Driving the Transition

Developments in Grid & Long Duration Energy Storage

18 June 2024

Foresight

Introduction

Energy infrastructure enabling deep decarbonisation

Speakers

Dan Wells
Partner, FEIP Fund Manager

Joined in 2012

24 years
infrastructure experience

Previously Sindicatum, EY

Richard Thompson
Partner, FEIP Fund Manager

Joined in 2012

19 years
infrastructure experience

Previously Carillion

Agenda

- The Context: Clean Energy Investment Landscape
- Need for Storage and Grid Investments in the Energy System
- Key Technology Sectors and Investment Characteristics
- Policy Support for Enabling Infrastructure
- Investment Opportunities
- Q&A

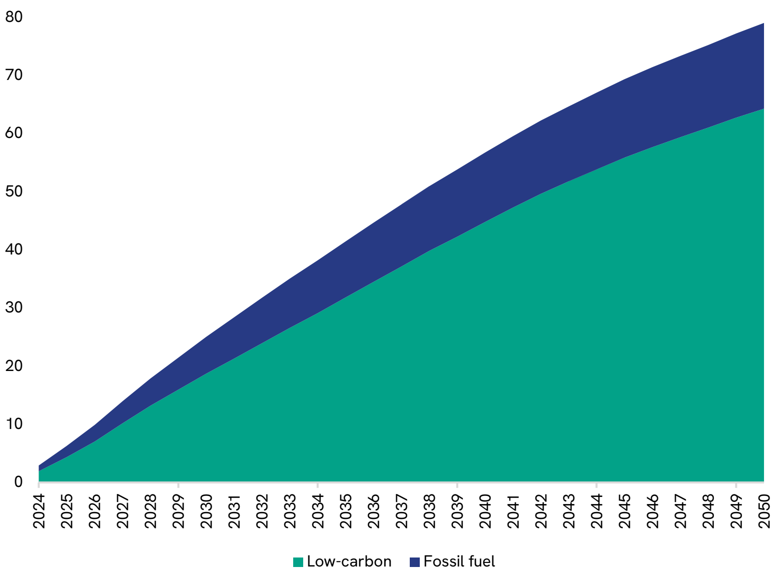
Foresight

Energy Supply Investment Requirement

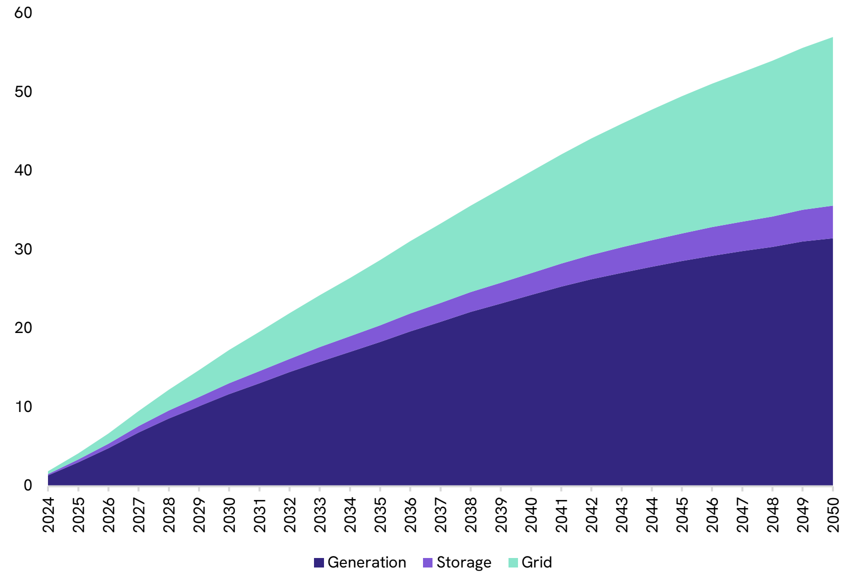
Capital flowing toward low-carbon solutions must dramatically increase to get on track for net zero

$79Tn	c. $3Tn	98%	c. $900Bn
Total investment required (2024-2050)	Average annual investment required (2024-2050)	Low carbon share of total generation investment (2024-2050)	Average annual power networks investment required (2024-2050)

Global cumulative investment required - energy supply[1]



Global annualised investment required – generation, storage & grid[1]



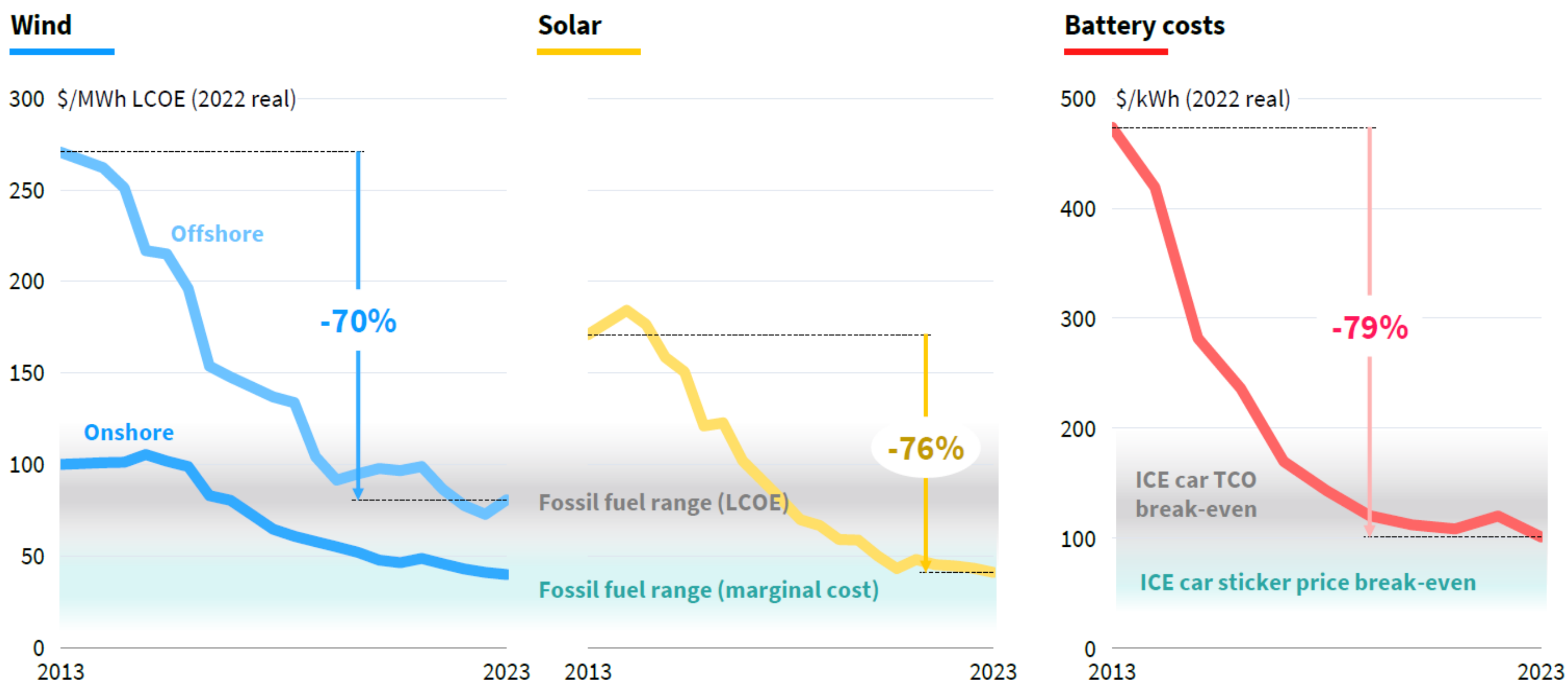
Fossil-fuel supply investment must drop from $1.1 trillion (2023) to $0.54 trillion per year between 2024 and 2050, while annual investment volumes for energy supply need to more than double, averaging $2.9 trillion per year to 2050

