Net-zero power

Long duration energy storage for a renewable grid

Report overview and Q&A

January 19th, 2022

LDES LONG DURATION ENERGY STORAGE COUNCIL

REA RENEWABLE ENERGY ASSOCIATION

We are joined today by several LDES Council members - as well as McKinsey, Knowledge Partner of the Council

LDES Council members

Rachael Reid
Strategy Lead: Hydrogen and CCUS, bp

Colin Roy
Executive Chairman, Highview Power

Council's Knowledge Partner

Godart van Gendt
Expert Associate Partner, McKinsey & Company

Covered today

LDES Council Introduction	**10’**
Presentation of the report findings	20’
Q&A	10’
Closing remarks	5’

The Long Duration Energy Storage (LDES) Council was launched at COP26

Signing of statements of intent and launch ceremony

Introduction to the Council

Networking lunch

To date, 35 leading companies have joined the LDES Council to accelerate decarbonization

Technology providers

Highview Power
AZELIO
Form energy
ENERGYDOME
VOLTSTORAGE
ceres
ENERVENUE
Quidnet Energy
e-zinc
ENLIGHTEN
Stiesdal
TORC
eos
MALTA
ESS INC
redflow
ECHOGEN power systems
INVINITY ENERGY SYSTEMS
MAGALDI Dependable technologies
Ambri
cellcube
KRAFT BLOCK

Anchors

Industry and services customers

RioTinto
Google

Capital providers

Breakthrough Energy

Equipment manufacturers

ALFA LAVAL
SIEMENS energy
Baker Hughes

Low-carbon energy system integrators & developers

bp
Greenko
NEOM نيوم
Ørsted
corre energy

Membership overview on January 13th 2022

Key principles of the LDES Council

- CEO-led
- Global
- Fact-based
- For societal benefit
- All types of energy storage, not just electrochemical

The LDES Council is united in a clear mission

The LDES Council is a **global**, **CEO-led organization** that **strives to accelerate decarbonization of the energy system at lowest cost to society** by driving innovation, commercialization and deployment of **long duration energy storage.**

LDES Council **provides fact-based guidance and information** to governments, industry and broader society, drawing from the experience of its members, which include **leading energy companies, technology providers, investors and end-users.**

Numerous areas identified for LDES Council to make a difference

Varied LDES terminology used to describe market and value proposition

Individual LDES technologies making their own case

Limited ability to monetize value created by LDES technologies in energy and power markets

A converging LDES language and fact-base on the industry to build momentum

Cross-technology LDES narrative to build strength of sector as a whole

An amplified voice towards stakeholders and investors to unlock efficient market designs

The LDES Council has unique strengths that sets it up as a thought-leader in decarbonization

Benefits from global footprint and provide perspective on industry trends and Net-zero pathways

Leverages and develops advanced power models driving analytical insights

Objective and neutral standing, using external credible benchmarks (e.g., IEA, Hydrogen Council, BNEF)

Taps into unique data sets from real technology deployments provided by leading LDES technology members

Provides deep technology and application understanding of LDES tech and anchor members, incl. real business case

Includes access to wide network and stakeholder contacts across individual members to amplify reach

- **Actionable insights** – develop perspectives on technologies, cost trajectories etc.
- **Respected fact-base** – provide independent and industry informed benchmarks

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- **Proactive communication** – catalyze active discussions with external stakeholders
- **Amplified voice** – elevate LDES vision through a coordinate action between members and societal stakeholders

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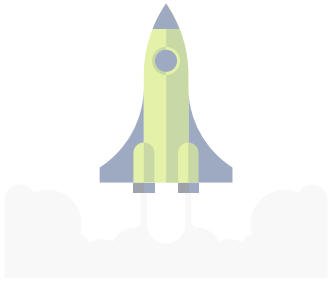
- **Community building** – convene stakeholders across the value chain with diverse perspectives on sector priorities
- **Tackling the hardest problems together** – ideate collaborative solutions to sectoral issues

The LDES Council vision is to be a globally leading voice on LDES technologies, deployments, and insights

Activity Vision



2021

- Kickstart Council membership and insights
- Launch at COP26 and release first report
- Align on Council vision, activities and governance

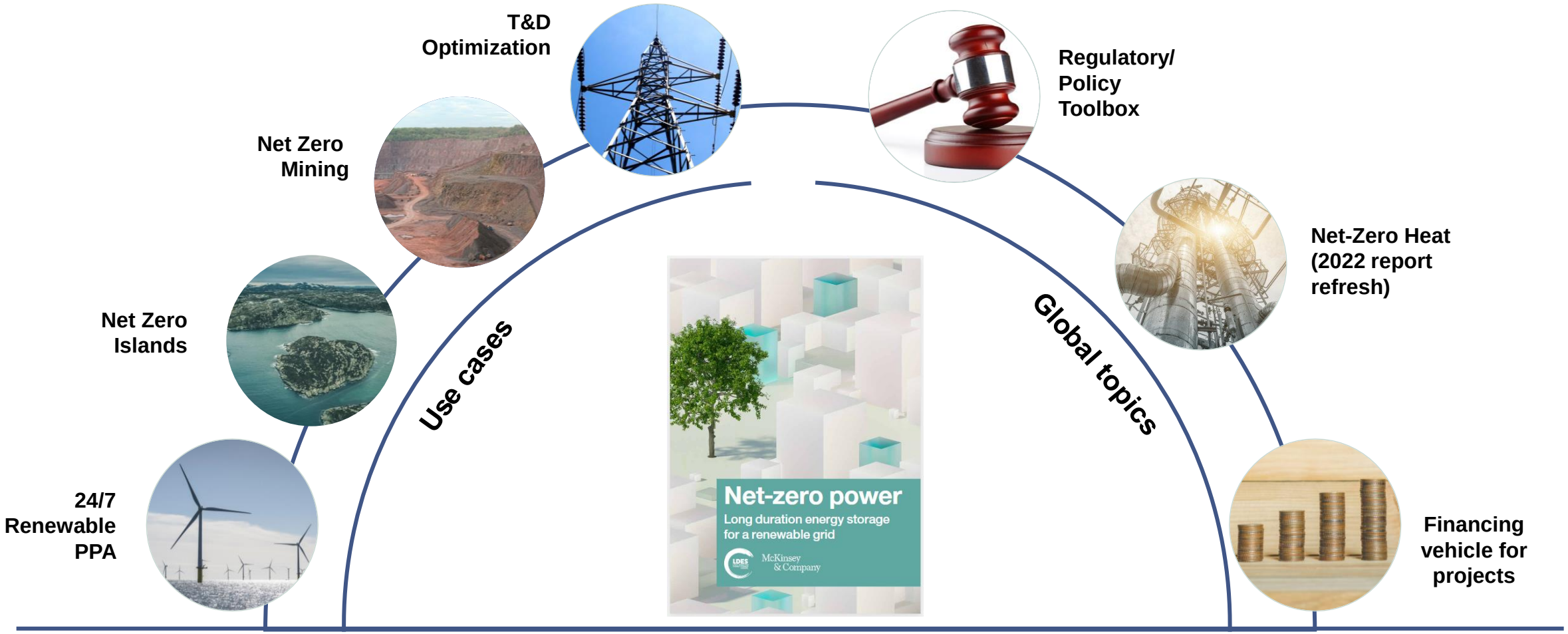
2022

- Establish the Council as a thought-leader
- Formalize Council structure and elect President and Board
- Grow Council membership
- Disseminate initial report broadly and develop follow-on publications

