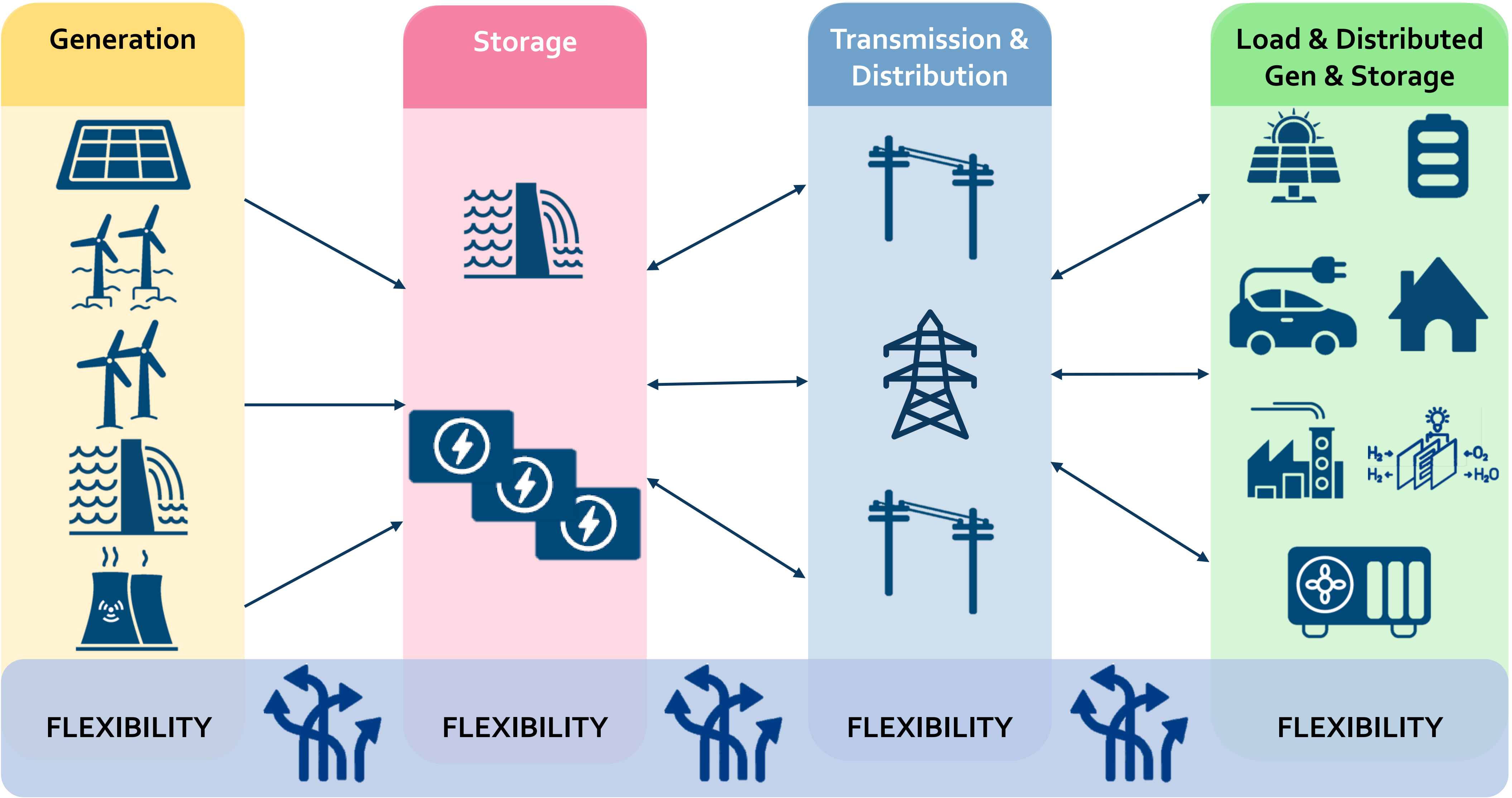
Infrastrutture elettriche, accumuli e flessibilità: soluzioni e tecnologie per la transizione e la sicurezza energetica

CESI

Inspired with innovation

Bruno Cova – Power System Excellence Manager

The enablers to decarbonization of the power sector: from RES integration to deep electrification