Achieving net-zero emissions globally by 2050 calls for $31.5 trillion in global power generation ($23 trillion for renewables), $4.2 trillion in storage and $21.4 trillion in power grid investment to support the build-out of low-carbon generation

Source: 1. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C.

Drivers of Clean Energy Investment: (i) Cost

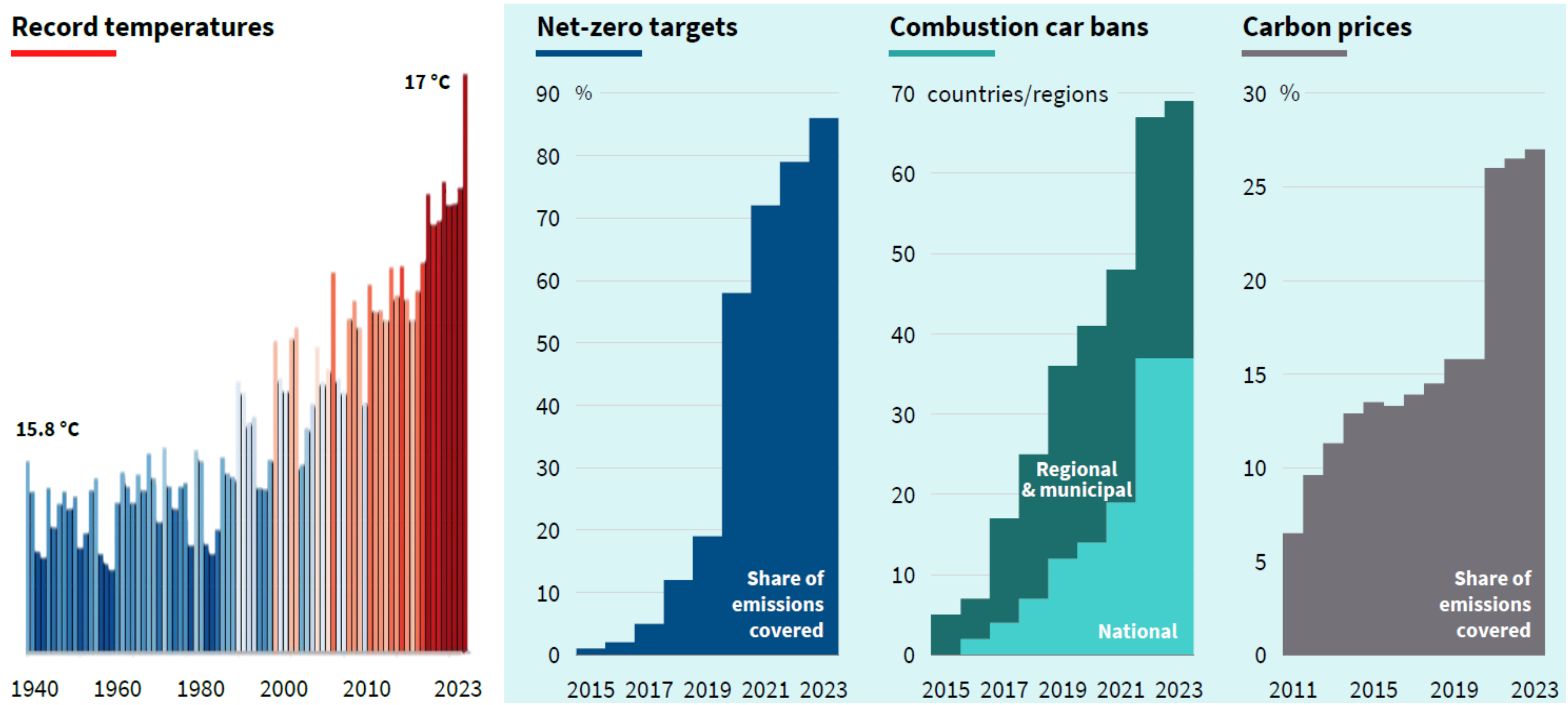
Renewable energy is the cheapest form of electricity, globally



Source: 1. RMI, *The Cleantech Revolution*, June 2024.