Our vision

- Grow to become the leading, trusted voice in industry and society
- Uphold reputation for high quality insights
- Tackle the critical & most challenging problems
- Empower a flourishing community of diverse and engaged members

In 2022, the Council will pursue insights supported by the expertise and engagement of its growing membership



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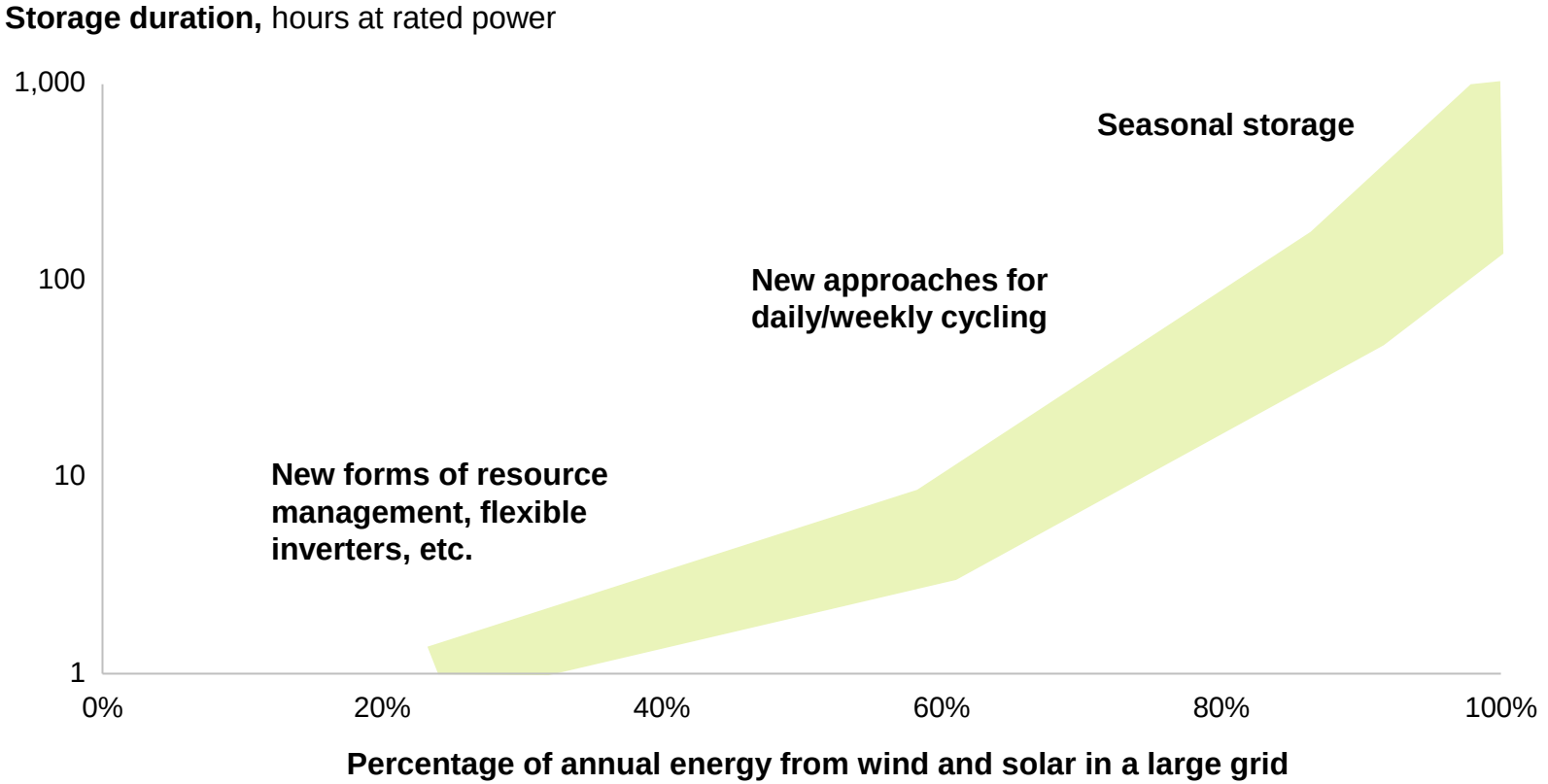
Flexibility is critical for decarbonisation of power systems

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



Source: Advanced Research Projects Agency–Energy

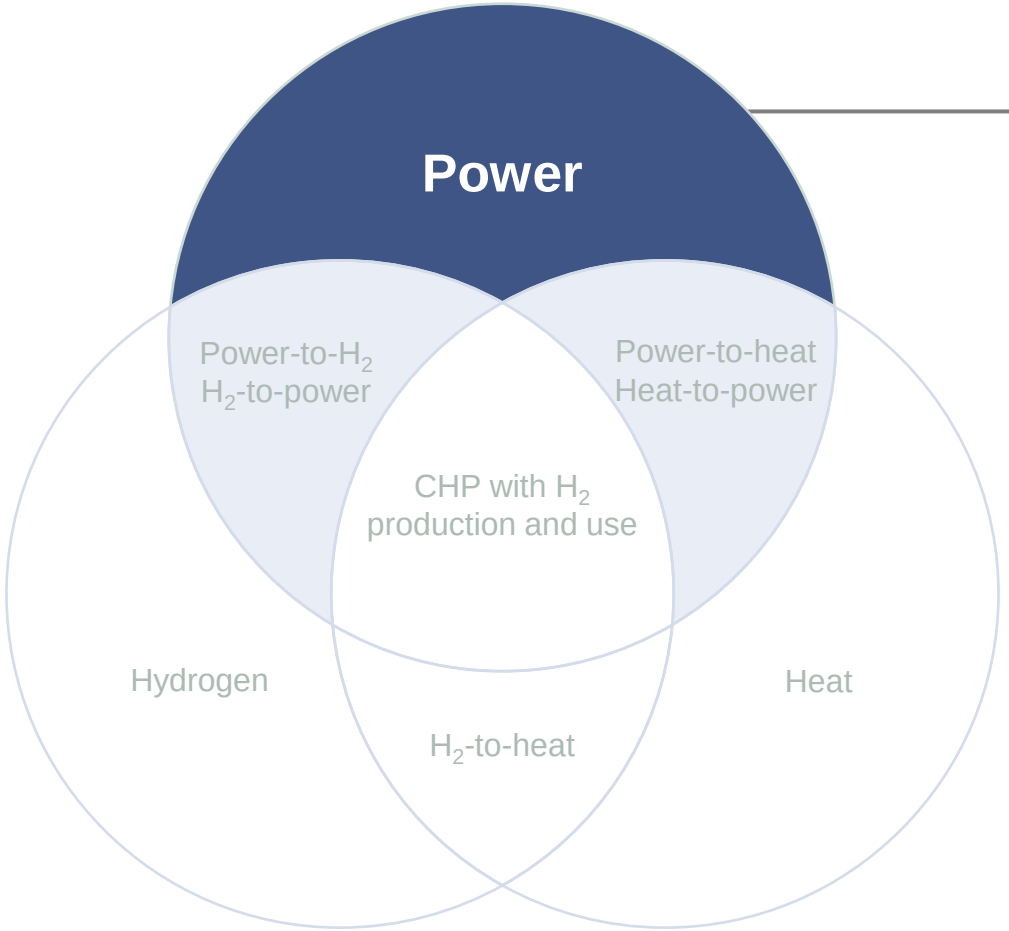
RES integration leads to new system challenges

- 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

1st report of Council focuses on power system flexibility

Scope of this first report

LDES operates at the nexus of power, heat and hydrogen energy systems



Power system flexibility – role of LDES

Cost and performance analysis

Real LDES system cost down trajectories, LCOS analysis etc.

