atomexpo

Roland Berger

Forewarned is forearmed: Winning strategies in e-storage

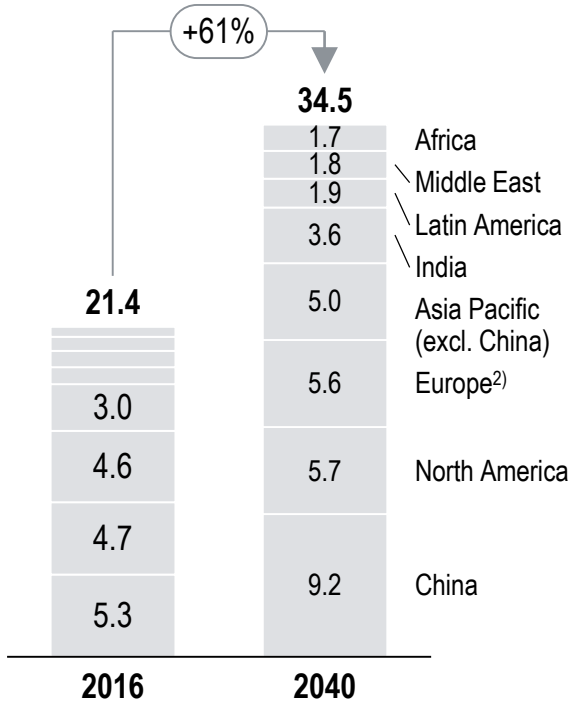
Key theses for the report
at the "Low-carbon generation" section

Sochi, April 15, 2019

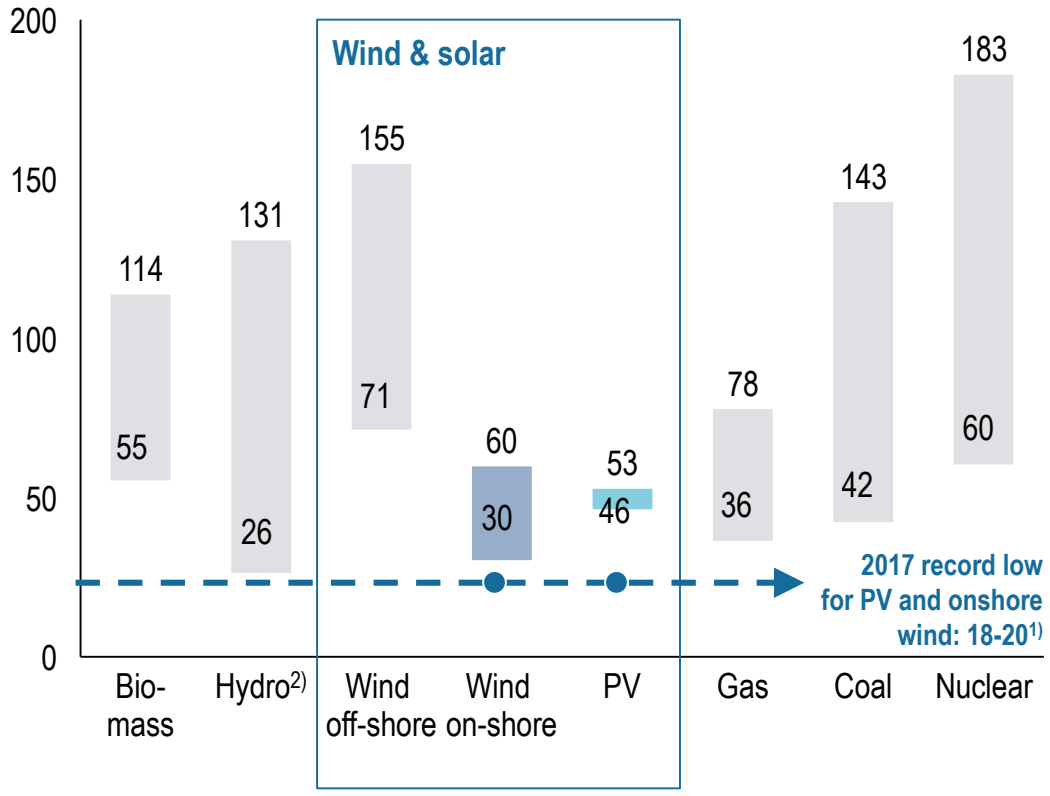
As RES are (becoming) cheaper than conventional generation its installed capacity will grow tremendously (~4.8 TW to be added)

Electricity demand and cumulative gross power plant capacity additions by region[1)]