Drivers of Clean Energy Investment: (ii) Climate

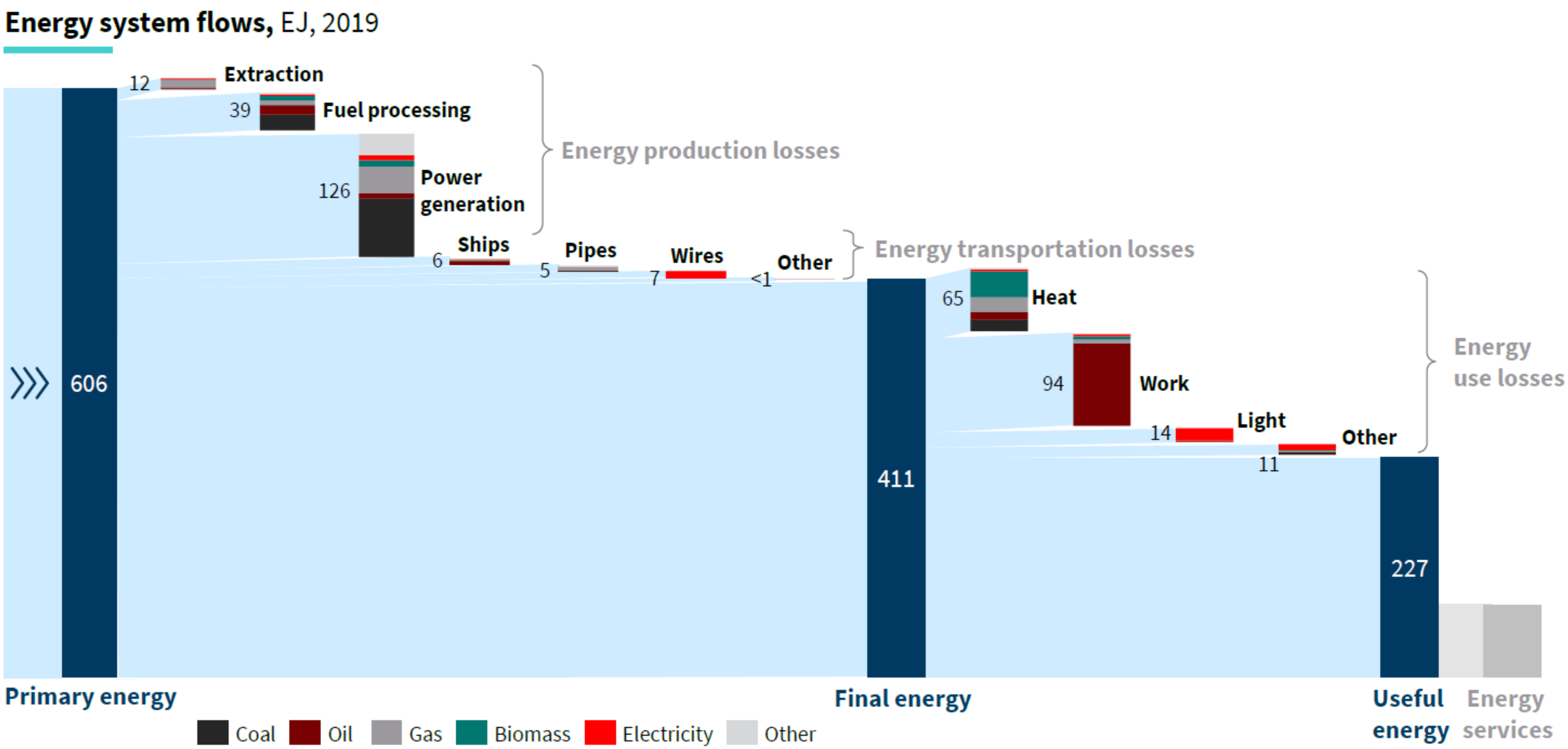
Policy pressure continues to rise across the world



Source: 1. RMI, *The Cleantech Revolution*, June 2024.

Drivers of Clean Energy Investment: (iii) Efficiency

Two thirds of all fossil fuel primary energy is wasted in thermodynamic and system losses

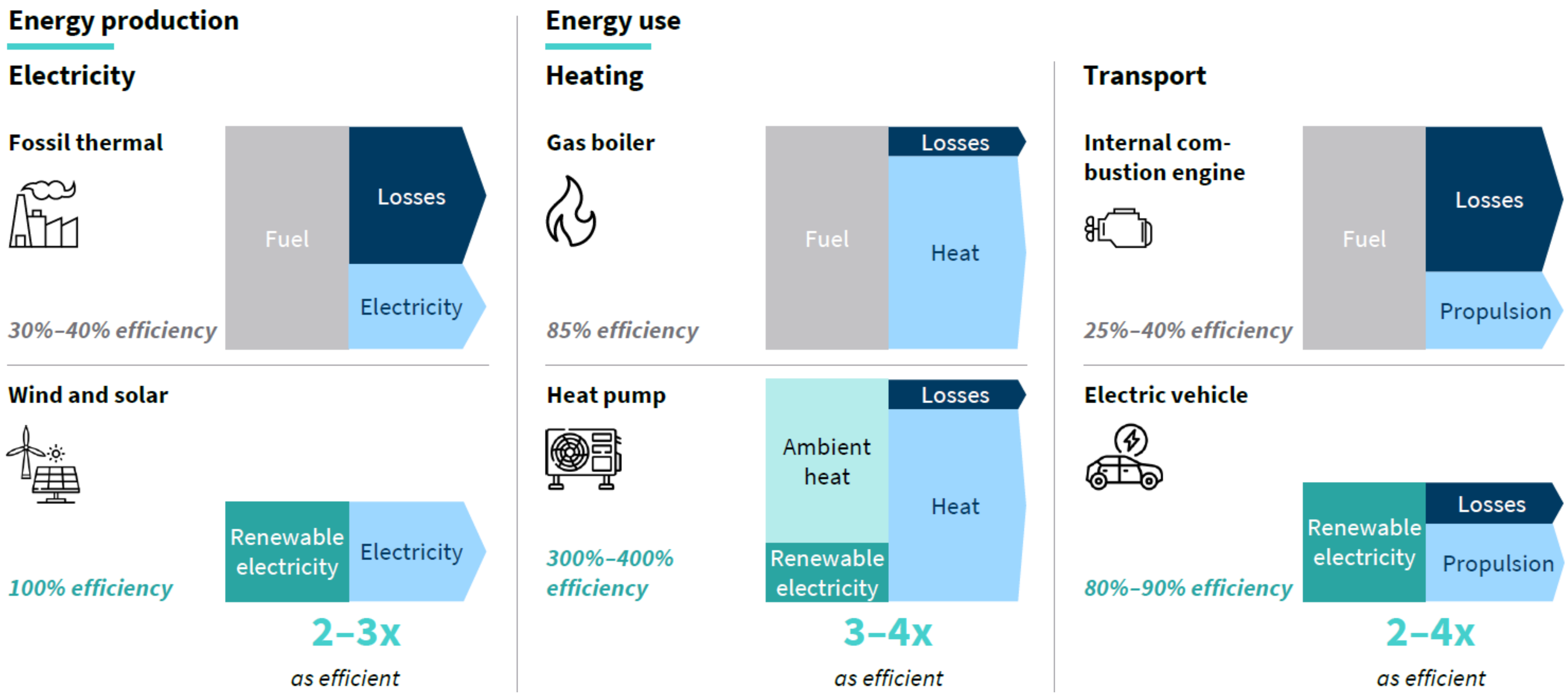


Source: 1. RMI, *The Cleantech Revolution*, June 2024.

