WHEN TRUST MATTERS

Overview and State of Play on Energy Storage in Asia

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Modini Yantrapati, Senior Consultant – Energy Storage Services APAC

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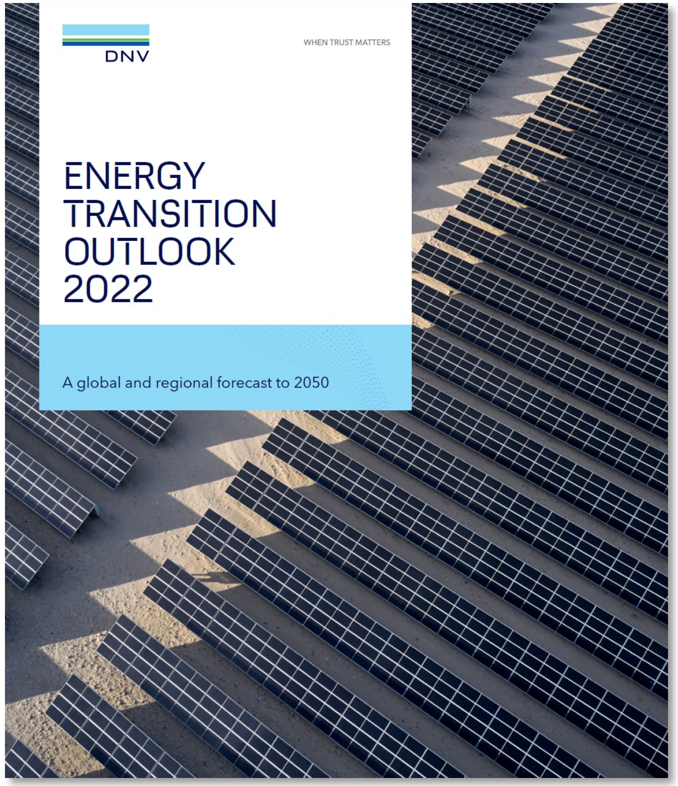
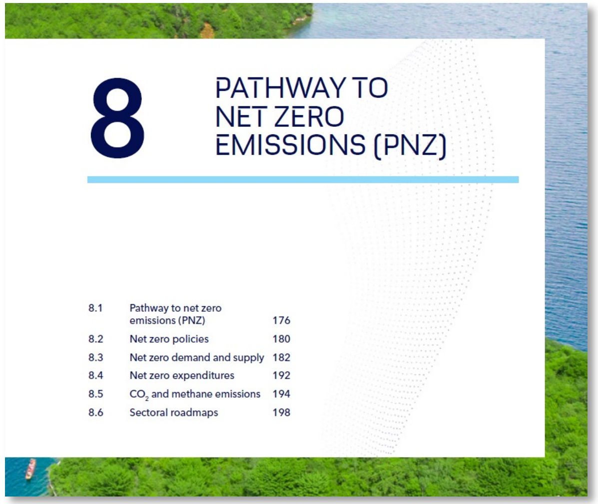
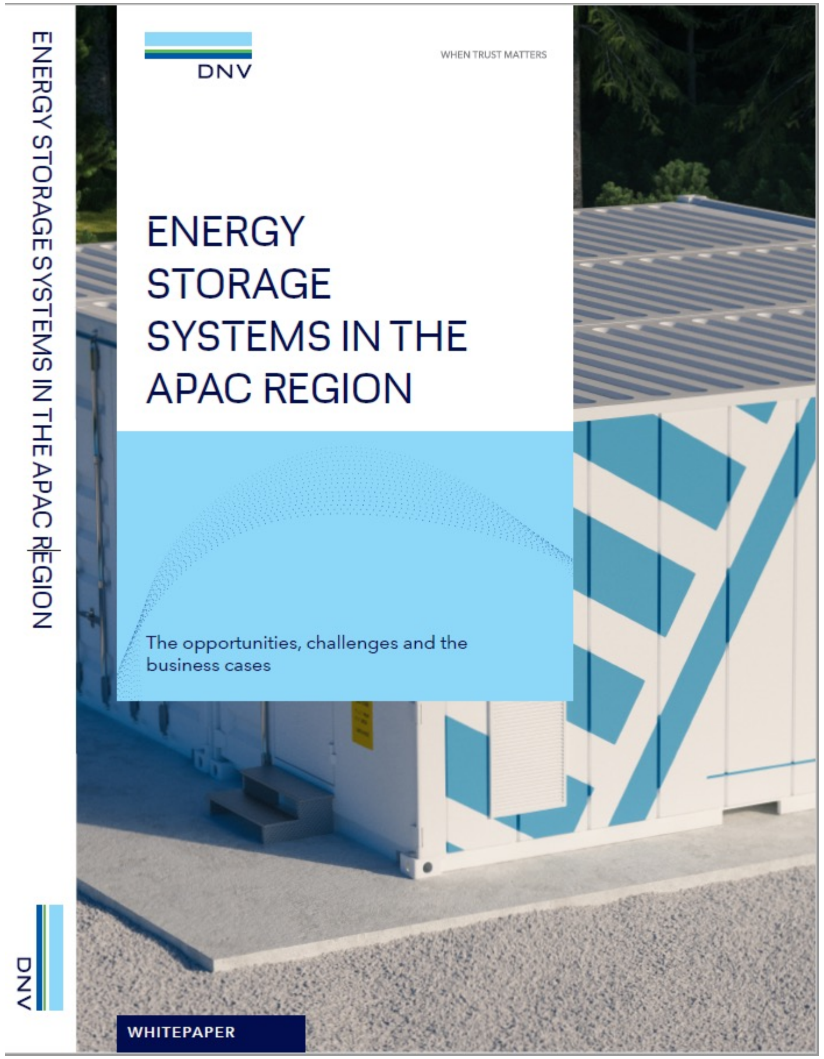
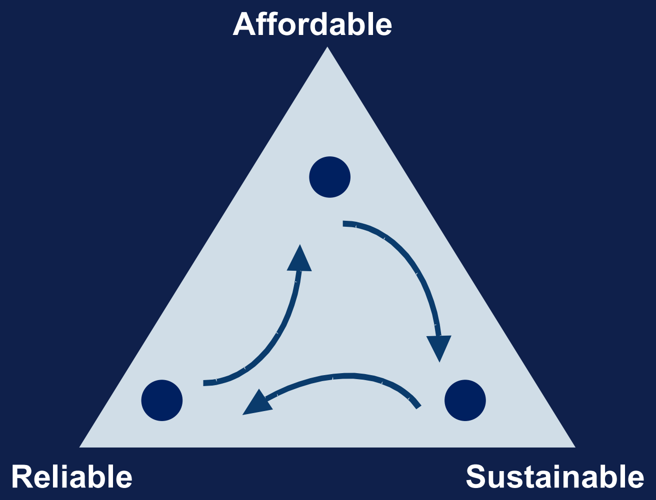


