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Electricity Market Integration of Battery Energy Storage Systems

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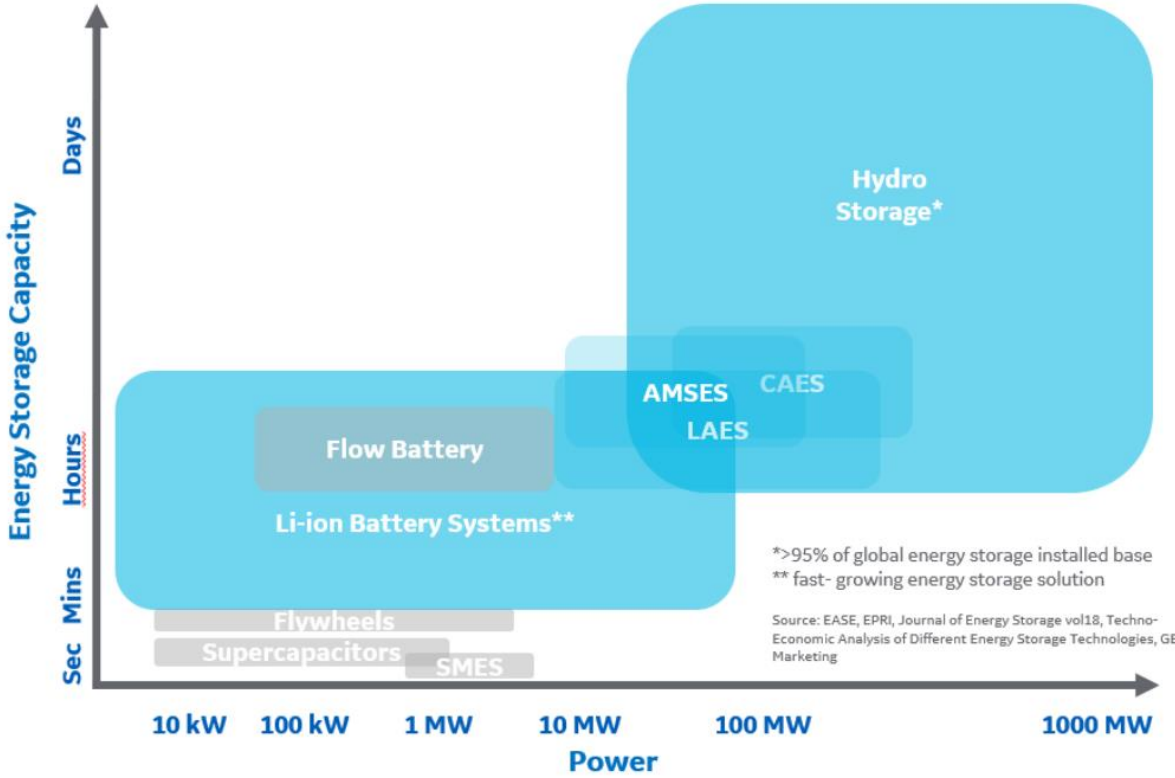
on behalf of Clean, Affordable and Secure Energy (CASE) for Southeast Asia

Industry Trends

Energy Storage Technologies

- **Mechanical**
  - Pumped Storage Hydro
  - Compressed Air Storage
  - Flywheel
- **Electro-chemical**
  - Secondary Battery (Pb-A, Na-S, Li-ion, Ni-Cd etc.)
  - Flow battery (vanadium redox and Za-Br)
- **Thermal**
  - Sensible Heat
  - Latent Heat
  - Chemical
- **Chemical**
  - Hydrogen
- **Electrical**
  - Supercapacitor

There are many types of energy storage – some are commercial, some are promising technologies for the coming decade ... of these, pumped storage hydropower (PSH) and chemical batteries (BESS) are of interest

