



The role of Batteries in Europe's Power System,

Michael Lippert



Graz, 2 December 2025



The backbone of electrification



Source: EU Publications Office; PBL Netherlands Environmental Assessment Agency, 2018; IEA, IRENA, UN Statistics Division, World Bank Group, WHO, 2019; World Economic Forum, Global Battery Alliance





01

The Electricity Sector



Variable Renewables in Europe (EU)



More power needed

- Electricity production is expected to double between 2023 and 2050

EU target for Renewables:

- 42% RES in its global energy consumption by **2030**, equal to **69% of its electricity consumption**
- In 2023, RES contributed 45% (1.2M GWh) to the electricity mix

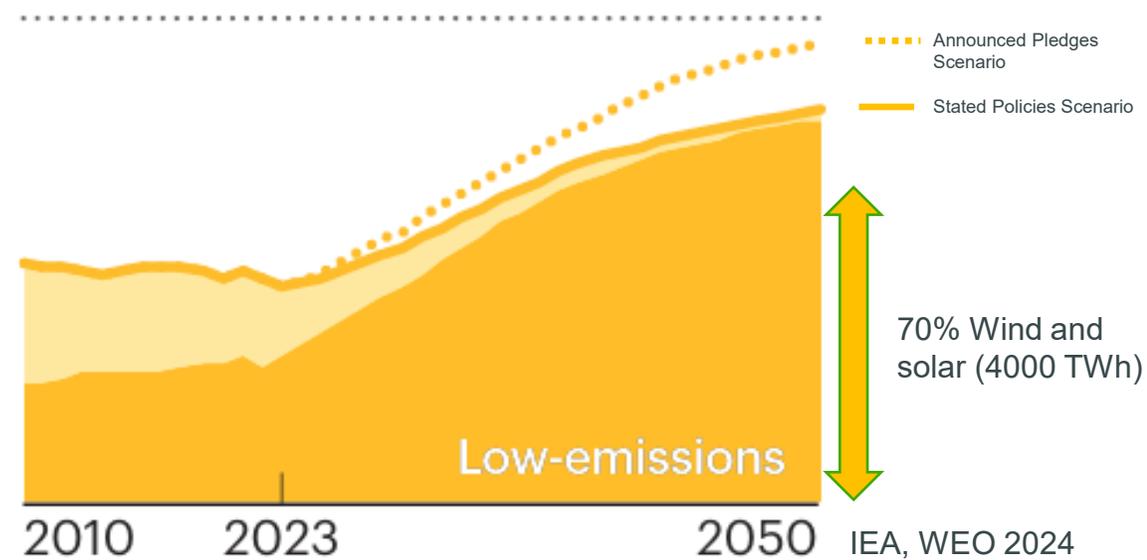
Variable Renewables ?

IEA forecast for Wind and Solar in the EU Union

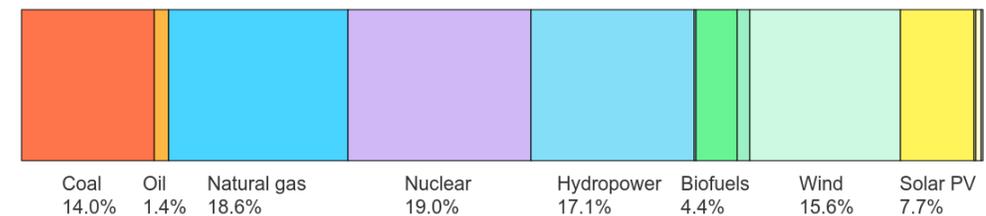
- 700 TWh of wind and solar 2023 → 26% of annual electricity
- 1900 TWh of wind and solar 2030 → 53% of annual electricity
- 4000 TWh of wind and solar 2050 → 70% of annual electricity

Electricity generation

6 000 TWh



Electricity generation by source, Europe, 2023 (IEA)

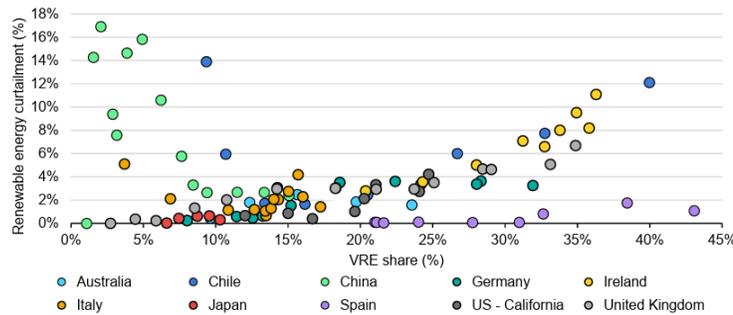


More Renewables...