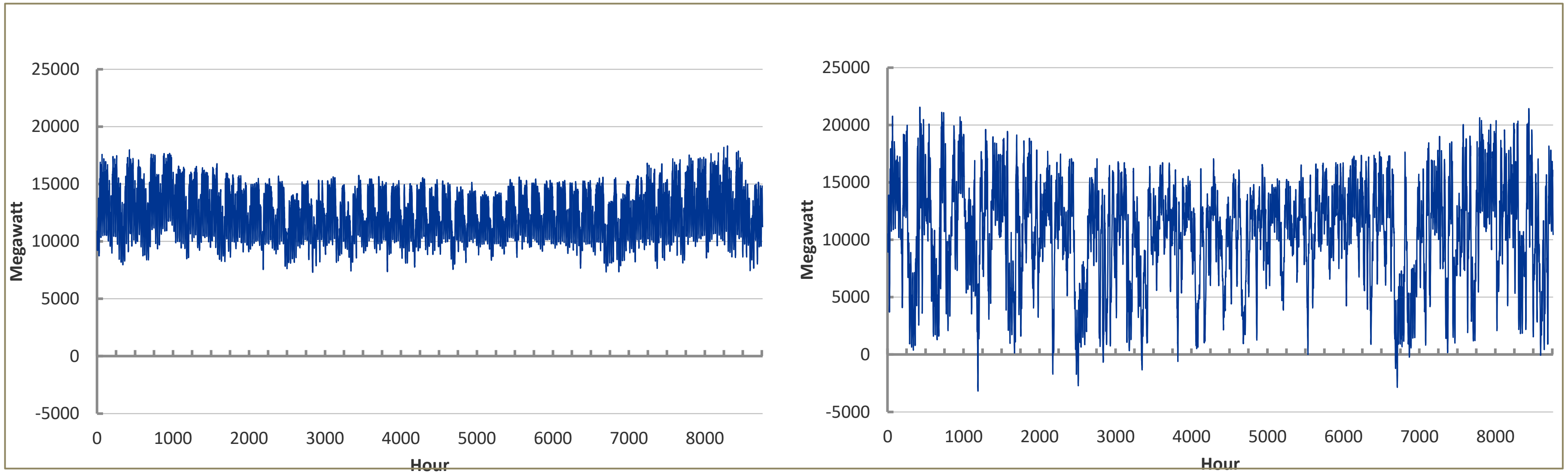




The energy transition and the need for flexibility



Energy transition will impact power flows and power quality



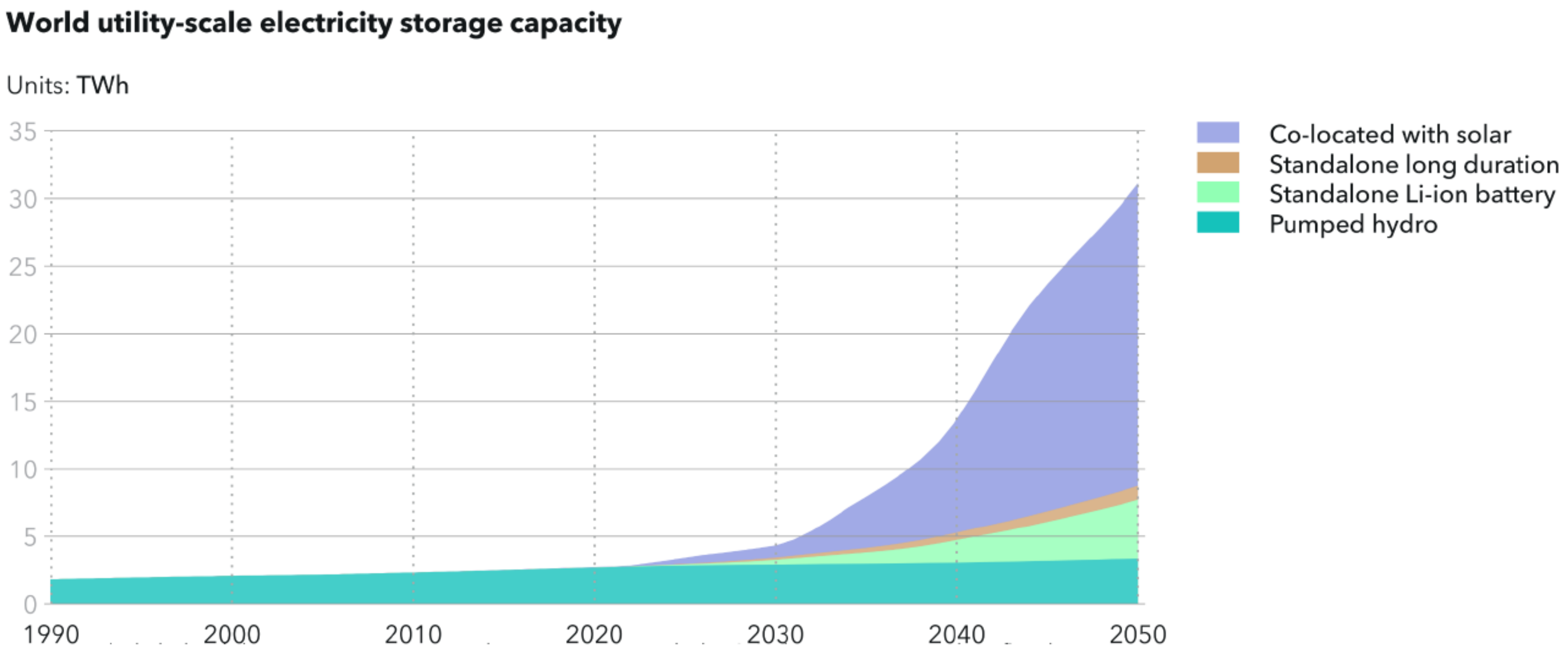
Energy transition will result in **larger fluctuations** in supply and load – mainly in electricity markets

Large number of **inverters** (PV solar) will result in **voltage issues**

Both developments put pressure on **reliability of electricity supply**

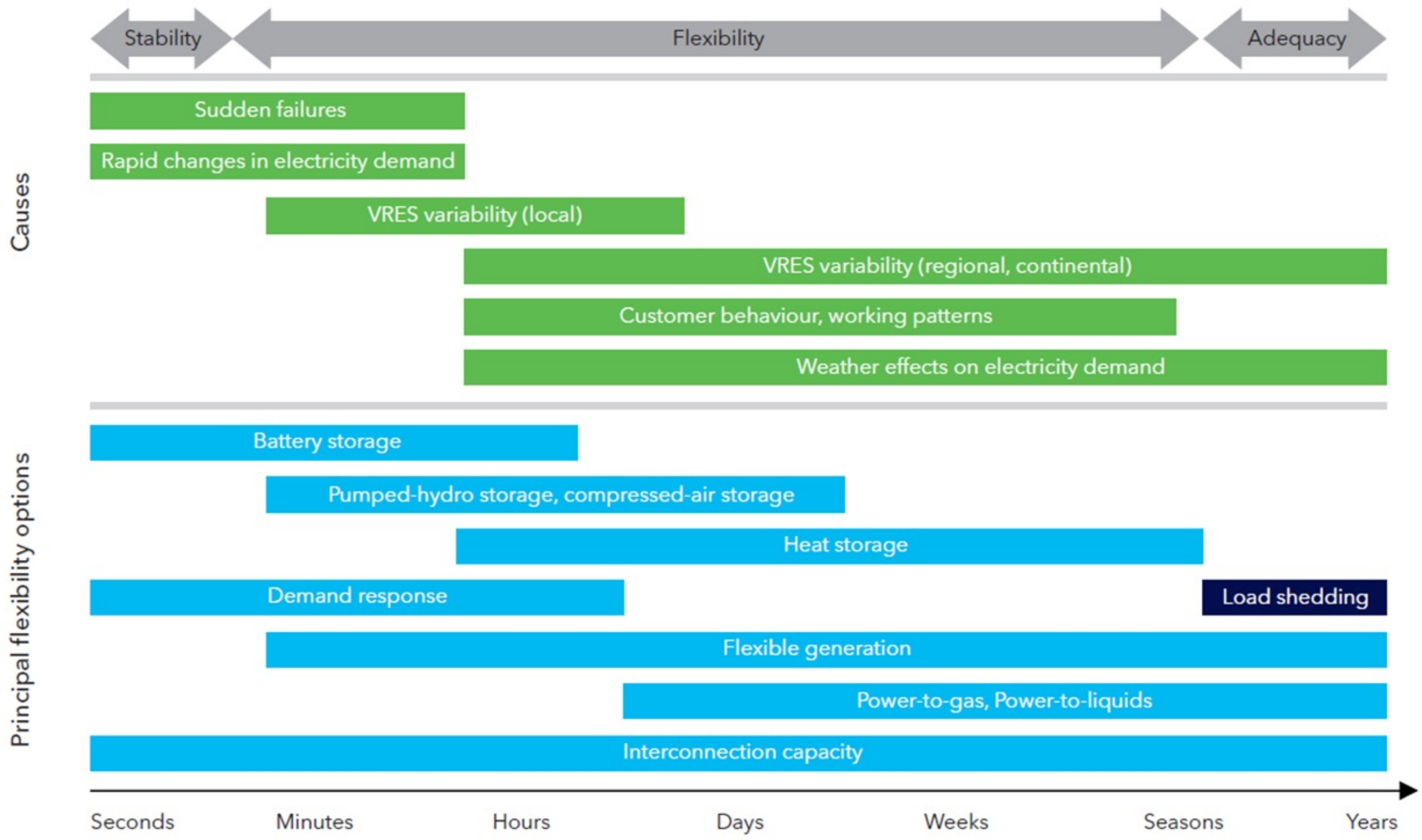
Energy storage provides solutions for various players