Modelling the flexibility needs of future power systems

LDES market size, deployment projections, investment etc.

Business cases from customers' perspective and market unlocks

NPV, investment values etc.

The analysis uses the McKinsey Power Model and 10,000+ data points from tech providers

Country requirements and constraints (electrification, CO2, RPS, policy)

Exogenous fuel demand (e.g., H2, EV charging)

Asset cost and technology performance

Assumptions from other sources (e.g., NREL, BNEF, H2 Council)

NREL NATIONAL RENEWABLE ENERGY LABORATORY

BloombergNEF

Hydrogen Council

MPM Model optimization

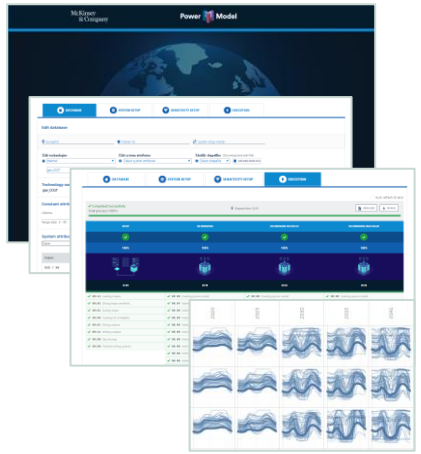
Lowest cost pathway for net zero power system

Total addressable market for LDES

Capacity and generation mix, incl. flexibility

Societal cost savings

Investment required



MPM determines which **investments and operating decisions minimize costs** to meet net zero targets

10,000+ data points from members processed by independent clean team

Coupled with deep insights from Council members, McKinsey, external experts

Respected public sources leveraged

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 Absorb surplus generation to avoid grid congestion	**24+ hours LDES**
Seasonal duration	Support during seasonal imbalances Mitigate extreme weather events	**Hydrogen**

Grid services

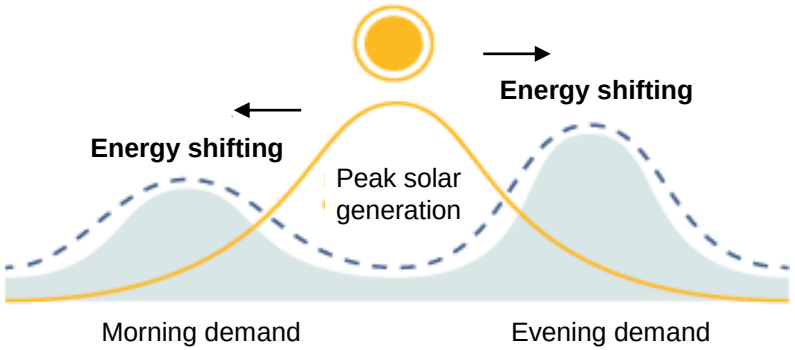
Grid services offered by LDES

- **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

Long Duration Energy Storage deployed in different contexts

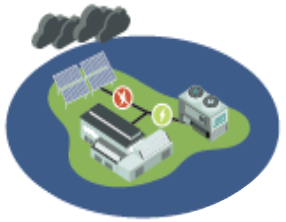
LDES unlock many different use cases



Energy shifting

Grid services

Optimising transmission & distribution investment



Firming renewable PPAs

Supporting island grids

Supporting industries with remote and unreliable grids

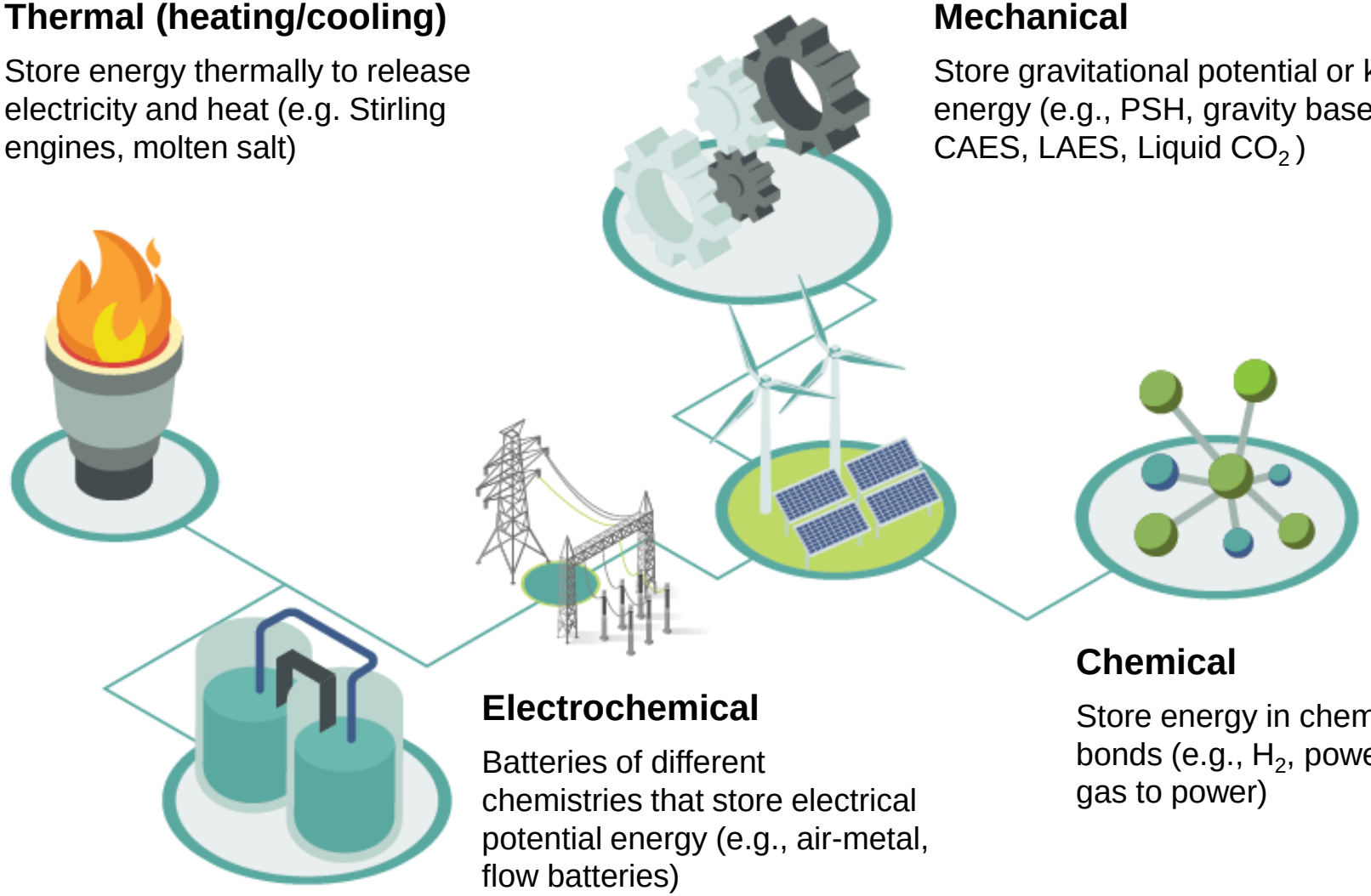
Many technological approaches tackle the same fundamental need

Thermal (heating/cooling)

Store energy thermally to release electricity and heat (e.g. Stirling engines, molten salt)

Mechanical

Store gravitational potential or kinetic energy (e.g., PSH, gravity based, CAES, LAES, Liquid CO_2)