...lead to curtailments

Annual VRE shares in generation and technical curtailment for selected countries and regions



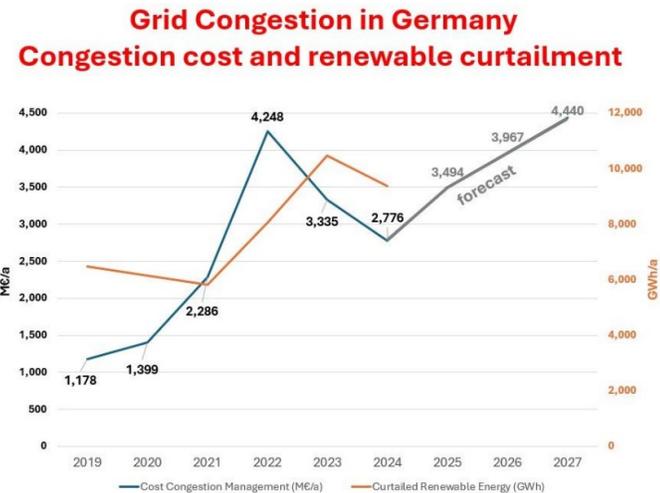
IEA. CC BY 4.0.

Notes: Each dot represents one year. Data points indicate officially reported curtailed or constrained energy generation and combine various schemes, depending on the country. VRE refers to solar PV and wind unless otherwise specified. The United Kingdom includes wind only. Technical curtailment is the dispatching-down of renewable energy for network or system reasons; dispatched-down energy due to economic or market conditions is not included. The graph covers 2010-2024, but the range varies among countries depending on data availability. Values for 2024, when included, are based on daily, monthly or quarterly data up to June.

Up to 10 % of RE generation curtailed

x 10 until 2040 : 310 TWh wasted ?

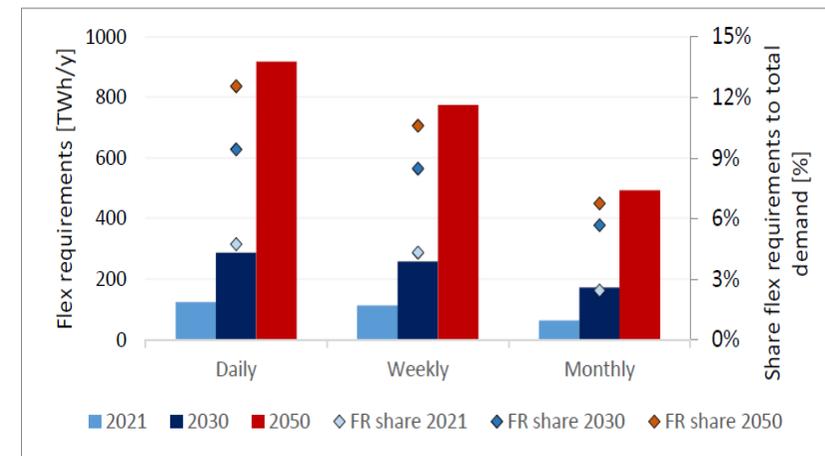
...lead to grid congestion



Exponential cost increase

x 20 until 2040 : 100 bn€ spent ?

.... need more flexibilities



Source: JRC analysis.

Daily, weekly and monthly flexibility requirements and their share in total demand (FR share) in the EU for 2021, 2030 and 2050

2 - 3 times more daily flexibility needed
~10% of total demand



What are the challenges ?