Storage is essential for the inclusion of variable renewables in electricity

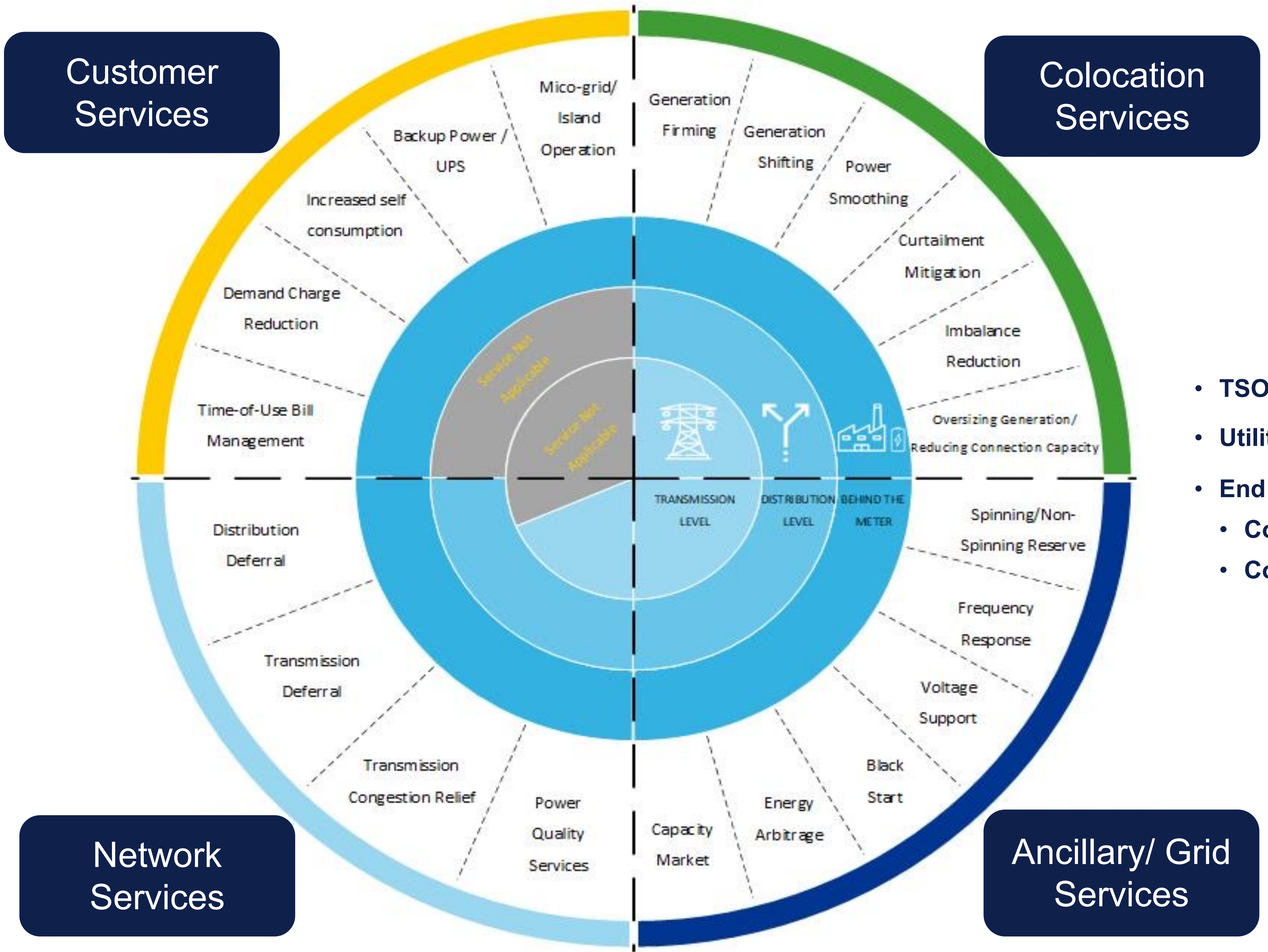


From: DNV Energy Transition Outlook, 2022

Flexibility options



From: DNV GL Energy Transition Outlook, 2019



- **TSOs/DSOs**
- **Utilities**
- **End users**
    - **Commercial & Industrial**
    - **Consumers**

Energy storage technologies
Classification

Grid-connected energy storage (electrical output)

Electrical

CAPACITOR
- Capacitor
- Supercapacitor
  - El. double-layer cap. (EDLC)
  - Li-ion capacitor

SUPER CONDUCTOR
- Superconducting magnetic energy storage (SMES)

Electrochemical

ROOM-TEMPERATURE BATTERY
- Lead-acid
- Nickel-metal hydride
- Lithium-ion (Li-ion)

HIGH-TEMPERATURE BATTERY
- Sodium-sulphur (NaS)
- Sodium-nickel chloride

REDOX FLOW BATTERY
- Zinc-bromine
- All-vanadium
- Polysulphide-bromine

Mechanical

POTENTIAL ENERGY IN STORAGE MEDIUM
- Pumped hydro
- Compressed air (CAES)
- Liquid air (LAES)

