APEx WEBINAR
AGENDA
18 February 2021
3:00-4:00 PM EST
Via Webex

"Wholesale Market Design to Accommodate Storage"

Introduction	**Cecilia Maya (*Moderator*)** COO Markets, XM	3:00-3:05 pm
Overview	**Francisco Boshell (*Panelist*)** Leader Innovation, IRENA	3:05-3:20 pm
American Perspective	**Greg Cook (*Panelist*)** Executive Director Market and Infrastructure Policy, CAISO	3:20-3:35 pm
European Perspective	**Christoph Grafe (*Panelist*)** Director Market Integration UK & Ireland, Nord Pool	3:35-3:50 pm
Asian Pacific Perspective	**Farhad Billimoria (*Panelist*)** New Energy, AEMO	3:50-4:05 pm
Interaction with Panel	**Audience** Ask questions/comments using "Chat" Feature	4:05-4:30 pm

IRENA
International Renewable Energy Agency

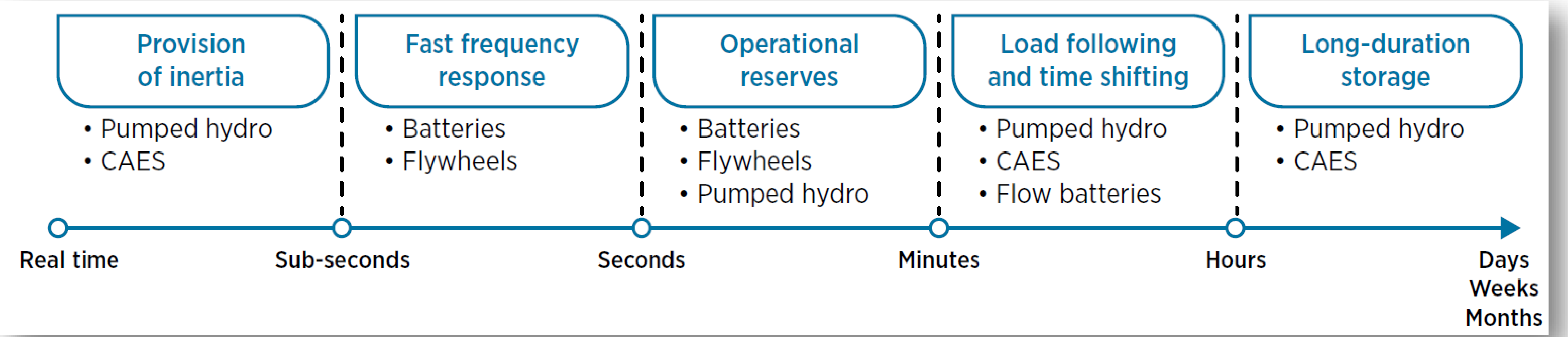
Electricity Storage Valuation Framework:

Assessing system value and ensuring project viability

Wholesale Market Design to Accommodate Storage
18 February 2021

The role of electricity storage for VRE integration

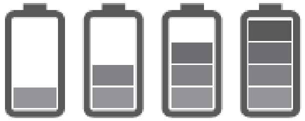
- Solar and wind power are variable and uncertain affecting system operations at various time scales, thus a set of solutions is needed to support system flexibility
- **Electricity storage can support system operations at all time scales**



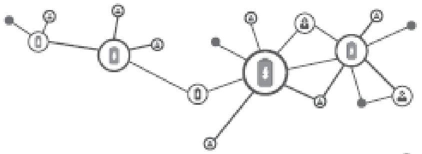
Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

IRENA's Electricity Storage Valuation Framework

Phase 01



Identify electricity storage services to support the integration of VRE



Phase 02

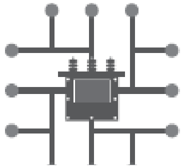
Map storage technologies with identified services

Phase 03

Analyse the system value of electricity storage compared to alternative flexibility options