Foresight

Drivers of Clean Energy Investment: (iii) Efficiency

Clean technology is around 3x more efficient that fossil fuel technologies across applications



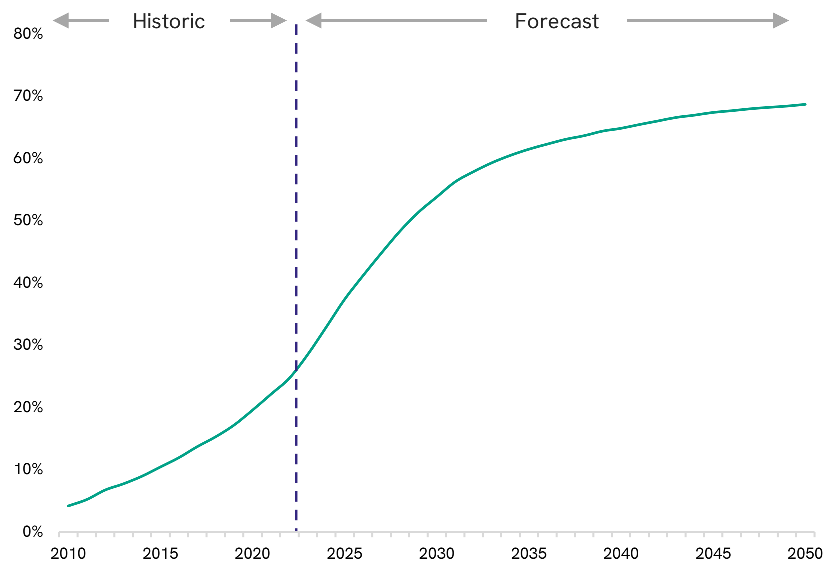
Source: 1. RMI, *The Cleantech Revolution*, June 2024.

Need for Storage and Grid Investments

The growing share of variable, clean energy in total energy capacity drives the need for investment in enabling infrastructure to alleviate system bottlenecks

Energy Transition

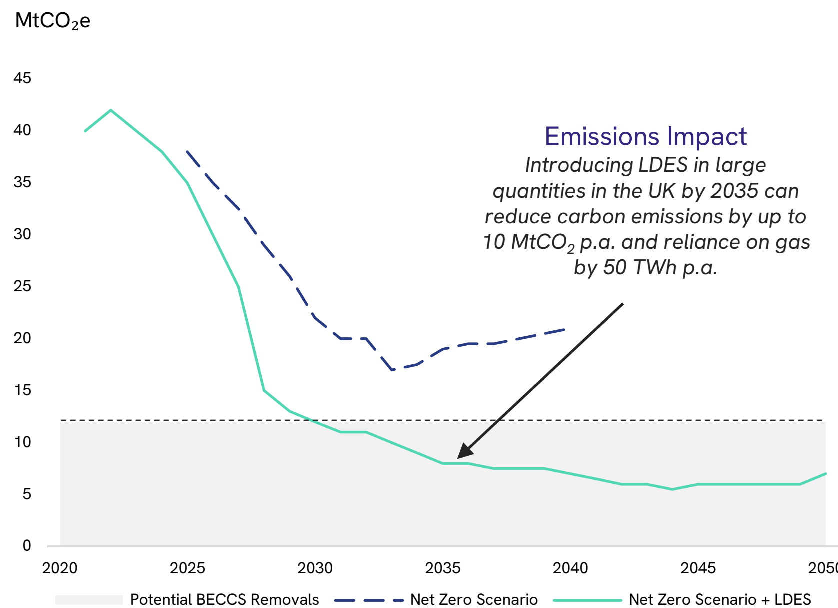
Variable renewable energy as a % of total energy capacity[1]



As the share of variable renewable energy is increasing, the limiting factor to the energy transition is no longer clean energy generation, but rather storage and grid infrastructure

Systems-Level Sustainability Impact

Total power sector carbon emissions (before BECCS)[2]



Investing in "bottleneck" enabling infrastructure assets (e.g., storage and grid) creates positive systems-level impacts both in terms of costs (deploying up to 20GW of LDES is estimated to result in system savings of up to £24bn[3]) and carbon emissions

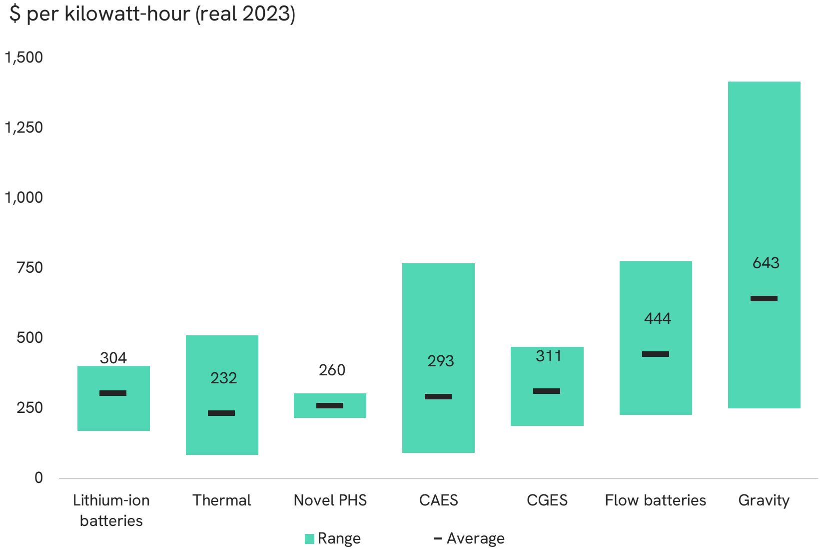
Sources: 1. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C. 2. Aurora Energy Research, 2022. Bioenergy with carbon capture and storage ("BECCS") is the implementation of CCS to bioenergy systems. 3. DESNEZ, 2024.

Enabling Infrastructure Cost Trends

Interest in storage and grid assets is increasing, with cost competitiveness varying by technology and advancements and policy support deemed essential for cost reduction and widespread deployment

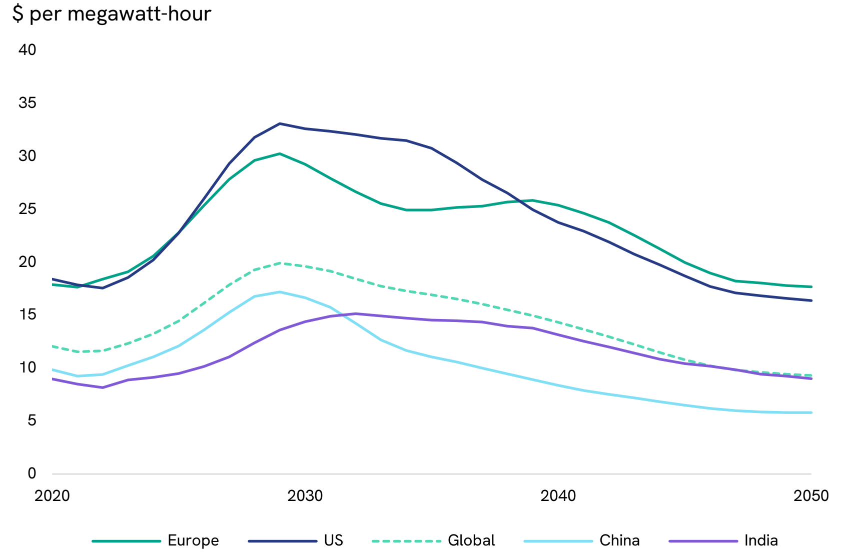
Cost Competitiveness of LDES Technologies

