International Renewable Energy Agency

BATTERY STORAGE

ACCELERATING THE ENERGY TRANSITION

MICHAEL TAYLOR

MTAYLOR@IRENA.ORG

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Renewable Energy Costs, Technologies and Markets

WHY BATTERY STORAGE IS IMPORTANT

The Energy Sector is Being Transformed

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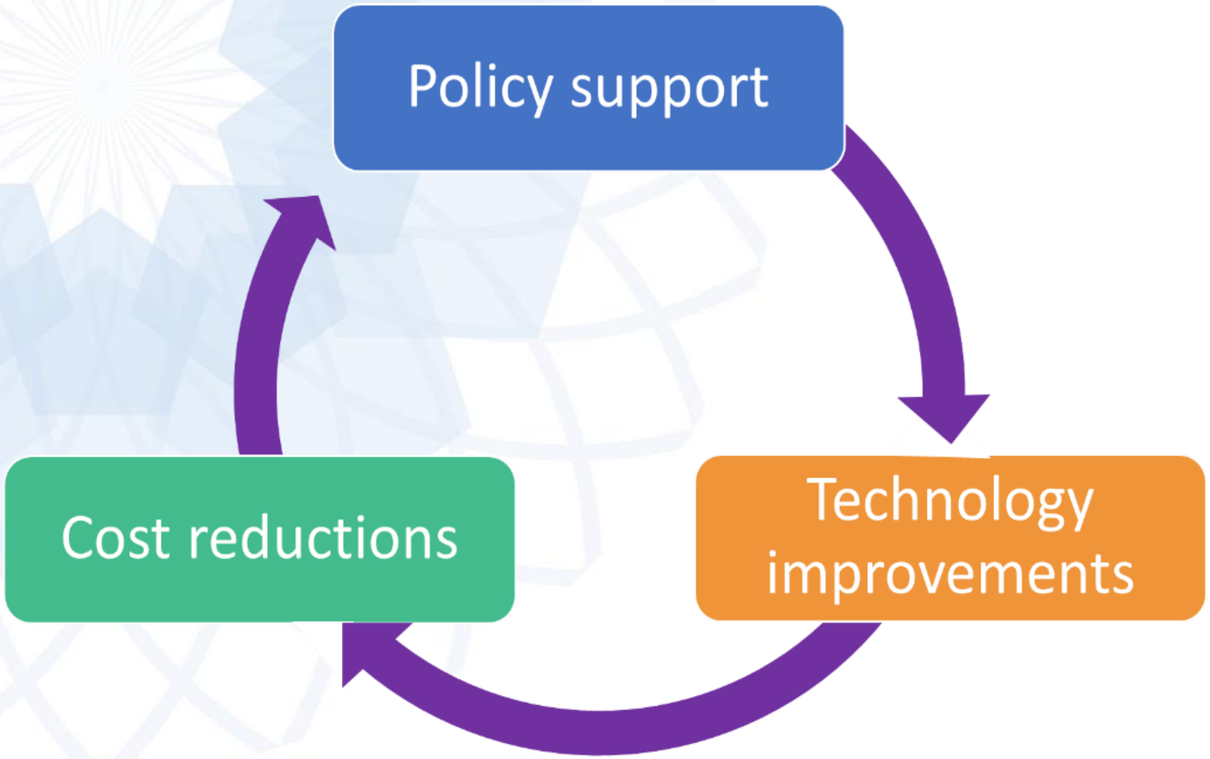
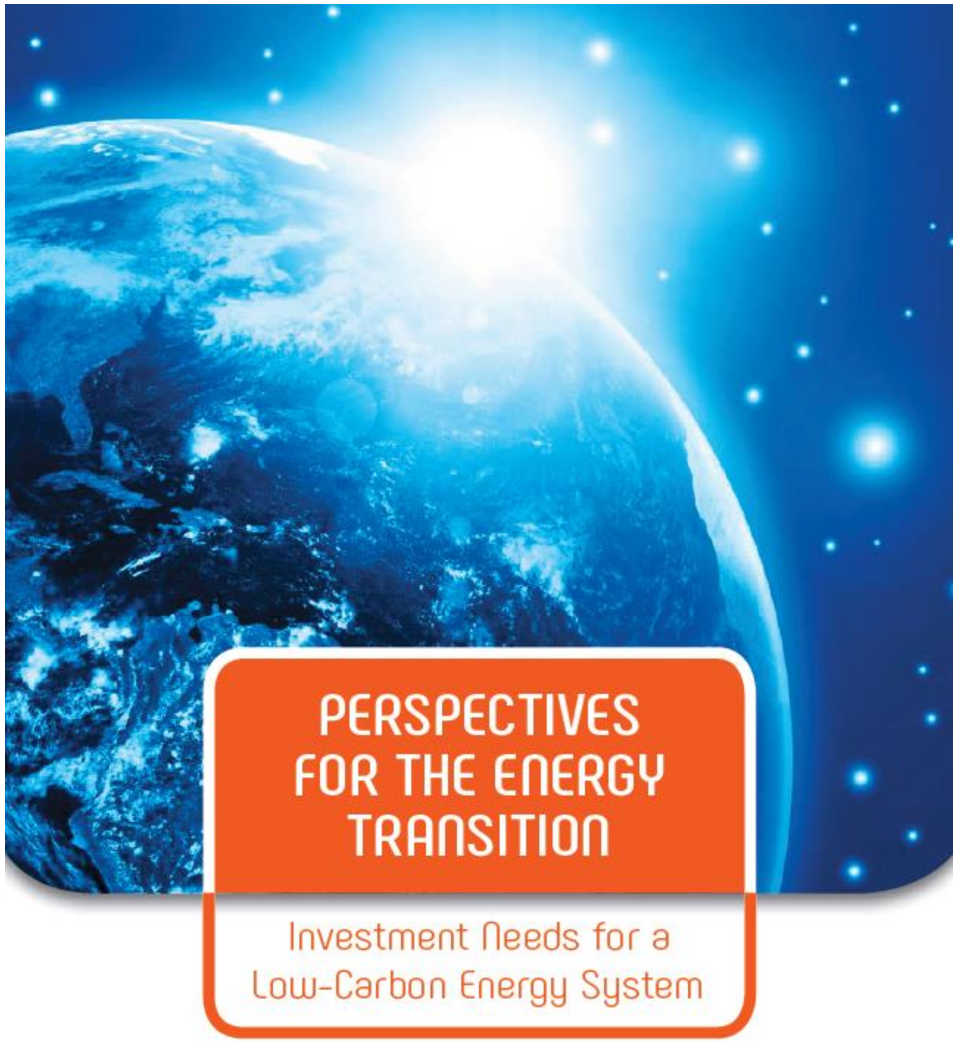
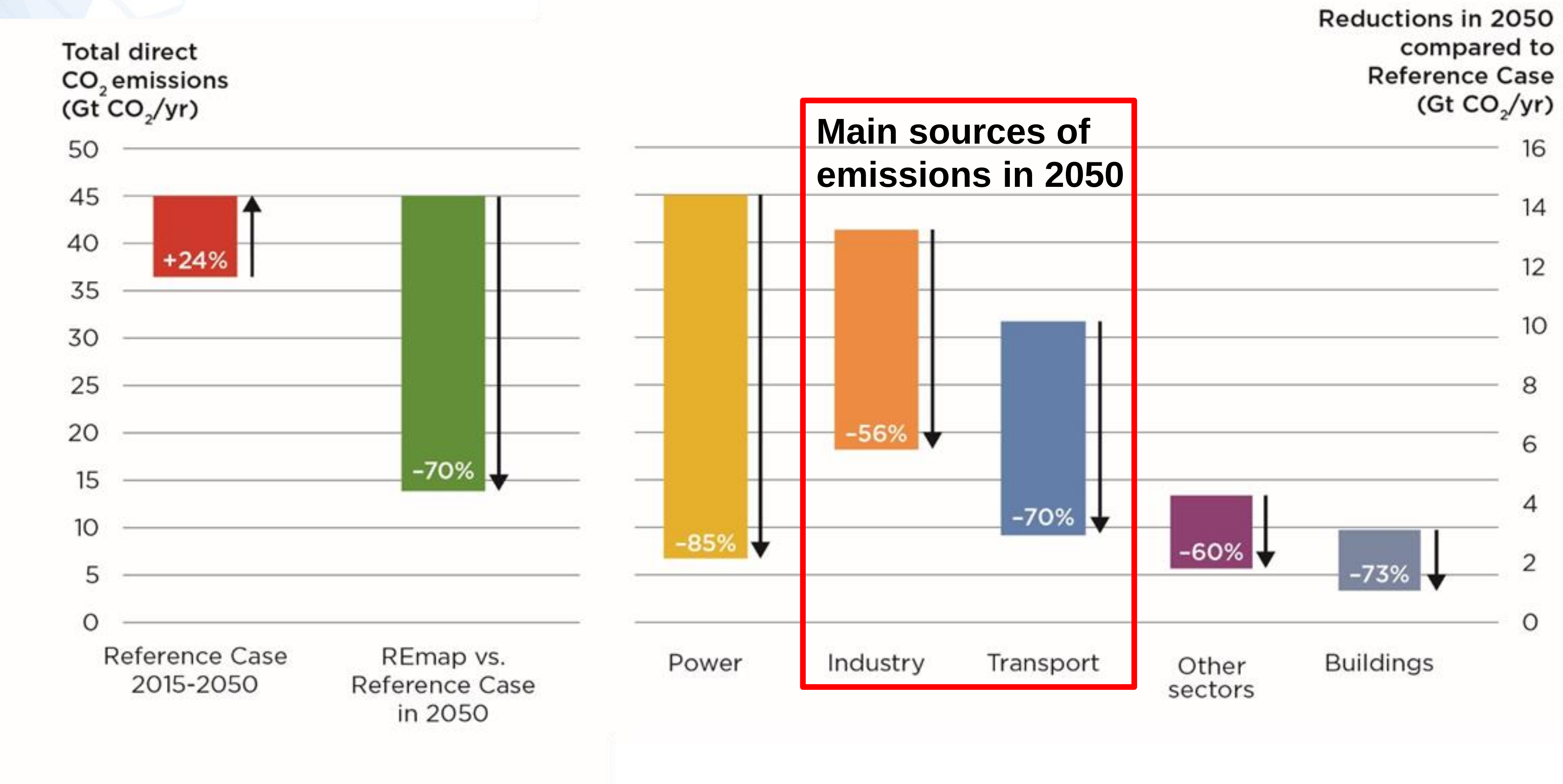