Electrochemical

Batteries of different chemistries that store electrical potential energy (e.g., air-metal, flow batteries)

Chemical

Store energy in chemical bonds (e.g., H_2, power to gas to power)

Findings: LDES will play a major role in net-zero power systems

Renewable penetration and LDES cost-down potential…

60-70%

% renewables of overall capacity for widespread LDES deployment

~60%

LDES cost reduction expected by 2040, driven by scale, innovation and supply chain improvements

… leads to widescale LDES deployment and positive business cases

1.5-2.5 TW

Total deployed LDES by 2040

USD 1.5-3 tr

Total investment in LDES capex required by 2040

3-15%

IRR range for example modelled LDES applications[1]

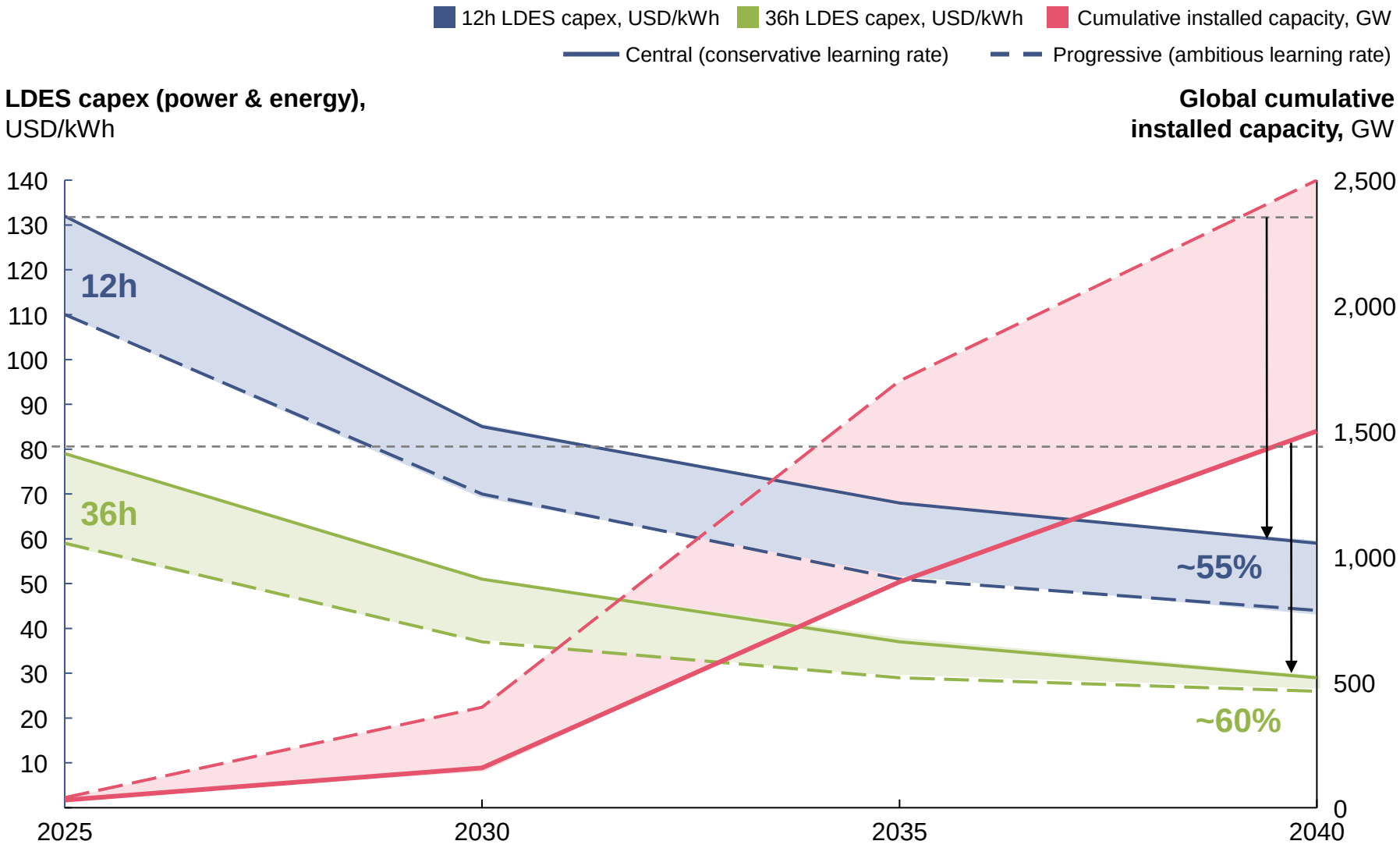
>50%

LDES as portion of all installed power flexibility capacity in 2040

1. Excluding potential improvement from implementing market mechanisms, regulatory adjustments, and carbon prices

Cost performance is expected improve sharply (-60% by 2040), boosting capacity deployment