Fully-installed energy storage system capital costs[1]



Capital Expenditure Trends of Power Grids

CapEx on power grids per MWh of electricity consumption[2]



Duration, project size, and location all affect costs. Gravity energy storage has the highest average capital cost at $643 per kWh, whereas thermal energy storage ($232/kWh) and compressed air storage ($293/kWh) are the least expensive technologies

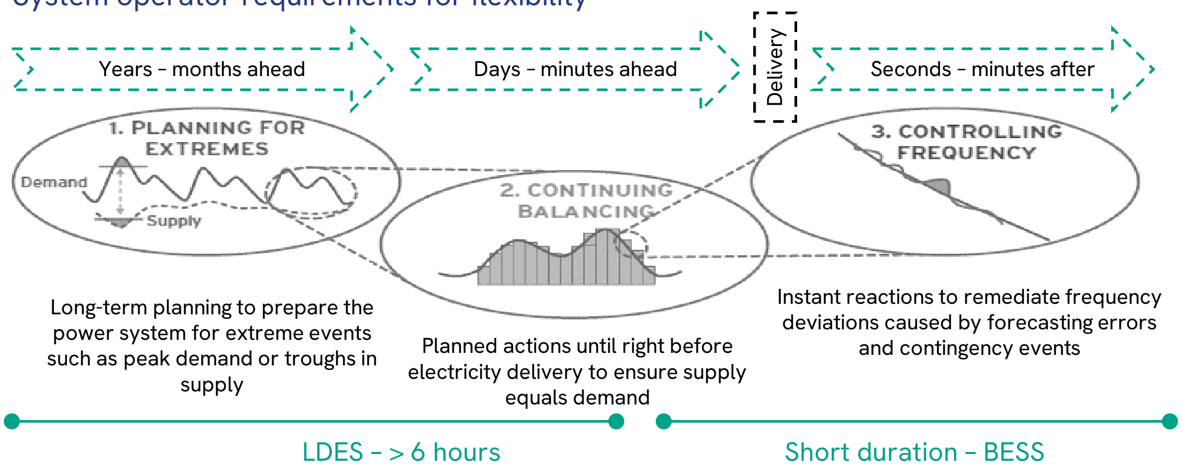
Global CapEx on power grids per MWh is forecast to increase until 2030 ($20/MWh). After this, grid investment stays roughly constant, benefiting from economies of scale, but power consumption rises, resulting in lower capital expenditures per MWh of power demand

Sources: 1. Bloomberg NEF, 2024. 2. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C.

Understanding Energy Storage

A net-zero power system will need flexibility resources at different duration levels, where LDES play a crucial role

System operator requirements for flexibility[1]



Existing and emerging solutions[2]

Flexibility duration	Power system challenge	Dispatchable generation	Grid reinforcement	Curtailment or feed-in management	Li-ion batteries	LDES	Demand-side response
Intraday	Intermittent daily generation	✓		✓	✓	✓	✓
	Reduced grid stability	✓			✓	✓	(✓)
Multiday, multiweek	Multi-day imbalances	✓	(✓)	(✓)	(✓)	✓	
	Grid congestion	✓	✓	✓	(✓)	✓	
Seasonal duration	Seasonal unbalances	(✓)	✓			✓	
	Extreme weather events	✓				✓	

Source: 1. Bloomberg NEF, 2016. 2. LDES Council & McKinsey & Company, 2021.

Power System Challenges

- Shifting to a power system that predominantly relies on renewable energy presents 3 key challenges:
  - Power supply and demand imbalances
  - Change in transmission flow patterns
  - Decrease in system inertia
- As a result, new low-carbon flexibility sources are emerging, including LDES technologies
- A diversified suite of solutions is likely to be deployed to achieve the decarbonisation of the grid

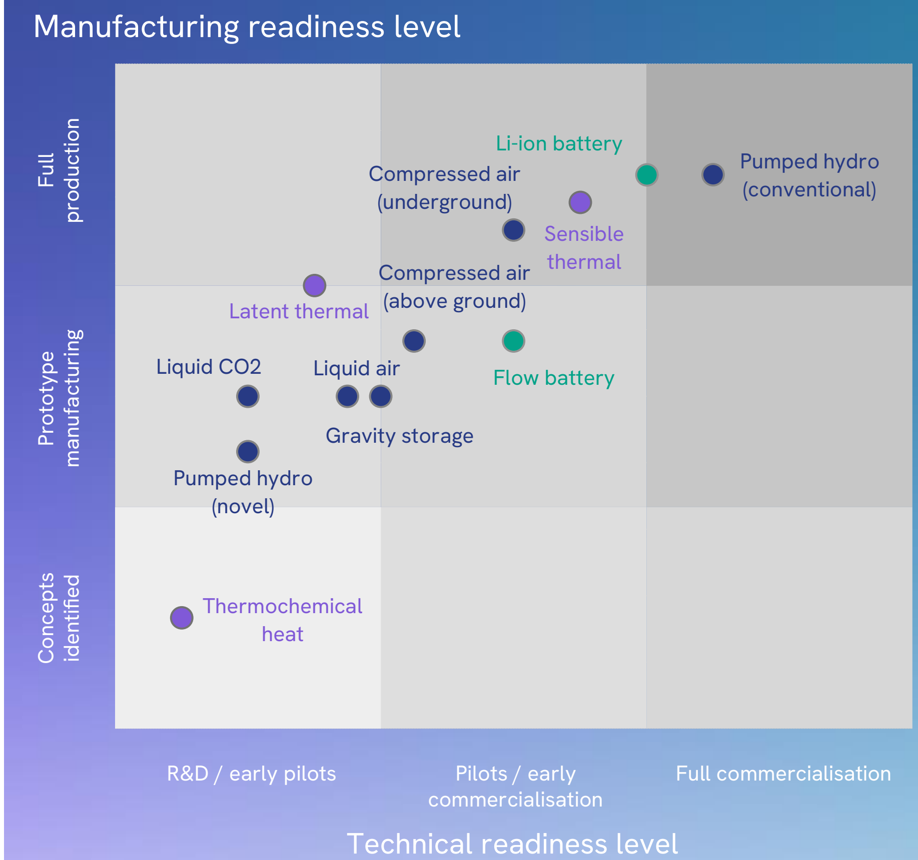
Key LDES Technologies

LDES are a host of different technologies that store and release energy through mechanical, thermal, electrochemical, or chemical means