A ***virtuous cycle*** is unlocking the ***economic***, ***social*** and ***environmental*** benefits of renewables



Development in CO_2 emissions by sector

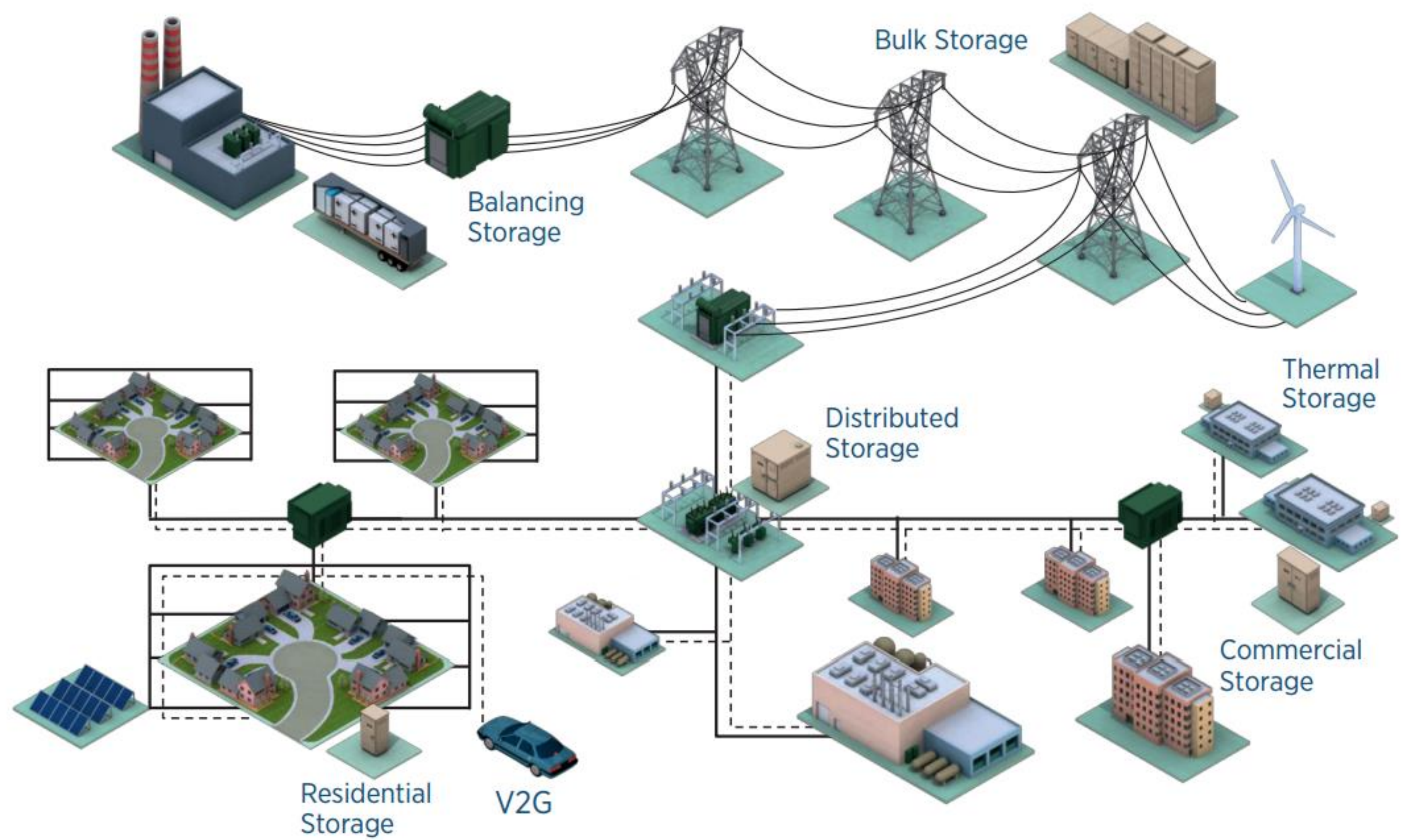


By 2050, total energy-related CO_2 emissions will need to decrease to below 10 Gt/yr

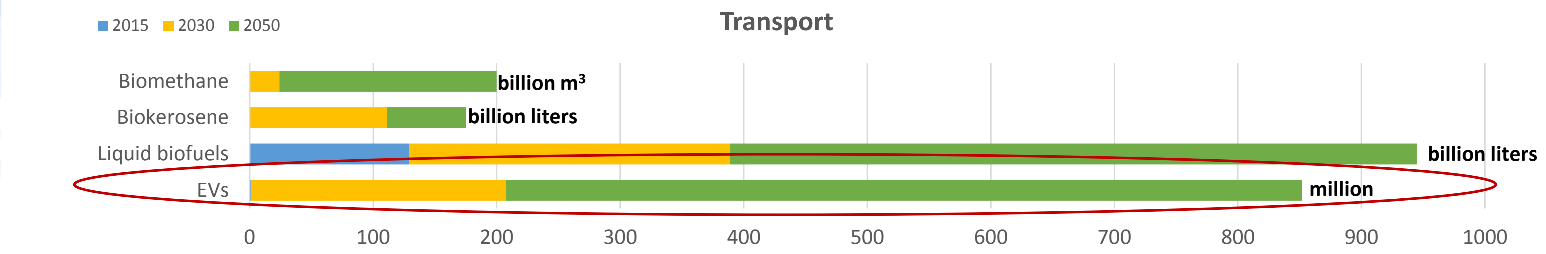
CO_2 emissions from the power and buildings sectors will be almost eliminated