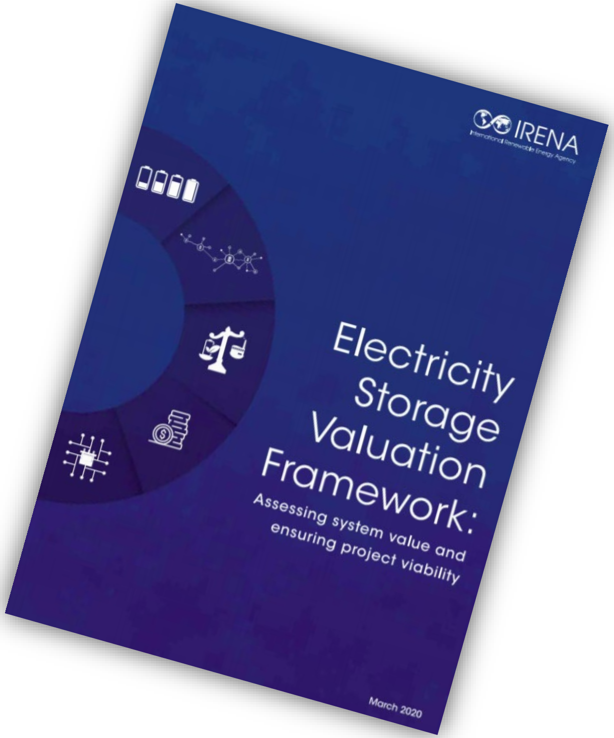
Phase 04

Stimulate storage operation and stacking of revenue



Phase 05

Assess the viability of the storage project



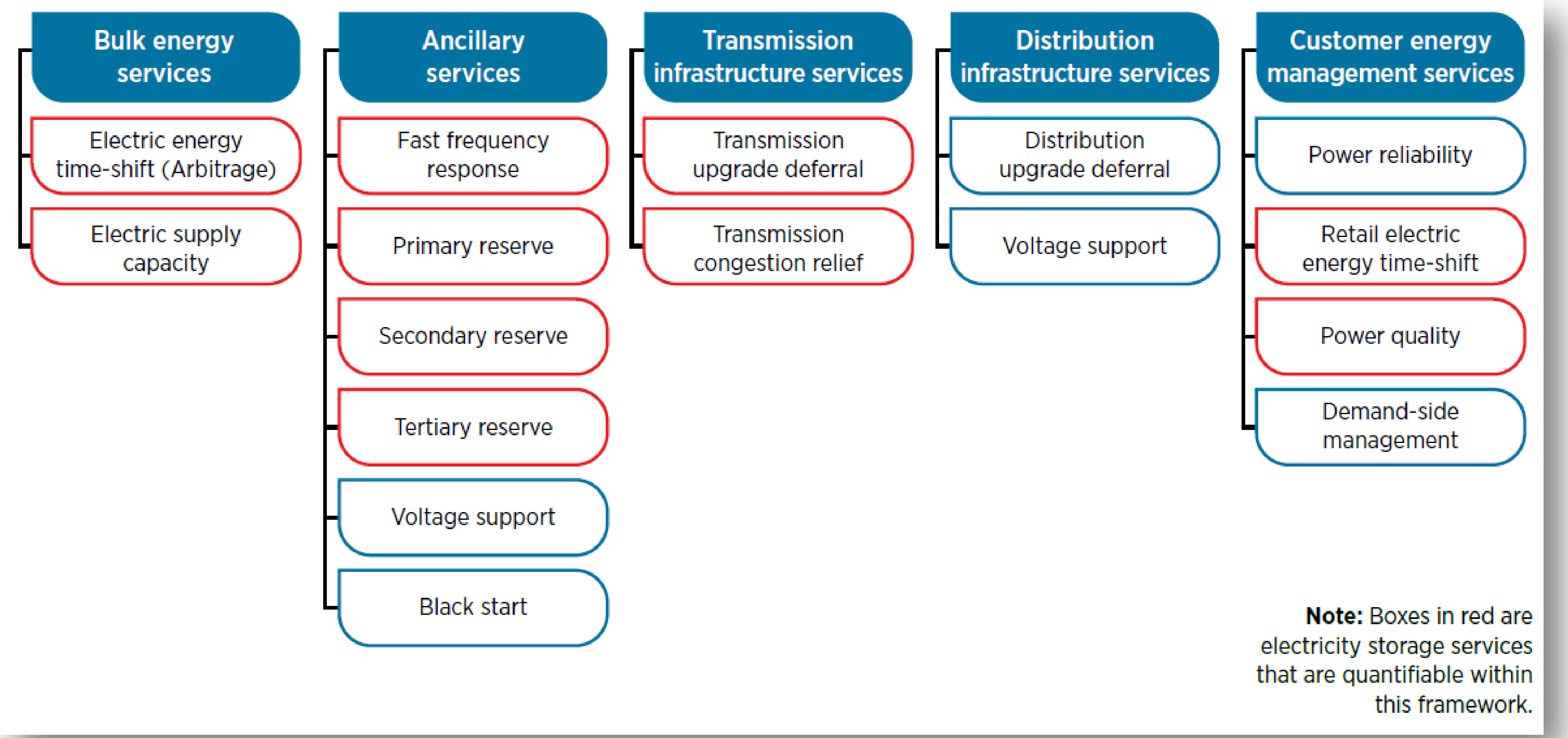
Download for free at www.irena.org/publications

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Phase 01 - Identify electricity storage services

- Electricity Storage (ES) is capable of providing a variety of services in parallel to the grid (i.e. load following and primary reserve)

- Understanding the landscape of value opportunities is the first step to develop assessment methodologies



Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Phase 02

- Storage Technology Mapping

1. Define a suitability matrix for different use cases

Parameters	VRLA	Pumped Hydro	CAES	Flywheels	NMC	NCA	LFP	LTO	NaS	NaNiCl2 (Zebra)	ZBB	VRB
Renewable Shifting	0.8	1.0	1.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Renewable Smoothing	0.8	0.3	0.3	1.0	1.0	1.0	1.0	1.0	0.3	0.3	0.3	0.3
Flex Ramping	0.8	1.0	1.0	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ancillary Services	0.5	0.3	0.3	1.0	1.0	1.0	1.0	1.0	0.3	0.3	0.3	0.3
T&D Deferral	1.0	1.0	1.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Reactive Power Management	1.0	0.3	0.3	1.0	1.0	1.0	1.0	1.0	0.3	0.3	0.3	0.3
BTM Power Management	1.0	0.0	0.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

2. Define weighted scores for each technology and service

Parameters	VRLA	Pumped Hydro	CAES	Flywheels	NMC	NCA	LFP	LTO	NaS	NaNiCl2 (Zebra)	ZBB	VRB
Renewable Shifting	2.81	3.97	3.68	0.71	3.80	3.79	3.56	3.23	3.39	3.35	2.76	3.29
Renewable Smoothing	2.96	0.95	0.87	3.26	4.00	3.81	3.82	3.62	0.82	0.80	0.69	0.81
Flex Ramping	2.81	3.97	3.68	1.41	3.80	3.79	3.56	3.23	3.39	3.35	2.76	3.29
Ancillary Services	1.98	0.95	0.87	3.26	4.00	3.81	3.82	3.62	0.82	0.80	0.69	0.81
T&D Deferral	3.88	3.32	3.31	0.75	4.04	4.01	3.86	3.47	3.55	3.46	2.94	3.33
Reactive Power Management	3.43	0.91	0.84	2.85	3.75	3.71	3.52	3.36	0.79	0.77	0.66	0.77
BTM Power Management	3.62	-	-	0.71	3.93	3.86	3.70	3.43	3.17	3.10	2.57	2.95

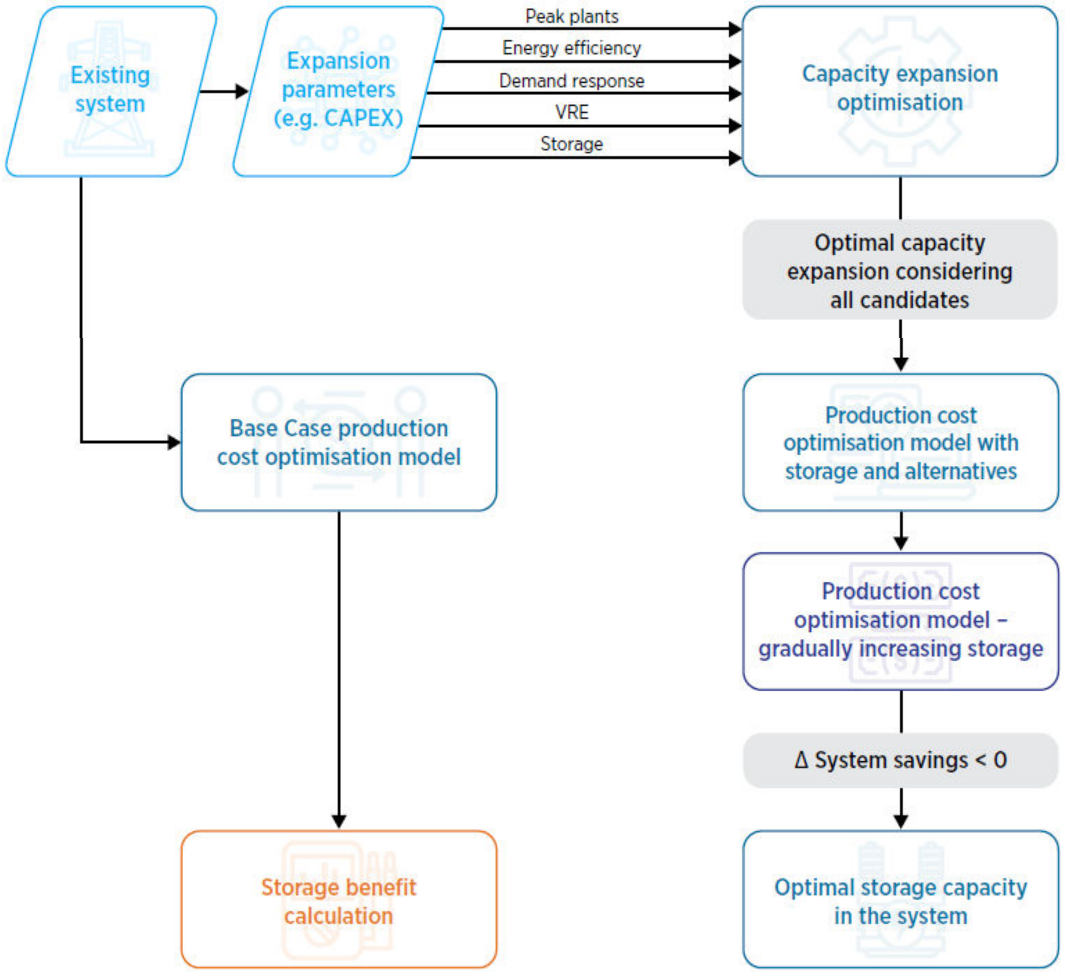
3. Calculate application ranking (1: Best, 10: Worst)