LDES capex evolution vs. power capacity additions

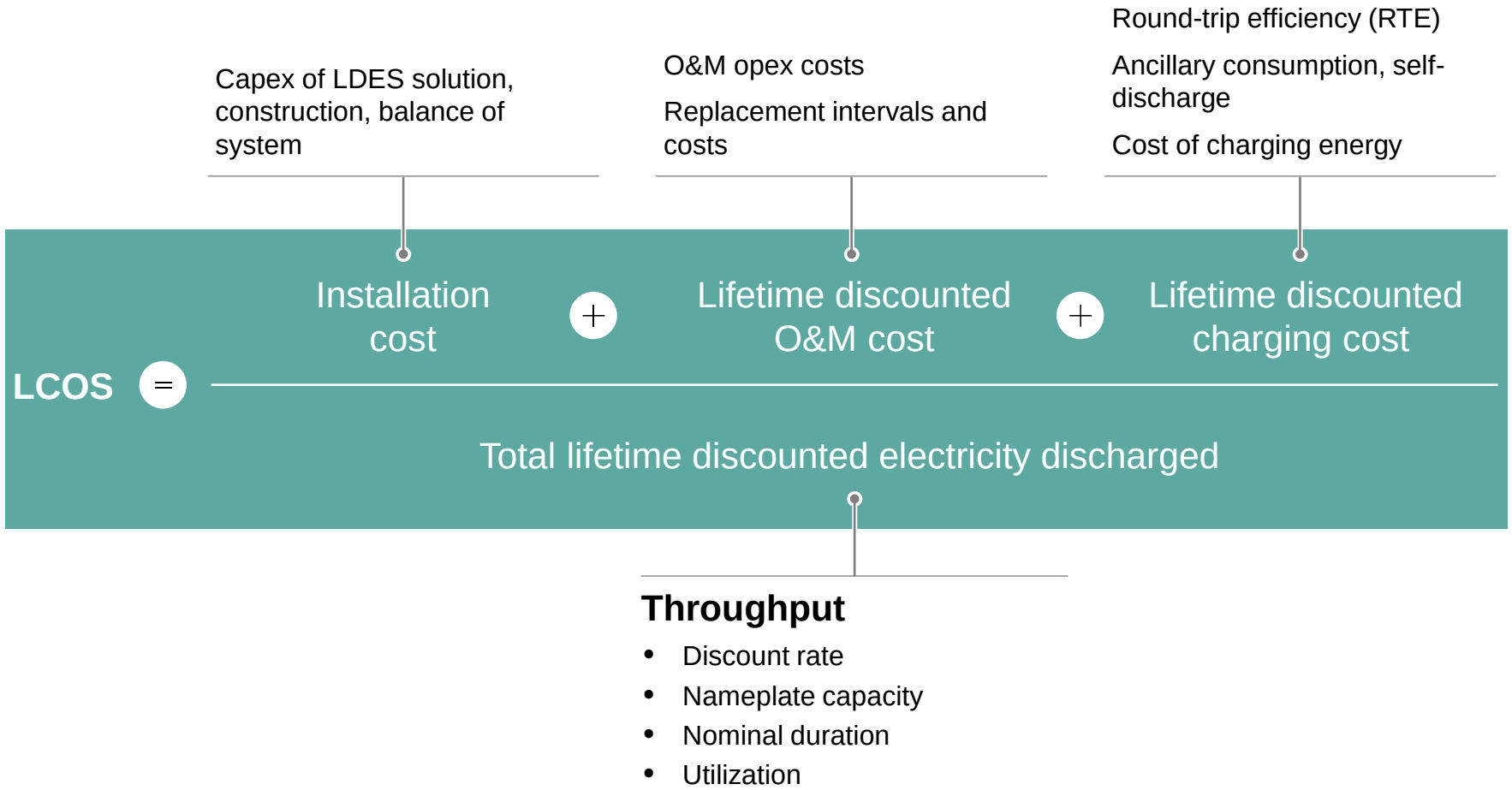


Insights

Cost reduction driven by

- Scale effects
- Technology advancements
- Increasing supply chain efficiency

LCOS used to compare cost competitiveness of LDES in realistic operating conditions



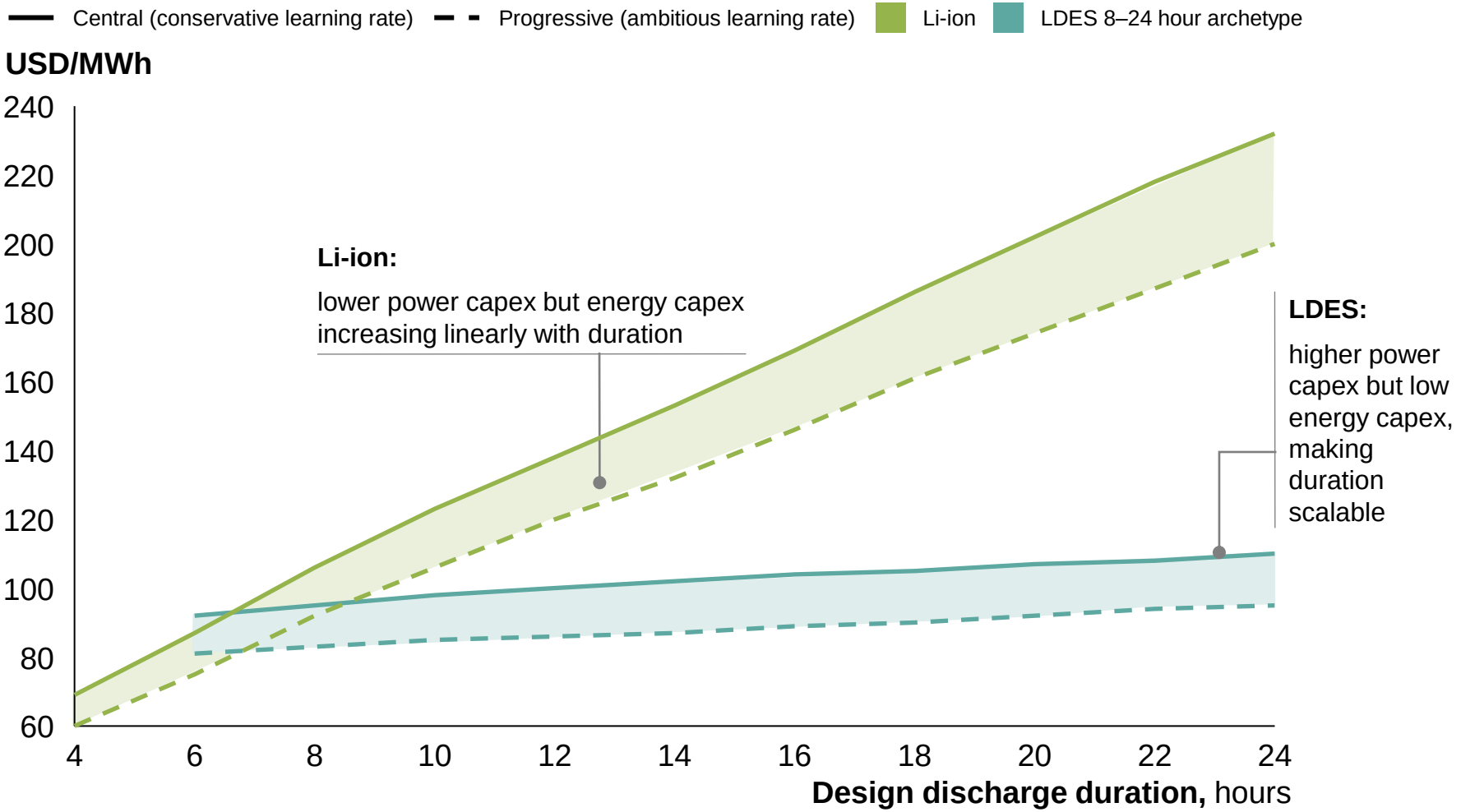
Insights

LCOS is comparable to LCOE and represents a tool for cost comparison of electricity storage

LCOS depends heavily on the operations of the system but allows a like-for-like comparison

LDES likely cost-competitive for durations >6-8 hours

2030 energy storage LCOS competitiveness by duration for selected technologies (USD/MWh)



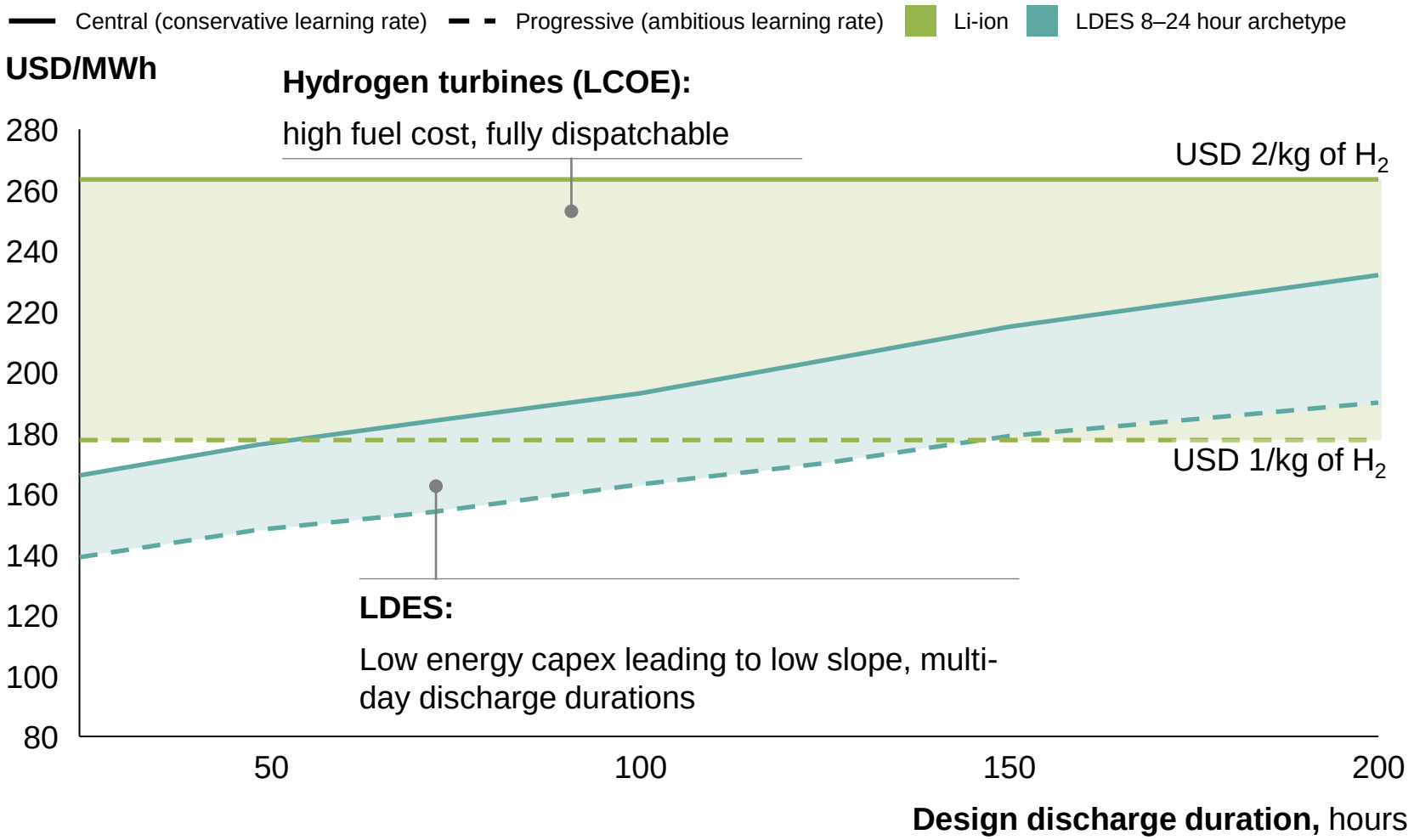
Source: LDES Council member technology benchmarking