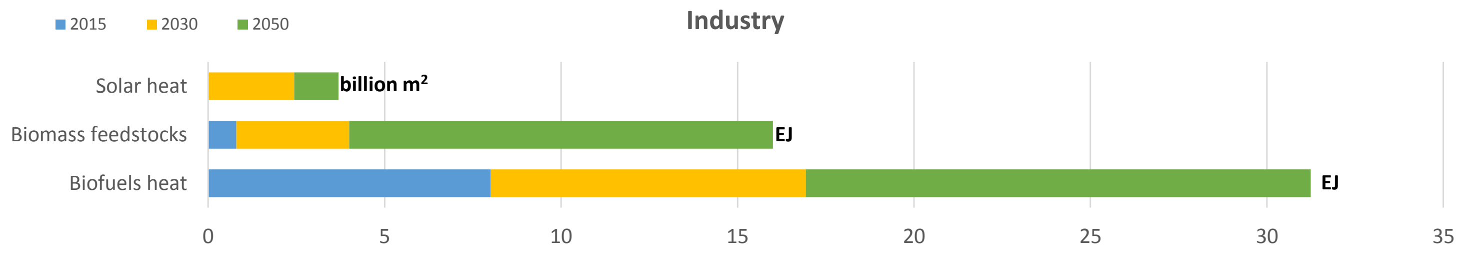
Power systems

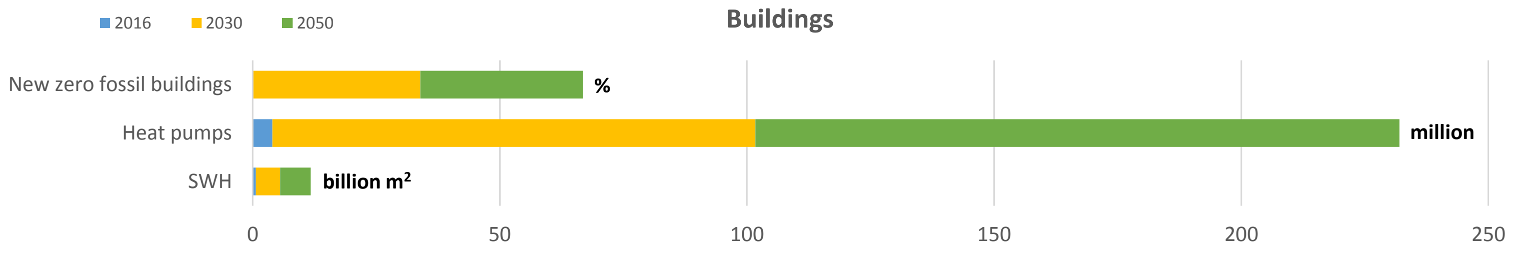
Potential locations and applications of electricity storage

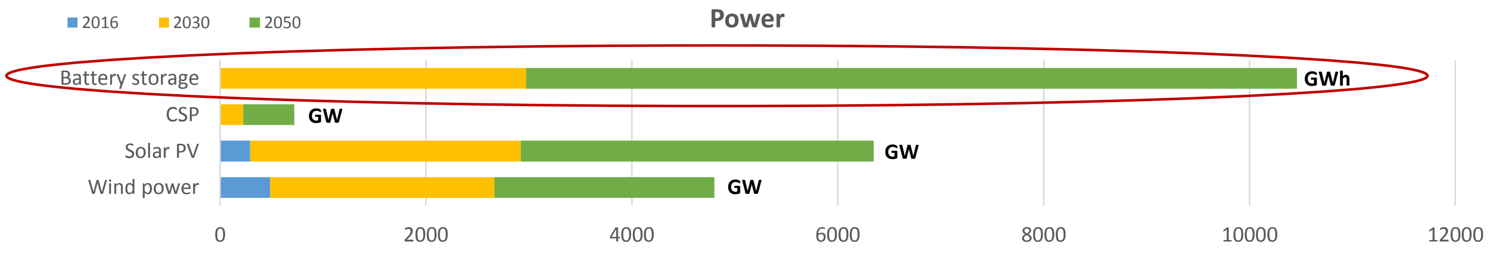


The end-use sectors transition: untapped area









Transport

- Will traditional car makers able to catch up?
- Significant biofuel trade
- Materials needs (e.g. rare earth for EVs)

Industry

- Industry is the most challenging sector

Buildings

- Significant acceleration of buildings renovation

Power

- Growing equipment industries
- Materials needs (e.g. for batteries, inverters)

Storage

The importance of battery storage and roles

- Battery storage important part of transition now to medium-term (e.g. SHS, islands, frequency response and EVs)
- Long term to integrate v high share of VRE)
- In the next 3-5 years, the storage industry is positioned to scale
- Incremental improvements in energy storage technologies, developments in regional regulatory and market drivers, and emerging business models are poised to make energy storage a growing and viable part of the electricity grid
- In the stationary sector, increased economic applications due to cost declines are expected for grid services

BATTERY ELECTRICITY STORAGE FOR STATIONARY APPLICATIONS

Context

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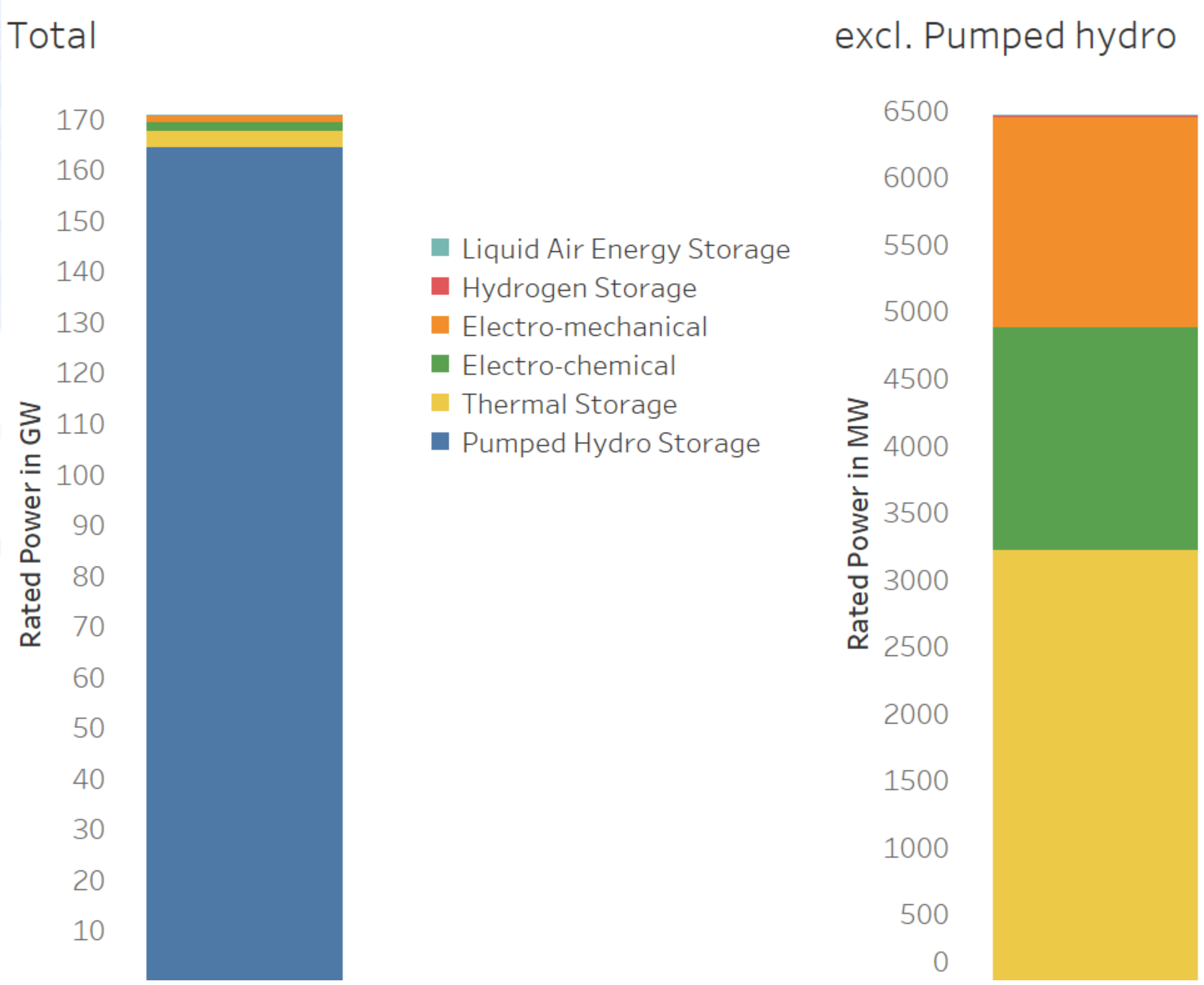
IRENA's RE costs and markets team is preparing a study to analyze and discuss stationary battery electricity options and costs