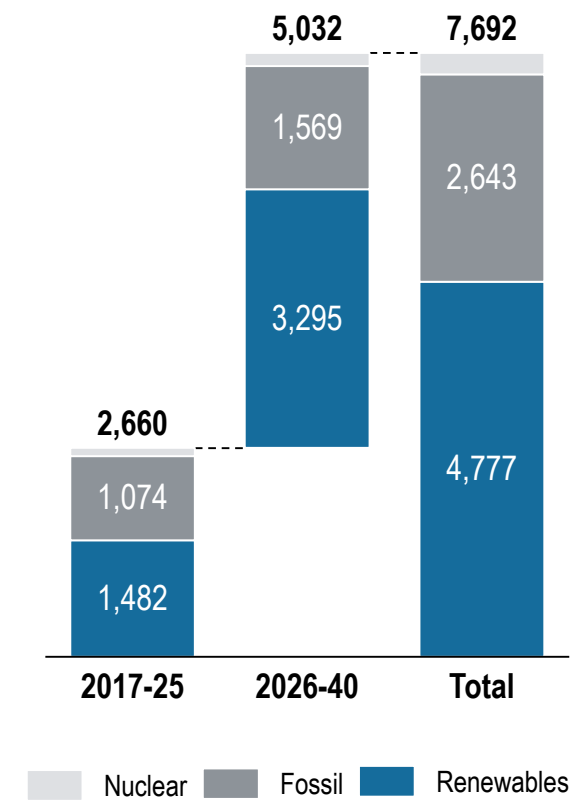
Electricity demand [PWh]



LCoE ranges 2017 [USD/MWh]



Extra power capacity [GW]



1) In IEA's New Policies Scenario, excl. replacement for retired capacity, 2) 2015, 3) USD 18 / MWh in Saudi Arabia 2017; USD 20 / MWh in India 2017

Source: WEO 2017, Lazard 2017, REN21 Global status report 2016, Roland Berger

Small and large energy storage systems profit from renewable energies, while UPS and telecom are driven by mobile society

E-storage market drivers and trends

	Drivers and trends
 **ESS – Large storage (>10 kWh)**	> Integration of **renewable energies** and their volatile power supply is challenging the stability of power grid > Switch from fossil fuels to renewable energy (and the subsequent abolishment of nuclear power in certain geographies) is requiring peak shaving and **load leveling**
 **ESS – Small storage (<10 kWh)**	> Idea of "**net zero energy homes**" with using self-generated energy > Potential new business case with storing exceeding energy during peak times and resupplying during shortages > **Government subsidies** financially support the individual with the installation of private PV equipment
 **Uninterruptable power supply (UPS)**	> **Modern mobile society** is sending and receiving vast amounts of data unrestricted of location – **new data centers** are constructed to keep up with the staggering amounts of data > **Companies are partly depending on a steady power supply** to keep production or service facilities running and thus hedge against risk of power outage
 **Telecommunication**	> Introduction of the smartphone and the resulting mobile data usage came along with **required bandwidth increases** > **TC equipment development** for 2G, 3G, 4G and 5G infrastructure

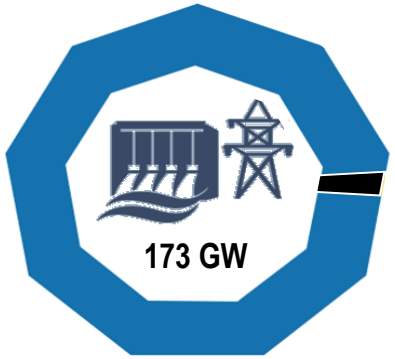
Source: Avicenne Report; Roland Berger

LiB techs still account for only a minor share of global ESS, while battery-based ESS are a only fraction of all LiB used – Automotive leads …

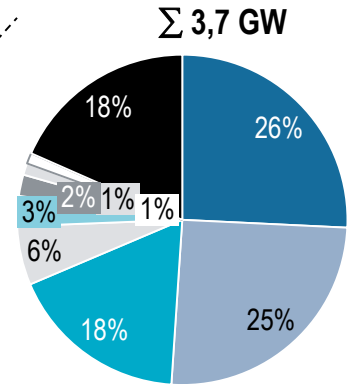
E-storage market structure by technologies

Storage technologies structure in the global electricity system [GW]