Insights

>8 hours duration, due to low energy capex, LDES offers lower LCOS

LDES likely cost-competitive for discharge durations <100-150 hours

2030 energy storage LCOS competitiveness by duration for selected technologies (USD/MWh)



Source: LDES Council member technology benchmarking

Insights

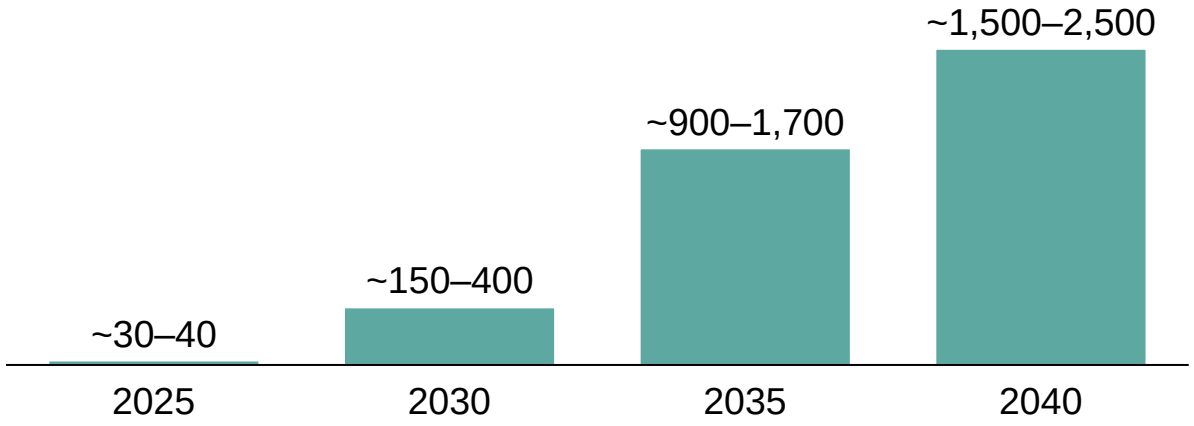
Hydrogen turbines are likely competitive above 150 hours duration

Total market size for LDES can reach a 1.5 to 2.5 TW by 2040, supporting the required flexibility in net-zero power systems

Global LDES deployment through 2040

GW

Cumulative installed power capacity



TWh

Cumulative installed energy capacity

2025	2030	2035	2040
~1	~5–10	~35–70	~85–140

USD bn

Cumulative capex investment

2025	2030	2035	2040
~50	~200–500	~1,100–1,800	~1,500–3,000

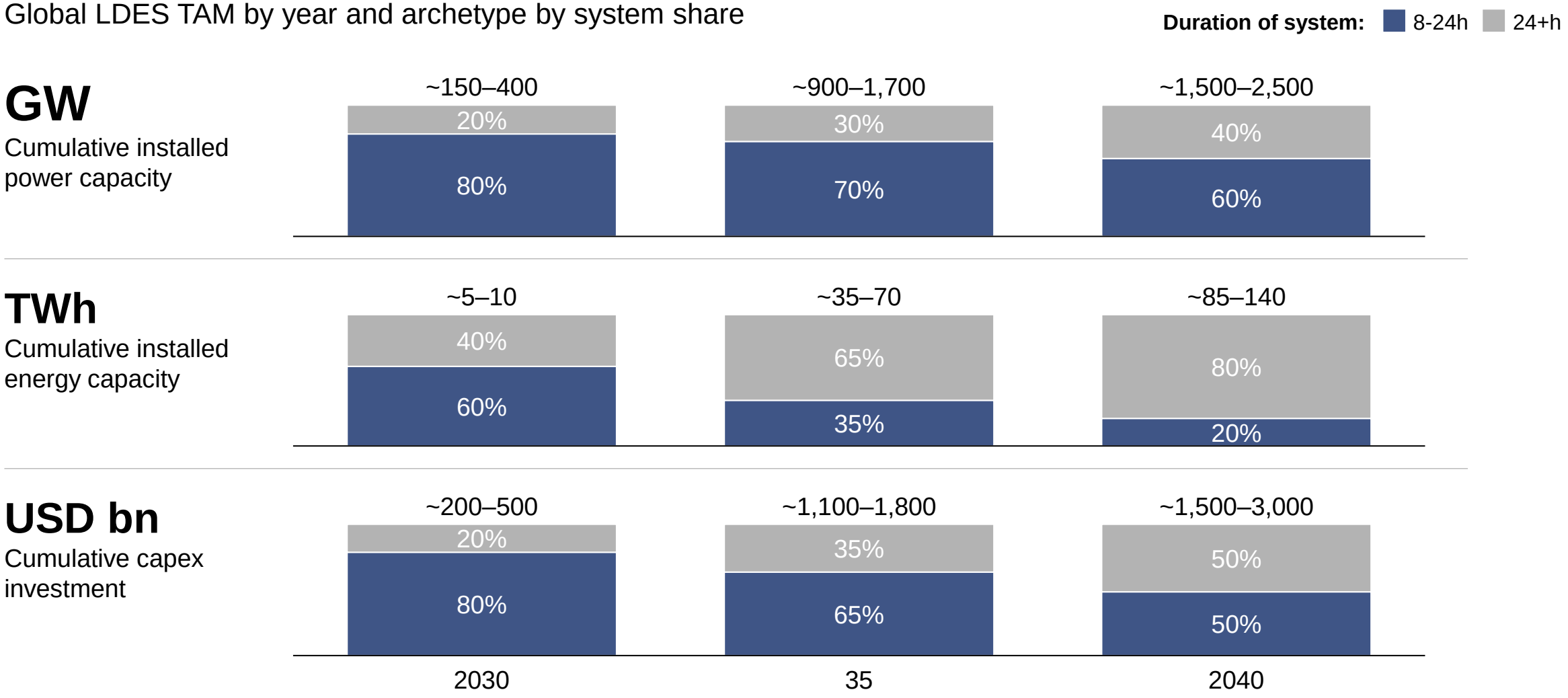
Insights

USD ~50bn investments required over the next 5 years

2040 cumulative investment equal to the current global T&D investment made every 2-4 years