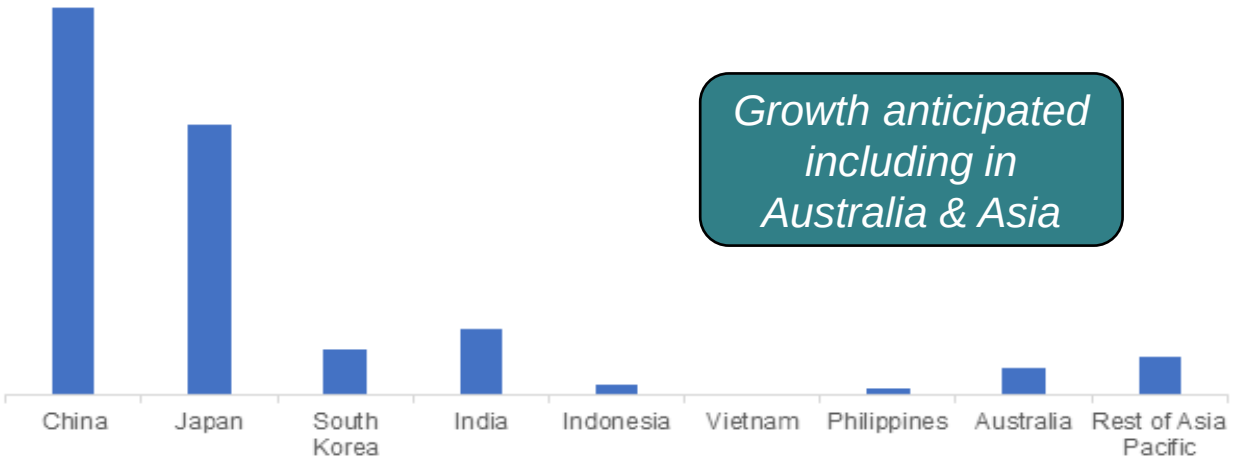


Source: https://www.hydro.org/wp-content/uploads/2021/09/2021-Pumped-Storage-Report-NHA.pdf

Pumped Storage Hydro (PSH)

- PSH is a mature and well-established technology
- It is not a bi-directional technology within a 5-minute market as it is unable to change quickly from a pumping mode to generating mode
- Growing necessity for grid stabilization & peak load management is driving significant PSH growth
- PSH's have minimal environmental impacts across natural habitats & availability of non-connected water streams

Asia Pacific Pumped Hydro Storage Market, By Country, 2021 (GW)