Pump storage hydro

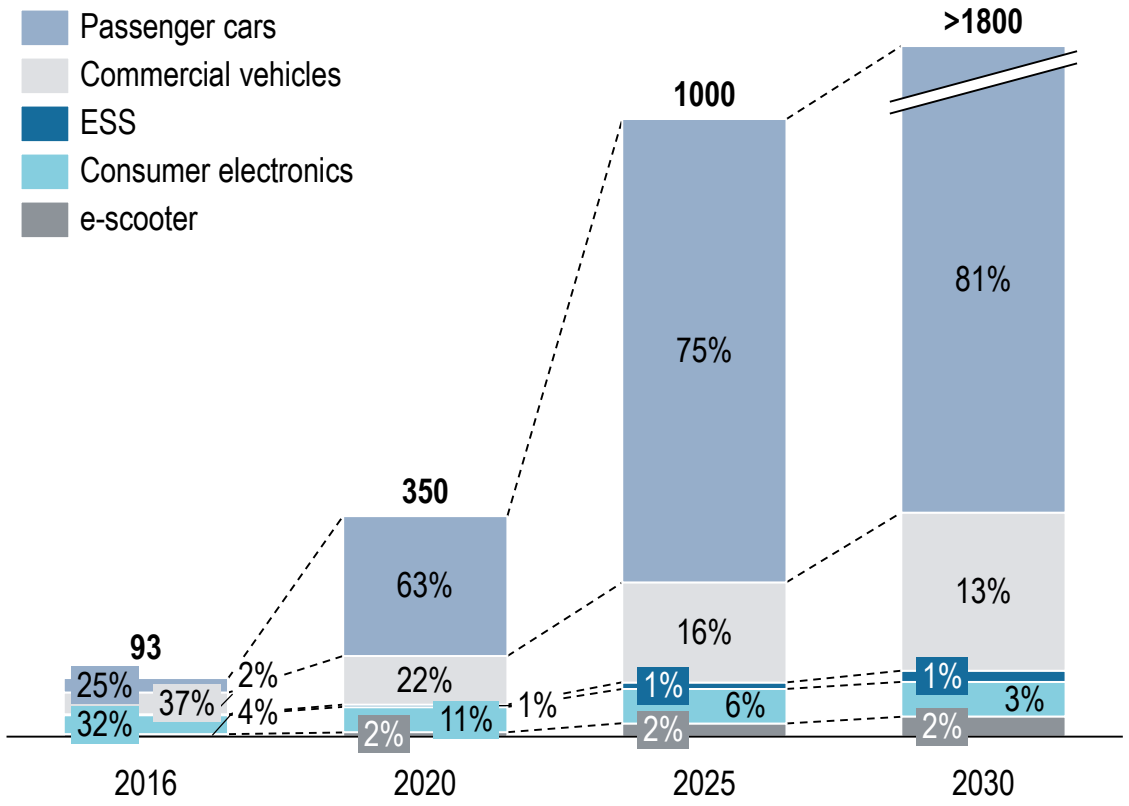


Other storage technologies



Lithium-ion
Flywheels
CAES[1)]
Adv. lead-acid/lead acid
Capacitor
Redox flow battery
Nickel-cadmium
Others

LiB demand dynamics by market segment, 2016-2030 [GWh/a]



1) Compressed air energy storage

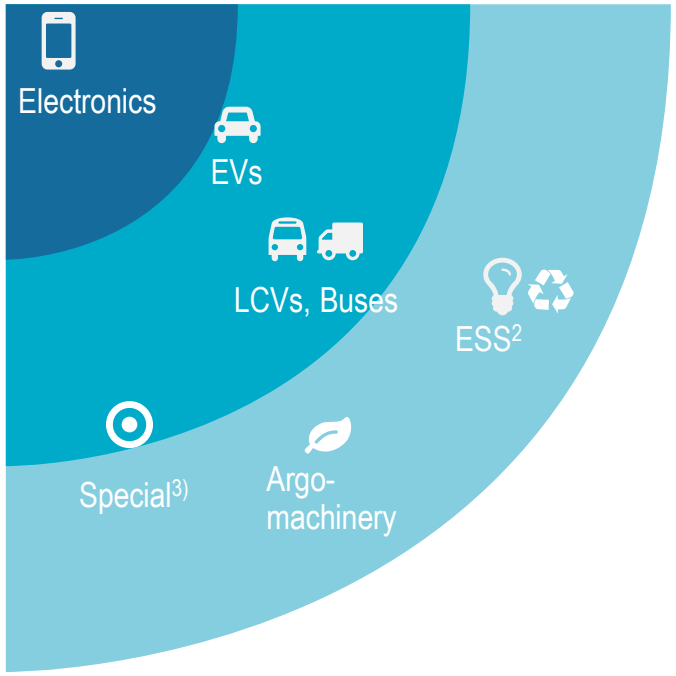
Source: IRENA (2018), Roland Berger

1

… as it's one of the most mature LiB applications, driven by notable well-to-wheel costs competitiveness vs. ICE cars

Required well-to-wheel energy by car type [MJ/100 km]