- Existing market and technology options
- Latest performance and cost data (and the breakdown of costs into components) for electricity storage technologies in different geographic markets and market segments/applications.
- Cost reduction potential, competiveness of battery storage for different services and market growth in detail for electricity storage devices, focusing on batteries to 2030

Stationary storage today



- Source: DOE

Technology overview

Scope of analysis

Electrical
- Superconductive Magnetic Coil
- Super-Capacitor

Mechanical
- Pumped Hydro
- Compressed Air
- Flywheels

Chemical

Lithium-Ion Batteries
- NMC/LMO
- NCA
- LFP
- LTO

Lead-Acid Batteries
- Flooded
- VRLA

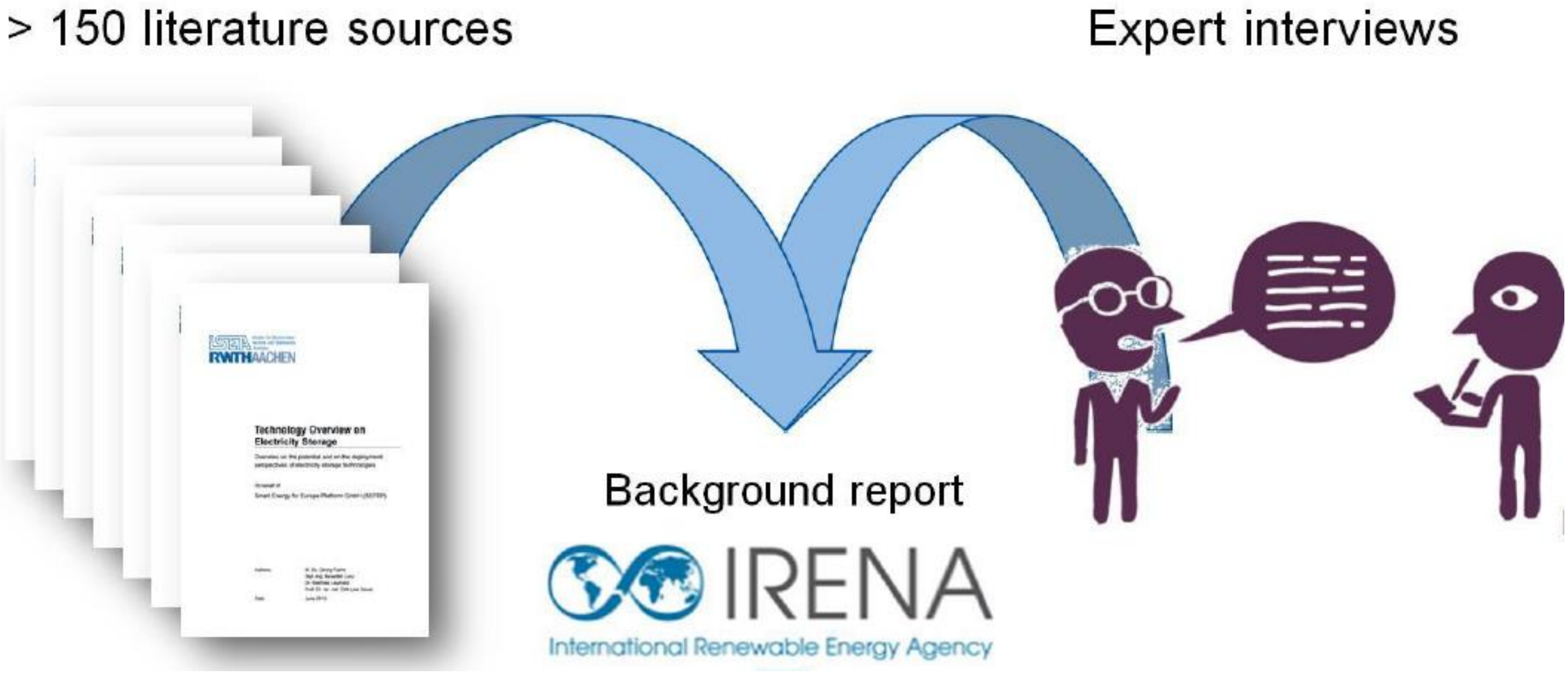
High Temperature Batteries
- NaNiCl
- NaS