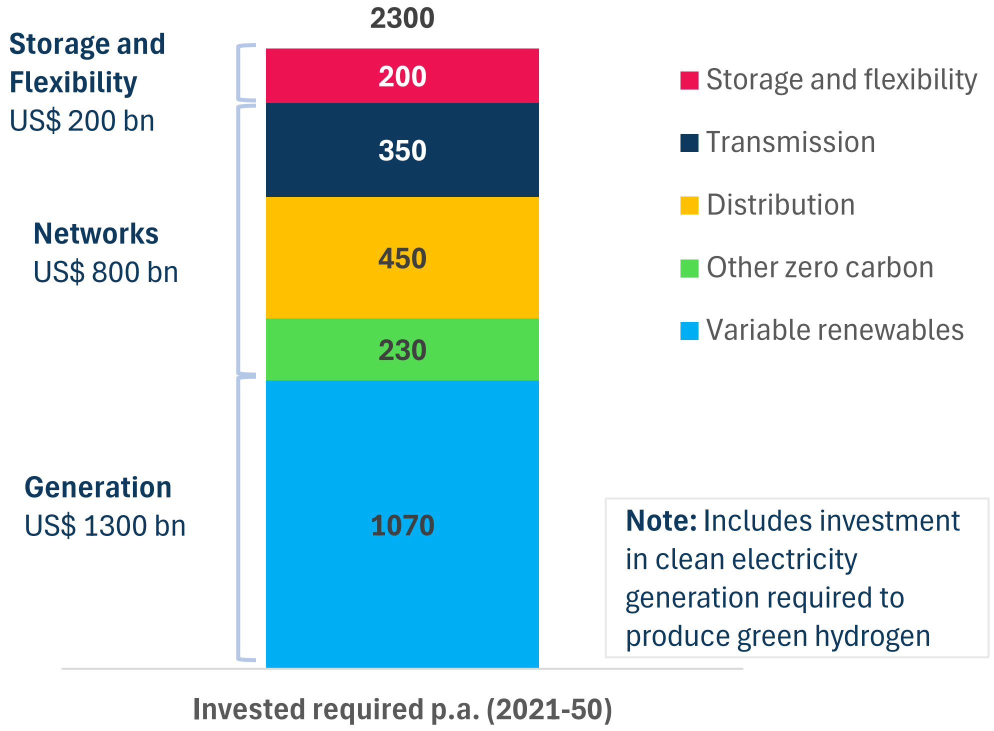


The grid: the backbone of the electrical sector

Electricity as a share of final energy demand will need to grow from around 20% today, to between 55–70% → total direct electricity use will need to grow from around 28,000 TWh today to over 60–70,000 TWh

To deliver the required expansion of grids, **annual investment in transmission and distribution networks needs to rise to $800 billion per year, growing by over 2.5 times compared with today's levels [~$300 billion p.a.]**. Cumulatively, this would equate to over $22.5 trillion between 2022–2050.

Source: ETC



Source: CESI Elaboration of ETC "Building grids faster: the backbone of the energy transition", September 2024, Version 1.0

The grid: the backbone of the electrical sector

Priority of accelerating investments on grid and storage has been recognized at COP29 held in Baku in November 2024

COP29 Baku Azerbaijan

- ✓ launch of the **Global Energy Storage and Grids Pledge**: commitment to:
  - add or refurbish 25 million kilometres of grids globally by 2030, recognising the need to add or refurbish an additional 65 million kilometres by 2040
  - a collective goal of deploying 1,500 GW of energy storage globally by 2030—more than six times the capacity of 2022.
- ✓ launch of the **Green Energy Pledge: Green Energy Zones and Corridors**. focusing on:
  - promoting connecting green energy zones and corridors to the communities most in need by developing larger intraregional and interregional interconnected power grids

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- ✓ Total investments on grids in the period: 2025-2050: **€ 1950 bn** (ERT) ÷ **€ 2600 bn** (eurelectric) → **€ 75 ÷ 100 bn/yr**
- ✓ Investment on the **transmission grid** accounts for about **one third** compared to the **distribution grid** (about **two thirds)**

Source: ACER 2024 – Monitoring Report

The grid: solutions and technologies

Long distance energy corridors to transfer massive green energy to load centres (CESI is involved in most projects)

Hardware solutions for long distance power transmissions

Mid-small distance enhanced power transfer capacity to relieve congestions from higher volatility of G&D