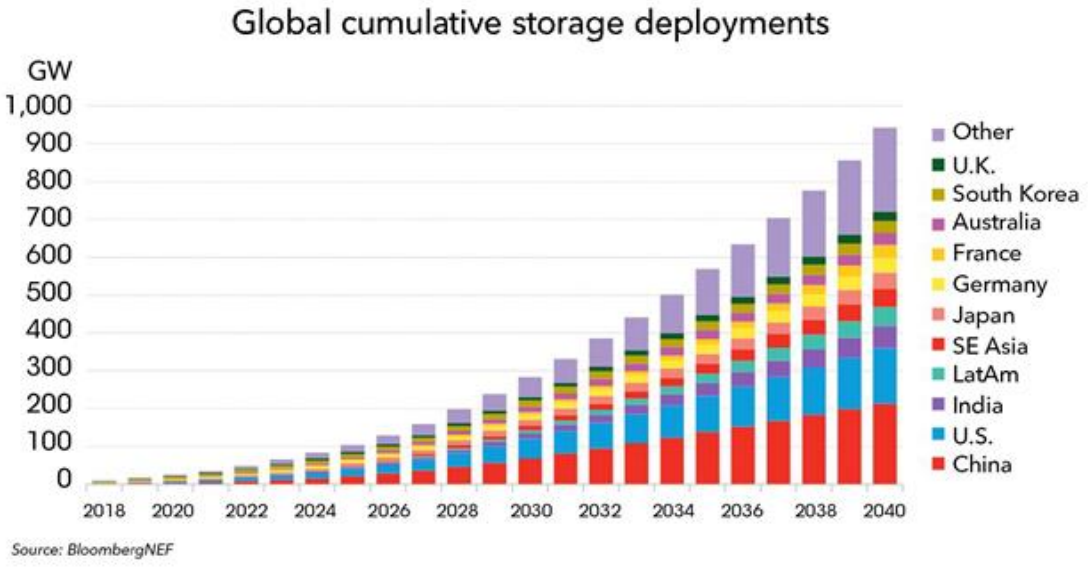


Growth anticipated including in Australia & Asia

Source: www.gminsights.com

Battery Energy Storage Systems

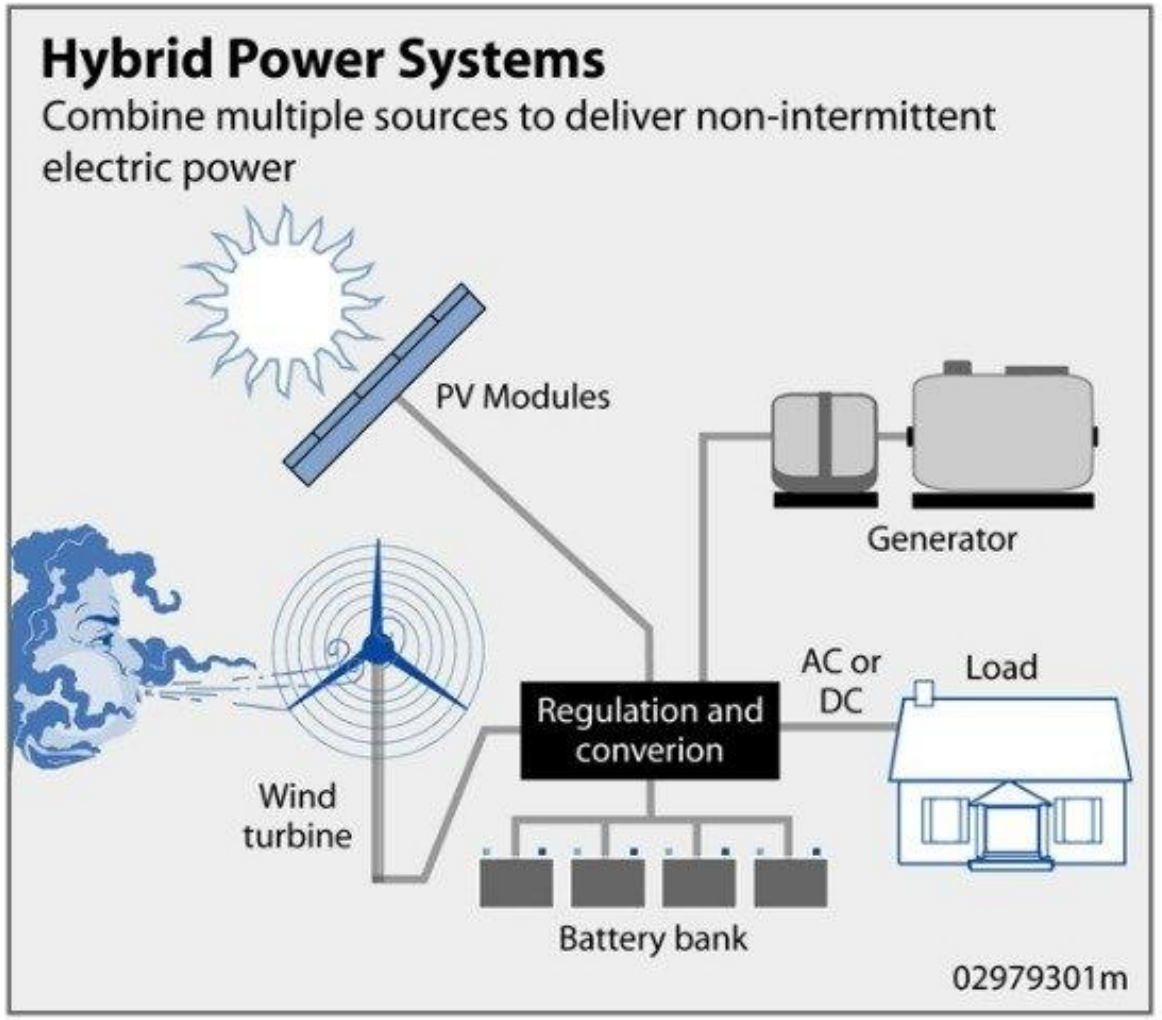
- Flexible operation - can provide power or energy
- Rapid charge / discharge response supporting power system security
- Can discharge economically for up to 4 hours
- Response to market signals is limited by the State of Charge (SoC) – storage size
- High flexibility ⇔ concern of market power exercise
- Market rules may not ensure an owner is fully compensated for all services provided



High growth in BESS (both utility & behind-the-meter) anticipated

Hybrid Storage Facilities

- A Hybrid Resource is a facility that comprises a mixed-fuel type power generation facility or a combination of different generation technologies physically and electronically controlled by a single owner/operator
- BESS and variable renewable energy (VRE) systems are increasingly being used to enable VRE to be more reliable
- Some schemes may involve only co-located systems; however, some may span multiple connection points in a power system