Flow Batteries
- Vanadium
- Zn/Br
- Zn/Fe

Nickel based
- NiCd
- NiMH
- NiFe

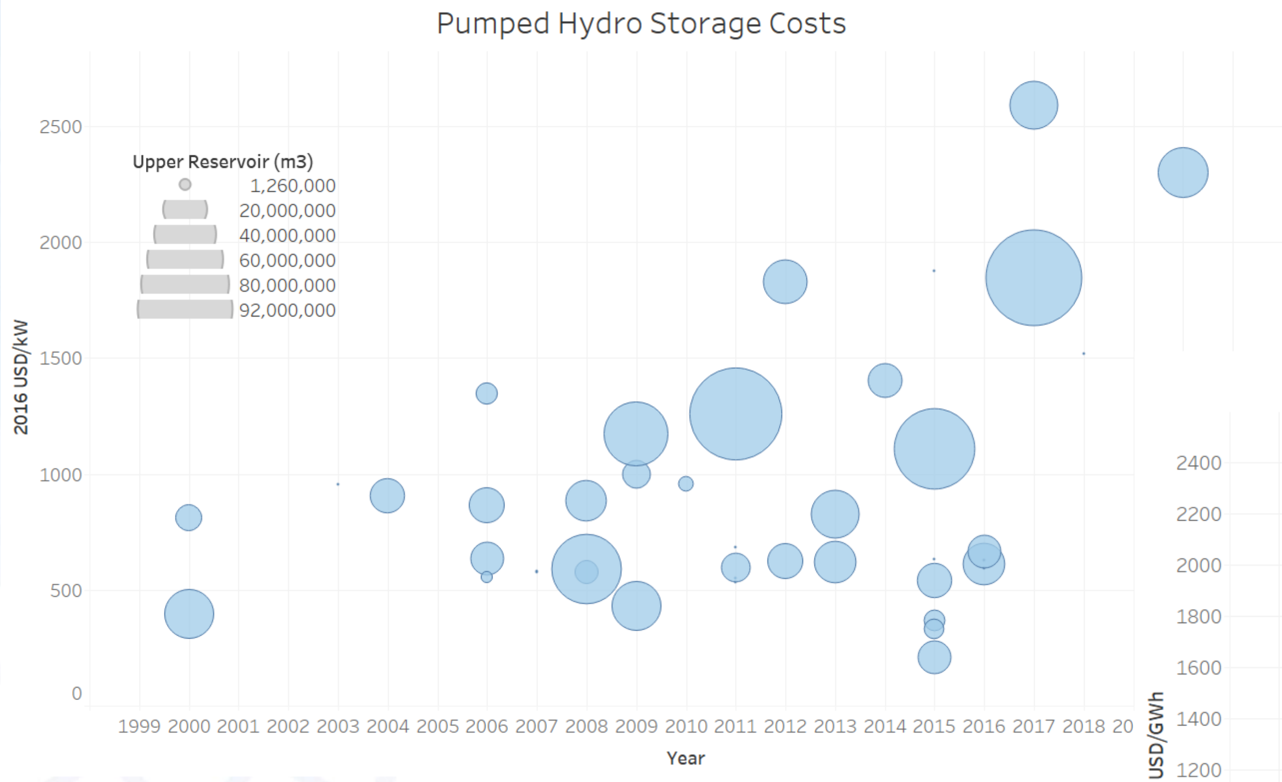
Gas Storage
- Hydrogen
- Methane

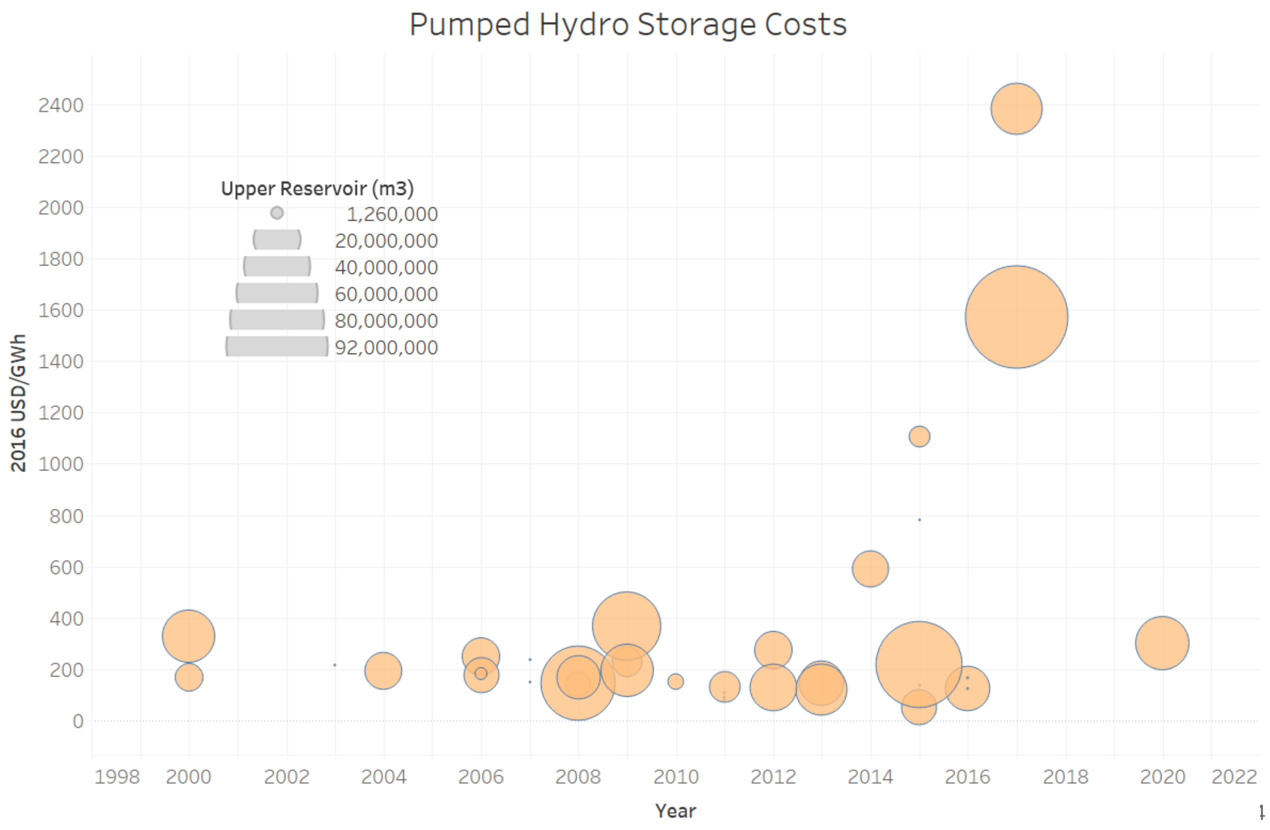
Methodology



COST AND TECHNOLOGY STATUS

Current prices: Pumped Hydro Storage





Small-scale: rapidly falling prices

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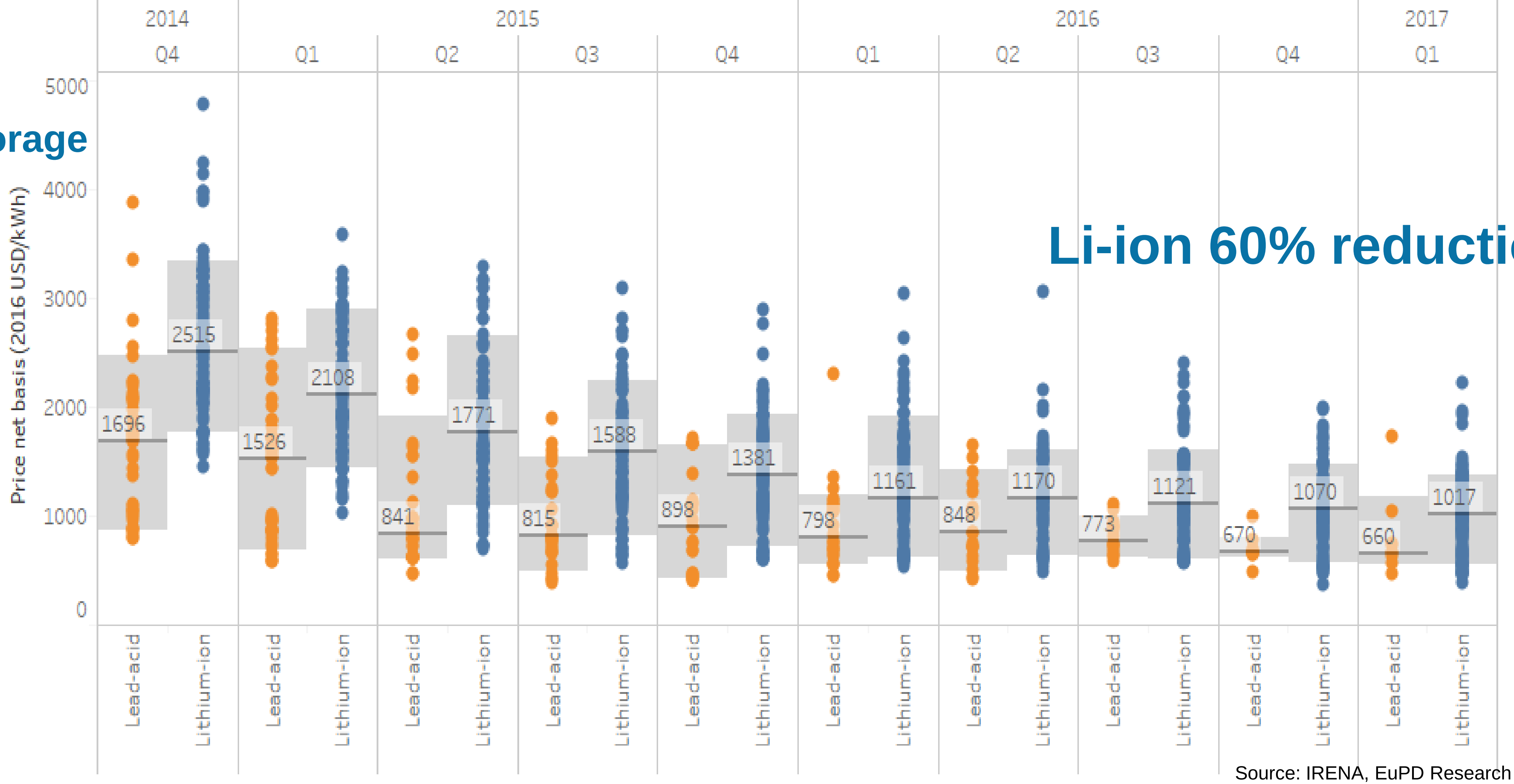
Home storage