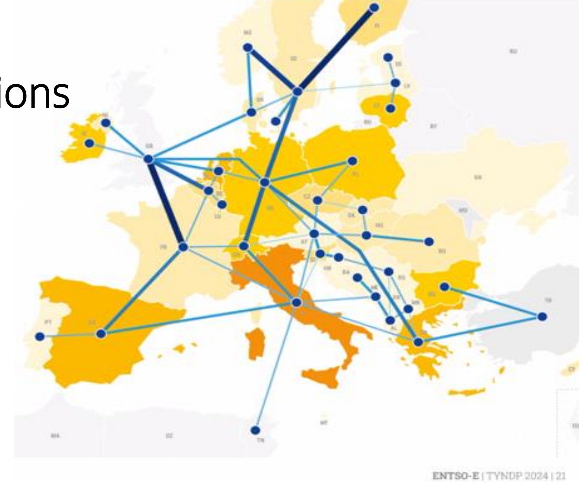
Both **New Grids** and **No-new Grid solutions**

entsoe
ELECTRIFYING EUROPE

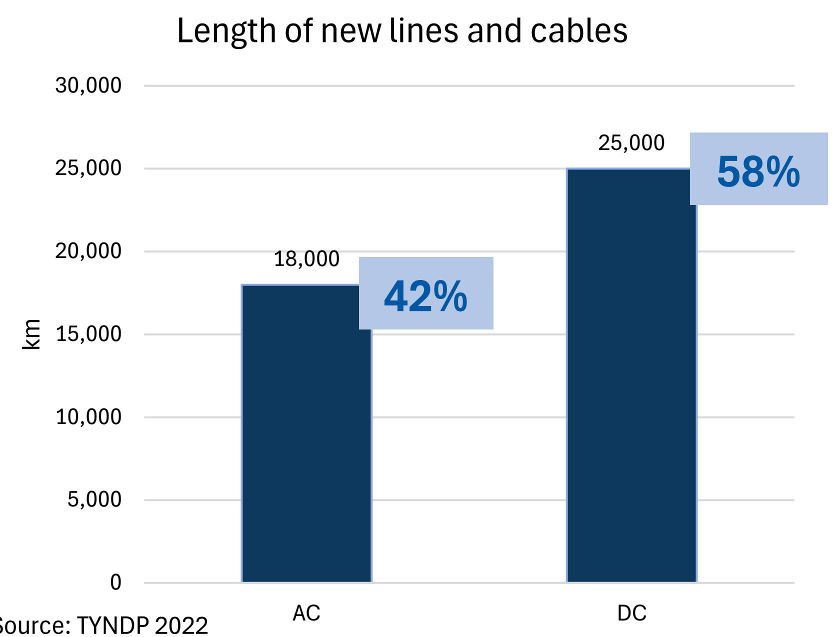
TYNDP // 2024

By 2030:
- ✓ 88 GW additional to the 161 GW of cross-border capacity expected by 2030
- ✓ 56 GW of storage

By 2040:
- ✓ 108 GW additional cross-border capacity
- ✓ 227 GW of storage



Technologies and solutions for long distance energy corridors



Source: TYNDP 2022

DC is becoming the most relevant technology in the ENTSO-e grids of the future

HVDC Evolving Drivers

CLASSICAL DRIVERS

- ✓ Interconnection between systems with different rated frequency (50/60 Hz)
- ✓ Interconnection between systems with different frequency performances
  - → Frequency control
- ✓ Marine crossings
- ✓ Very long lines
  - → Voltage control reactive power mngt

+

NEW DRIVERS

- ✓ Social acceptance (undergrounding, no EMF)
- ✓ Enhancement of power transfer capacity (AC to DC conversion of existing links)
  - → Environmental constraints
- ✓ Decarbonization of the power sector: off-shore grids
  - → Voltage control reactive power mngt
- ✓ Transfer of massive amount of power
  - → Loss reduction

Key Challenges

- ✓ High sea depth cables
- ✓ Fault clearing in meshed DC grids: HVDC circuit breakers
- ✓ Bottlenecks in the supply chain
- ✓ Financing and Business Models (LCOT comparable or even higher than LCOE)

Technologies and solutions for long distance energy corridors

Evolving limits of high depth DC Cables	
Tyrrhenian link	≈ 2200 m
Georgia – Romania	≈ 2200 m
Great Sea Interconnector	≈ 3000 m

→ Much longer cable length

→ Much higher mechanical tension when laying down cables

Vessels

Overall length 170 metres	Carousel Capability Up to 10,000 tons	100 tons cable pulling tension	Overall length 155 metres	Carousel Capability Up to 10,000 tons	75 tons cable pulling tension

New generation of vessels will allow a bollard pull more than 180 tonnes and simultaneous cable lay and burial