KINETIC ENERGY IN STORAGE MEDIUM
- Flywheel

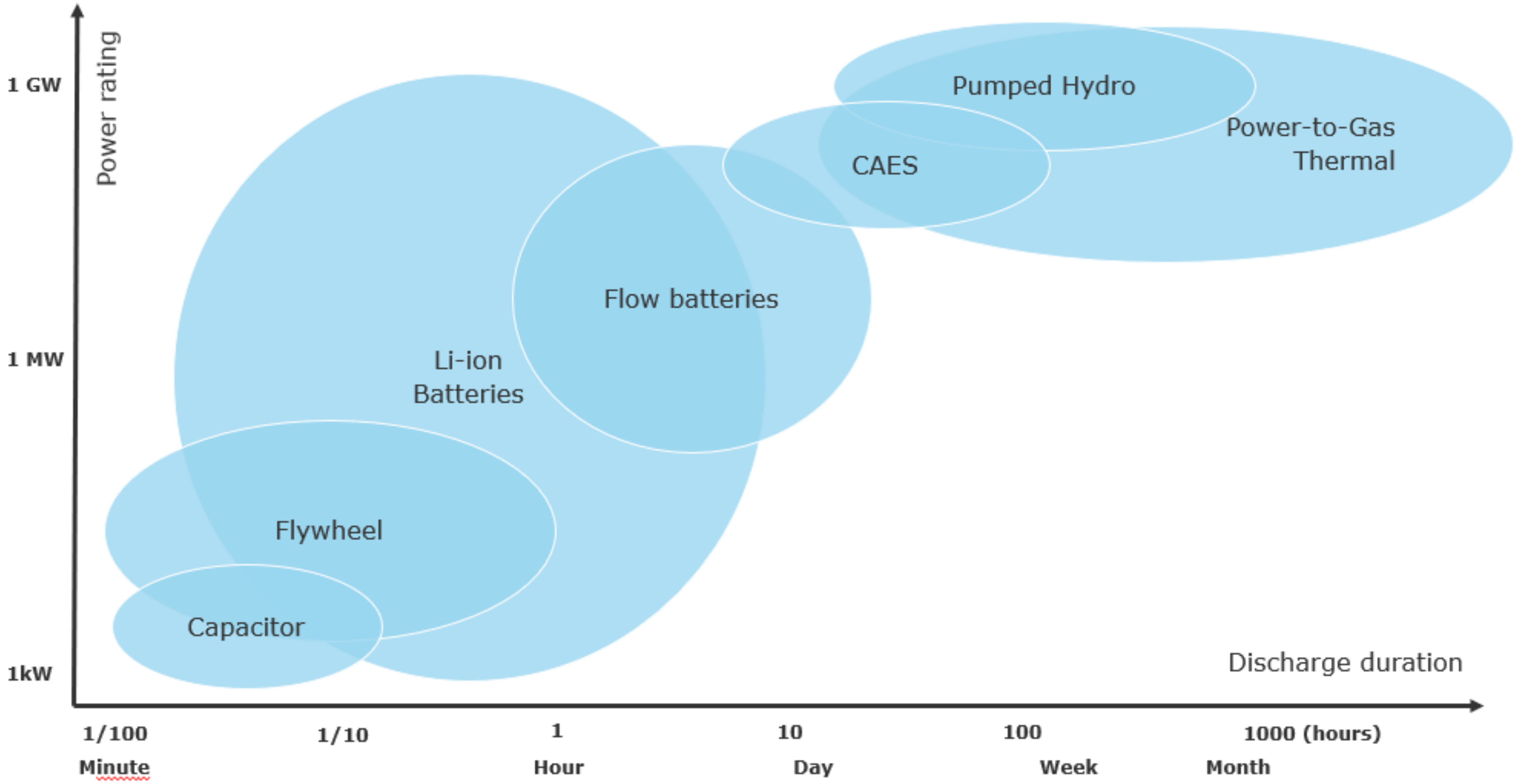
Chemical

- Power-to-gas

Thermal

- Sensible heat
- Latent heat (phase change materials)
- Sorption heat (thermochemical)

Energy Storage Applications

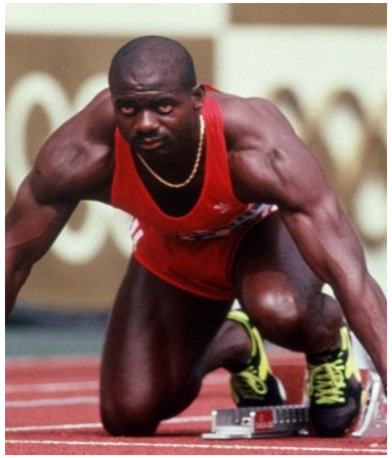


Energy Storage Applications

Duration and frequency of power supply

"Seconds to minutes" Short term energy storage systems, C>2 E2P ratio: < 0.5h	**Supercapacitors** **Flywheels**
"Daily storage" Medium term energy storage systems, 2<C<0.1 E2P ratio: 2 - 10h	**Batteries LiIon** **Pumped hydro** **Redox Flow**
"Weekly to monthly" Long term energy storage E2P ratio: 50 - 500h	**Power to Gas (H2)**

- **Grid services**
- **Compensation for day-night load imbalance**
- **Peak shaving, valley filling, load shifting**
- **Correction of forecast errors of renewable producers**
- **Prevention of re-dispatch**
- **Opportunity of spot market price fluctuations**



- **Future application to bridge periods of low wind and photovoltaic generation**
- **Decarbonization of transport**

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Energy storage technologies

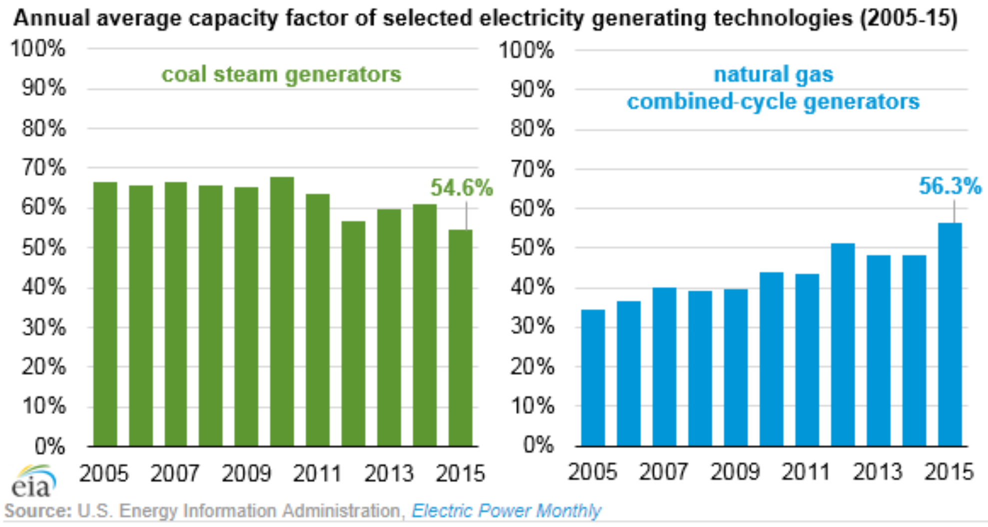
Example flywheel project: US – 20MW/5 MWh plant – 200 flywheels

Source: http://beaconpower.com/stephentown-new-york/

Energy Storage in Conventional Power Systems

- Traditional Power Systems have a very limited energy storage system
  - **Kinetic Energy in Rotating Generators**
  - **Pumped Hydro**

- Consequence of near “zero” storage :
  - Overcapacity
  - Lower asset utilization
  - Reduced operational efficiency
  - Reduced “Hosting Capacity” for “Variable Energy Resources” (PV, Wind…)



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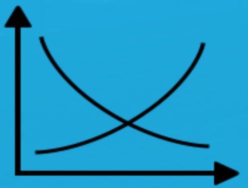
Ideal system characteristics for storage

High Penetration of Renewables

High usage of peaking diesel generators

Weak electrical networks and networks requiring upgrades

System Flexibility required to align supply and demand



Off-Grid Systems

Ability to maximise cheap grid connection potential

Policy and Regulation

Levelized Cost of Storage (LCOS) as a Comparison Index

- LCOE is typically used to assess the cost of electricity from different power plant types. In this analysis it has been transferred to storage technologies and therefore the term LCOS is used.
- It enables comparison between different types of storage technologies in terms of average cost per produced/stored kWh.

$$LCOS = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{el}}{(1+i)^t}}$$

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LCOS	**Levelized Cost Of Storage [$/kWh]**
I_o	Investment costs [$]
A_t	Annual total costs in year t [$]
M_{el}	Produced electricity in each year* [kWh]
n	Technical lifetime [years]
t	Year of technical lifetime (1, ..., n)
i	Interest rate (WACC) [%]