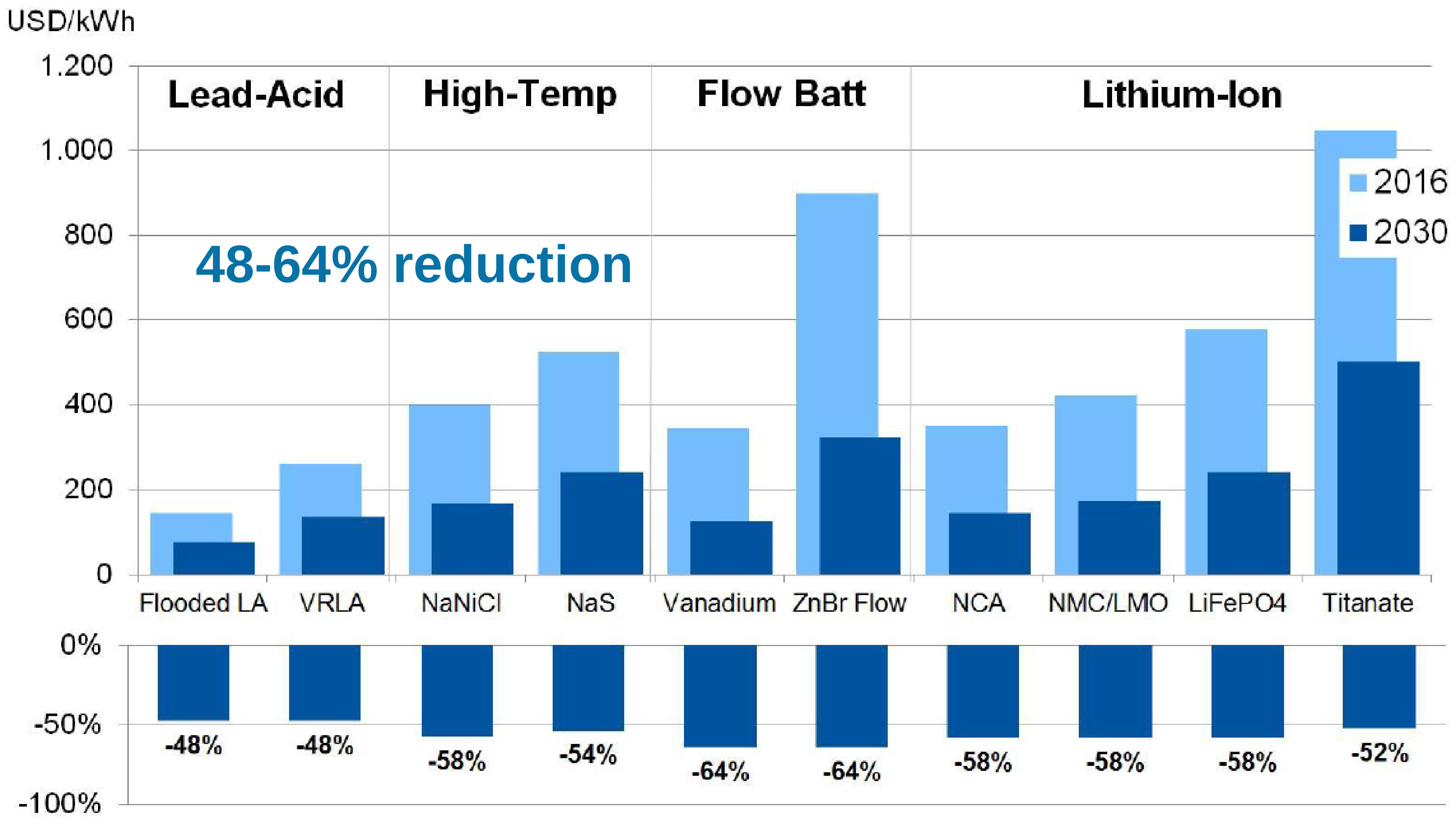
Li-ion 60% reduction!

Source: IRENA, EuPD Research

Median prices for lithium-ion based residential storage system offers in **Germany** have declined roughly 60% Q4 2014 to Q1 2017

Note: Horizontal bar shows median offer price, grey range 10th and 90th percentile.

Potential cost evolution



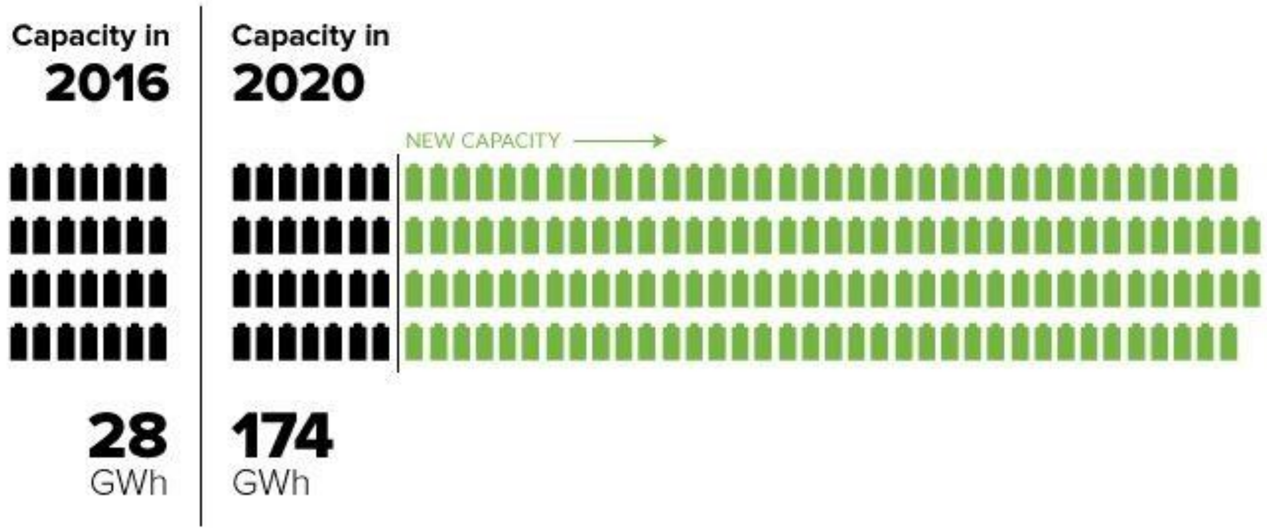
Prices in 2030
USD 80 - 400/kWh

Compared to 2016
USD 190 - 1050/kWh

CHINA IS LEADING THE CHARGE

Lithium-ion megafactories in China to grow capacity 6X by 2020

Global lithium-ion battery production capacity will increase by **521%** between 2016 and 2020.