Cables

Eco-friendly and High-sea-depth innovative cables

High strength synthetic fibres armour (light weight design)

Max depth up to 3000 m

New extruded solutions, thermoplastic (HPTE)

P-laser

Terrestrial applications

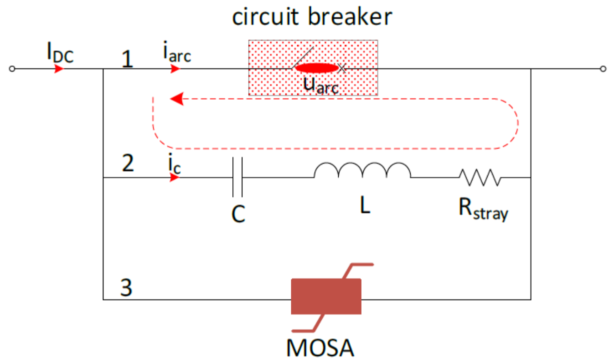
Source: Prysmian

Technologies and solutions for long distance energy corridors: key role of testing new components

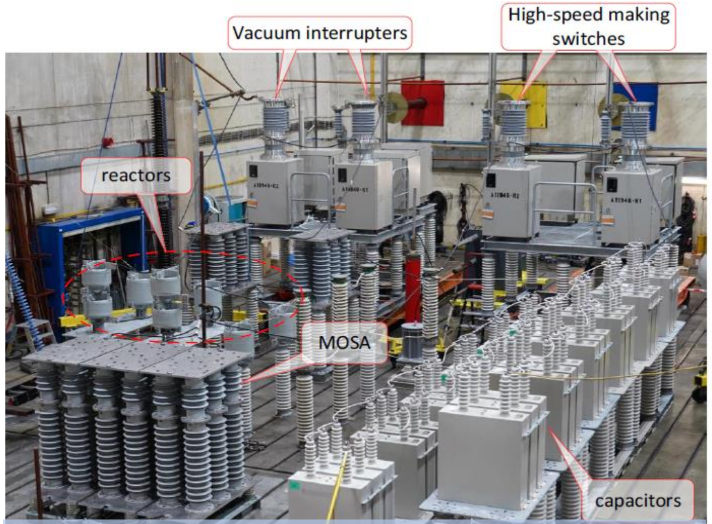
HVDC circuit breakers in meshed DC grids

Mechanical HVDC CB

consist of only mechanical CB(s), passive components in the CCB, and auxiliary circuit needed for local current zero creation in the commutation branch



- ✓ Operation speed (opening time of a gas CB ≈20 ms)
- ✓ Moderate maximum current interruption capability

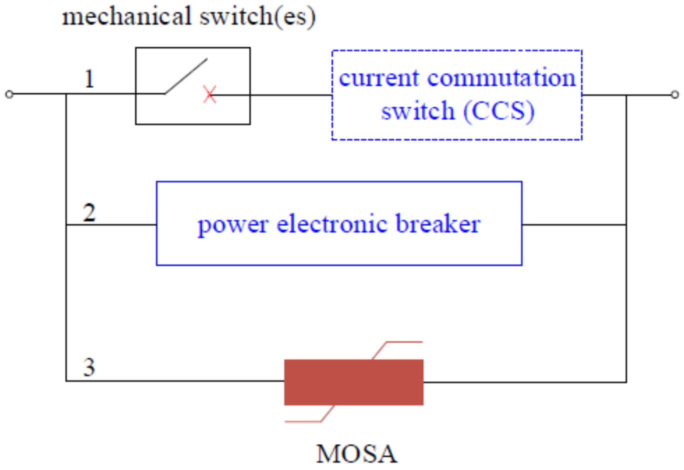


Active current injection HVDC CB – 160/200 kV prototype tested at KEMA Labs – courtesy Mitsubishi Electric

500 kV hybrid HVDC CBs based on Modified Topology (courtesy: NR Electric)

Hybrid HVDC CB

combine the features of mechanical switches with those of Power Electronic switches.



