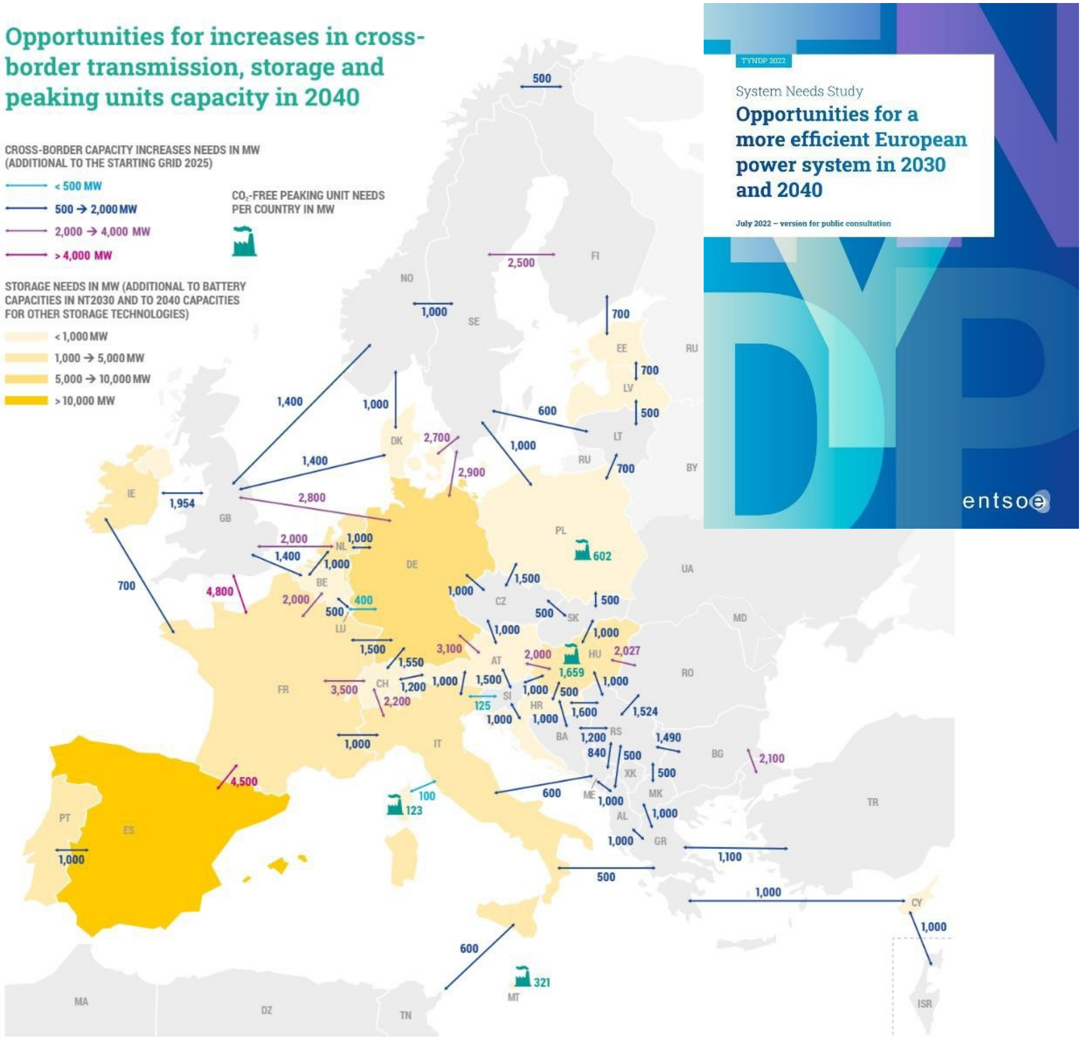
Additional system-level CO2 abatement when dispatch is partly optimized (80% instead of 100% matching level) with same system configuration