Input Variables	Elements	Example values
Investment costs [$]	Specific cumulative investment cost * rated power	700 - 1500 $/kW * rated power
Annual total costs in year t [$]	Operational costs (in %) * Investment costs	2% * Investment costs
Produced electricity in each year [kWh]	Rated power * Equivalent full-load hours * Efficiency	Rated power *1,460 h/a * 80%
Technical lifetime [years]	Technical lifetime	50 years
Interest rate (WACC)	Discount rate	8%

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- As the power system evolves and the role of storage changes over time, other technologies could have new opportunities if they can compete with lithium-ion battery prices.
- Long-duration energy storage can significantly enhance the utilization of renewable energy sources

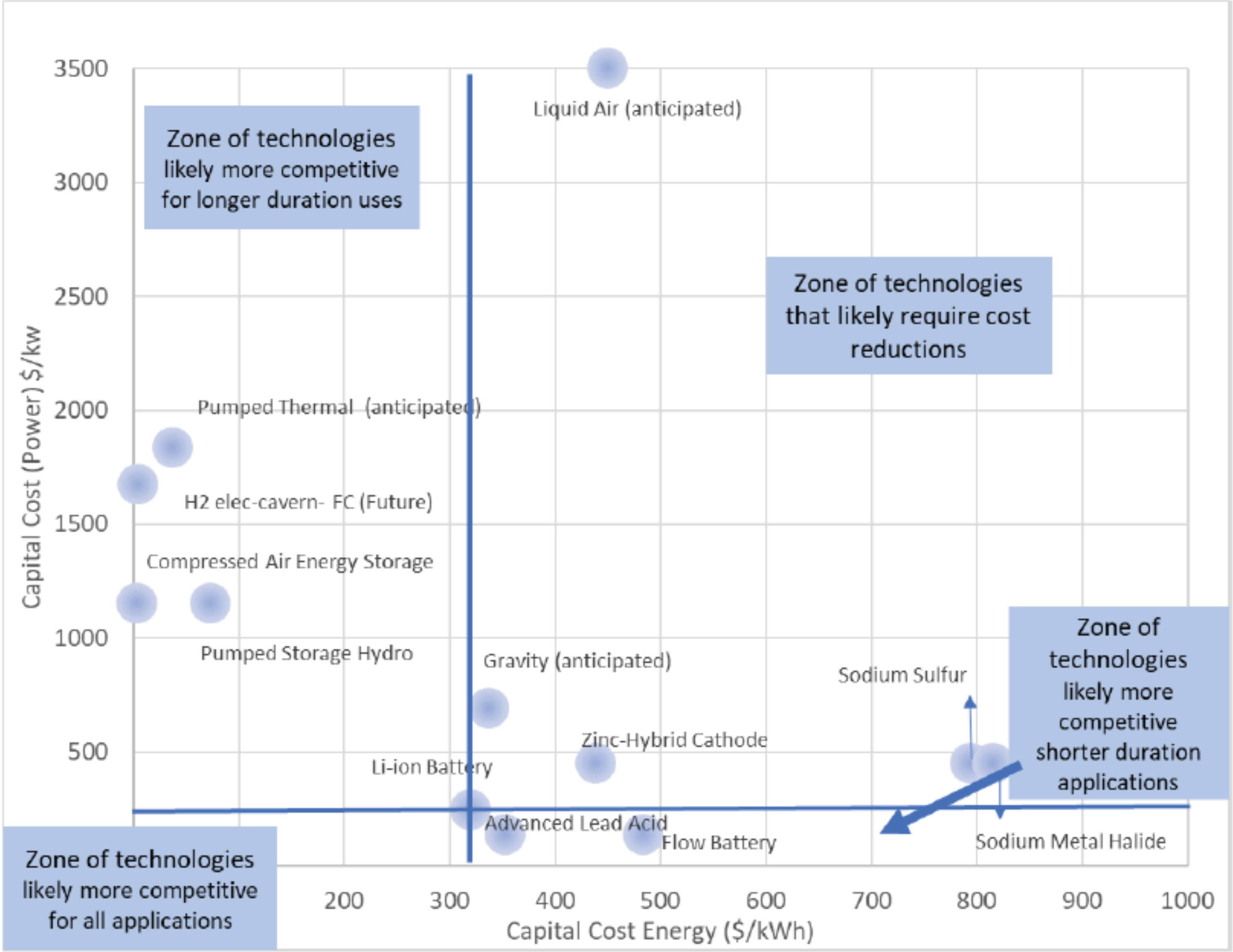

Figure 4. Capital cost for energy ($/kWh) versus capital cost for capacity ($/kW) for various technologies. Technologies with low power-related costs (but high energy costs) may be better suited for short-duration applications, whereas technologies with higher power-related costs and low energy related costs may be more competitive in longer-duration applications. Anticipated costs may change as technologies evolve and are commercialized.[2]

Source: NREL, Storage Futures Study, **Key Learnings for the Coming Decades**

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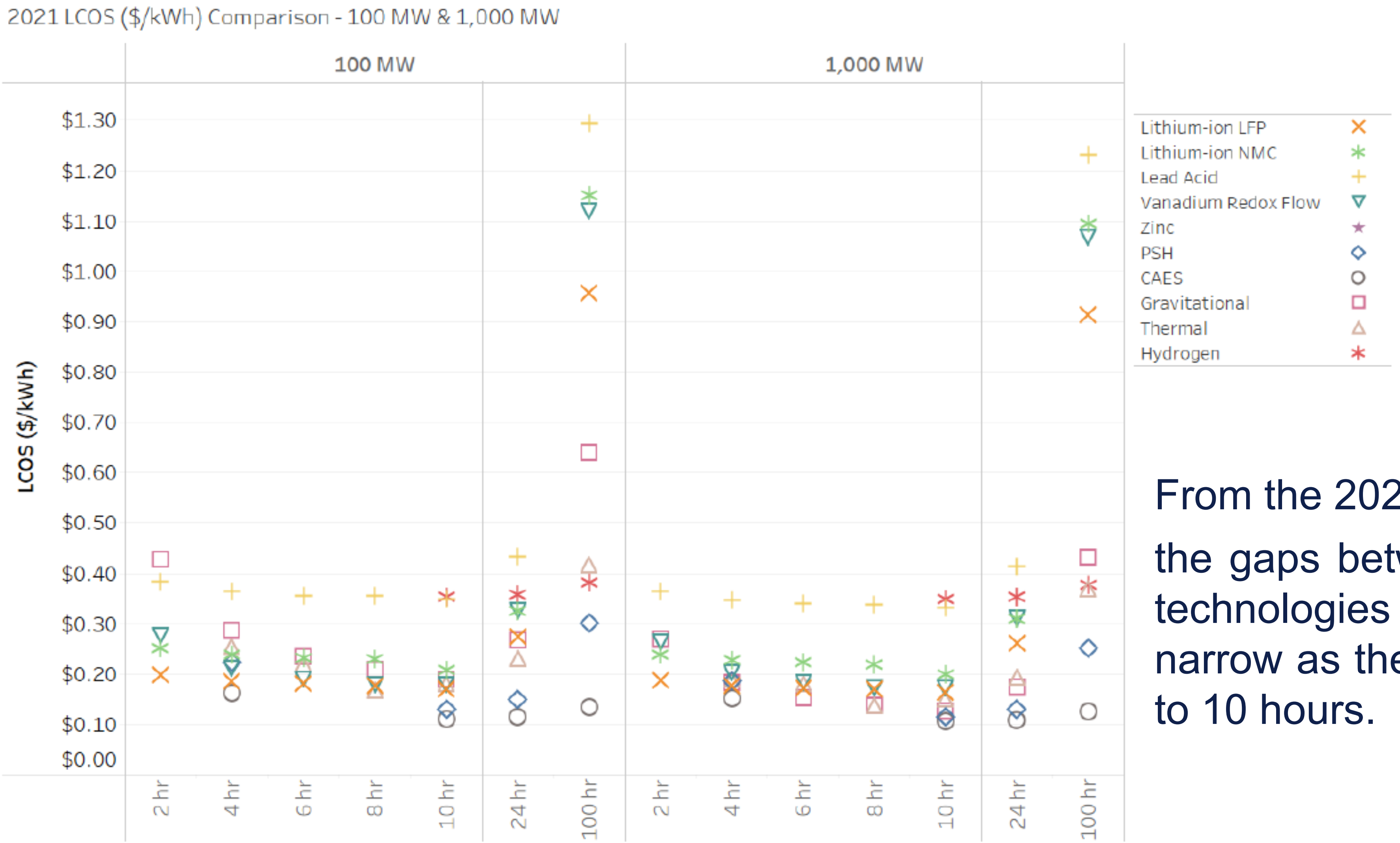