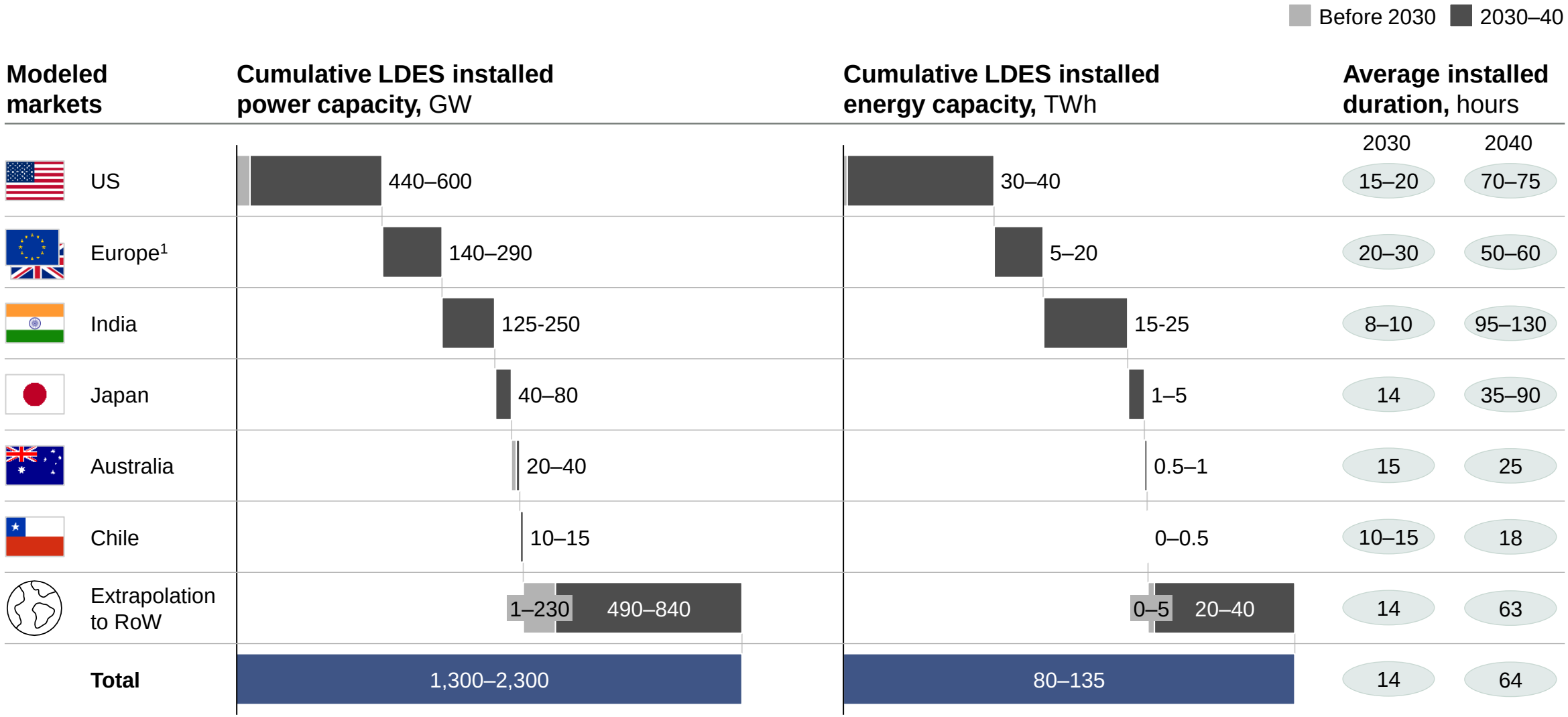
Average system duration increases over time

Global LDES TAM by year and archetype by system share



Significant opportunity for LDES across major power markets

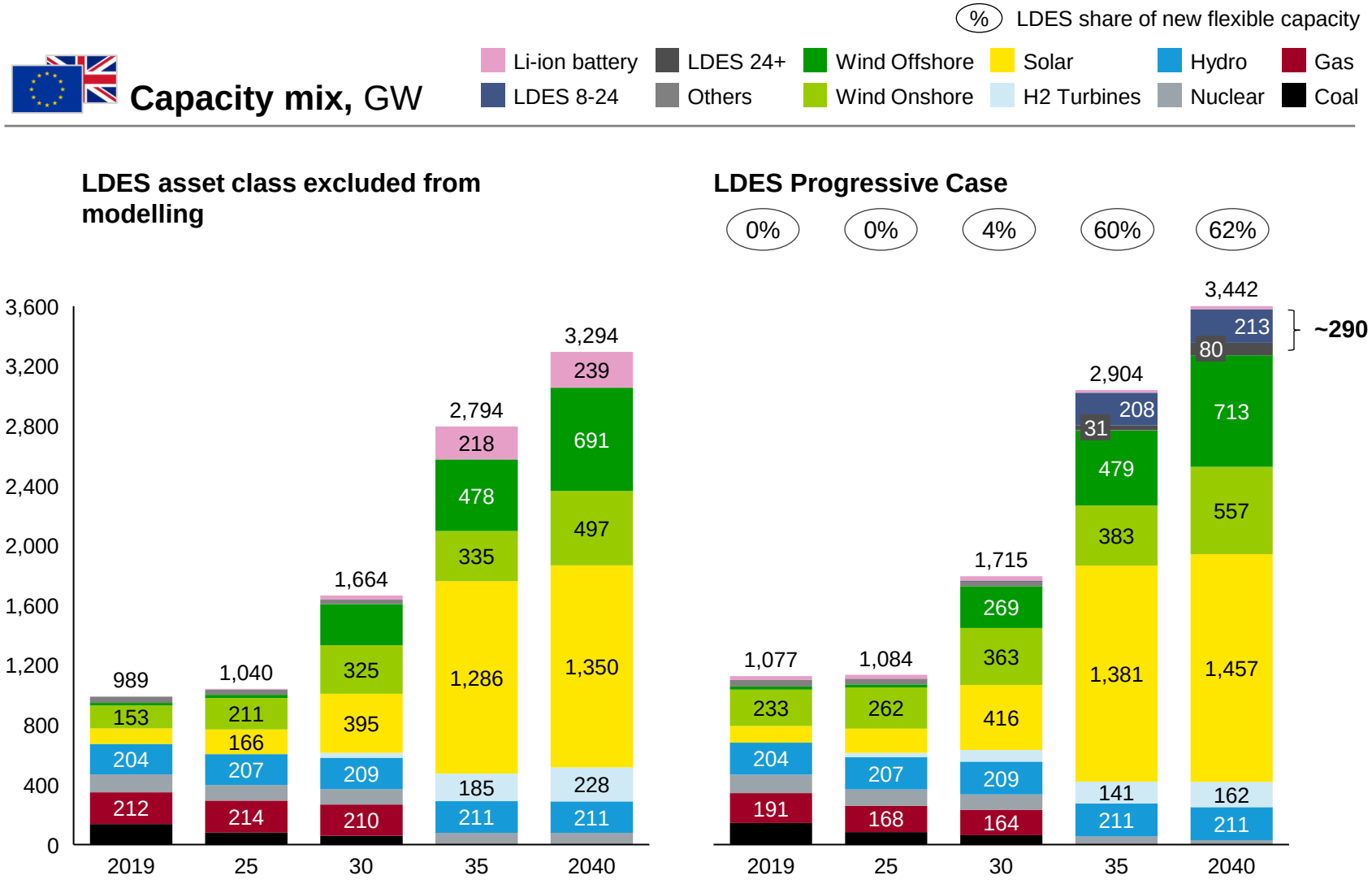
Summary of bulk power modeling results in key regions