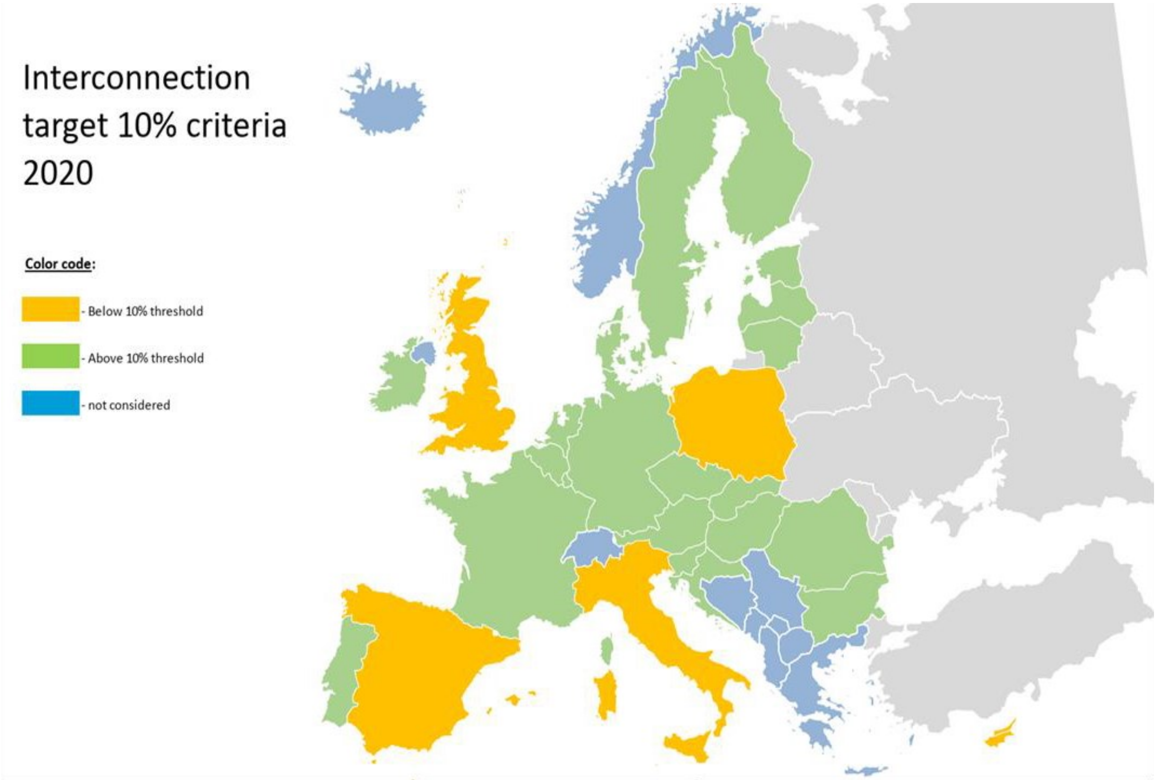
**10-30%**

Additional cost reduction potential when dispatch is partly optimized (80% instead of 100% matching level) with same system