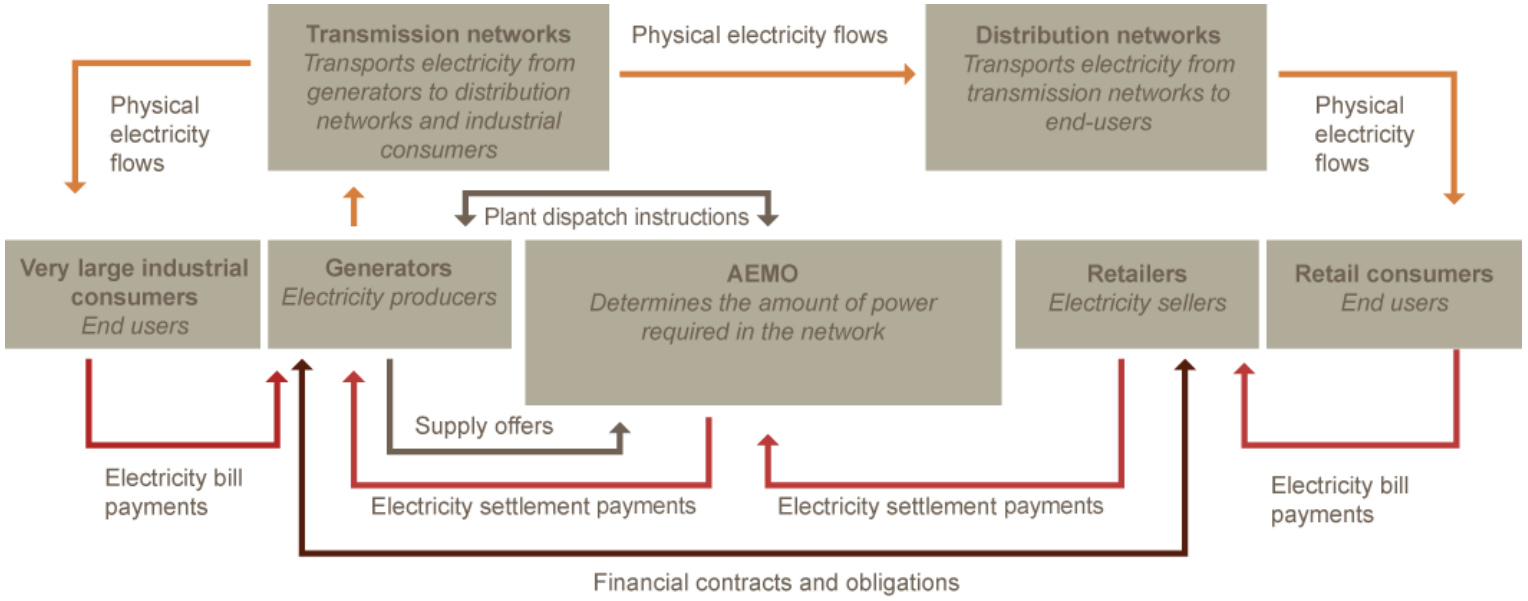


Source: https://www.energy.gov/energysaver/hybrid-wind-and-solar-electric-systems

Eletricity Market Integration

Electricity Markets & Challenges of ESS Integration

CASE for Southeast Asia



- Electricity markets based on real-time security-constrained economic dispatch and pricing algorithms
- Variations in market designs:
  - USA – Day-Ahead Market (DAM) & Real-Time Market (RTM)
  - Australia – RTM + pre-disaptch

Integration of BESS is challenging because of their high level of flexibility, ability to provide multiple services: ancillary services & energy, and relatively small storages (up to 4 hours) – this is further complicated by the advent of hybrid systems

Source: https://www.aemc.gov.au/energy-system/electricity/electricity-market/spot-and-contract-markets

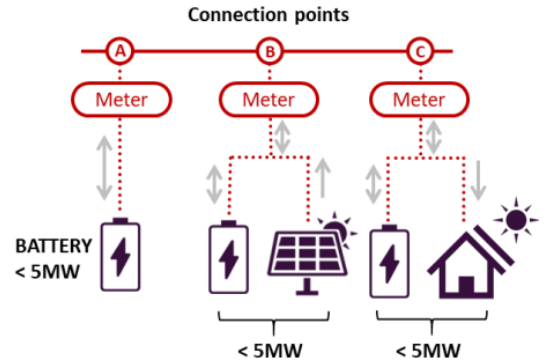
Principles to Guide Integration of ESS into Power Markets

- Allow BESS to set the wholesale price as both a buyer and a seller whenever it is the marginal resource that is dispatched
- Represent the physical parameters and capability of BESS in bidding rules
- Update BESS capability in real-time in the 5-minute market
- Allow BESS to self-manage their own SoC
- Permit BESS to de-rate their capacity to meet minimum run-time requirements
- Require BESS to follow instructions during system emergencies
- Monitor compliance with dispatch instructions
- Monitor for abuse of market power, especially when directly coupled with VRE

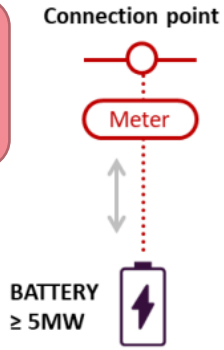
Market Registration

- System and market operators (SMOs) responsible for power system security & dispatching BESS for energy and ancillary services – important to ensure that the SMO has all information necessary to perform this function from the time of registration
- BESS & hybrid markets (both small & large scale) have required the registration process to be flexible to cater for a wider range of facility types
- Australia example – registration expanded from having simple registration of generation systems & loads to having many situations mainly based on size of the BESS:
  - BESS < 5 MW exempt (unless part of a larger system)
  - BESS >= 5 MW as stand-alone registered as both consumer & generator
  - BESS >= 5 MW in a hybrid system
  - BESS >= 5 MW in a generation system
  - Handling registration of a facility that spans more than 1 connection point
- This is important because it determines the interface between the facility and the SMO for bidding and for the SMO to run a security-constrained dispatch