Parameters	VRLA	Pumped Hydro	CAES	Flywheels	NMC	NCA	LFP	LTO	NaS	NaNiCl2 (Zebra)	ZBB	VRB
Renewable Shifting	10	1	4	12	2	3	5	9	6	7	11	8
Renewable Smoothing	6	7	8	5	1	3	2	4	9	11	12	10
Flex Ramping	10	1	4	12	2	3	5	9	6	7	11	8
Ancillary Services	6	7	8	5	1	3	2	4	9	11	12	10
T&D Deferral	3	9	10	12	1	2	4	6	5	7	11	8
Reactive Power Management	4	7	8	6	1	2	3	5	9	10	12	11
BTM Power Management	4	11	11	10	1	2	3	5	6	7	9	8

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Phase 03

- System Value Analysis



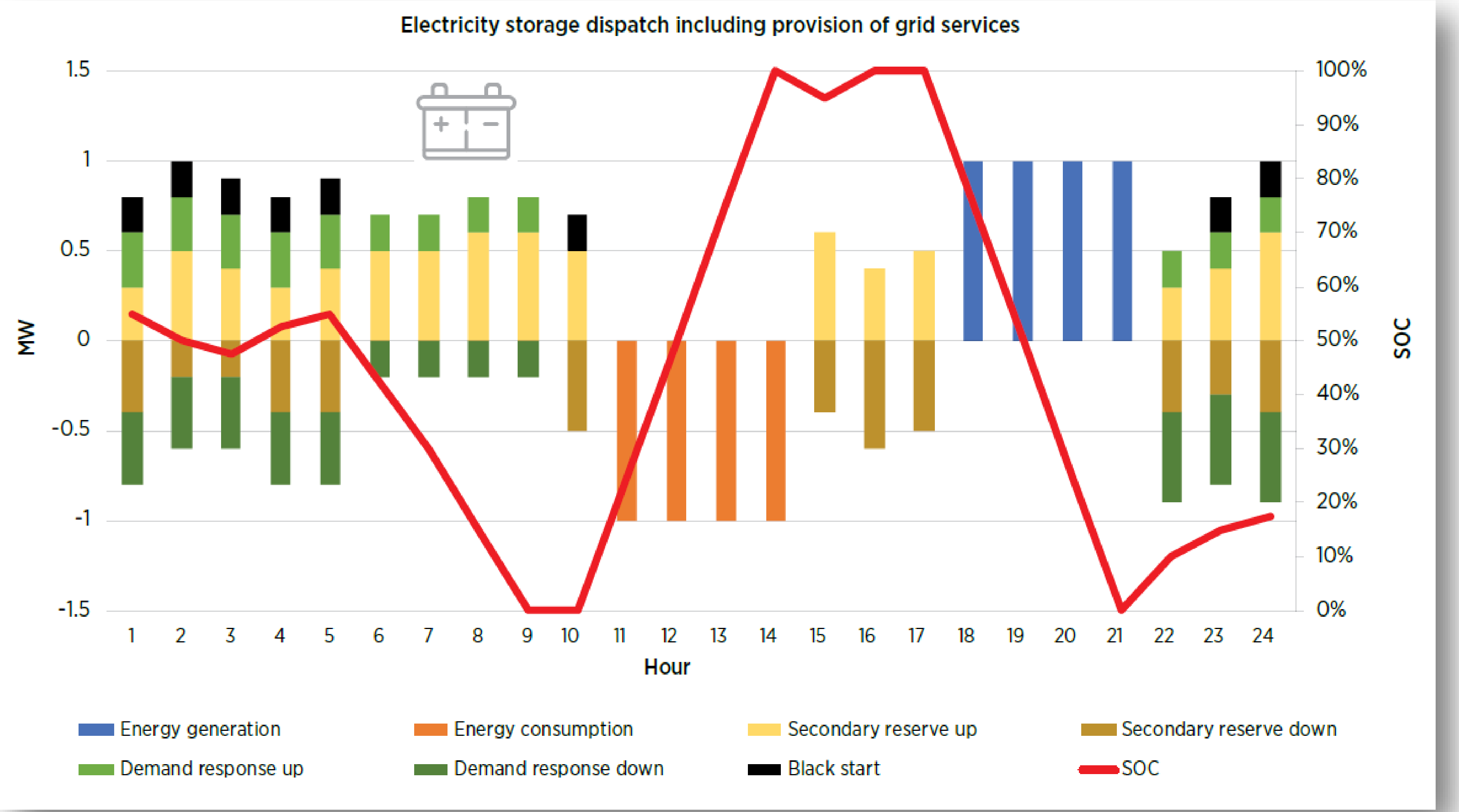
They key is to use a capacity expansion model for a first estimation but use an incremental production cost model to optimize electricity storage capacity