https://www.ldescouncil.com/assets/2205_ldes-report_247-ppas.pdf

# ENTSO-E maps needs for storage in 2040



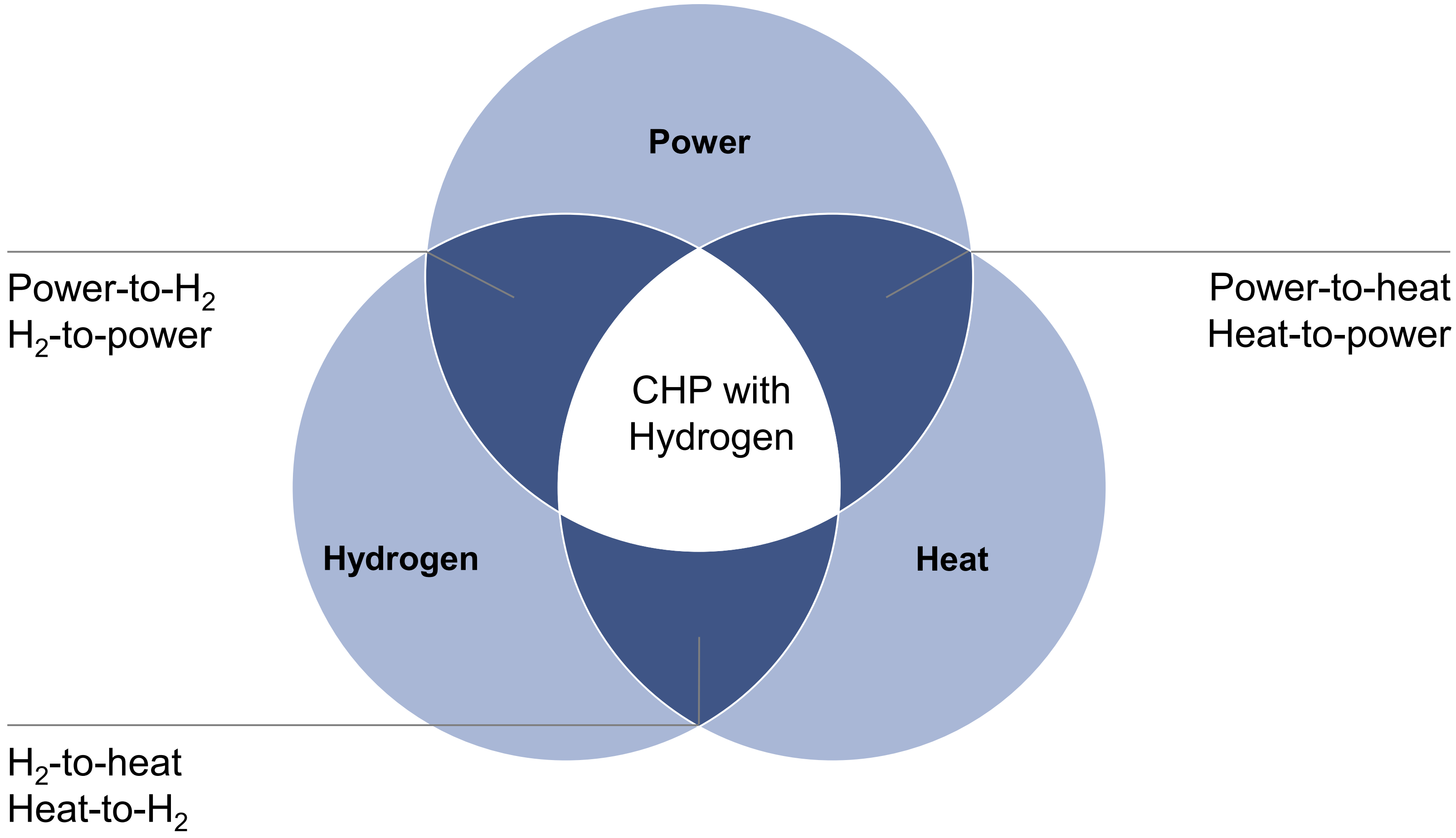

Fullfillment of the 10% EU interconnection target in 2020

https://eepublicdownloads.entsoe.eu/clean-documents/tyndp-documents/TYNDP2018/rgip_CSW_Full.pdf

Source: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/system-needs-report.pdf