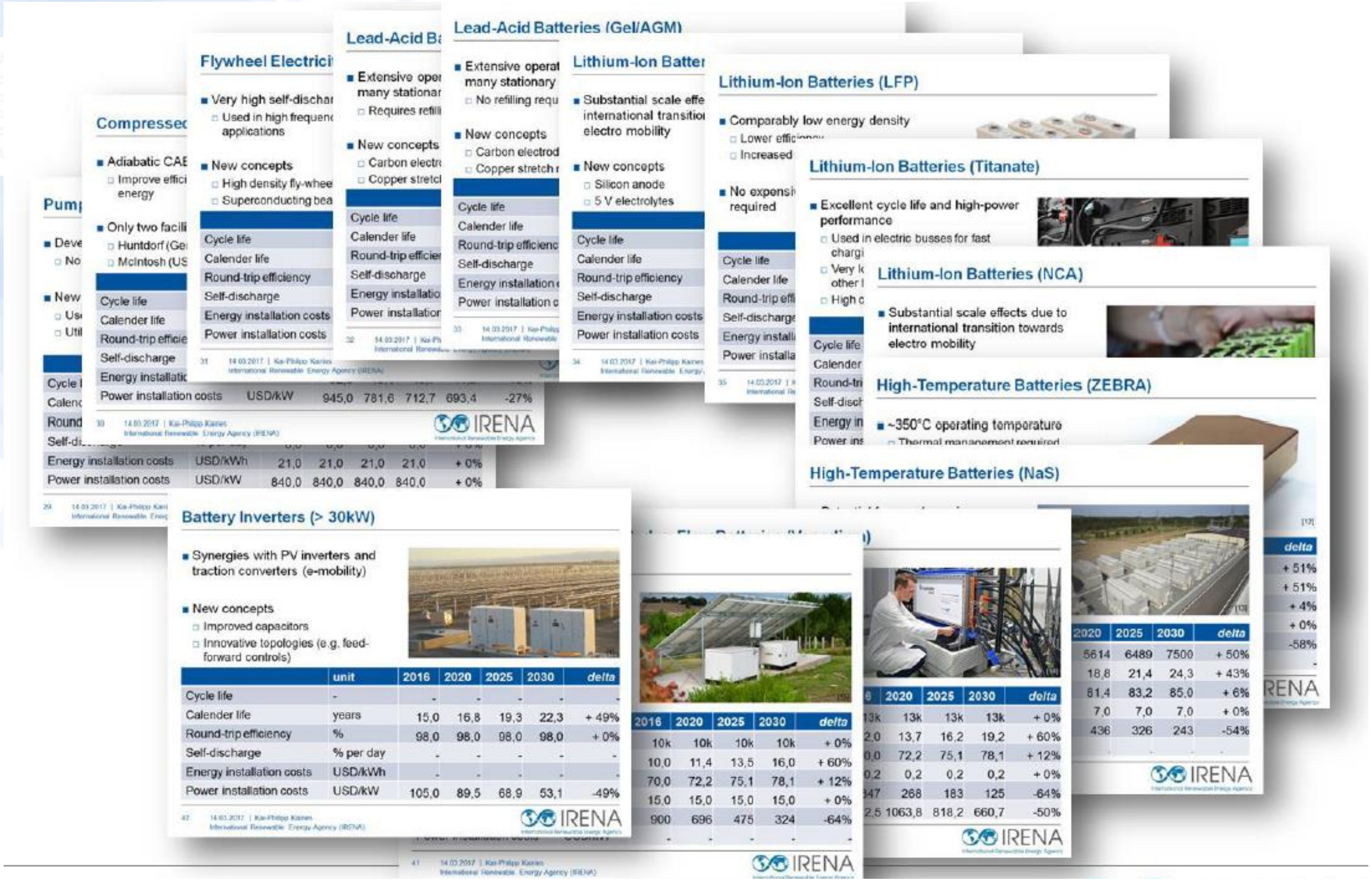


China's battery sector continues to be a hub for most of this growth.

Source: http://www.visualcapitalist.com/china-leading-charge-lithium-ion-megafactories/

	2016 Capacity (GWh)	2020 Capacity (GWh)	% of Global Total (2020)
United States	1.0	38.0	22%
China	16.4	107.5	62%
Korea	10.5	23.0	13%
Poland	0.0	5.0	3%
Total	**27.9**	**173.5**	**100%**

Tech sheets for 15 technologies



Main drivers: Lithium-ion

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- Differentiation between 4 different technologies
  - NMC/LMO, NCA, LFePO4 and Titanate
- International transition towards electro mobility leads to substantial scale effects (NCA NMC/LMO)
  - 70% price reduction since 2012
- > 170 GWh / year production capacities projected for 2020
  - Tesla Gigafactory / BYD / CALB /…
  - LG Chem / Foxconn / CATL / …

- Innovative developments
  - Mass production
  - Utilize silicon in anode
  - Durable LMO cathodes
  - 5 V electrolytes
  - Lithium-Sulphur
  - Lithium-Air

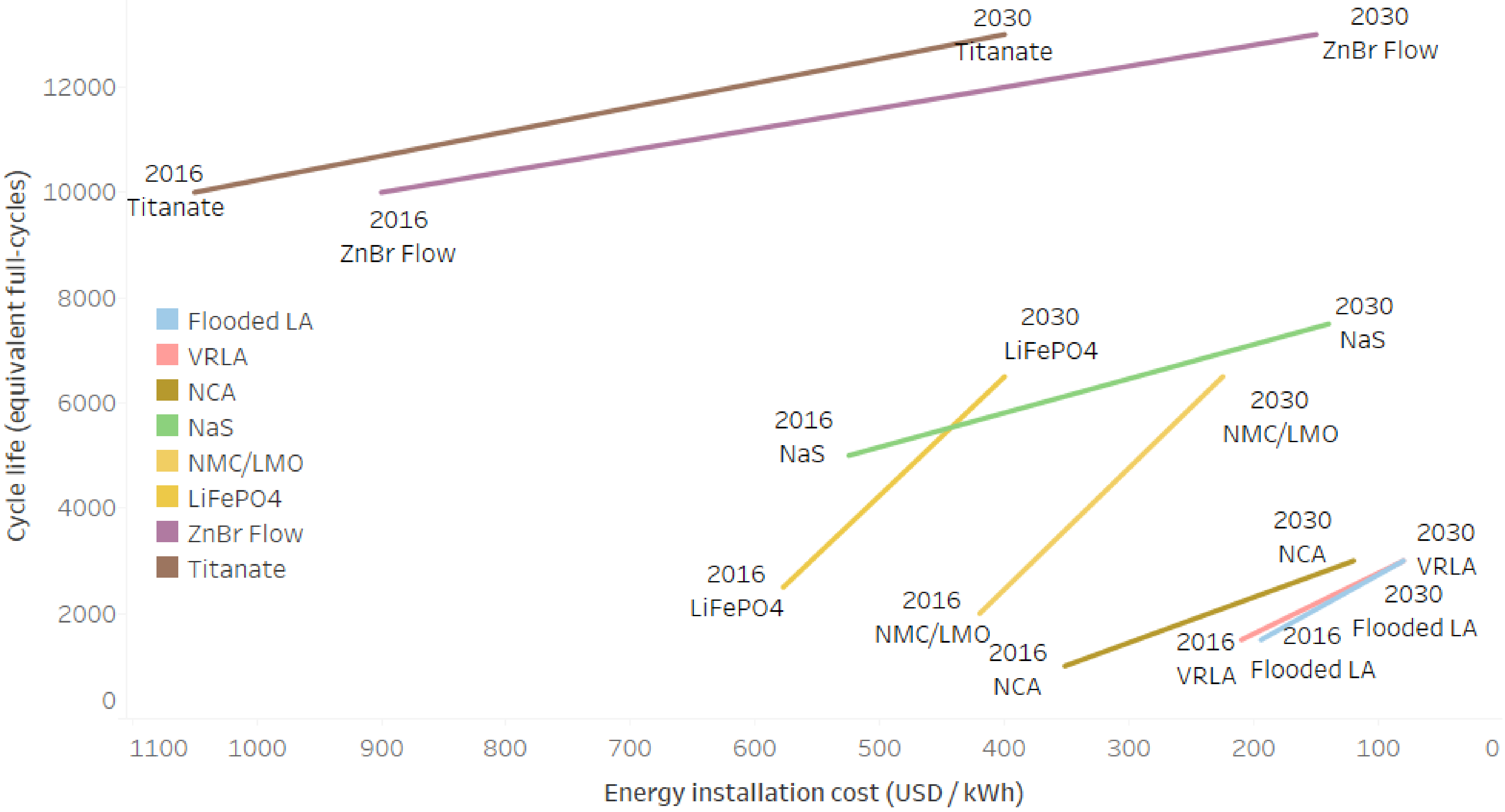
Example: Li-ion titanate

- Excellent cycle life and high-power performance
  - Used in electric busses for fast charging
  - Very low energy density compared to other lithium-ion batteries
  - High costs due to low scales

	unit	2016	2020	2025	2030	*delta*
Cycle life	-	10k	12k	15k	19k	+ 91%
Calender life	years	15,0	16,9	19,7	23,0	+ 53%
Round-trip efficiency	%	96,0	96,5	97,1	97,8	+ 2%
Self-discharge	% per day	0,1	0,1	0,1	0,1	+ 0%
Energy installation costs	USD/kWh	1050	880	665	502	-52%
Power installation costs	USD/kW	-	-	-	-	-

Performance

Opportunities arise also from the combined effect of higher lifetimes and lower energy installation costs