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Phase 04

- Simulated Storage Operation

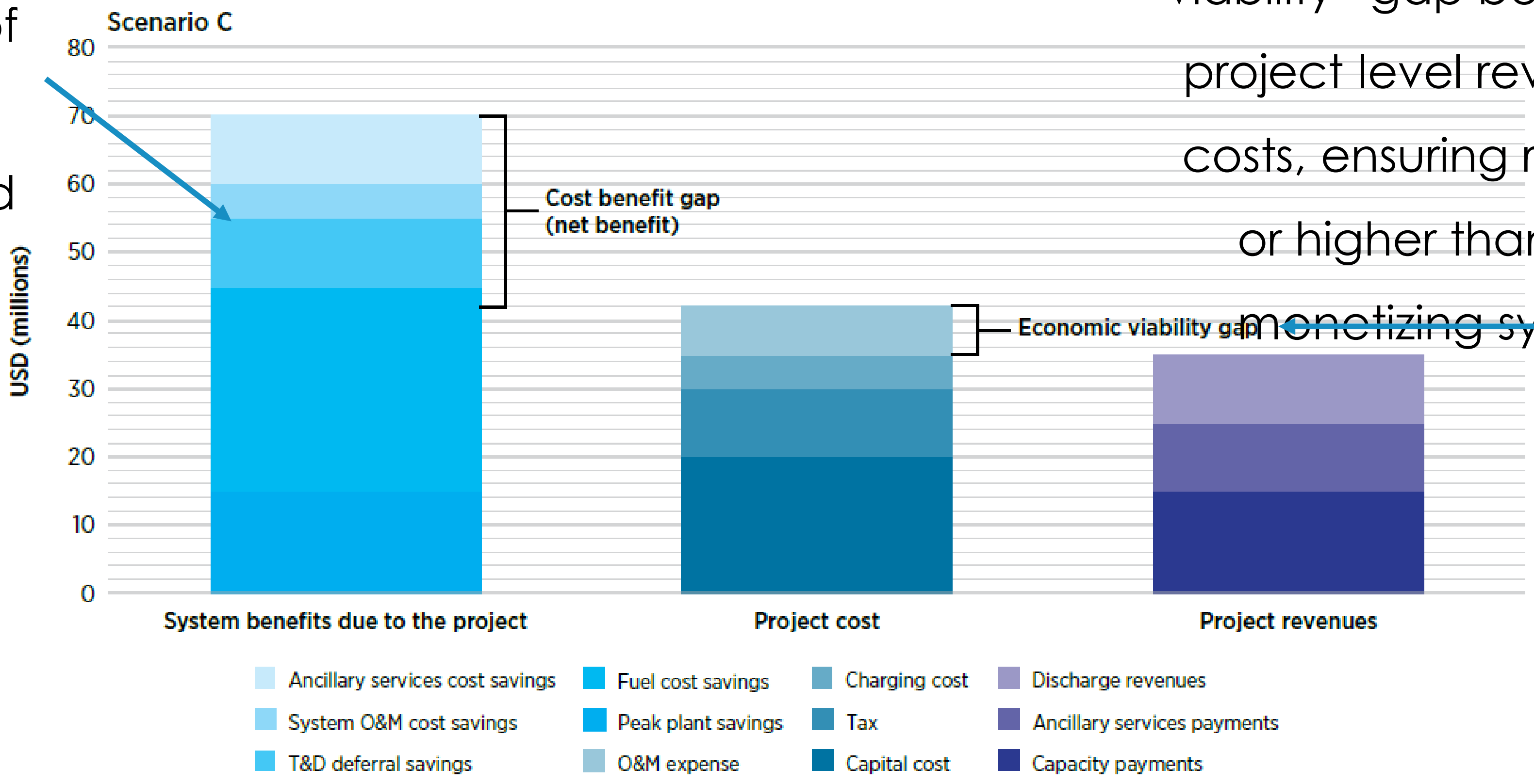
- Project level feasibility is assessed with a price taker dispatch optimization model



Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Phase 05 - Storage Project Viability Analysis

Reasoning: Some system benefits of ES cannot be monetized based on existing regulations



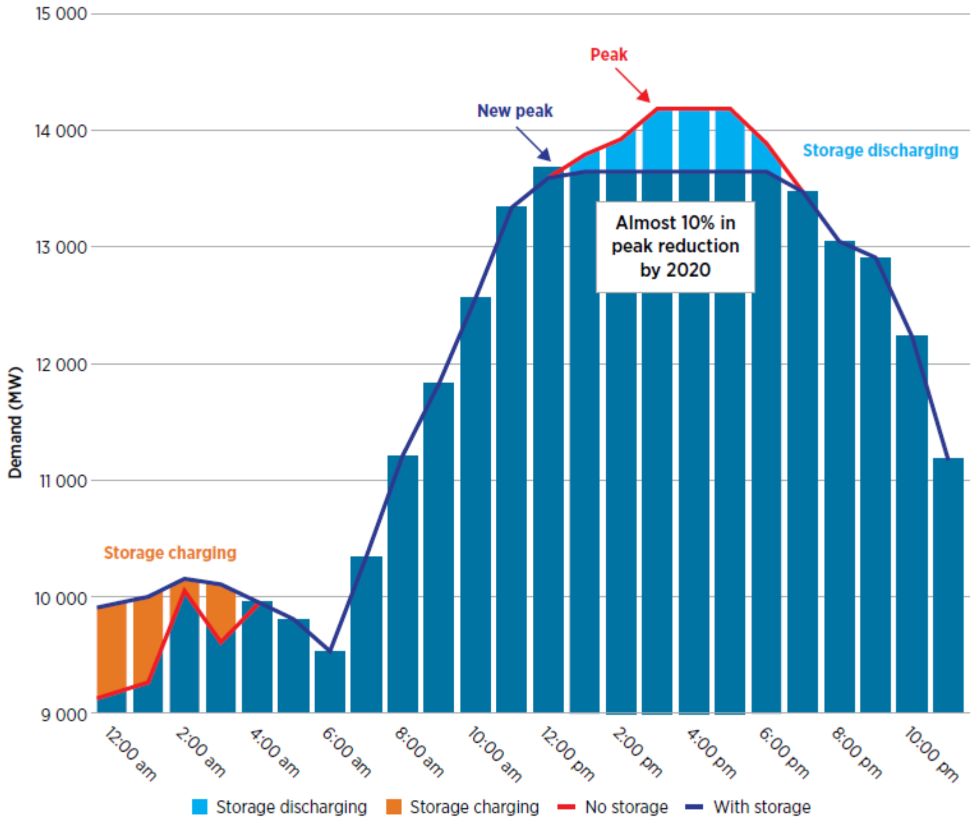
Goal: identify the "economic viability" gap between monetizable project level revenues and project costs, ensuring revenues are equal or higher than project cost by monetizing system level value

A project will only be expected to materialize if monetizable revenues are more than project costs