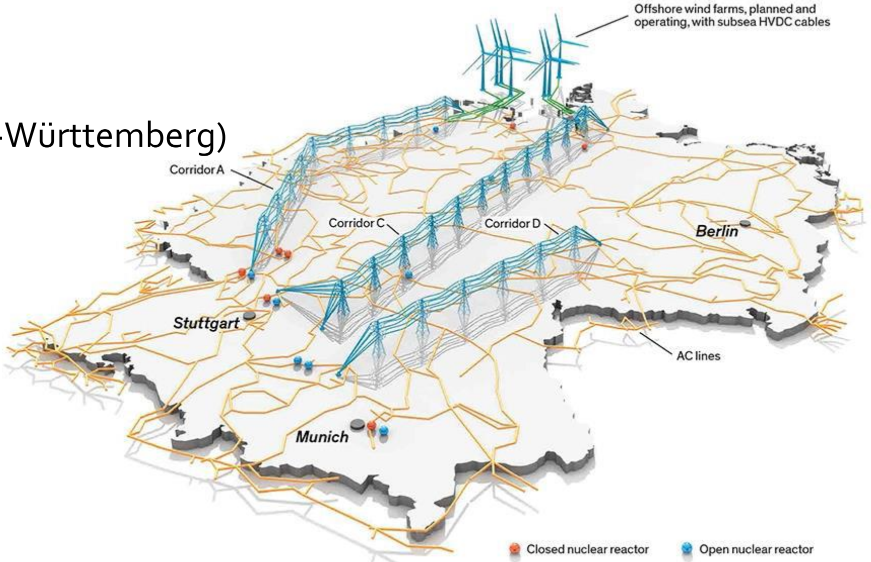
- ✓ High operation speed (3 ms)
- ✓ Higher ratings (25 kA)

Technologies and solutions for mid-short distance energy corridors: no new-grid solutions

Upgrading power transfer capability: **circuit conversion from AC to DC**

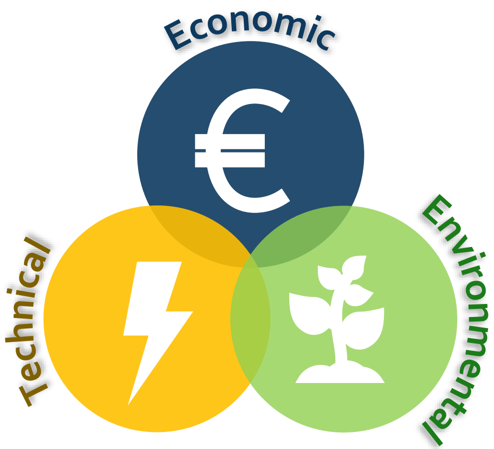
The HVDC Ultranet project (Germany)

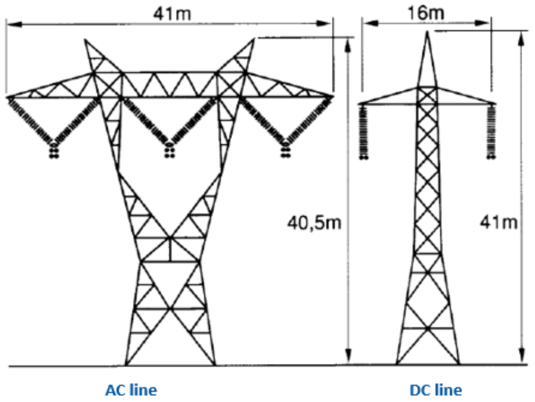
- ✓ **2 GW** HVDC connection from the Region of Osterath (Rhineland) to the Region of Philippsburg (Baden-Württemberg)
- ✓ **≈ 340 km** length
- ✓ **VSC MMC converter** applying a two-level multi-state control
- ✓ **Multi-terminal capability**, mastering DC faults and AC/DC inter-system faults



Source: Bundesnetzagentur - Netzausbau

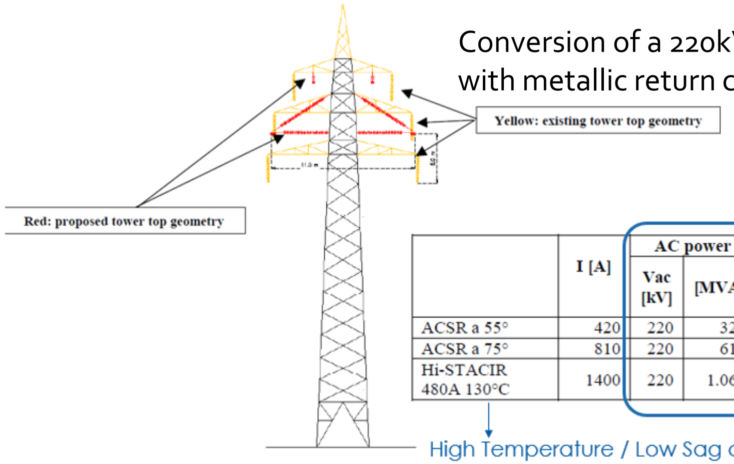
HVDC key advantages





- Reduced land use (less ROW) and visual impact
- No EMF (Electro-Magnetic Field)