Key Technologies

Types of LDES	Example	Description	Technologies
Mechanical		Utilises the movement of materials to store and release energy	Pumped storage hydro Gravity-based Compressed air Liquid air
Thermal		Stocks thermal energy by heating or cooling a storage medium	Sensible heat Latent heat Thermochemical heat
Chemical		Converts and stores power into the bond energy of new molecules via chemical reaction	Power-to-gas (incl. hydrogen, singas-to-power)
Electrochemical		Power is stored and further utilised through reversible chemical reaction in active materials through electrolyte	Lithium-ion batteries Flow batteries Others

Market Readiness



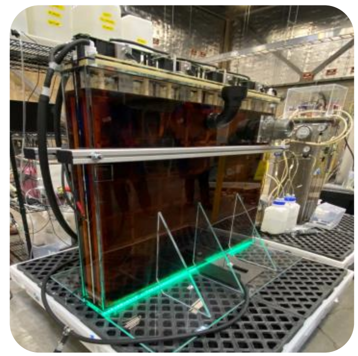
 Source: 1. Bloomberg NEF, 2022.

LDES: Future Developments

Securing funding is critical to ensure the advancement of technical readiness of LDES projects

Form Energy

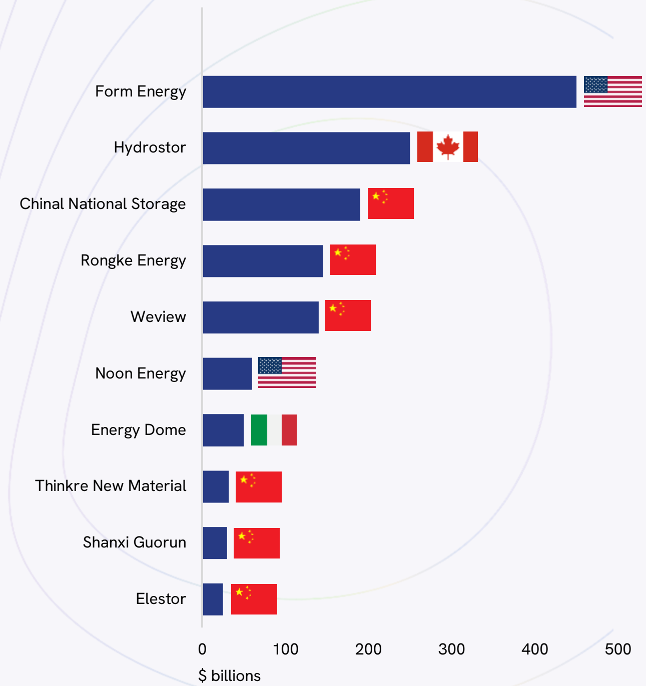
- US-based iron-air company
- Best-funded LDES startup, securing $450m in the past 2 years
- The start up develops multi-day LDES with a minimum 100 hours of duration (4 or more days)



Vantaan Energia

- One of Finland's largest energy companies
- Building the world's largest seasonal thermal energy storage plant in Vantaa, Finland
- The technology stores heat in underground caverns to heat buildings via the district heating network

LDES startups with the highest PE-VC funding, 2022-1H2023[1]



Source: 1. BNEF, 2023.

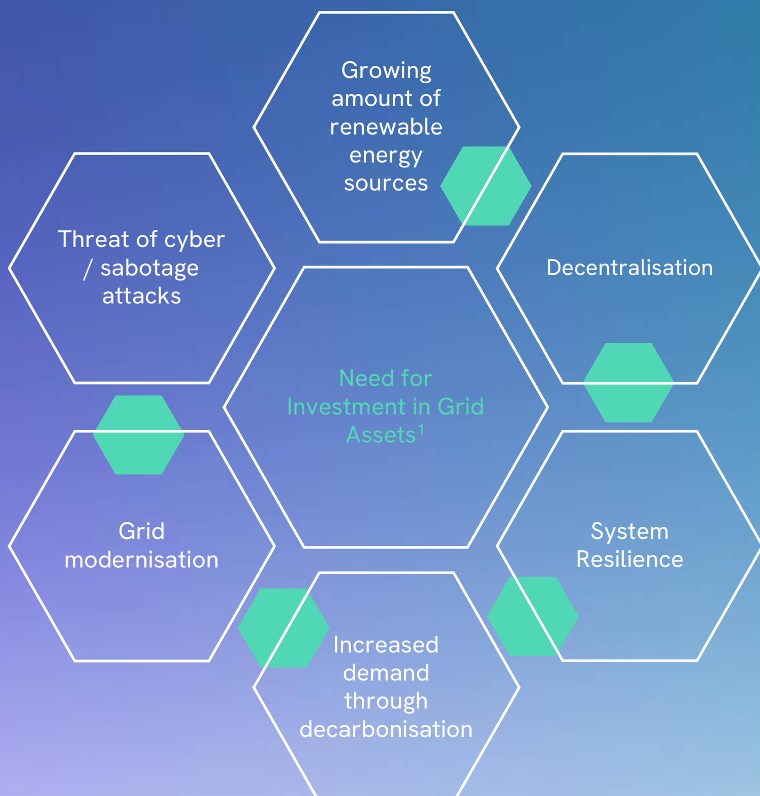
Foresight

Understanding Grid Investment

Connectivity assets are essential to decarbonise electricity supply and effectively integrate renewables

Grid Challenges

The record pace of renewable energy capacity installation is presenting unique challenges for power grids in integrating intermittent generation

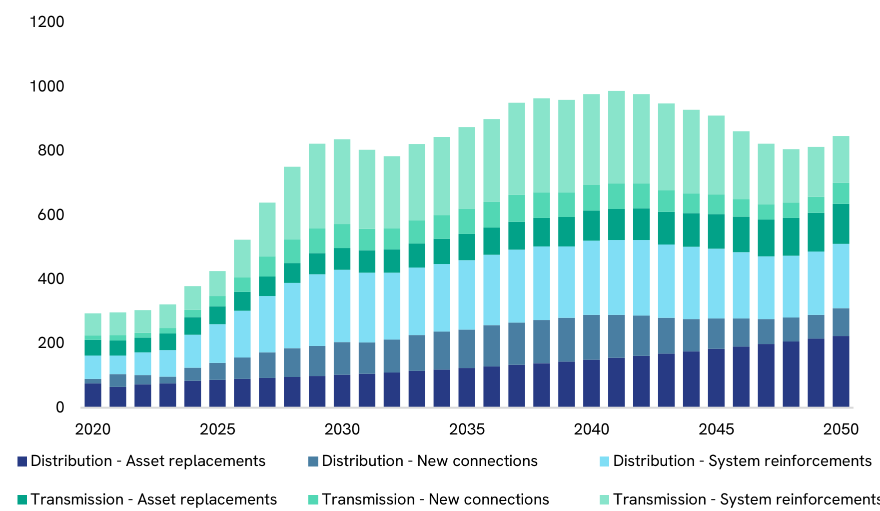


Global Market Growth

The shift to renewables and the electrification of transport, buildings and industry necessitates a concurrent overhaul of the power grid