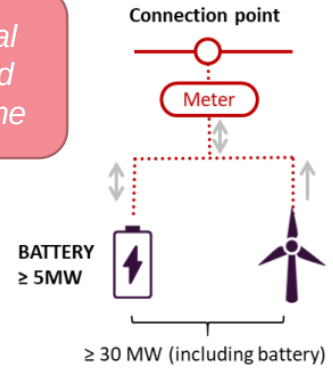
Examples of BESS < 5 MW

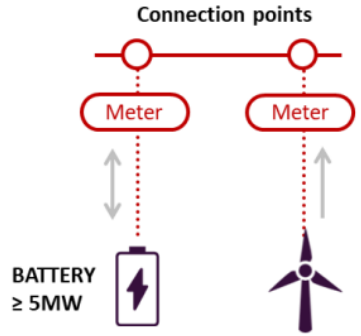


Stand-alone BESS >= 5 MW



Typical Hybrid Scheme





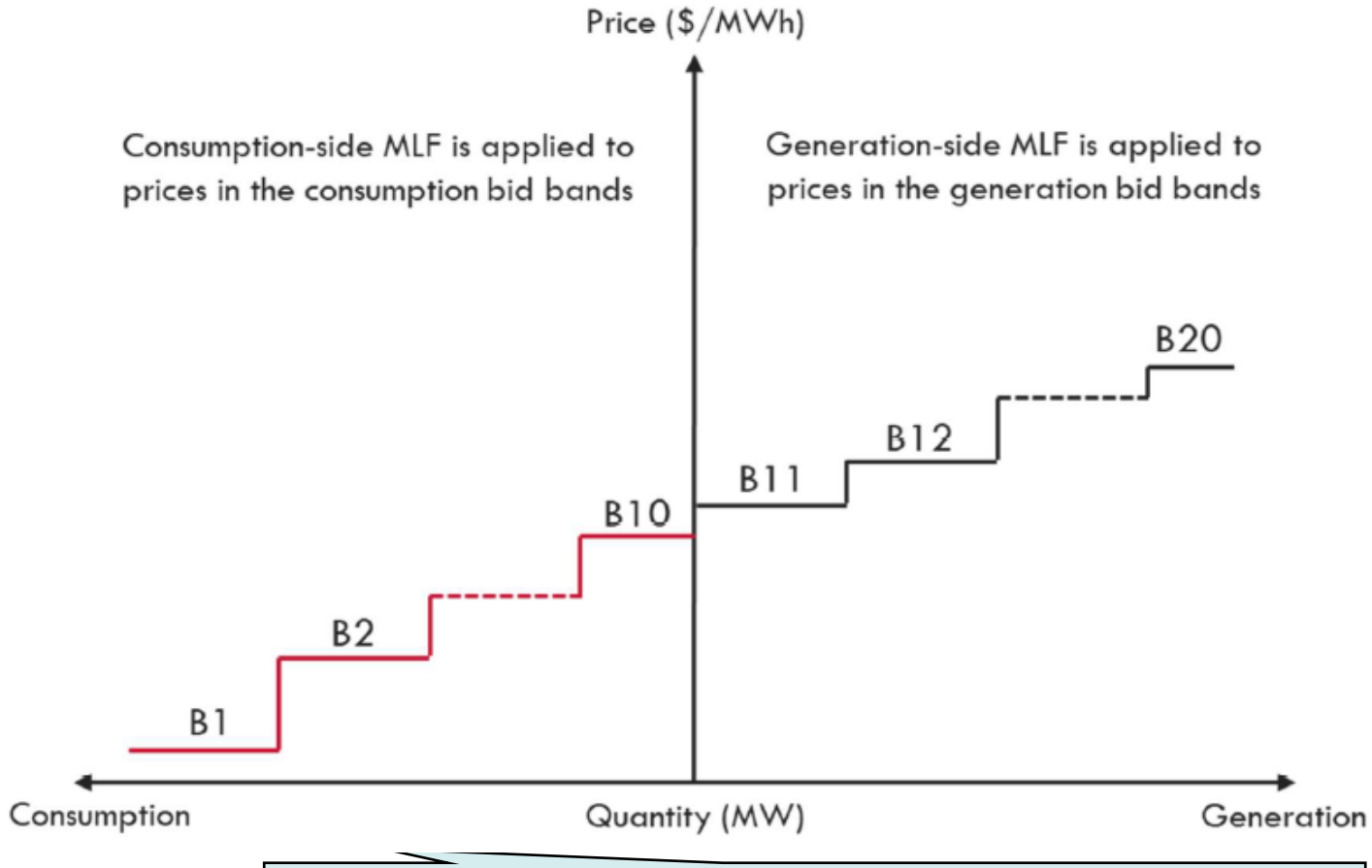
Example of facility spanning multiple connection points