Illustrative



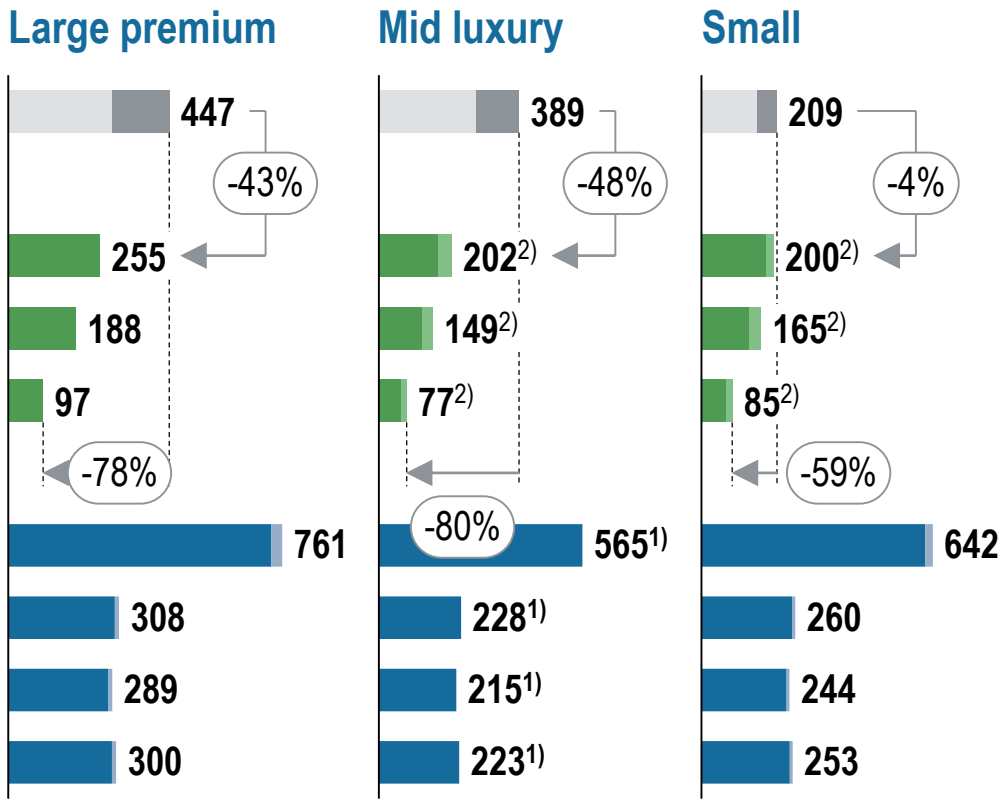
Gasoline

Electric

Typical EU mix
Natural gas (piped 4,000 km)
Wind/solar

Hydrogen

Compressed electricity - typical EU mix
Compressed natural gas
Compressed wind
Liquid wind



City energy consumption Highway energy consumption

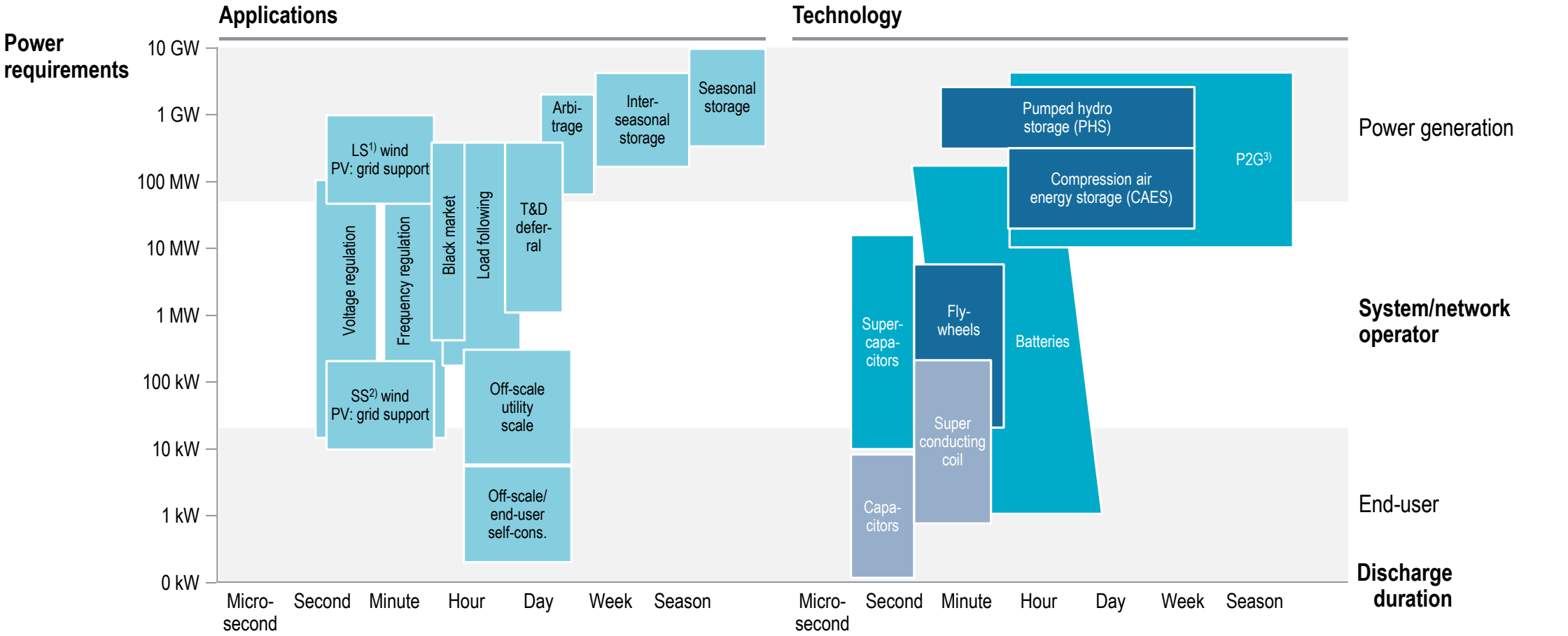
1) Equal efficiency on highway and in the city 2) More efficient in the city than on the highway 3) E.g. medical applications, marine, drones

Source: European Commission JEC WTW, Roland Berger

Available energy storage technologies differ by types, which pre-define their capabilities to serve specific applications