Figure ES-4. Comparison of LCOS ($/kWh) by Technology, Power Capacity, and Duration

From the 2021 results,

the gaps between LCOS values across technologies except for lead acid narrow as the duration increases from 2 to 10 hours.

Source: PNNL Report, 2022 Grid Energy Storage Technology Cost and Performance Assessment

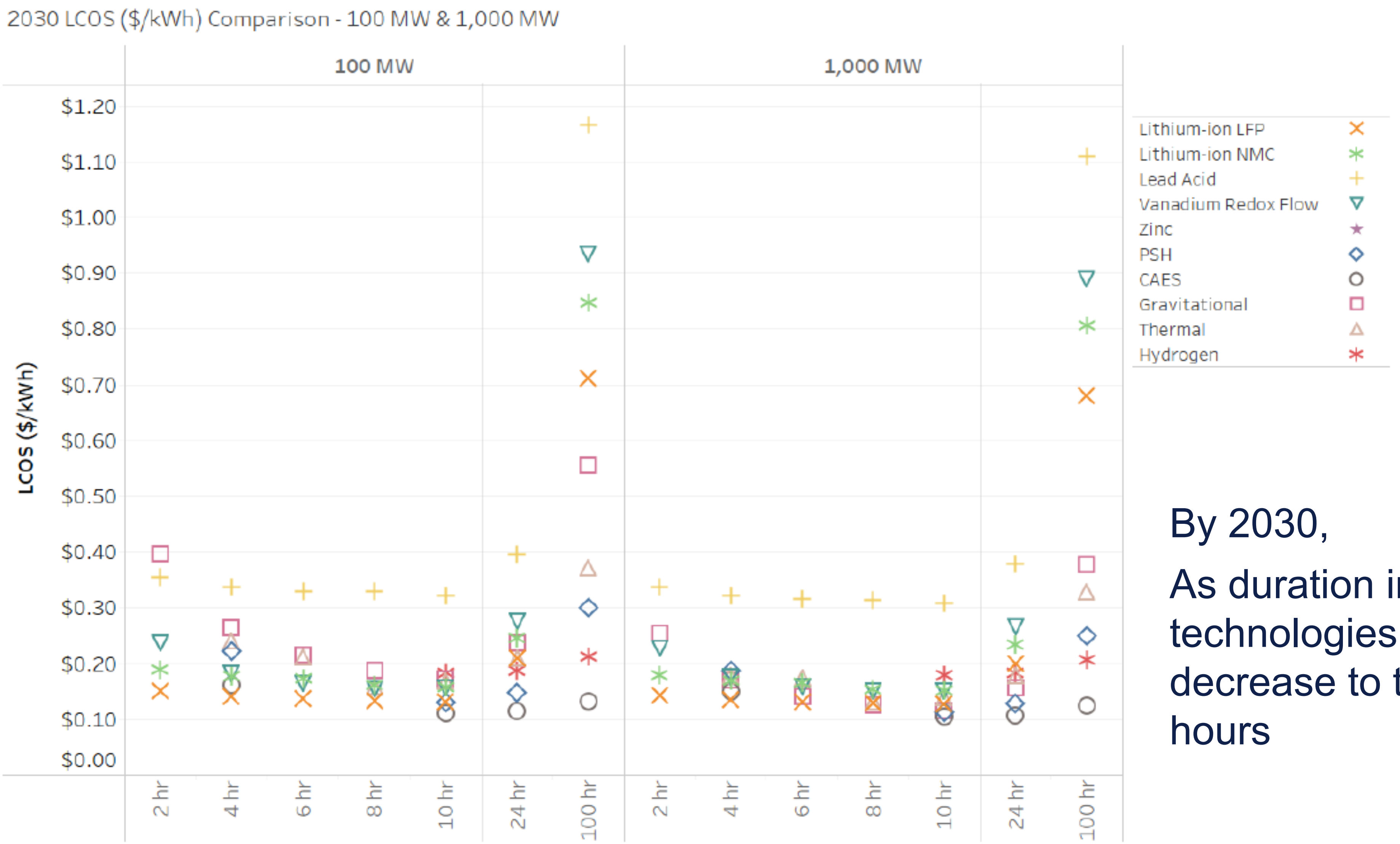

Figure 6.5. LCOS Results for 100 MW and 1,000 MW Storage Systems, 2030 Values

By 2030,

As duration increases, LCOS for all technologies are estimated to decrease to their minimum at ~ 10 hours

Source: PNNL Report, 2022 Grid Energy Storage Technology Cost and Performance Assessment

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ESS Overview in Asia – Pacific excl. ASEAN

Country	ESS capacity as of 2020	ESS Targets by 2030	Incentives	Business Models
Mainland China	33.1 GW of ESS	~120 GW for ESS and 47 GW for battery-specific	Government and province-level subsidies and grants. Priority status to storage + RE projects at permitting stage.	Energy Arbitrage, Frequency Reserve; Contingency Reserve
Australia	3.2 GWh	6 GWh	Rebates and subsidies for residential and small installations	Energy Arbitrage in NEM; Frequency response; contingency reserve
Japan	In January 2023, Japan announced 17 billion Japanese Yen worth of subsidies for BESS installations and water electrolysers via an application process New installations of 1MW and above capacity			Supply-Demand Adjustment Market, wholesale electricity market, capacity market and via individual trading
India	**Build-Operate-own (BOO)/ Transfer (BOOT):** SECI floated and awarded the first 500MW/1GWh BESS in the Rajasthan region. NTPC awarded a 3GWh tender to Pumped hydro storage on a 25-year basis **Funding for 4GWh of grid-scale batteries in its 2023-2024 annual expenditure budget**			Ancillary services
South Korea	8.6 GWh	25GW/127GWh storage target by 2036. Plans to increase ESS capacity for grid stability and demand response.	(1) Higher-weighted renewable energy certificates (RECs) for ESS projects; (2) Peak-shaving 'special tariff plan' for ESS installed behind the meter	KEPCO announced utility-scale ESS services such as ancillary services, power line deferral services, and transmission line congestion controls.