Less dispatchable generation

Reduction of coal & gas synchronous generators
→ **Less firm, flexible power and system services** like voltage and stability
→ **Less inertia**, less grid services



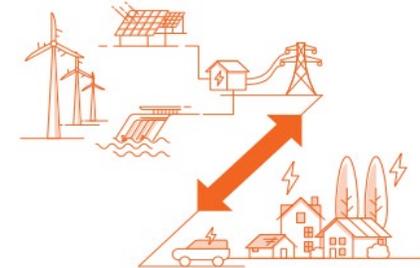
More asynchronous generation

Increase of renewable generators connected by inverter-based technologies increasing stability risk
→ Limited system services
→ **No inertia &**
→ **Lesser system strength**



More variable sources of generation

Increase of renewable generators based on intermittent, unstable and nature dependent source
→ Operation challenges
→ Increased power required
→ **Curtailment as well as capacity (non-spinning) needs**

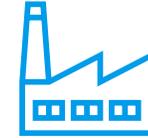


Generation moving to different areas

New generation located at network extremities with low demand such as offshore or distribution networks
→ **Network congestions**

Source: NG-ESO

Decarbonized Flexibilities



Supply – Demand Balance

- PV / Wind shifting
- Arbitrage
- Flexibility Markets



Security of Supply

- Capacity Markets

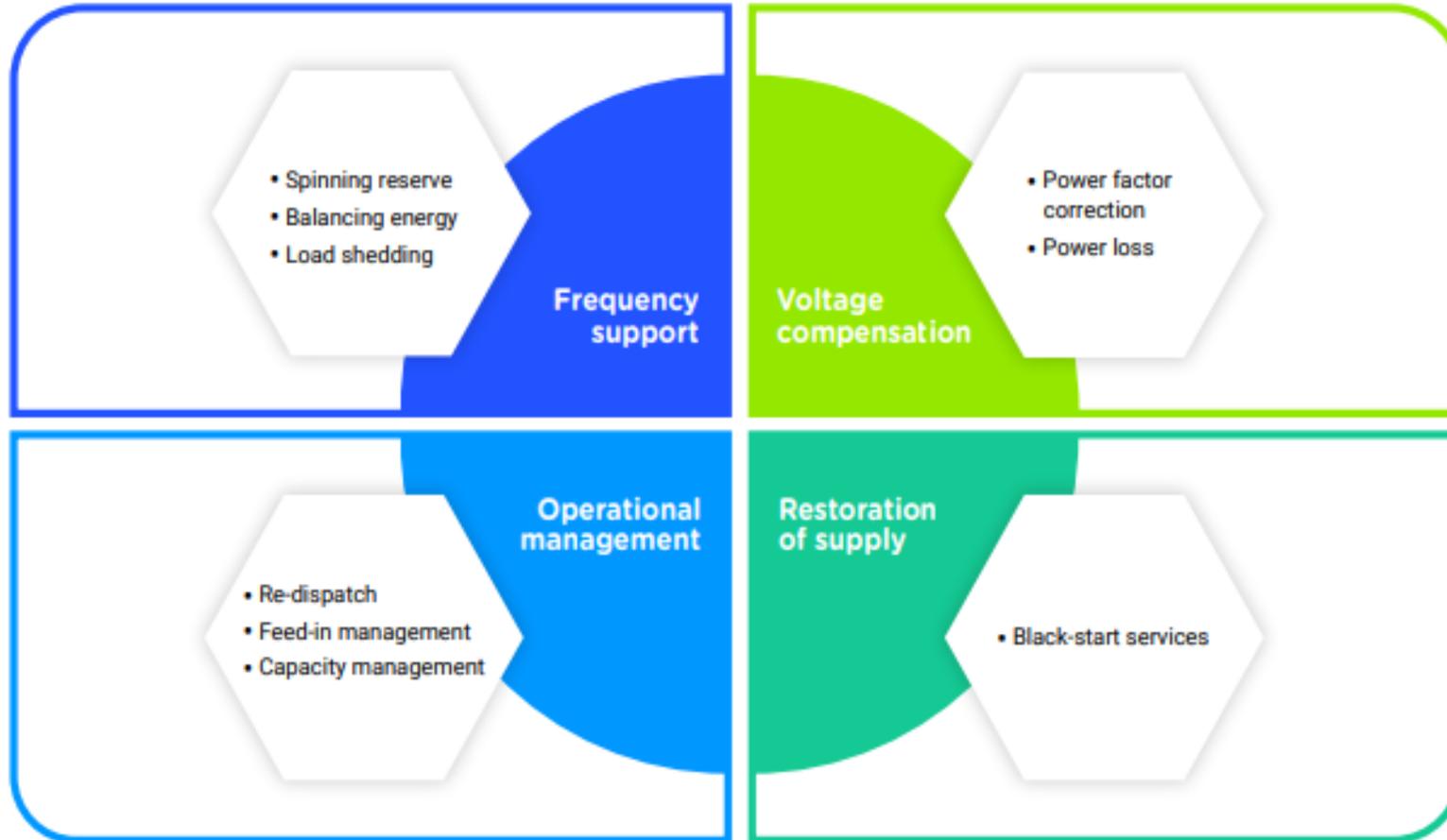


Grid Support

- Frequency / Inertia / Voltage Services
- Congestion / Curtailment avoidance
- Contingency / Blackstart



Grid Services segmentation



3C's: Congestion, Curtailment, Capacity





- Long-Duration Energy Storage
 - New chemistries with low cost/cycle for long durations
 - Based on abundantly available materials
- System Technology
 - Advanced BMS, EMS and digital twins
 - Power conversion
- Optimized Grid Integration