E-storage applications and technologies

Illustrative

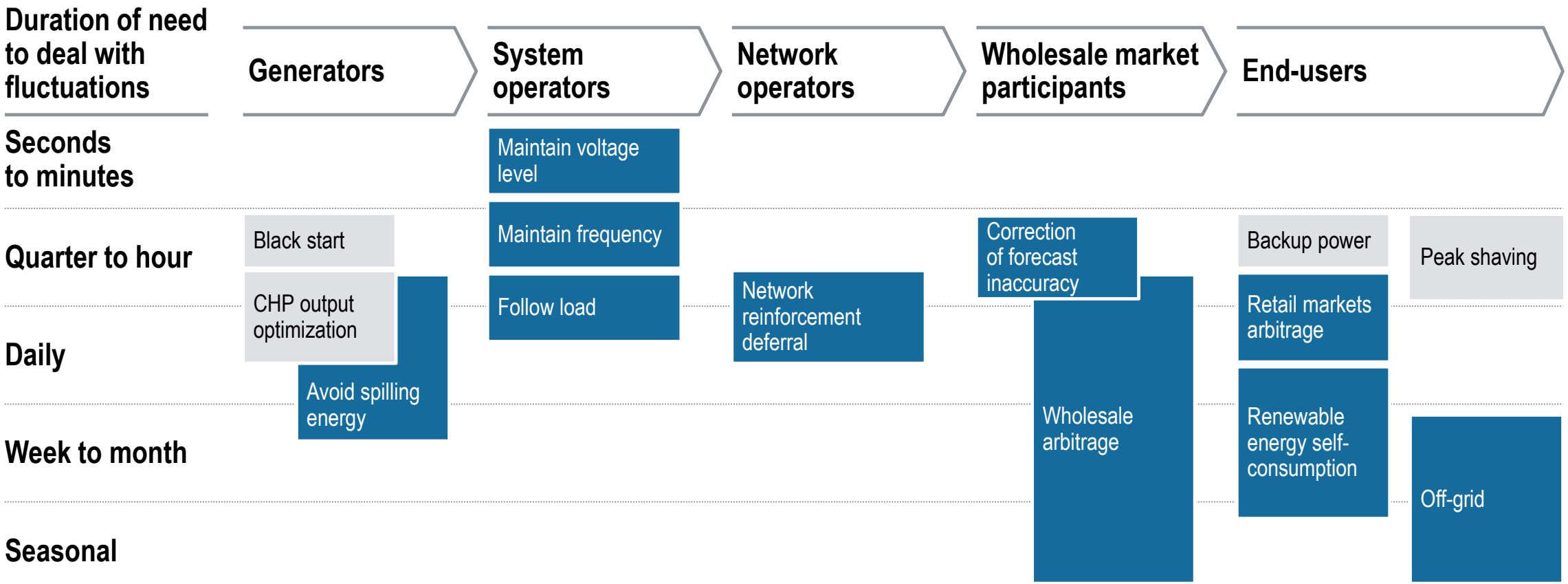


1) Large-scale 2) Small-scale 3) Power-to-gas

Source: IEA, Roland Berger

Imbalances between demand & supply create demand for storage solutions of different duration along the entire energy value chain

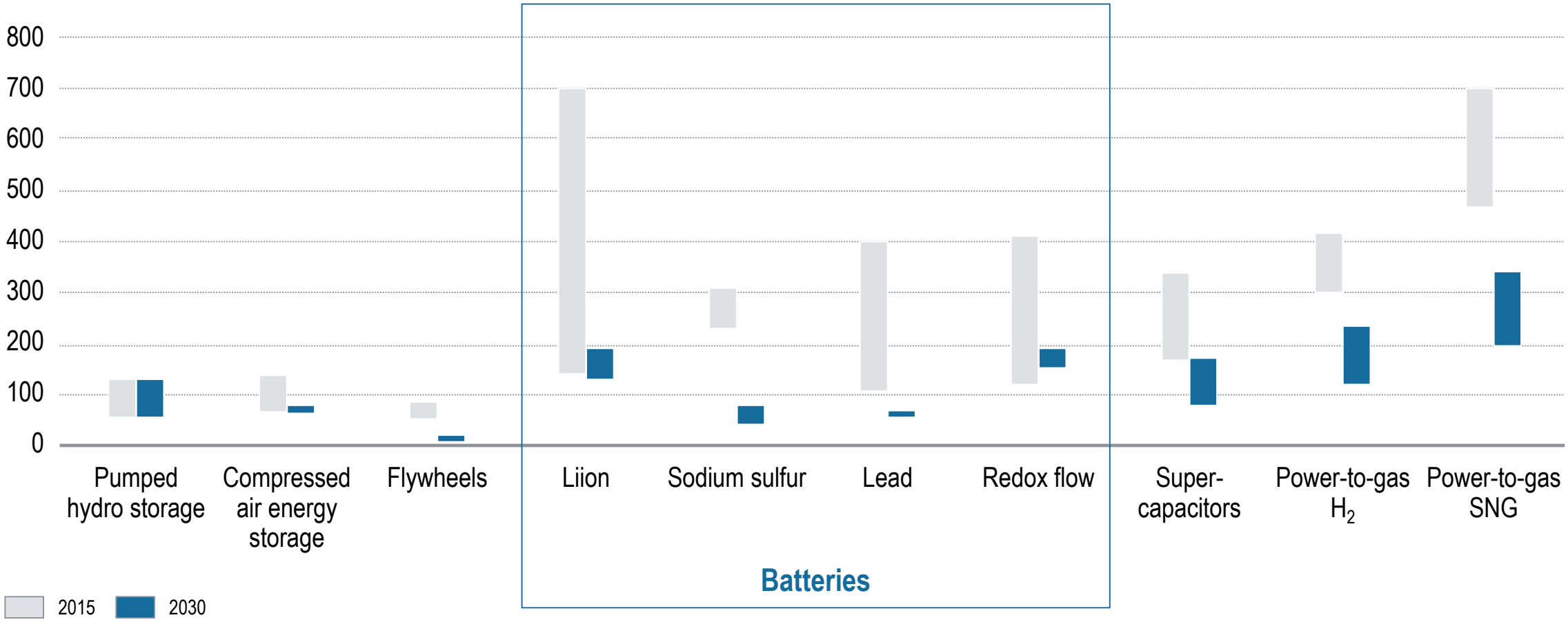
E-storage applications along the energy value chain