Distribution grid investment outlook 2024-2050[2]

$ billion (real 2023)



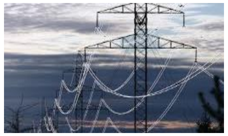
- A rapid buildout of renewables drives a first wave of grid investment on the transmission and distribution grid, with annual spend tripling from 2020 to 2035
- A second wave of grid investment between 2035 and 2050 is driven by new power demand rather than power generation, impacting primarily the distribution grid

Sources: 1. Fuergy, 2020. 2. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C.

Key Grid Technologies

Connectivity assets are essential to decarbonise electricity supply and effectively integrate renewables

Asset Characteristics[1]

Asset Class	Description	Cumulative Length (km, '000) 2020	Cumulative Length (km, '000) 2050	Annual Growth Rate	Example
Transmission Lines	High-voltage lines that transport electricity over long distances from power plants to substations	5,000	12,000	2.9%	
Distribution Lines	Lower-voltage lines that distribute electricity from substations to end-users	61,000	98,000	1.7%	
Underground Cables	Cables buried underground to transport electricity, typically in urban areas	10,000	17,000	1.8%	
Submarine Cables	Cables laid on the seabed to transmit electricity across bodies of water	18	55	3.8%	
High-Voltage Direct Current Transmission Lines	High-voltage direct current lines used for efficient long-distance electricity transmission	118	212	2.8%	

Grid Enhancements

Grid Reconductoring[2]

Retrofitting existing power lines with advanced conductors can quickly expand the grid, facilitate new clean energy projects, avoid the need for new rights of way, and significantly accelerate transmission build-out

Capacity Optimisation[3]

Dynamic Line Rating and Ambient Adjusted Rating are two pivotal technologies that can drive efficiency, cost reduction, and the evolution of a smarter, adaptable power network by enhancing capacity, preserving asset health, and bolstering grid reliability

Sources: 1. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C. 2. Forbes, 2024. 3. Utility Dive, 2023.

Policy Support for Enabling Infrastructure (1)

Europe

EU Commission's PCI/PMI Grant

Funding of key cross-border energy infrastructure projects

The EU Commission announced an €850mn grant call for cross-border infrastructure projects of the list of Projects of Common Interest ("PCI"s) and Projects of Mutual Interest ("PMIs"), for the first time including offshore electricity grids[1]

EU Grid Action Plan

Strategies for enhancing and Europe's energy grid

The Action Plan aims to address the main challenges in expanding, digitalising and better using EU electricity transmission and distribution grids and identifies concrete actions to help unlock the needed investment to get European electricity grids up to speed[2]

Energy Storage Recommendations

Guidelines for advancing energy storage technologies in Europe

Provides member states with concrete recommendations and action points to help facilitate the fast and broad deployment of energy storage in their energy systems[3]

Net-Zero Industry Act

Measures to accelerate the transition to climate neutrality

Supports the expansion and modernisation of electricity grids, facilitates the development and deployment of various energy storage systems, and creates a favorable regulatory environment to encourage investment in these solutions

Sources: 1. EU Commission, 2024. 2. EU Commission, 2023. 3. EU Commission, 2023. 4. EU Commission, 2023.

Policy Support for Enabling Infrastructure (2)

UK

Policy Framework

Policy framework to encourage investment in LDES

The Government is designing a policy framework to enable investment in long duration electricity and has launched a consultation on a cap and floor scheme[1]

Transmission Acceleration Action Plan

Initiative to bolster grid development and reliability

The Plan reforms projects' grid connection process and will halve the amount of time it takes to build network infrastructure[2]

Energy Act 2023

Measures to fast-track energy storage deployment

The Energy Act establishes the National Energy System Operator which is meant to drive net zero and produce a Strategic Spatial Energy Plan to set out the optimal location of generation and storage infrastructure needed to meet 2050 targets[3]

Trade and Cooperation Agreement

Cross-border agreement promoting electricity trade

The UK and EU agreed the Trade and Cooperation Agreement 2021) to enable the efficient trade of electricity over interconnectors and cooperate on the development of offshore wind[4]

Sources: 1. DESNZ, 2024. 2. DESNZ, 2023. 3. DESNZ, 2023. 4. UK Government, 2020.

Policy Support for Enabling Infrastructure (3)

Global

G7 Storage Grid and Investment Charter

Initiative for international cooperation

G7 summit of Climate, Energy and Environment ministers' resulted in a commitment to massively scale-up ambitions for energy storage (a six-time increase by 2030) and grid investments[1]

US Inflation Reduction Act

Incentives for the development of renewables

Energy storage-specific initiatives such as the energy community adder, qualifying advanced energy project credit programme, direct pay and transferability of ITC, wind and solar tax credits[2]

US Long Duration Storage Shot

Initiative to enhance US grid reliability and flexibility

In the US, the Government launched the 2021 U.S. initiative called the Long Duration Storage Shot, which seeks to reduce costs for LDES by 90% by 2030[3]

US Bipartisan Infrastructure Law

Legislation to improve the US's clean-power infrastructure

The $1.2 trillion bill includes a wide range of grants for various energy solutions – among them, electricity grid resilience and energy storage systems[4]

US Loan Programs Office

Programs supporting innovative energy projects

Various loan and loan guarantee programs promoting clean energy technologies and grid modernisation, with c.$290bn requested by loan applicants[4]

Sources: 1. IRENA, 2024. 2. Energy Storage News, 2024. 3. US Department for Energy,, 2021. 4. White House. 2024. 5. Loan Programs Office, 2024.