 - Combined, high-speed use of ESS across the system
 - Cybersecurity
 - EV charging infrastructure
 - ...



02.

Aerospace & Defense



HOW DOES A COMMERCIAL AIRCRAFT BATTERY WORK?

Custom-tailored battery solutions

Each battery is developed in collaboration with the aircraft manufacturer based on OEM specific technical requirements to ensure perfect association with the electrical system and critical components of the aircraft.

All large aircraft use **28-volt batteries**, either **nickel-based** or **lithium-ion batteries**.



Capacity: from 20 to 60 ampere hour (Ah)
Number of batteries per aircraft: from 2 to 4.

Auxiliary Power Unit

It allows an aircraft to operate autonomously without reliance on ground support equipment. It can be started using only the aircraft batteries and, once running, will provide electrical power to aircraft systems as well as bleed air for air conditioning and for engine start.

Life cycle monitoring

After use, batteries can be disassembled for recycling.



Maintenance

Each battery, made up of cells, undergoes maintenance at regular intervals in "repair shops". If the test criteria are not met, cells, cell packs or even the battery, are replaced.



Charger



Battery



Cell

Batteries

Its main function is to start the engines and APU system of the aircraft.

In case of an emergency, the battery is the primary power source for radio communication with air traffic control, the instruments that give guidance and orientation information and the systems that control the airplane.