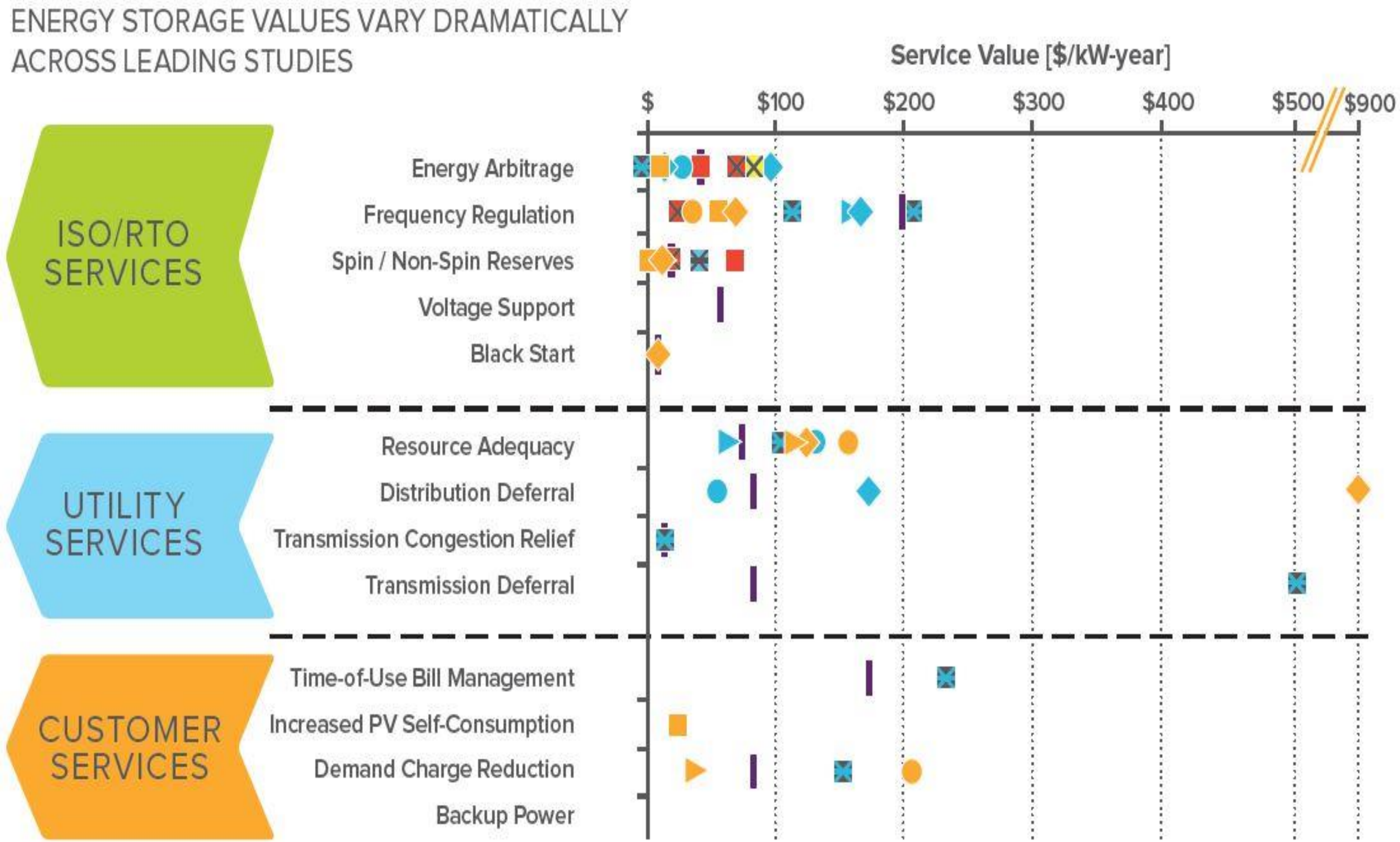
COST VS VALUE: A COMPLEX SUBJECT

Cost of service calculations:
Potential market segments to examine

- Grid Services
  - Enhanced Frequency Response
  - Frequency Containment Reserve
  - Frequency Restoration Reserve
  - Energy Shifting

- Behind-the-meter
  - Solar Self consumption
  - Community Storage
  - Increased Power Quality
  - Peak Shaving
  - Time-of-Ise

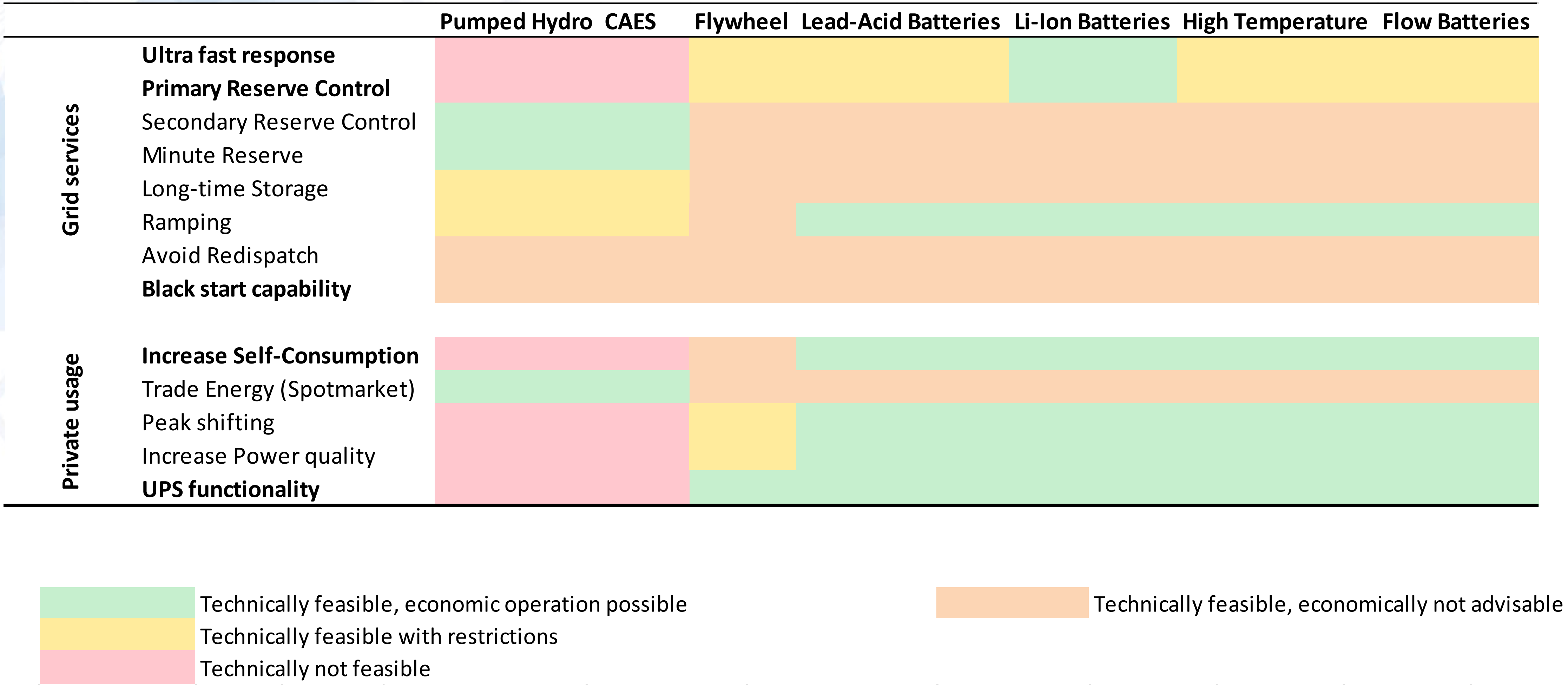
- Off-grid
  - Nano-grid
  - Village Electrification
  - Island Grid



Source: Rocky Mountain Institute

Feasibility

Applications examples



Highlights

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Rapid recent cost reductions

Technology and performance improvements will continue

Economies of scale and cost innovation key also very important

Scale and cost reductions will open up new markets

Batteries facilitate a renewable future!

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