Source: AEMO

Bidding Interface into Market

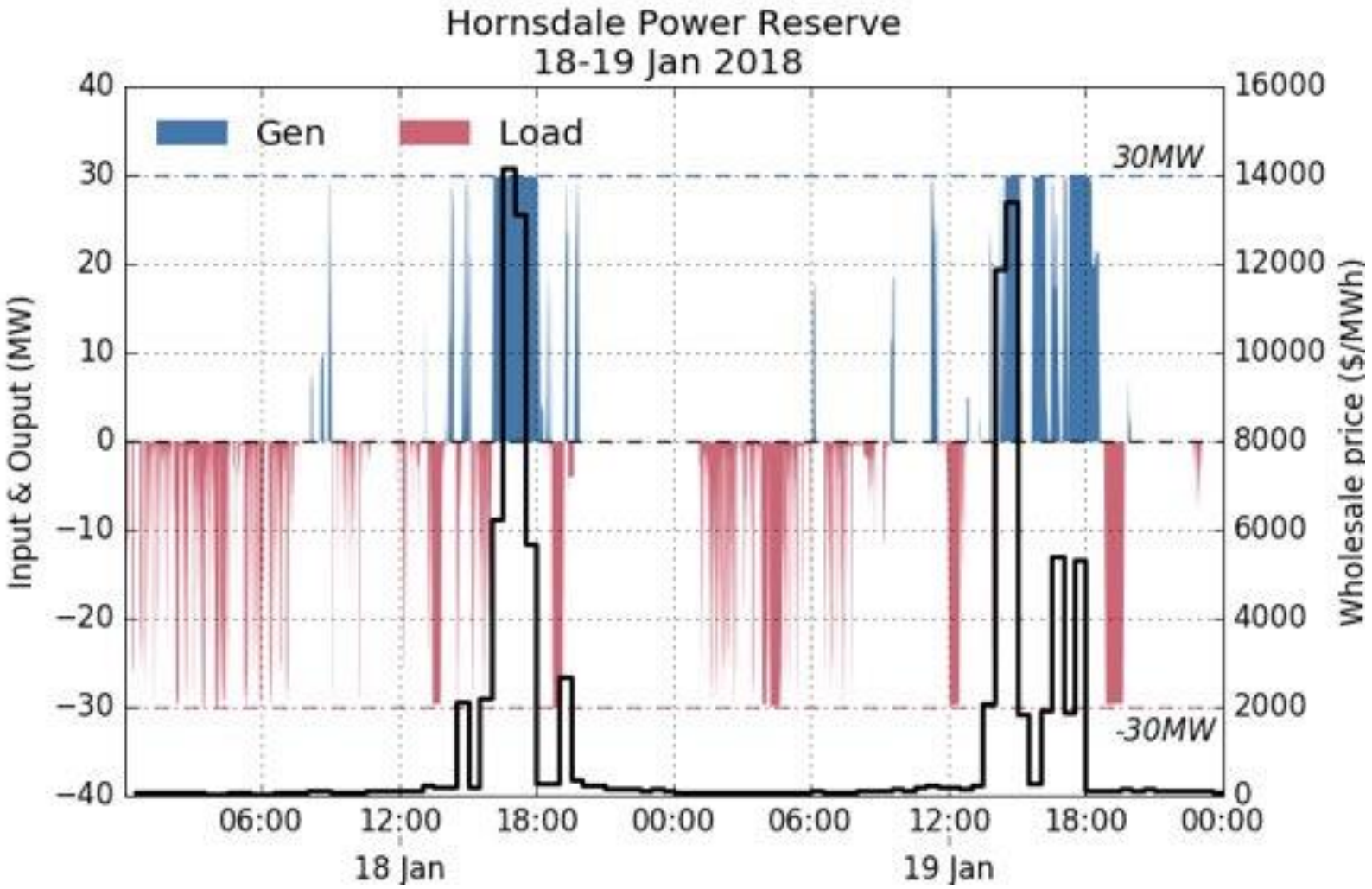
- USA, Australia, Philippines markets have introduced “bidirectional bidding” for BESS as they are able to transition rapidly between consuming & generating
- Allows BESS to be optimized for generation or consumption
- Management of SOC is important:
  - USA day-ahead markets based on centralized management
  - Australia market leaves this a decentralized issue
- Extension to hybrid systems for bidding – provide flexibility to market participant

Figure 3 Up to 20 bid bands for scheduled BDUs.