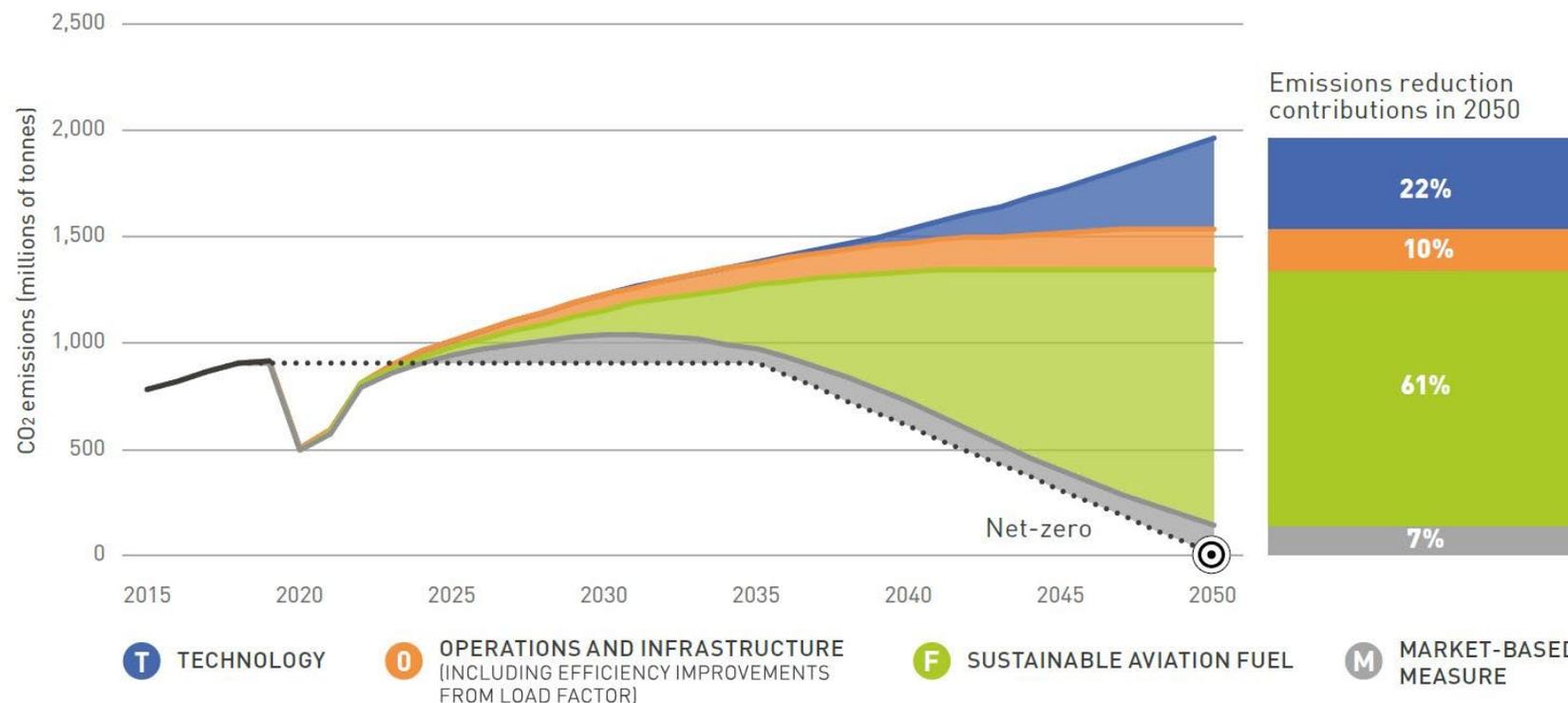


Aviation Climate Neutrality Road Map



Scenario 1: pushing technology and operations

“Prioritised development of electric and hybrid electric aircraft in the short-range and <100 seat category with entry into service from 2035/2040 and further enhancements for larger aircraft.”



Source: Waypoint 2050 project led by AIR TRANSPORT ACTION GROUP

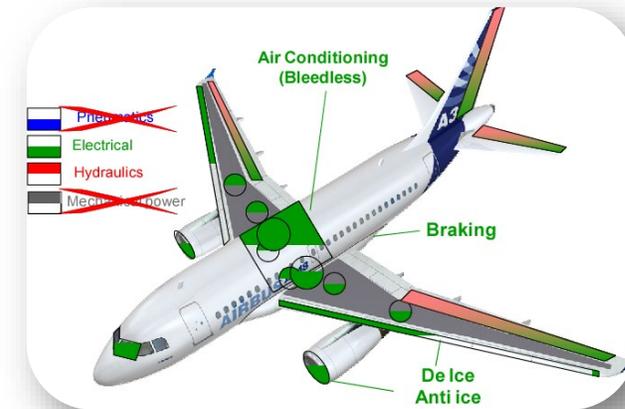


Emerging Market on High Voltage batteries



More Electrical Aircraft

- Hydraulics/pneumatics/mechanical to electric
- Batteries per aircraft x 5 - 10



Electrical propulsion

- Full electric propulsion 2026-2030
 - Battery
 - Fuel cell + Battery
- Hybrid propulsion commercial, regional... (2030+)
 - Combustion engine + battery
 - Combustion engine + Fuel cell + battery
- Batteries per aircraft: x 100



VTOL - airtaxi



General Aviation



Regional aircraft



Commercial aircraft



Today's and Tomorrow's requirements



- **Safety**
 - Criticality of incidents
 - Management of temperature, gases, ... in confined environment
- **Altitude**
 - pressurized or non pressurized area, external pressure due to altitude variation up to 55000 fts
 - HV/LV isolation including at high altitude: 2500Vdc
- **Performance**
 - Energy density: weight is critical for energy consumption and autonomy
 - Power density: APU start, take-off, fast recharge