Source: IEA, Roland Berger

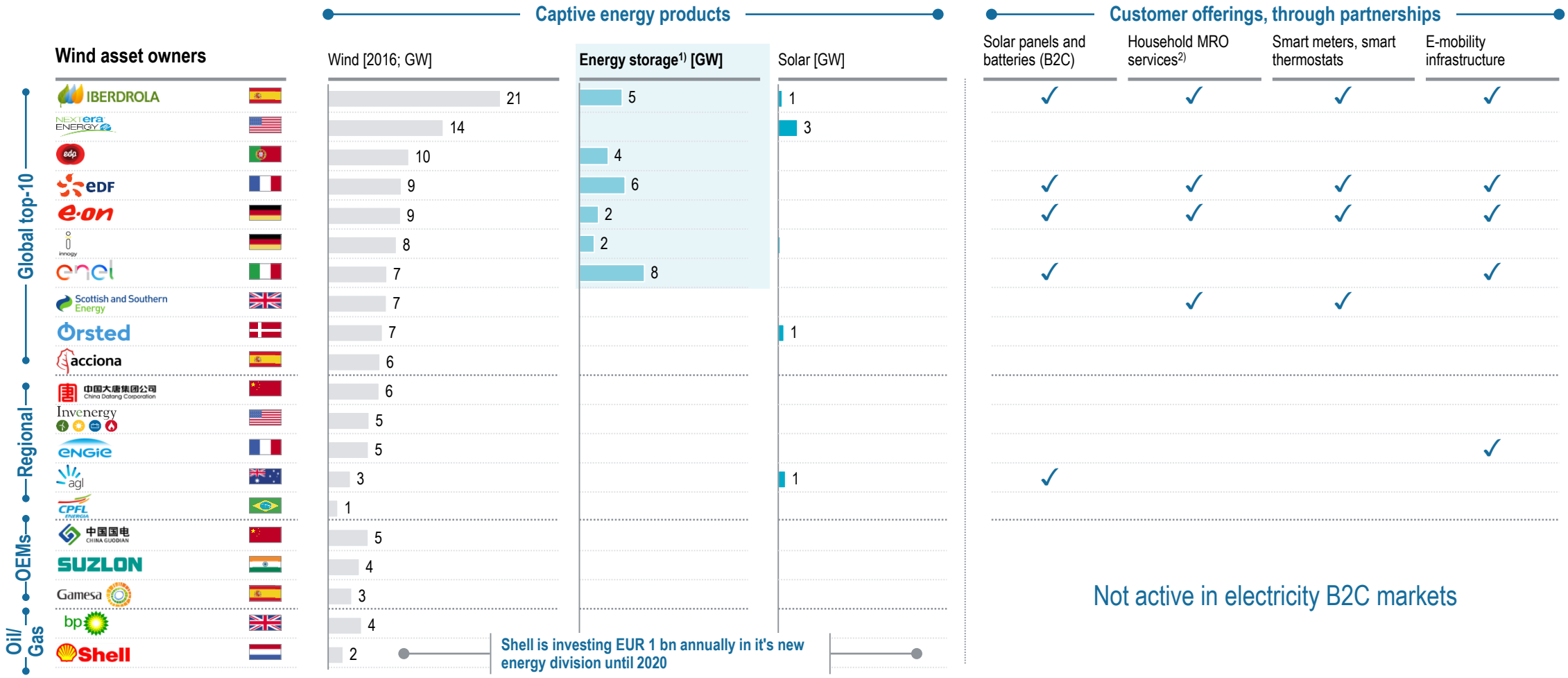
Levelized cost of energy storage is expected to drop significantly by 2030, especially for batteries

Levelized costs of e-storage, 2015 vs. 2030 [EUR/MWh, 2014 price level]



Source: World Energy Council, Roland Berger

Power utilities active in RES have made significant investments in e-storage as part of their asset portfolio; O&G majors also in the race