Source: DNV White Paper titled "Energy storage systems in the Asia Pacific region"

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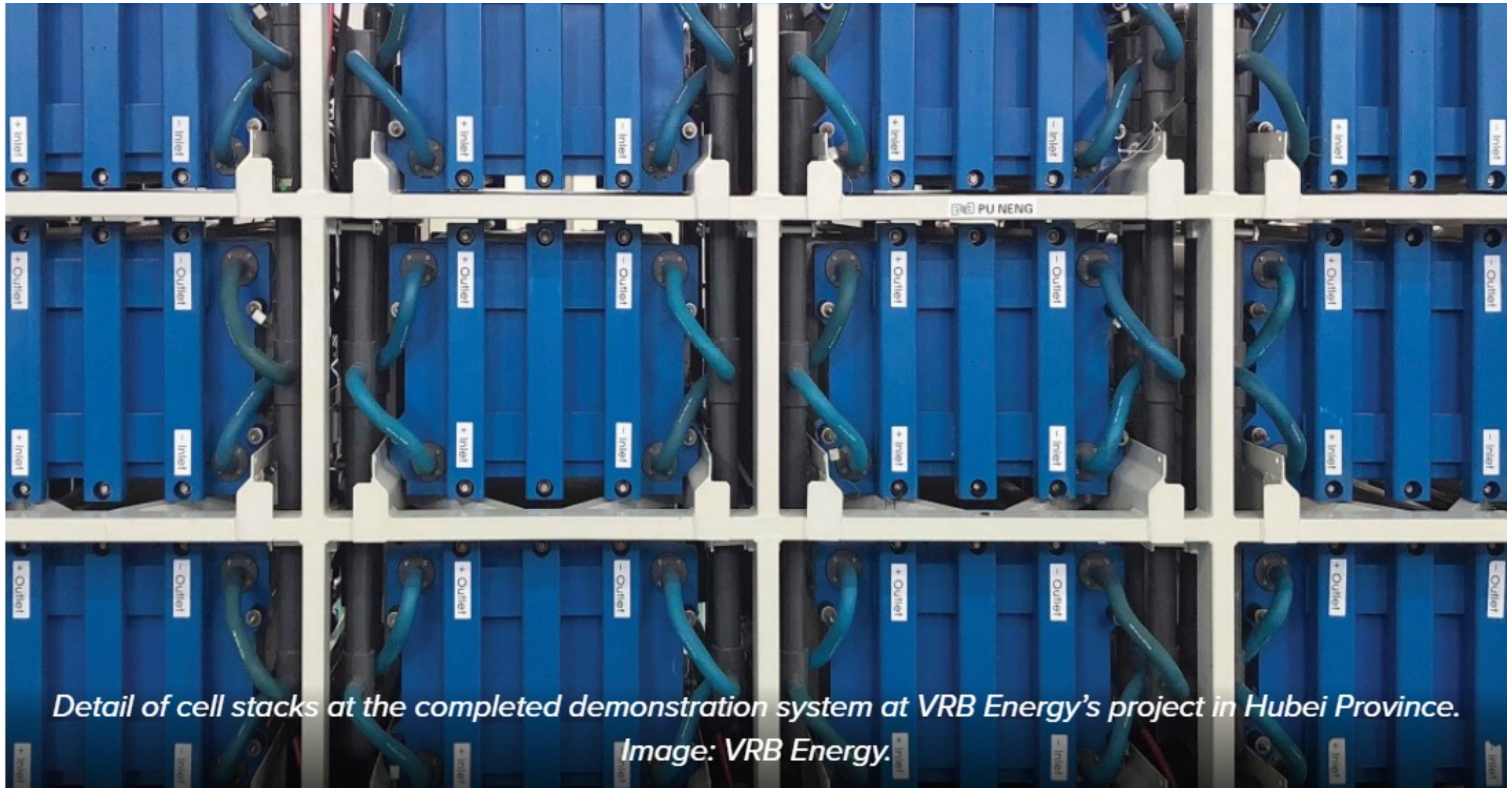
First Utility Scale Flow Battery 2022



Detail of cell stacks at the completed demonstration system at VRB Energy's project in Hubei Province. Image: VRB Energy.

- Commissioning has taken place of a 100MW/400MWh vanadium redox flow battery (VRFB) energy storage system in Dalian, China
- The biggest project of its type in the world today, the VRFB project's planning, design and construction has taken six years.

https://www.energy-storage.news/first-phase-of-800mwh-world-biggest-flow-battery-commissioned-in-china/

ASEAN grid connections plan signals more ESS opportunities

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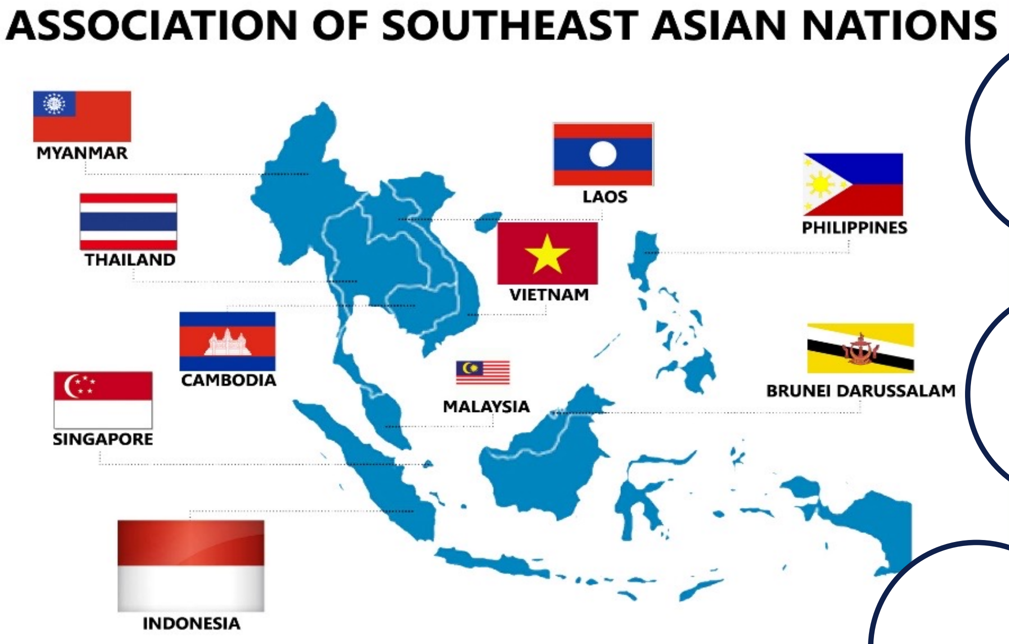

ESS opportunities in Asia receive a medium-to-long-term boost under the ASEAN Plan of Action and Energy Cooperation (APAEC) Phase II: 2021–2025

Malaysia: 500 MW (100 MW planned to be installed annually from 2030–2034) - Investment incentives for ESS include Green Investment Tax Allowance (GITA) and Green Income Tax Exemption (GITE)

Vietnam: FiTs for solar and wind were revised in 2020, but ESS still lacks an incentive. RE projects face curtailment issues, so it is possible that the policy/regulatory environment will change to support ESS in the next few years.

Philippines: Island nation favourable for microgrid applications for congestion management through frequency regulation/ energy shifting applications.