Addressing System Challenges

To address system challenges, further policy initiatives could include enhanced revenue support, streamlined permitting processes, and strengthened supply chain resilience

Revenue Support

LDES Cap and Floor Regime[1]

- A cap and floor revenue support regime is currently in operation in the UK to enable investment in electricity interconnectors
- The interconnector regime provides a minimum level of revenue certainty for investors (floor) and a regulated limit on revenues (cap) to avoid excessive returns
- A similar LDES cap and floor scheme would unlock greater private sector investment by providing the required revenue certainty to investors
- The scheme is also expected to reduce the Weighted Average Cost of Capital for LDES projects by reducing the overall investment risk, which is particularly important in addressing high upfront costs

Permitting

Accelerated Permitting Processes[2]

- Faster permitting is crucial to reach EU targets for renewables by 2030, and for climate neutrality by 2050, and is key to increasing energy security by reducing dependence on Russian fossil fuel imports in particular
- The EU 2023 Flagship Technical Support Project:
  - Establishes clearer, faster, and more transparent processes for application and granting of permits for renewable energy projects
  - Facilitates the sharing of best practices among Member States
  - Supports authorities in improving processes to identify areas suitable for renewable energy deployment
  - Increases public involvement and acceptance of renewable energy

Supply Chains

Energy Market Supply Chain Resilience[3,4]

- US:
  - The IRA brings improvement to manufacturing and the supply of domestic contents that can bring investment opportunities
  - However, there is still a need for clearer regulatory guidance / domestic policy on onshore manufacturing
- EU:
  - The Net-Zero Industry Act provides a coordinated European roadmap to reduce Europe's high dependency on imports from single suppliers of net-zero technologies
  - The goal is to increase the resilience of Europe's clean energy supply chains to avoid disruption in global energy markets

Sources: 1. DESNZ, 2024. 2. European Commission, 2022. 3. Energy Business Law, 2022. 4. EU Commission, 2023.

Investment Opportunities: Case Studies

Investing in enabling infrastructure assets offers attractive returns coupled with measurable climate impact

MaresConnect

Interconnector – 750MW

Development stage investment delivering large upside potential

Overview

- Development and construction of two High Voltage Direct Current ("HVDC") interconnector cables under the Irish Sea
- HVDC cables will run approximately 250km between two onshore converter stations

Highlights

- Decarbonisation of UK and Irish grids, enabling greater renewable rollout
- Resultant arbitrage of both markets will lead to lower customer prices

Policy Support

- OFGEM window 3 process for cap & floor
- UK Ireland MOU on energy market cooperation
- Irish Interconnector Policy issued July 2023 requiring increased interconnection by 2030
- Named in Ireland's National Energy & Climate Plan 2023

Glenmuckloch

Pumped Storage Hydro – 210MW

Scottish construction stage investment delivering long-term sustainability impact

Overview

- Co-located 1,600MWh storage capacity PSH and 34MW wind farm
- PSH is capable of generating at a rate of 210MW for up to 8 hours, continuously
- PSH is capable of exporting power in 10 seconds and stop in 2 minutes

Highlights

- Repurposes a disused coal mine that would have otherwise remained a scar on the landscape
- Creation of an upper and lower reservoir, with the lower reservoir located in the 18m^3 dormant coal mine

Policy Support

- UK Government issued consultation regarding its intention to develop regulated revenue mechanism
- Proposal is for a cap-and-floor mechanism similar to model used for interconnectors

Silvermines

Pumped Storage Hydro – 360MW

Landmark Irish energy project driving system stability

Overview

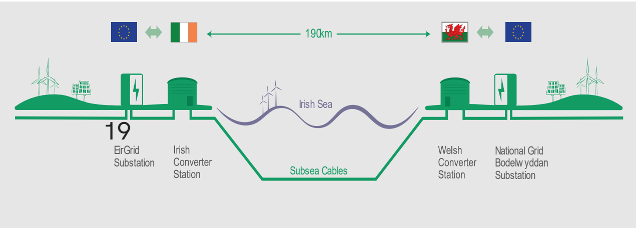
- 1,800MWh capacity PSH generating at a rate of 300-360MW for up to 5-6 hours
- PSH is capable of exporting power in 10 seconds and stop in 2 minutes
- Creation of a new 2.6m3 upper reservoir, with a similarly sized lower reservoir

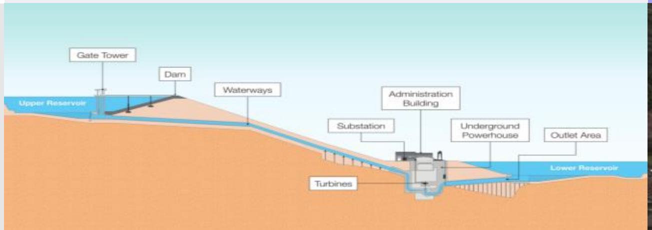
Highlights

- Transforms a former mining site into one of Ireland's leading green energy facilities
- Make use of excess power on the grid during periods of high renewable generation, reducing transmission system constraints

Policy Support

- PCI Status asset yielding expedited and mandated engagement by the state on Grid, Planning and project Viability
- Named in Ireland's National Energy & Climate Plan 2023
- Strong political support from the Minister for the Environment, Climate and Communications, E. Ryan





Key Takeaways

Enabling infrastructure investments, driven by high investment needs and policy support, yield attractive risk-adjusted returns and sustainability impacts but require specialist managers due to their complexity

Drivers

High Investment Needs

- $23 trillion is required for renewable power generation and storage by 2050 to reach net zero[1]
- $21.4 trillion is required in power grid investment by 2050 to reach net zero[1]

Strong Policy Support

- New legislation and initiatives in the UK, EU and US, regarding decarbonisation and industrial policy
- These new policy frameworks will drive the acceleration and the build out of enabling energy infrastructure

Enabling Infrastructure Investments

Characterised by a greater degree of complexity, such assets require the expertise of specialist investment managers

Outcomes

Attractive Risk-Adjusted Returns

- Uncorrelated or negatively correlated assets across generation, storage and grid
- Harnessing these correlation profiles can lead to significant, portfolio-level diversification benefits

Systems-Level Sustainability Impacts

- Addressing system bottlenecks allows further investment in clean energy generation
- Adding enabling infrastructure to power grids results in both systems-level cost and emissions impacts

Source: 1. BNEF New Energy Outlook 2024. The BNEF Net Zero Scenario illustrated above is based on a pathway consistent with a 1.75°C temperature rise by 2050 (with a 67% likelihood) with no overshoot or the need for net-negative emissions post-2050. This trajectory gives a 33% chance of staying within 1.5°C, but a better than 67% chance of staying below 2°C.

Q&A

Foresight

For further information, please contact:

Dan Wells

+44 (0) 7976 813 839
DWells@ForesightGroup.eu

Richard Thompson

+44 (0) 7808 241 539
RThompson@ForesightGroup.eu

Foresight Group Luxembourg S.A.

Europe Building
55, Allée Scheffer
L-2520 Luxembourg
Luxembourg