1. Europe incl. UK

Source: McKinsey Power Model

In Europe, LDES could constitute ~10% of all power generation and ~60% of new flexible capacity



Source: McKinsey Power Model

Insights

LDES archetypes expected to play major role within "new flexible capacity" (i.e. Li-ion, H2 turbines, LDES)

Until 2030, existing gas limits LDES

By 2040, >60% of new flexible capacity might be LDES systems

Business cases for diverse LDES use cases explored in the report

Applies to case study | Does not apply

Customer example	IRR 2025 (potential improvement)	Value drivers for LDES: T&D optimi-zation	Capacity provision	RE cur-tailment reduction	Grid support	Firmed PPA premiums	Produc-tion cost savings	CO_2e cost savings
Integrated utilities with significant RE build-out and transmission bottlenecks	**~3%** (+11%)	■	■	■	■			■
RE developers or owners selling corporate RE PPAs with firmed capacity	**~7%**					■		
Isolated island power systems	**~7%** (+5%)				*May apply for larger systems*		■	■
Industrial customers (e.g. mine)	**~15%** (+4%)				*May apply for larger systems*		■	■

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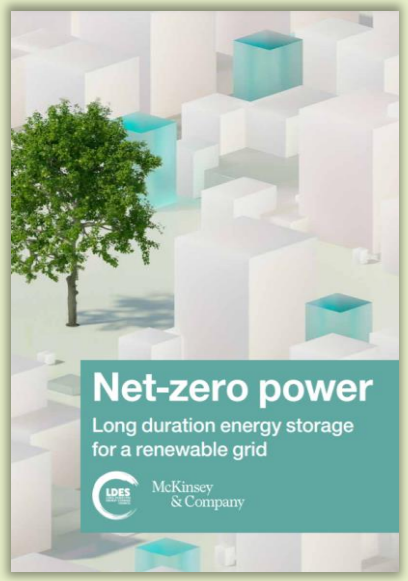
Ways to engage with the LDES Council

Download the full report



Net zero power systems: long duration energy storage for a renewable grid

www.ldescouncil.com

Explore becoming a member

LDES LONG DURATION ENERGY STORAGE COUNCIL

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info@ldescouncil.com

Visit our website and follow us on social media

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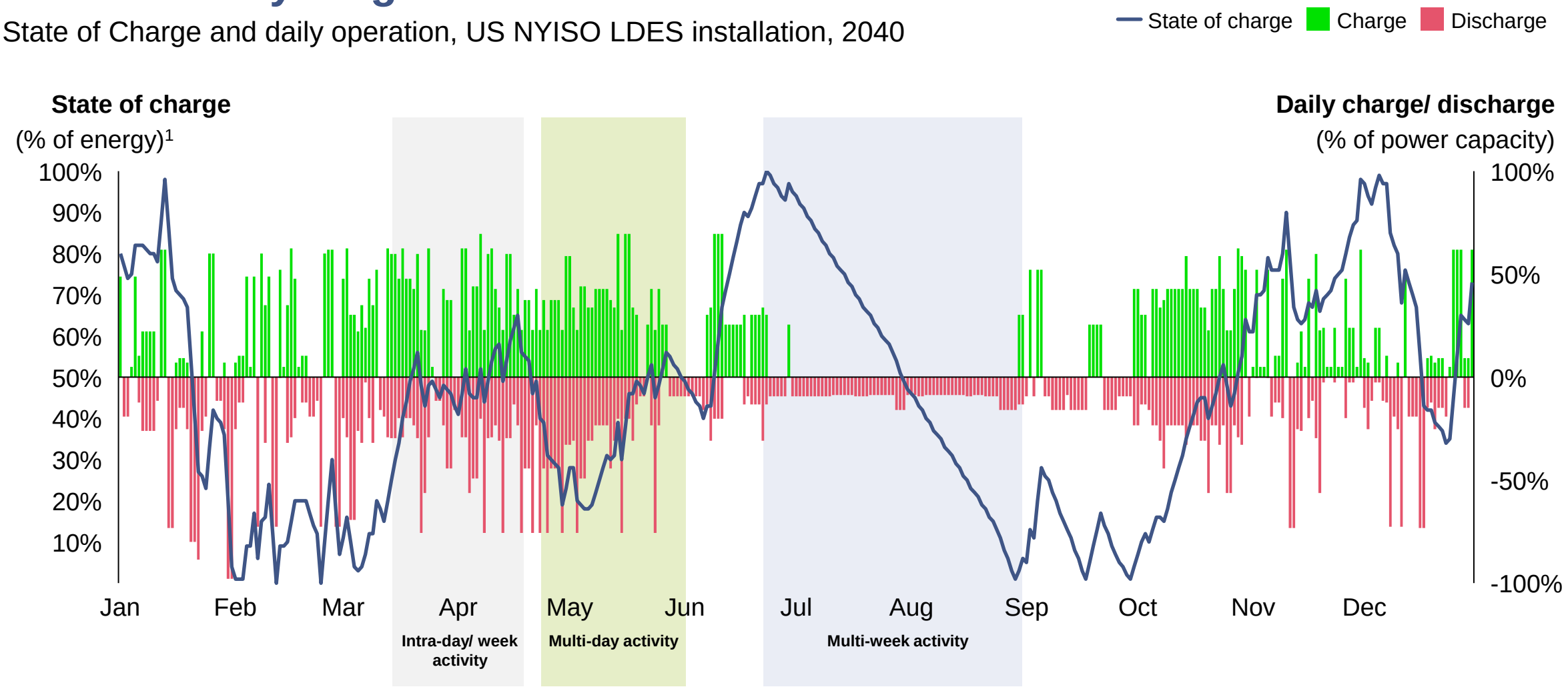
REA

RENEWABLE ENERGY ASSOCIATION

Backup

We observe LDES playing multiple roles across intra-day, multi-day and multi-week cycling

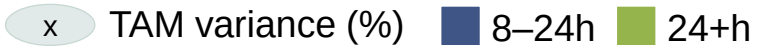
State of Charge and daily operation, US NYISO LDES installation, 2040



Source: McKinsey Power Model, 2040 US results

The deployed LDES capacity is highly sensitive to cost

2040 GW



Changes in model	Variance to central scenario in the US, 2040, GW	Result observed
Weaker cost and performance for 8–24 hour archetype (median assumed instead of 1st quartile)	**-151** -249 98 **+50%** **-100%**	+210 GW Li-ion storage; replacing 8–24 hour archetype as Li-ion becomes more competitive in short-durations
Weaker cost and performance for 24+ hour archetype (median assumed instead of 1st quartile)	**-8** -122 114 **-65%** **+45%**	+50 GW of H_2 turbines; LDES less competitive in firm capacity provision
Weaker cost and performance for both archetypes (median assumed instead of 1st quartile)	**-247** -249 2 **+1%** **-100%**	+260 GW Li-ion storage and +70 GW H_2 turbines; LDES 24+ hour archetype energy capacity halved

Source: McKinsey Power Model