Bidirectional units in the Australia market can submit “bidirectional bids” which provide for charging & discharging operation

Market Dispatch & Price Arbitraging



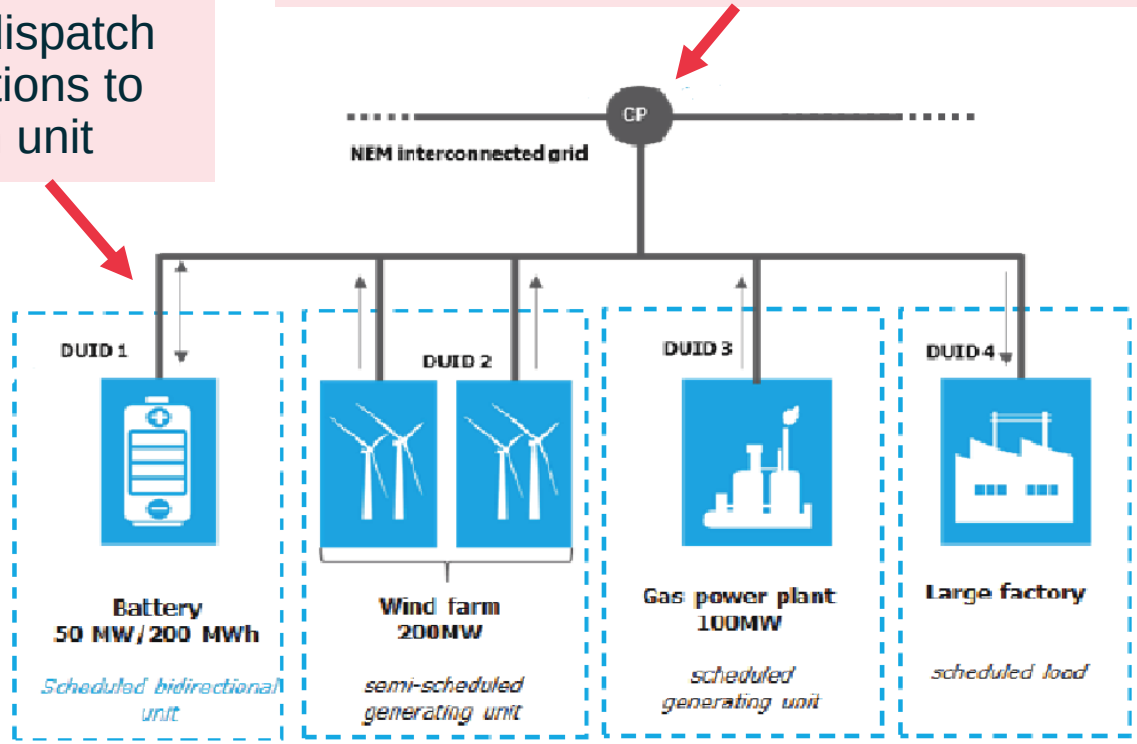
- BESS operates as price arbitragers – arbitraging between times of high and low prices
- Example: 18-19 Jan 2018 when the wholesale spot price for electricity in South Australia rose due to hot weather, BESS its owners an estimated A$1,000,000
- Raises concerns about market power – however, the key to management of market power is to ensure there is a high level of competition. As more BESS enters the market – so long as it there is a sufficiently large number of independent traders, prices should become more efficient

Dispatch & Dispatch Compliance

- Monitoring compliance with dispatch instructions continues to be important
- General experience is that the same logic for conventional resources can be applied however, fitted to hybrid systems
- With potential penalties for non-compliance

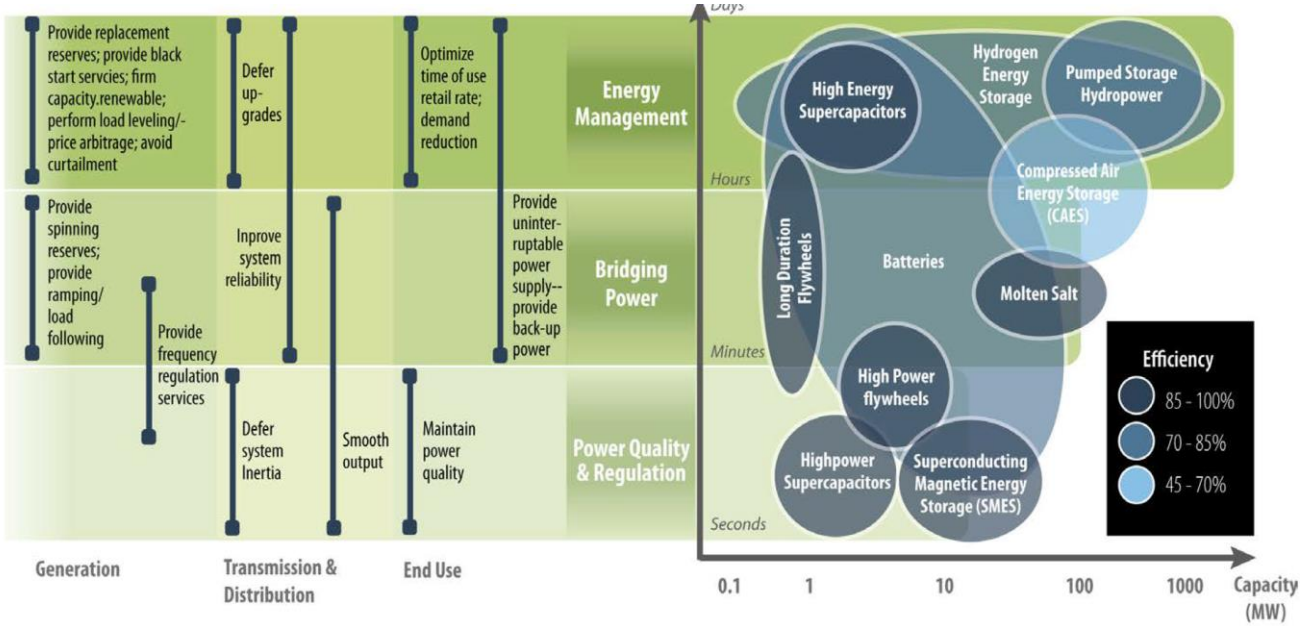
Scheduling at the unit level for both the energy and AS markets. AEMO sends dispatch instructions to each unit