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Case studies

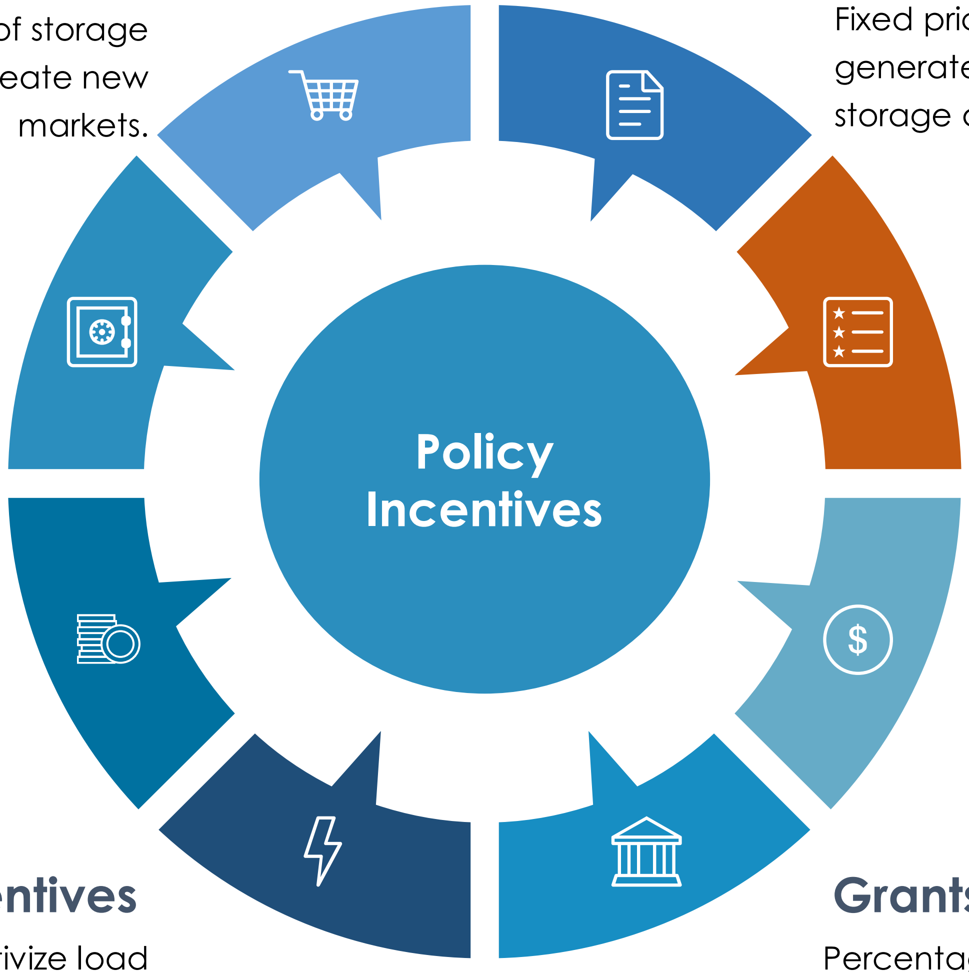
- The eight use cases selected are the following:
    1. Operating reserves
    2. Flexible ramping
    3. Energy Arbitrage
    4. VRE Smoothing
    5. Transmission and Distribution Deferral
    6. Reduced peaking plant capital savings
    7. Enabling high shares of VRE in an off-grid context
    8. Behind-the-meter electricity storage



2020 demand curve in Massachusetts with and without electricity storage
Source: (Customized Energy Solutions et al., 2016)

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Policies and regulations to support cost-effective storage deployment



Market mechanisms

Facilitate the participation of storage in existing markets and create new markets.

Feed-In-Tariffs (FITs)

Fixed price per kWh for electricity generated from a combine VRE and storage asset.

Accelerated Depreciation

Depreciation of the storage asset at an accelerated rate to receive tax benefits.

Feed-In-Premiums (FIPs)

The storage and VRE asset sells energy in the sport market and obtain a premium above the market price.

Investment Tax Credits (ITCs)

Percentage of CAPEX reduction only if the storage asset is charged from VRE above certain threshold.

Capacity Payments

Periodic payments to the project owner for its contribution to system adequacy.

Peak Reduction Incentives

Programmes that incentivize load reduction in peak periods.

Grants

Percentage of reduction of the capital cost of the storage asset.

Source: : IRENA (2020), Electricity Storage Valuation Framework: Assessing system value and ensuring project viability

Takeaways

- ES supports VRE integration and can provide considerable benefits to the power system
- Cost-benefit analysis of ES need to consider the following:
    - Technical suitability
    - Techno-economic comparison
    - Estimation of both monetizable and non-monetizable benefits
- Need for a perspective from the power system and the project investor
- Need to close the “missing money” gap
- Bridging the “missing money” requires regulatory restructuring and policy support

International Renewable Energy Agency

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Emanuele Taibi

Power Sector Transformation Strategies

&

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California ISO

Wholesale Market Design to Accommodate Storage

Greg Cook
Executive Director, Market and Infrastructure Policy
California ISO

APEx Webinar
February 18, 2021

California ISO facts

As a federally regulated nonprofit organization, the ISO manages the high-voltage electric grid California and a portion of Nevada.

50,270 MW record peak demand (July 24, 2006)

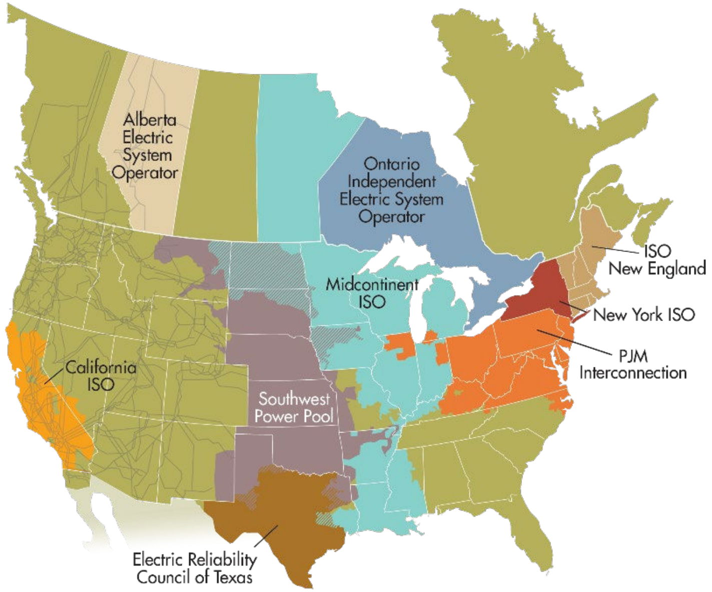
233 million megawatt-hours of electricity delivered (2018)