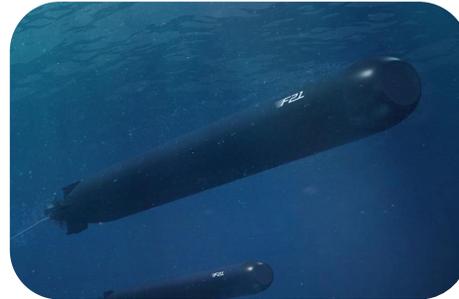
Space and Defense



- Aircrafts
- Helicopters



- GEO / MEO / LEO / Constellations Satellites
- Probes, observation vehicles
- Launchers



- Torpedoes
- Tactical and ballistic missiles



- Night vision
- Communication
- Soldier of the future
- Mobile base camp power



- Submarines
- Hybrid and full-electric vessels
- Defense vehicles
- Robots for hostile environments (ATEX)

Ni-Cd, Li-ion

Li-ion
NCA, NMC, LTO

Ag-Zn, AgCl-Mg, AgO-Al
Li primary, Li-ion

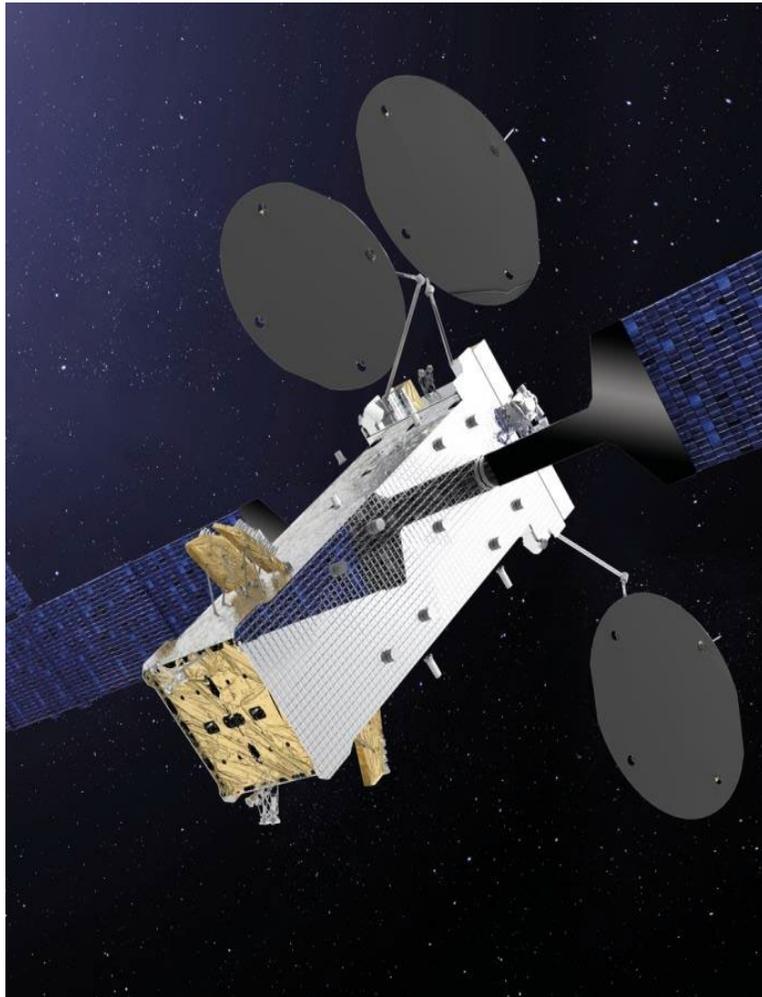
Li-SoCl₂, Li-ion

Li-ion, Ni-Cd



SAFT

Specific and evolving battery needs



Example Geostationary Satellites. Battery ~10 kWh

- Demonstrated lifetime in excess of 19 years in orbit
- Real time ground testing 15+ years
- Reliability
- Energy density
- Vibration & shocks, radiation, thermal management, etc.
- Configuration control, traceability

Performance requirements		Current	Future
Phase	duration		
Construction, tests		-	10 cycles 95%
Launching		1 cycle 95%	1 cycle 95%
Positioning		4 months	1500 cycles 75% 18 kW
Operation	Equinoxes	15 years	1350 cycles 75% 18 kW
	Keep position	15 years	11000 cycles 25% 1-3 kW

x 4

A submersible battery industry ?