# The transition to net zero requires an integrated energy system perspective

**Maximize energy system flexibility to integrate variable renewables**



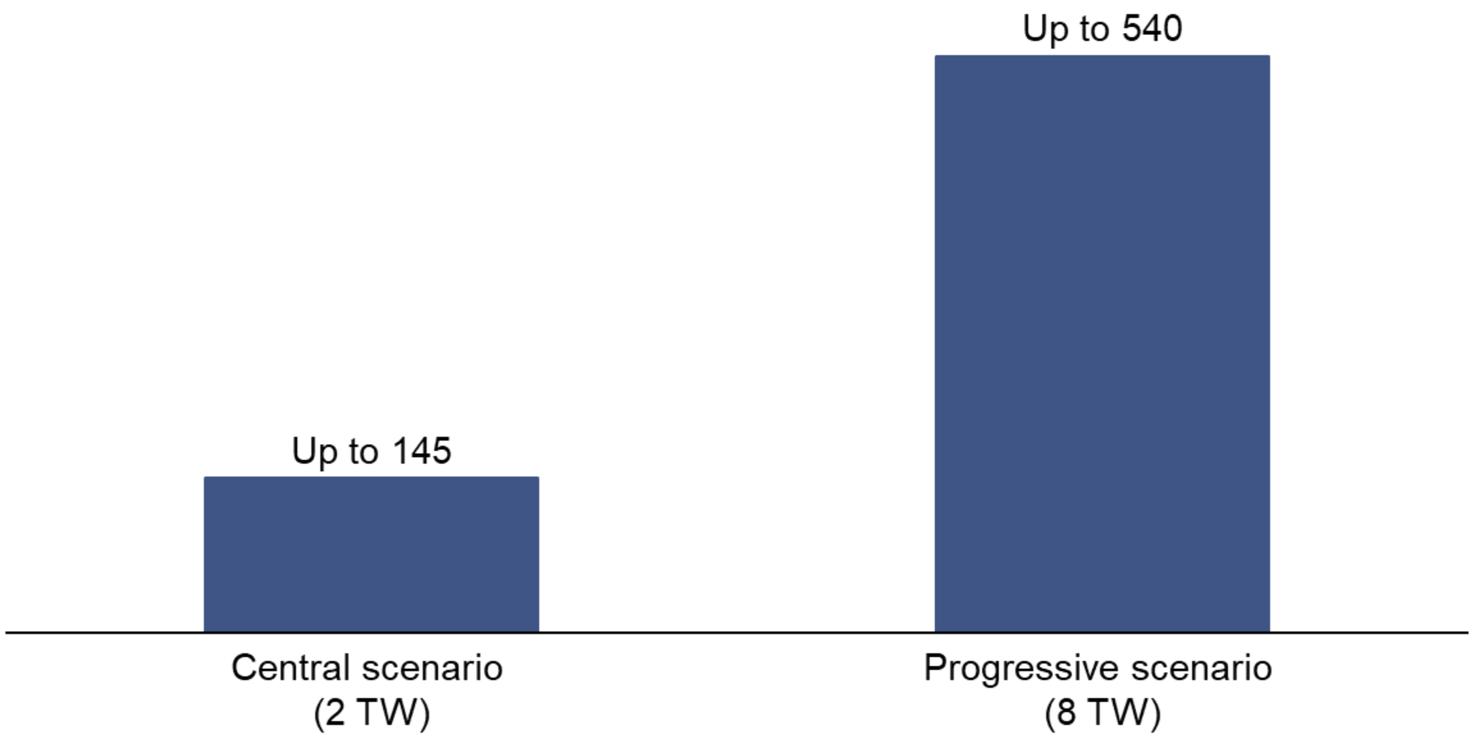

Maximize flexibility within power, hydrogen and heat to meet 24/7 energy system needs

Increase interconnections between power, hydrogen and heat

Increase fixed infrastructure utilization and improve resiliency

# System integration could save up to $540 billion annually

**Potential global savings generated by LDES in 2040**[1]
$ billions/year




1. Savings modelled based on estimated cost savings of up to USD 70 million per GW of LDES capacity installed, including fuel savings, and better utilization of variable generation resources

The introduction of LDES provides a longer duration firming capacity and thereby **reduces the need for energy curtailment or redispatch**

The system savings coming from LDES technologies are driven mostly by **reduction of fuel costs**

This system optimization translate into potential savings of USD 145 billion in a 2 TW case and **USD 540 billion annually** by 2040 in an 8 TW case

LDES
LONG DURATION
ENERGY STORAGE
COUNCIL

Thank you!