Source: DNV White Paper titled "Energy storage systems in the Asia Pacific region"

ASEAN overview

Country	ESS capacity as of 2022	ESS Targets by 2030	Incentives	Business Models
Singapore	200 MW	1 GW	EMA's Intermittent Pricing Mechanism (IPM) is a potential driver for ESS uptake	Energy arbitrage through time-of-use (ToU) tariffs; primary and contingency regulation reserve; and demand-side management.
Thailand	The first private sector initiative in the country to integrate utility-scale wind power (10 MW) generation with a BESS (1.88 MWh) was led by BCPG subsidiary, Lom Ligor, and was supported by the Asian Development Bank (ADB). A second storage initiative was sponsored by Blue Solar, a solar-focused Thai renewable energy company which deployed a 42 MW DC solar + 12 MW / 54 MWh ESS hybrid system. Under contract to provincial electric utility PEA, third-party developers are installing a few standalone BESS systems to support grid-constrained locations.			
Taiwan	Mainly pumped hydro and ~10 MW electrochemical ESS	Demand for ~600 MW by 2025 related to ancillary services	All ancillary services are procured by Taiwan Power Company through bilateral contracts.	Fast response; regulation reserve; spinning reserve; supplemental reserve

Source: DNV White Paper titled "Energy storage systems in the Asia Pacific region"

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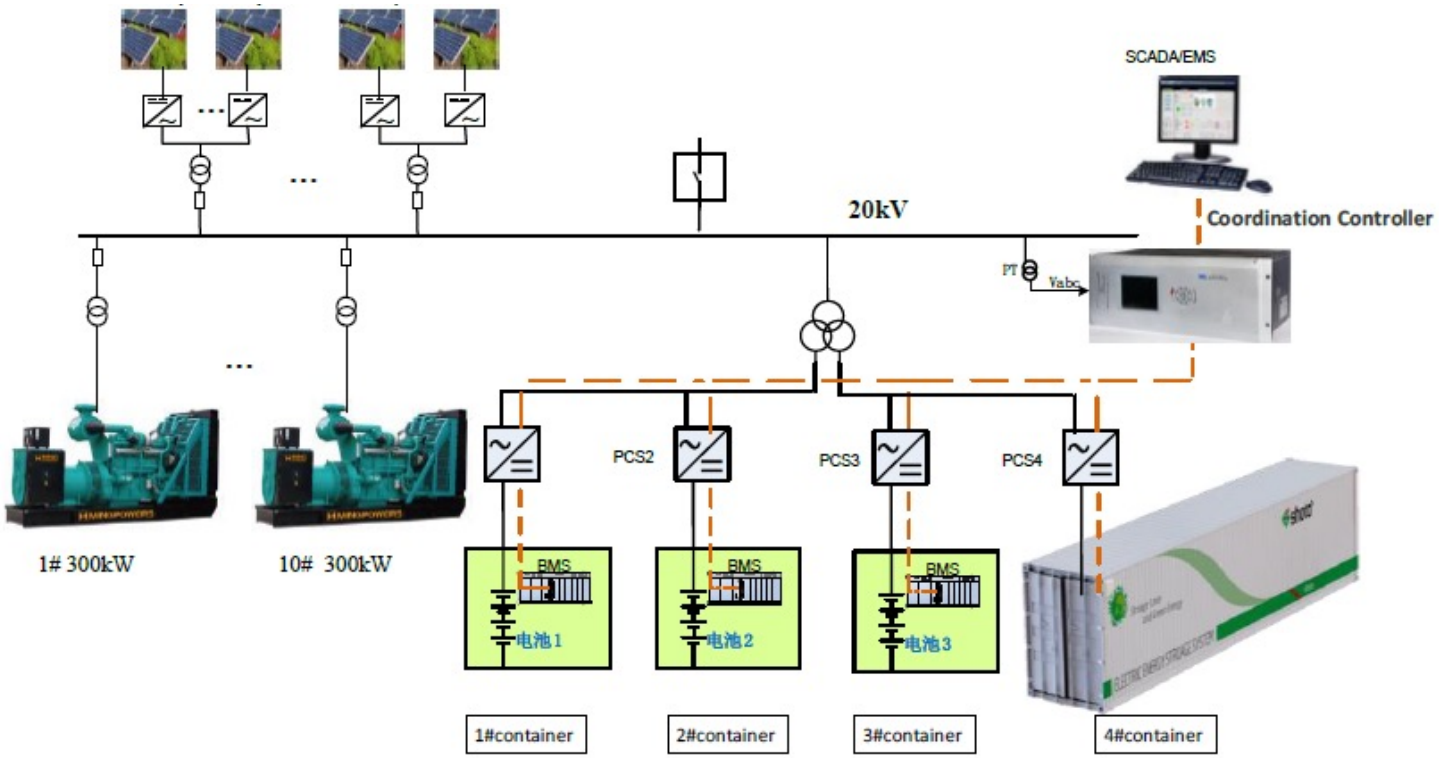
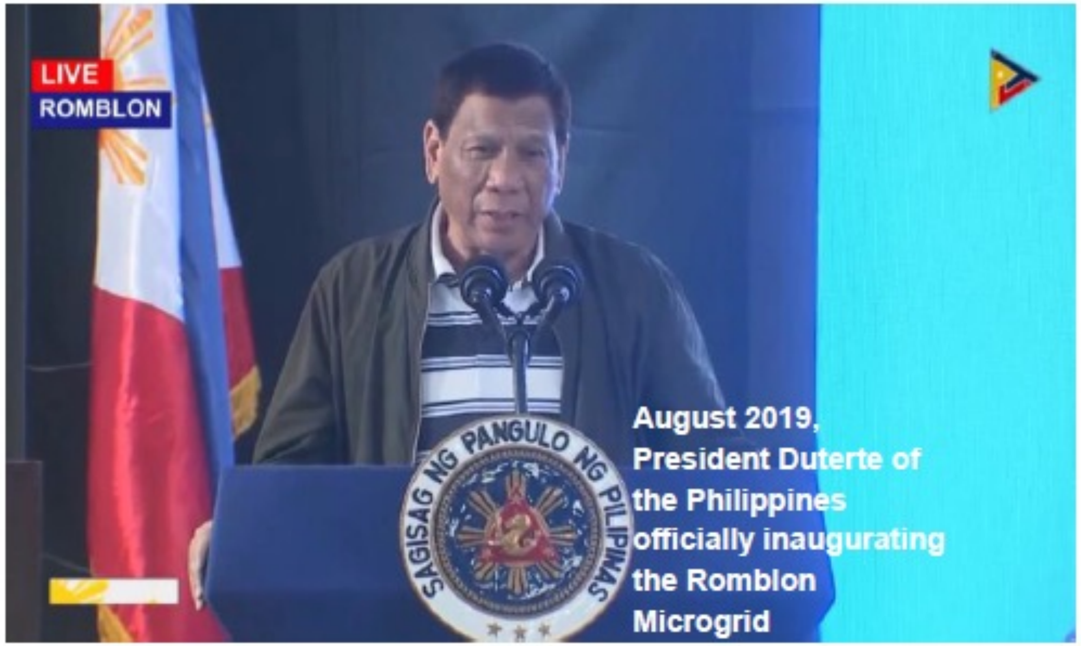
Example from Thailand: Transmission deferral with ESS



Example from the Philippines:
Romblon 16MW Microgrid (Solar PV+ BESS+ Diesel)



- The Isnad of Tablas has 150000 inhabitants.
- New hybrid system allowed the island to have stable energy and less dependency from Diesel.

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Developments and Trends

- Asia Pacific (APAC) maintains its lead in building on a power capacity (gigawatt) basis, representing 44% of global additions in 2030. China leads in deployments in the region, driven by local targets and compulsory renewable integration policies.
- Customer-sited batteries – both residential and commercial and industrial (C&I)– are also expected to grow at a steady pace. Australia is leading currently with Japan having a sizeable market.
- Pumped hydro makes a comeback attracting more investment than other long-duration storage technologies – India and Thailand with their capacity additions.
- Co-located renewables-plus-storage projects, in particular solar-plus-storage, are becoming commonplace globally.
- Ability of storage to provide firm capacity and time-shifting is a primary cost driver for cost-effective deployments.

Thank you!

Modini.Yantrapati@dnv.com
+65 / 97274249

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