Conversion of a 220kV AC double circuit to a DC ± 400kV bipole, with metallic return conductors (TERNA-CESI CIGRE G.S. 2010 - paper B2-201)



x2

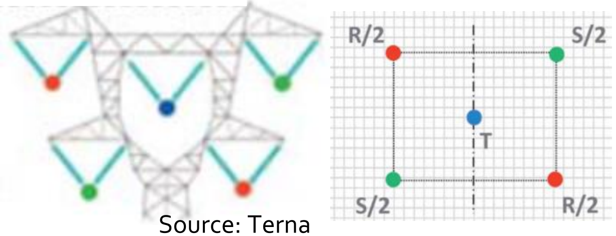
	I [A]	AC power		DC power	
		Vac [kV]	[MVA]	Vdc [kV]	[MW]
ACSR a 55°	420	220	320	400	672
ACSR a 75°	810	220	617	400	1.296
Hi-STACIR 480A 130°C	1400	220	1.067	400	2.240

High Temperature / Low Sag conductors

Technologies and solutions for mid-short distance energy corridors: no new-grid solutions

Line Design

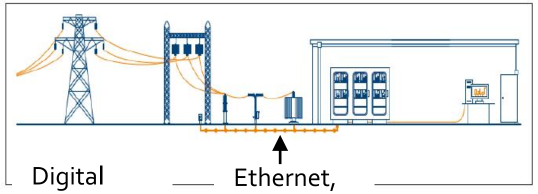
- ✓ Rearrangement of conductors: 5F central link project
- ✓ Substitution of conductors: HTLS alloys

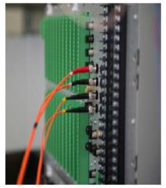


Source: Terna

Digitalisation

- ✓ Enhanced digitalization: dynamic loading
- ✓ Digital substations
  Enabler to increase safety & reliability while reducing costs and environment footprint





Source: ABB

Security & Market

- ✓ Changing security criteria
  => higher loading of components, accepting the risk of higher FOR
- ✓ Allocation of market-based transactions with FB vs ATC

Environment restoration

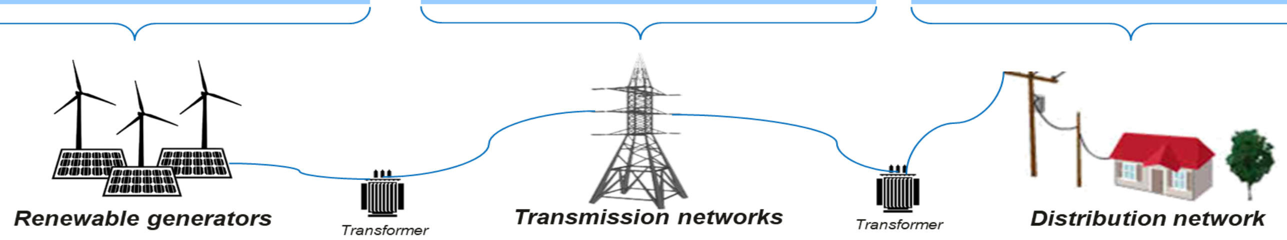
- ✓ Dismantling old lines when building new ones

Key Challenges

- ✓ Timely implementation of no-new grid solutions
- ✓ Supply chain of critical components

Energy storage: multiple objectives, many implications

RENEWABLE GENERATORS	SYSTEM OPERATION	INVESTMENT DEFERRAL
Reduced renewable curtailment	Frequency regulation	Transmission and distribution congestion relief
Renewable capacity firming	Flexible ramping	Energy shifting and capacity investment deferral
	Black start services	



Size

- ✓ Utility scale connected to T
- ✓ Small size storage connected to D

In-front of the meter | Behind the meter | Distributed V1G/V2G

Location

- ✓ Coupled with V-RE PP
- ✓ Distributed along the grid
- ✓ Close to demand

Duration

(E/P ratio depending on required performances)

- ✓ Frequency regulation
- ✓ Line congestion relief
- ✓ Peak shaving
- ✓ Load shifting