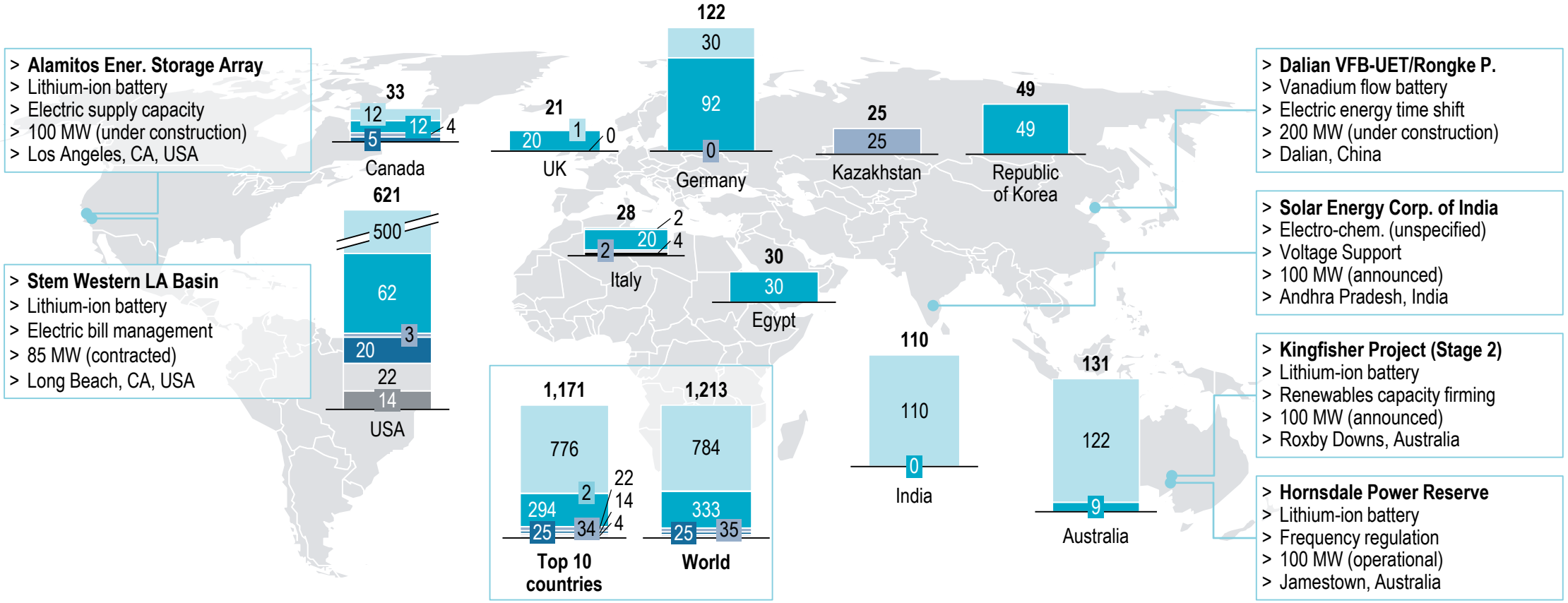


1) Operational or announced renewable energy storage projects
2) Insulation, heating devices and electrical appliances – installation, periodic revision, repair

Source: company data, Platts 2016, Windfarms 2017 – The Windpower, US DoE energy storage database, Roland Berger

E-storage projects are not confined to a certain geography – in contrast, those are being widely pushed in numerous countries

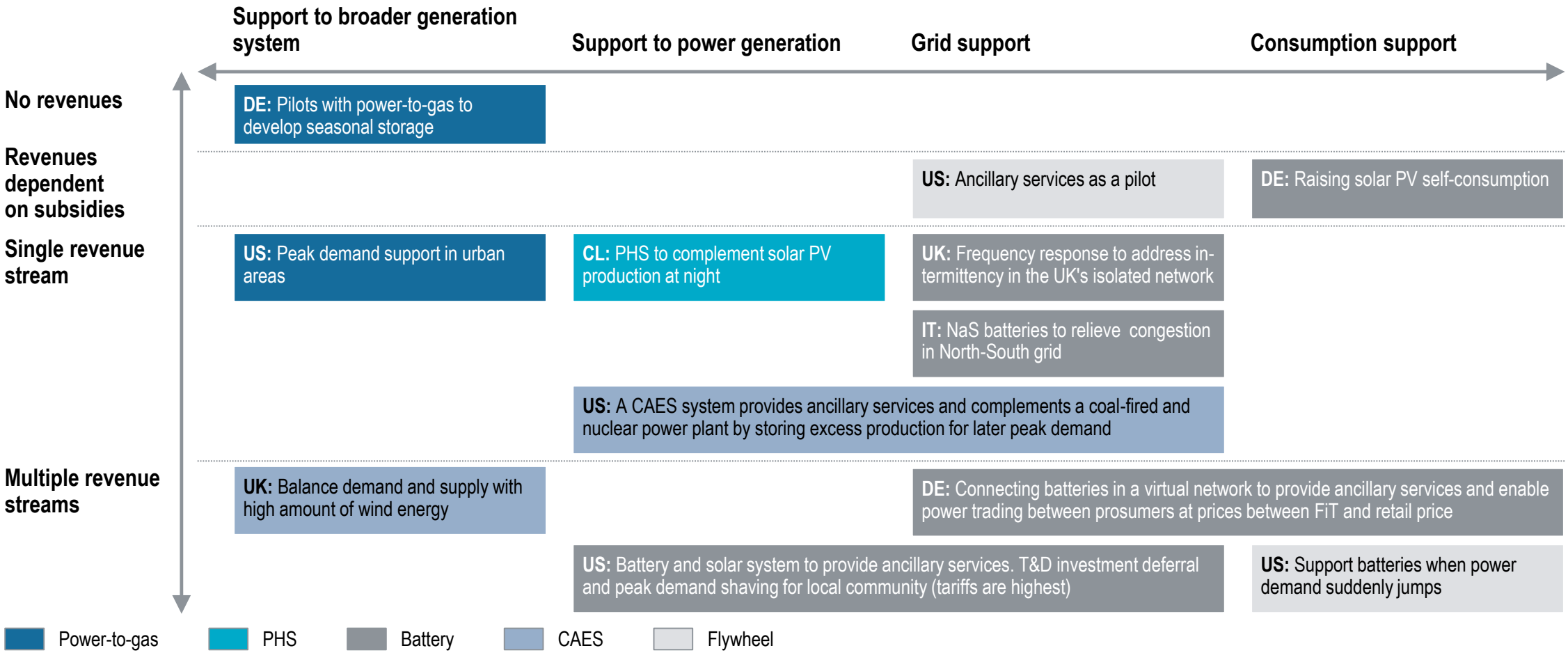
Announced, contracted & under construction e-storage capacity by technology [MW]