Compliance with dispatch assessed at the connection point or at unit level – another issue determined by SMO during registration

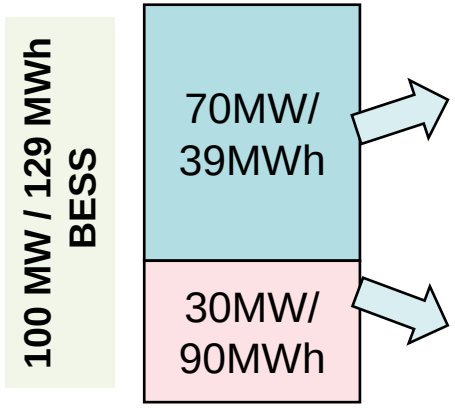


Market Registration

- BESS can provide a wide range of AS:
  - Frequency Control Ancillary services (FCAS)
  - Voltage regulation / reactive support
  - Black System Restart Services
  - Other applications: virtual transmission lines, special-protection schemes for critical transmission lines or “backup reserves”
- Market integration is the extent to which AS markets have been established and how BESS is allocated optimally across different services
- Energy-reserves co-optimization is one way of doing this for energy & FCAS
- A key issue is that the SOC is at a level that would not compromise the ability of BESS to provide such services
- Markets with incomplete or transitionary AS arrangements are being “tested” as BESS enters



Example: Hornsdale Power Reserve (Australia)



Contracted to South Australian government to provide grid stability and system security. It provides FCAS when needed and designed to last 10 minutes

Used as load shifting / VRE firming for the Hornsdale wind farm – 3 hours of storage dedicated to this

Ongoing Challenges

Ongoing Challenges Internationally

- Stages of ESS integration based on international review:
  - **Stage 1**: No energy storage integration at all
  - **Stage 2**: Limited energy storage integration (pumped storage hydro typically)
  - **Stage 3**: Stand-alone BESS integration
  - **Stage 4**: Stand-alone and co-located hybrid systems (integrated energy resource)
  - **Stage 5**: Stand-alone, hybrid systems and hybrid systems that may span multiple connection points
- Many electricity markets are in the process of transitioning towards Stage 4 or 5
- Other markets – where the integration of energy storage (pumped hydro) hasn't been considered, are focused on moving to Stage 3
- Framework for the management of ancillary services need to continue to evolve to ensure all services of new technologies (BESS and hybrid systems) are leveraged
- As distributed generation resources become more viable, electricity markets have had to cater to these new technologies while seeking to provide a consistent and holistic framework for power market & system operations

Lessons for Vietnam

- Electricity markets have needed to evolve rapidly as the share of Variable Renewable Energy (VRE) has increased – and with decarbonization policies to reach net zero targets by 2050, the increase in VRE's share in the generation mix will continue to increase
- Energy storage technologies are critical for managing increased shares of VRE in the system and hence a critical issue for Vietnam is to establish a Roadmap for ESS integration in the form of a commercial framework that provides an appropriate incentive for ESS
- Components of this framework include:
  - Vietnam Wholesale Electricity Market enhanced to enable participation of ESS as a bidirectional resource in the power market
  - Improvements to ancillary services frameworks to make them open and competitive
- Other important considerations:
  - Expand regulatory framework for transmission to enable BESS to be considered transmission assets as well (this does not need to exclude a market-based mode of participation in the electricity sector)
  - Improvements to planning processes to consider impact of ESS over time – particularly increased distributed / behind-the-meter applications for BESS technologies

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