Daily | Weekly/seasonal

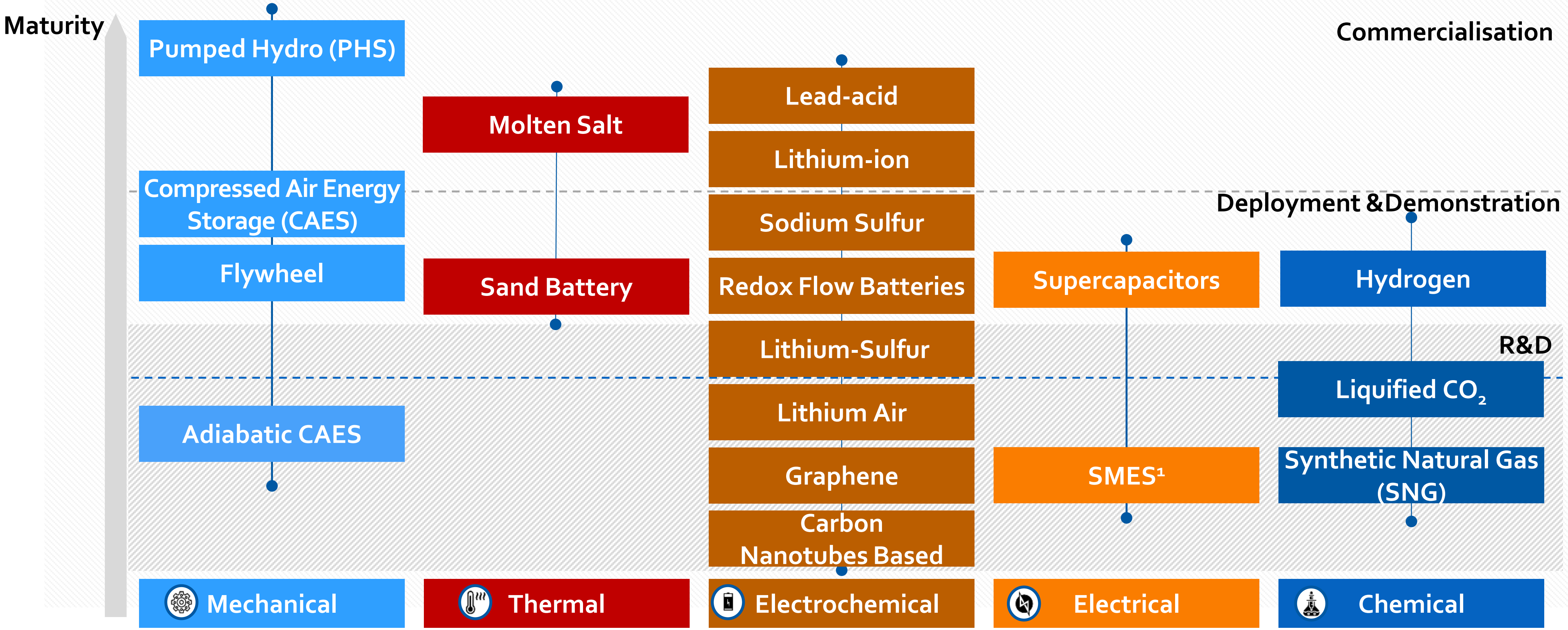
Implications on:

Technologies

Business models

- ✓ Full merchant
- ✓ Forward markets (GR; UK; IT-MACSE-;…)

Key energy storage technologies and maturity stage



Source: World Energy Council, IEA, Rocky Mountain Institute, Strategy&/CESI analysis

1) Superconducting Magnetic Energy Storage

Key Challenges

- ✓ Diversification into new technologies: role of R&D
- ✓ Set up mechanisms to attract investments on storage with focus on new technologies