75,747 MW power plant capacity
Source: California Energy Commission

1,119 power plants
Source: California Energy Commission

32 million people served

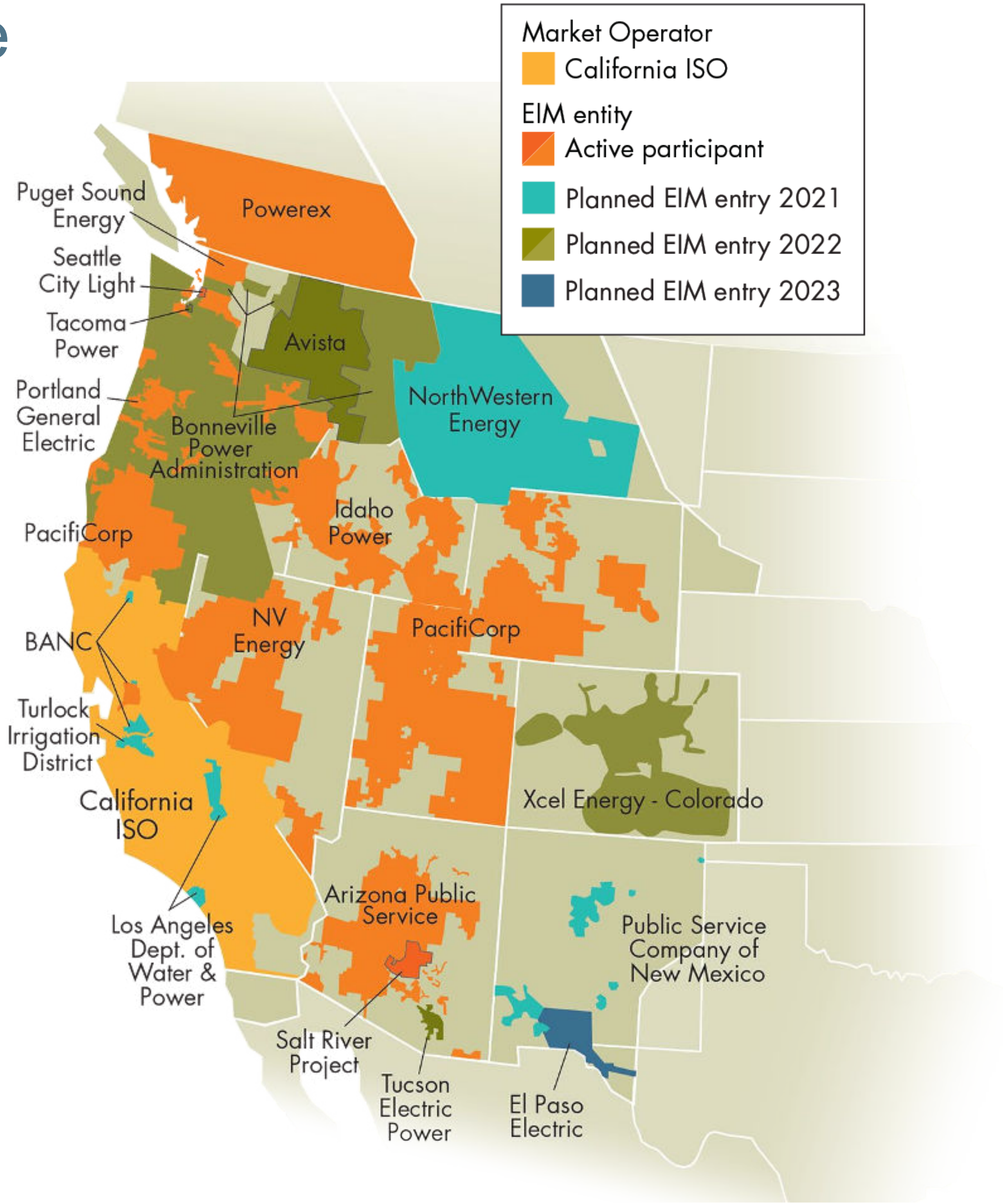
One of **9** ISO/RTOs in North America



Western Energy Imbalance Market (EIM)

Since its launch in 2014, the Western EIM has enhanced grid reliability, generated millions of dollars in benefits for participants, and improved the integration of renewable energy resources.

- Gross benefits exceeding $1 billion
- Reduced over half a million metric tons of CO_2



California ISO is expecting rapid development of storage resources

- Storage development driven by several factors:
  - Procurement mandate
  - Environmental legislation/retirement of thermal generation fleet
  - Tight supply conditions
- Currently 550 MW of battery storage on system
- 1,750 MW expected by this summer
- 3,300 MW expected within 2 years

Many new storage resources interconnecting to the system as hybrid resources

- Resources with different technologies located behind the same point of interconnection
  - Typically battery storage added to existing solar sites
  - Combined resource output often in excess of interconnection limit
  - U.S. Government provides significant investment tax credits for storage resources charged by onsite renewable resource

- Requires new policy development to reliably and efficiently integrate hybrid resources

California ISO developed two models for hybrid resource operators

- **Co-located resource model** – Individual resource ID for each generator behind a single point of interconnection
  - Each component modeled similar to other resources on the grid today
  - Market used to optimize the dispatch of each resource to align with grid operational needs
    - Manage dispatch of co-located resources to be within interconnection limit
    - Resources priced at the point of interconnection
- **Hybrid resource model** – A single resource ID aggregating multiple generators at a single point of interconnection
  - ISO has visibility to a single resource which enables flexibility for hybrid resource management
  - Manage investment tax credits

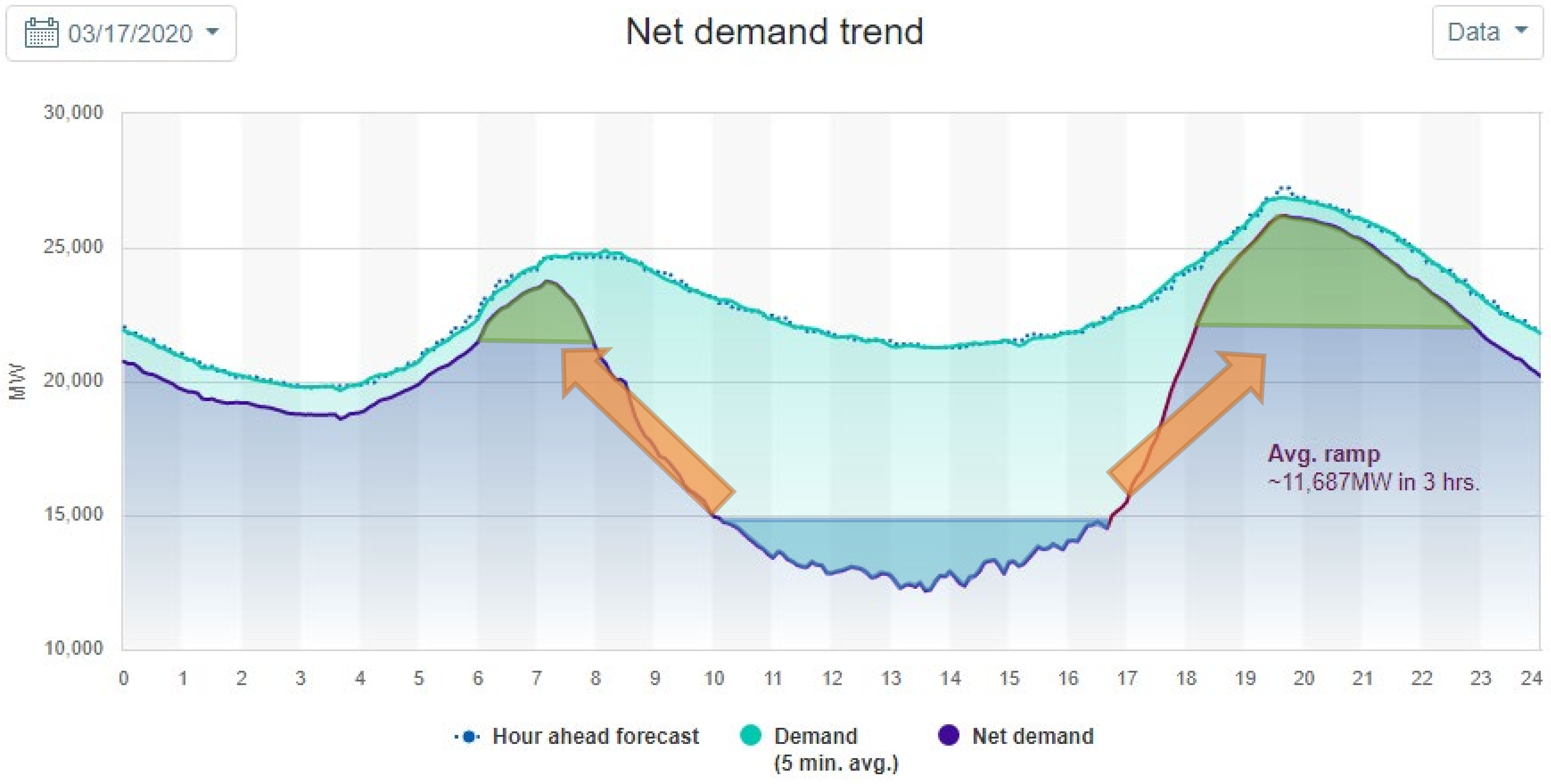
Resource adequacy requirements for storage resources