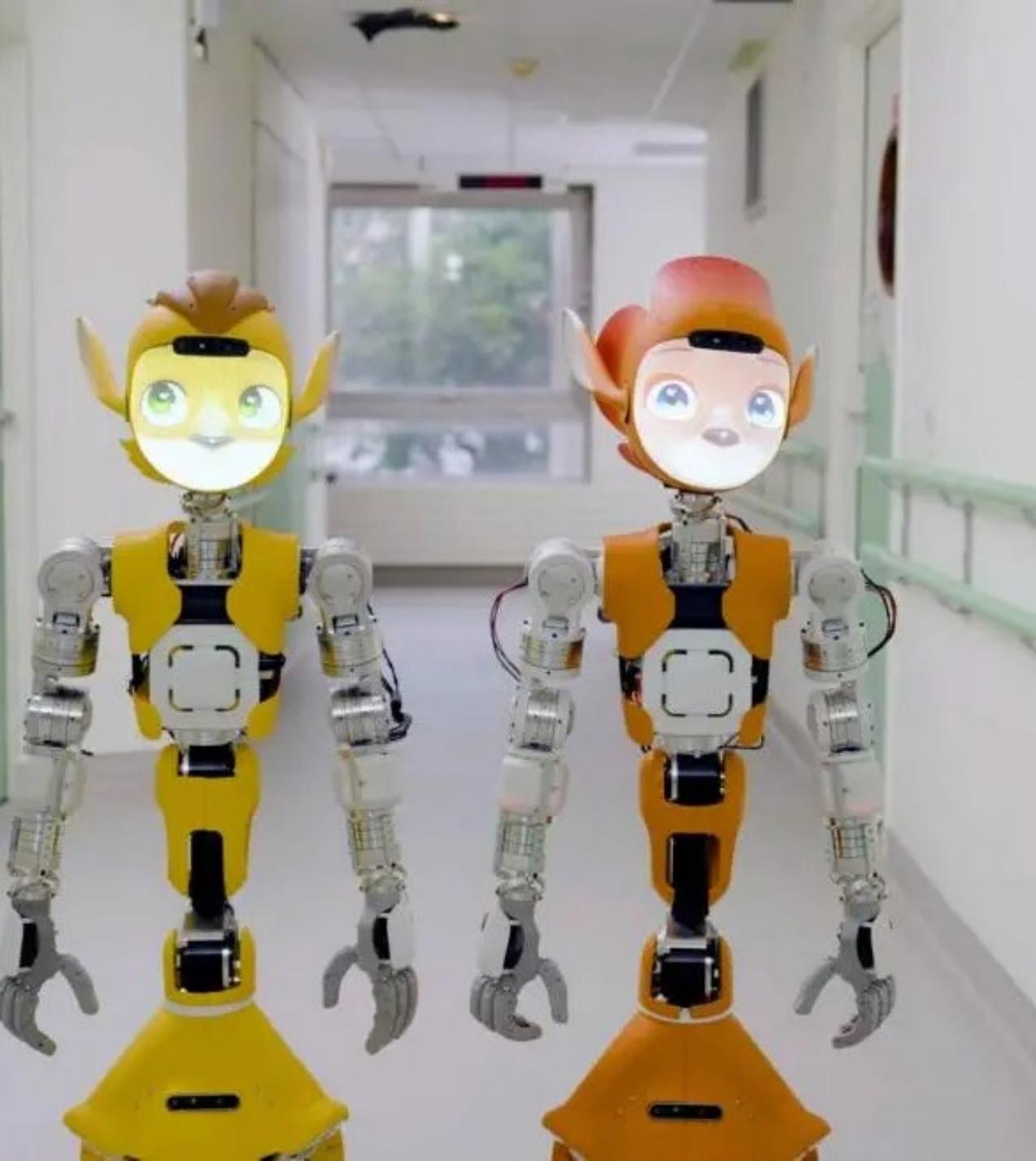


Growing needs

- Geopolitical threats drive military expenses
- Electrification of systems
- More complex functionalities
- Specific requirements: cells & systems

Growing dependence

- Battery cell market >90% dominated by China
- Chinese export restrictions
- Technology ownership: cells → systems → equipment
- Obsolescence



TotalEnergies

THANK YOU

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