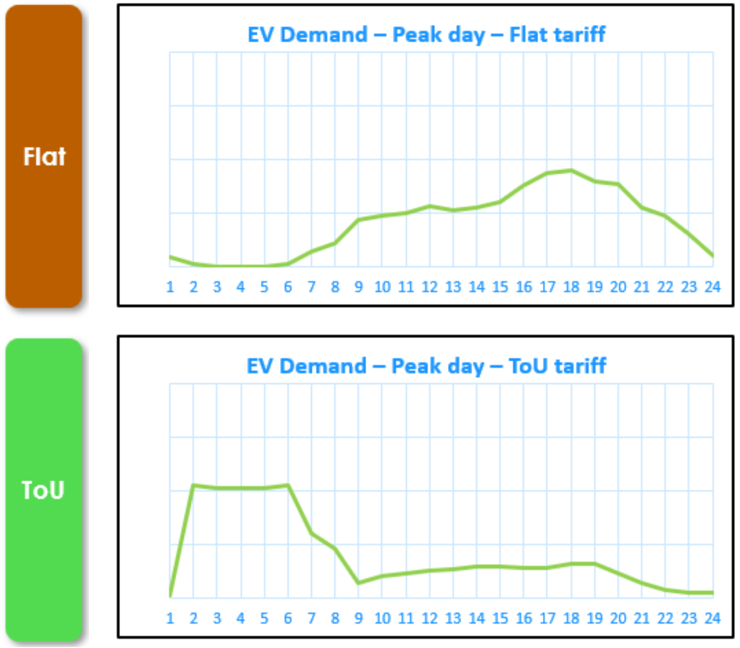
Flexibility: the role of the demand

As we move towards a full decarbonisation, all segments of the power supply chain (G-T-D-L) shall contribute to flexibility

The concept of flexible load is one of the components for balancing electricity supply and demand. The deep electrification (EVs, heat pumps, etc.) offers higher potential of flexibility

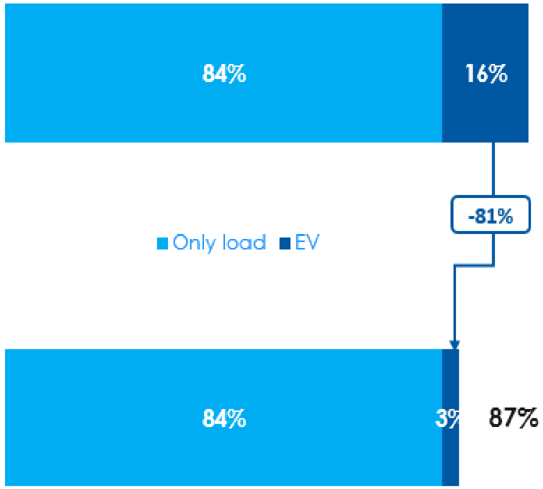
Flexibility for deferring grid investments

Chile – 2035 – 13%



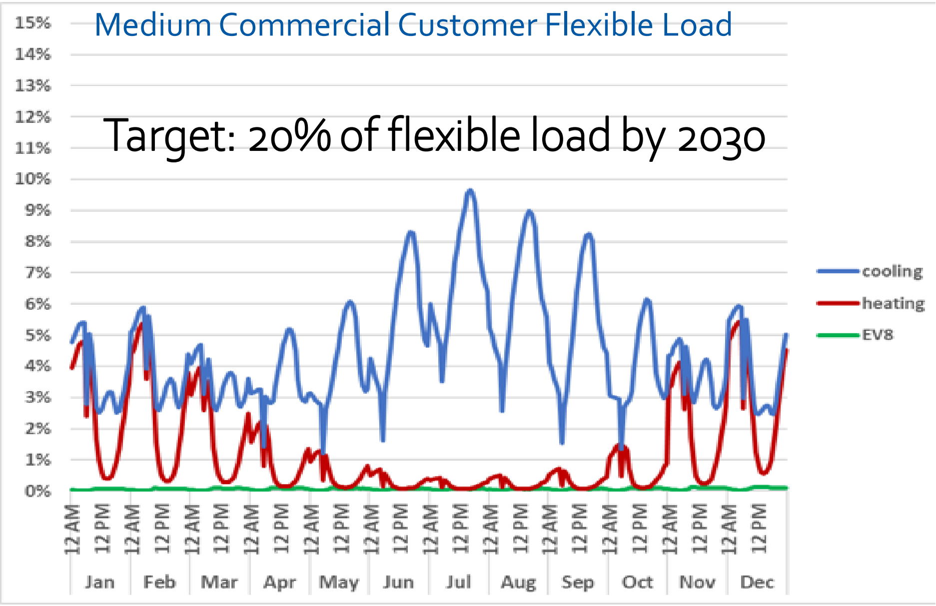
Source: CESI

Investments on distribution grid



Flexibility for providing system reserves

Southern California - 2023



Source: CESI/ENERNEX

Key challenges:

✓ Load disaggregation: high granularity of load profiles for categories of users

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Milan (IT) · Arnhem (NL) · Berlin (DE) · Mannheim (DE) · Prague (CZ) · Chalfont (US) · Knoxville (US) · Dubai (AE) · Santiago de Chile (CL) · Rio De Janeiro (BR) · Shanghai (CN)