- Capacity value determined by 4-hour output capability

- Developing new provisions for to ensure both capacity and energy needs are met by resource adequacy fleet

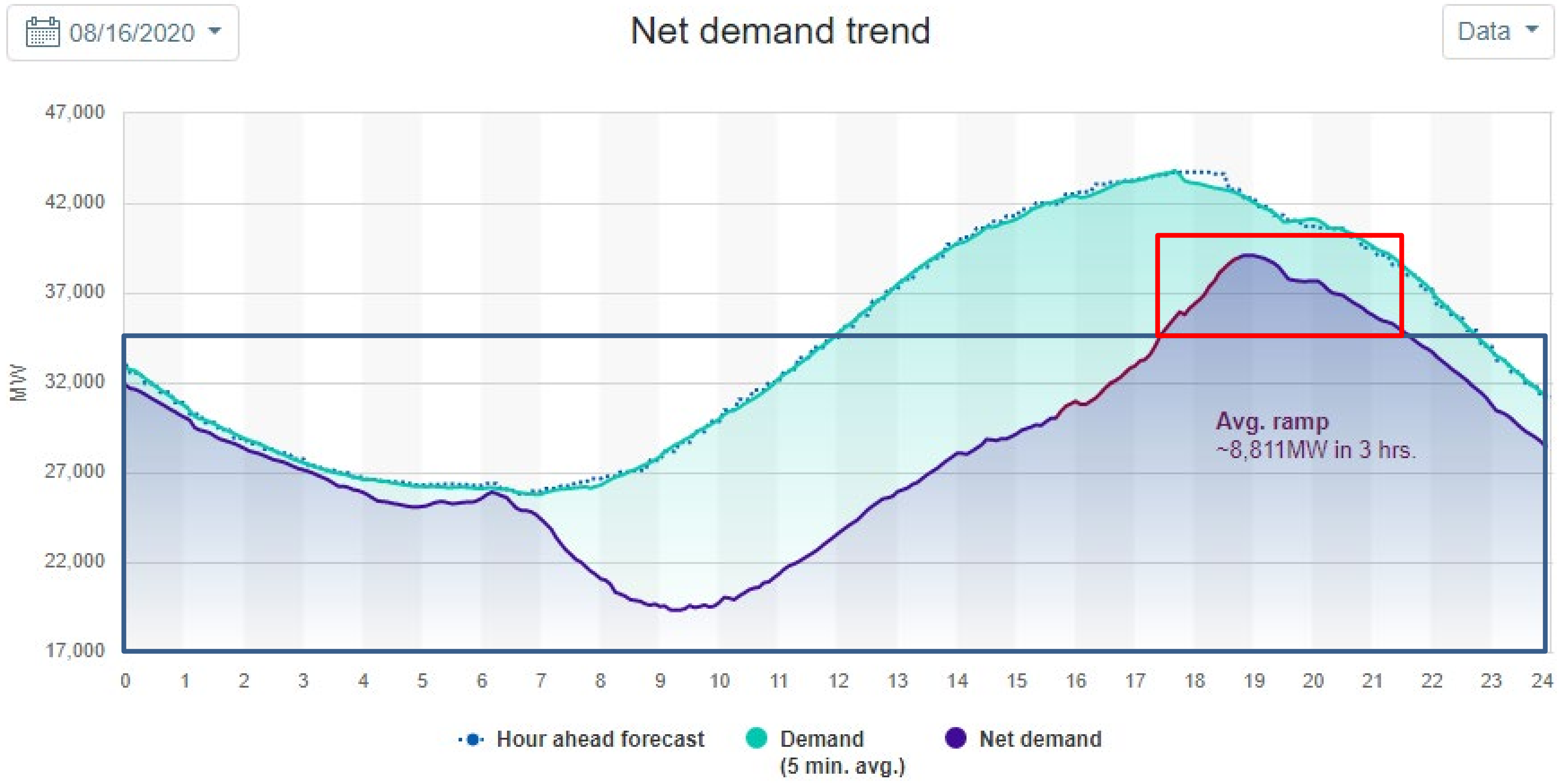
- Requires temporary real-time state of charge requirements to maintain grid reliability until further market enhancements can be implemented

Planning for storage resources assumes ‘arbitrage’ of day-ahead energy prices for batteries



California ISO

In the future storage will be critical for meeting load on days with the highest ***net load*** peak



Real-time market enhancements will help to efficiently and reliably integrate storage resources

- End-of-hour state of charge parameter provides real-time management of future use commitments of storage resources
  - enables storage resources to submit a minimum and maximum MWh range
  - Implemented by this summer
- Market power mitigation designed to ensure that storage resources are dispatched efficiently when market power mitigation is applied
  - Default energy bid: energy procurement costs, marginal costs to charge and discharge, and an opportunity cost component
- Future enhancements include development of new state of charge product