Source: US DOE 2017, Roland Berger

E-storage industry comprises multiple possible profit models, many of which already have real-life use cases globally

E-storage use cases by revenue streams and position in the energy value chain



Source: Roland Berger

Two key considerations for the e-storage market going forward – how to reduce repurposing costs in the second life battery market …

Second life battery market

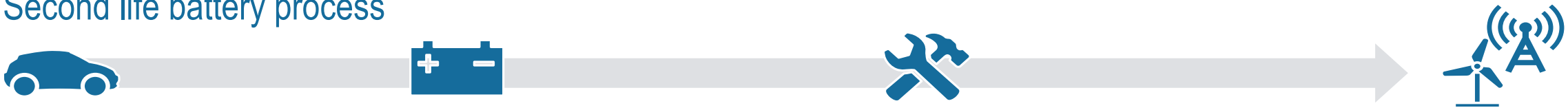
2nd life of automotive cells for ESS

Future competition from new batteries	> Key advantage of second life batteries compared to new batteries is low price, but will diminish in near future
Repurposing costs	> Currently second life battery repurposing costs are with approx. EUR 50 per kWh too high to be a real alternative > As such re-manufacturing process costs need to be reduced, but likely this will be overcome in near future
Lack of data	> Current pilot projects aim to gather data, since currently only few data available regarding performance and product life of second life batteries

*"Storage of renewable energy is a key aspect of climate protection and the new energy landscape in Germany. […] important **contribution to sustainable energy supply** by smart control of **used vehicle batteries**."*

Catrin Jung-Draschil, VP Bosch Portfolio & Bus. Dev. Wind Unit

Second life battery process



> Extract battery from xEV

> Capacity after 8..10 years at ~80%

> Remanufacturing

> Secondary life as energy storage for e.g. antennas

Source: Bundesverband Erneuerbare Energien Report, Company press releases; Roland Berger

… and how to mitigate supply chain risks while also researching into chemistries with less cobalt

Supply chain risks for currently used battery material

	Cathode materials[1)]	Anode materials	Separator	Electrolyte
Risks by primary products	> **Slightly balanced market shares** with Japan 31%, Belgium 24%, China 19% > Umicore (24%) dominating supplier followed by SUMI-TOMO (16%), Internal (11%); **new entrant: BASF**	> **Japan (66%) and China (33%)** dominating market for battery **graphite** > Market for **CU-foil** dominated by **Japanese (45%) and Korean (41%)** companies	> Potentially high country allocation in **Japan** (58%) > **Few companies dominating** the market – Asahi (25%), Toray (23%), Celgard (14%)	> Potentially high country allocation in **China (51%)** > Three coequal market leaders with Cap Chem (15%), GTHR (14%), Mitsubishi Chem (13%)
Risks by raw materials	> **Cobalt** is **most critical** raw material with **Congo (50%)** dominating **mined** cobalt and **China (39%**) for **refined** cobalt	> **China** is main supplier for **graphite** with 67% > **Chinese supplier** dominate market for **refined cupper (**30%) > **Lithium** can be partly critical (price risks)	> -	> **Currently highly depended on LiPF6 production** and thereby strongly related to raw materials Lithium, Fluor and Phosphor
Future outlook	> **Dependency** on few countries will **increase** due to low new mining activities, political uncertainty and high environmental burden for e.g. Cobalt > **Very high price risk for Co**	> **Graphite with high risk** due to strong increase in market demand and slow increase of production volume – Substitution by artificial graphite is possible (jeopardize cost targets)	> In future an increased market share of Chinese companies is expected > **Not relevant for solid-state chemistries**	> In future a further increased market share of Chinese companies is expected > **Not relevant for solid-state chemistries**

1) Cathode material risks apply also to currently developed solid state technology

Source: Roland Berger

Thank you!

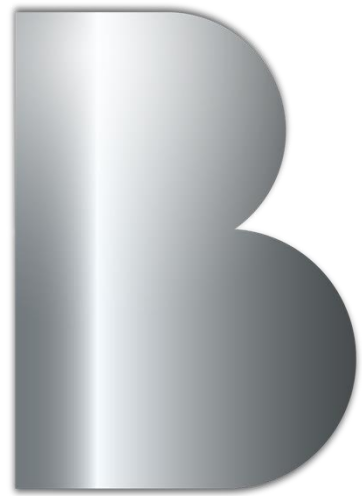
Denis Borisov

Senior Project Manager

Competence Centers
"Energy & Utilities" and
"Infrastructure"

Tel. +7 495 225 76 45
Mob. +7 967 268 10 92
Denis.Borisov@rolandberger.com
101000, Moscow, Chystoprudny blvd. 17-1

Roland Berger



Think:Act