Insights from Europe

Christoph Grafe
Director Market Integration, UK & Ireland

APEx Annual Virtual Conference

18th February 2021

NORD POOL

At a glance

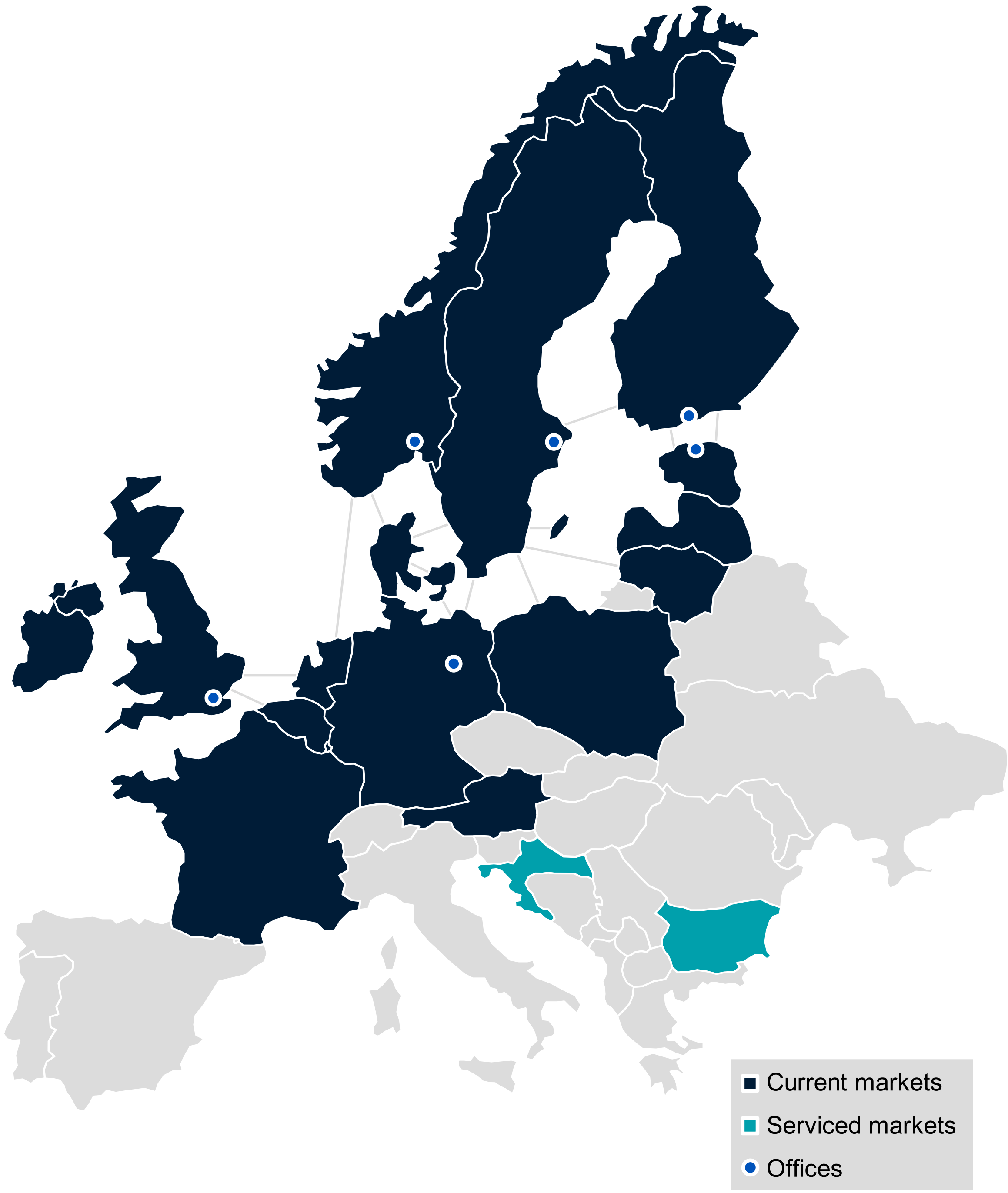
- Nord Pool offers day-ahead and intraday trading, clearing and settlement services
- More than 360 customers from 20 countries trade on Nord Pool's markets
- Operates in 15 European countries
- Service markets
- ~140 employees, 25 nationalities, offices in Oslo, Stockholm, Helsinki, Tallinn, London and Berlin

969 TWh
day-ahead

26 TWh
intraday

360
customers

NORD
POOL



Headlines from Europe

Future role and challenges of energy storage

European Commission

Study on energy storage – Contribution to the security of the electricity supply in Europe

- The main energy storage reservoir in the EU is currently by far pumped hydro storage. As their prices plummet, new batteries projects are rising
- Lithium-ion batteries represent most of electrochemical storage projects. The recycling of such systems should be strongly taken into consideration, as well as their effective lifetime
- The segment of operational electrochemical facilities is led by the UK and Germany
- Behind-the-meter storage is still growing, but highly dependant on local markets and countries: as a new market, it is still driven by political aspects and/or subsidies

Short- and medium-term actions for EU energy policy

- Strategic: Developing vision for role of storage in integrating RES; investment support where technologies support climate targets
- Consumers: Supporting development of consumer-based services linked with local RES gen, smart meters and smart grids
- Markets: Developing a level playing field – removing barriers related to accessing neighbouring markets and X border trading;
- Regulatory: Adjustments to enable storage to facilitate the progress towards a single internal electricity market in Europe;
- Technology: Mapping storage potential, storage technology development and demonstration including the interoperability of different smart energy networks and deployment

NORD POOL

Providing better foundations for storage to deliver value

Recent developments in Great Britain

ofgem
Making a positive difference
for energy consumers

GB regulator clarifies regulatory regime for storage (Dec 20)

- Include definition of ‘electricity storage’ and ‘electricity storage facility’ in the electricity generation licence
- Introduce new storage-only applicable licence condition which requires to provide accurate information on storage facility to their relevant suppliers

Department for Business, Energy & Industrial Strategy

UK Ministry for Energy enshrines role of storage in policy statement (Dec 20)

- Seek to define ‘storage’ in primary legislation
- Support programme to assist further commercialisation of storage technologies for long-term, large-scale energy storage
- Link data policies with decarbonization ambition of heat and transport

nationalgridESO

GB system operator allows for revenue stacking in balancing mechanism (Jan 21)

- Soft launch to unlock stacking within balancing mechanism (dynamic containment – frequency response)
- Aims to deliver increased efficiency of battery assets by allowing for additional flexibility and revenue stacking

NORD POOL

Developing the business case for storage solutions

- Allowing access to full markets spectrum for storage asset providers
- Encouraging nascent storage markets through targeted regulatory interventions
- Extending trading opportunities on integrated exchange platforms (and integrated markets)

Christoph Grafe

Thank you

nordpoolgroup.com

Market Design and Dynamics for Storage in the National Electricity Market

APEx 18 February 2021

Farhad Billimoria

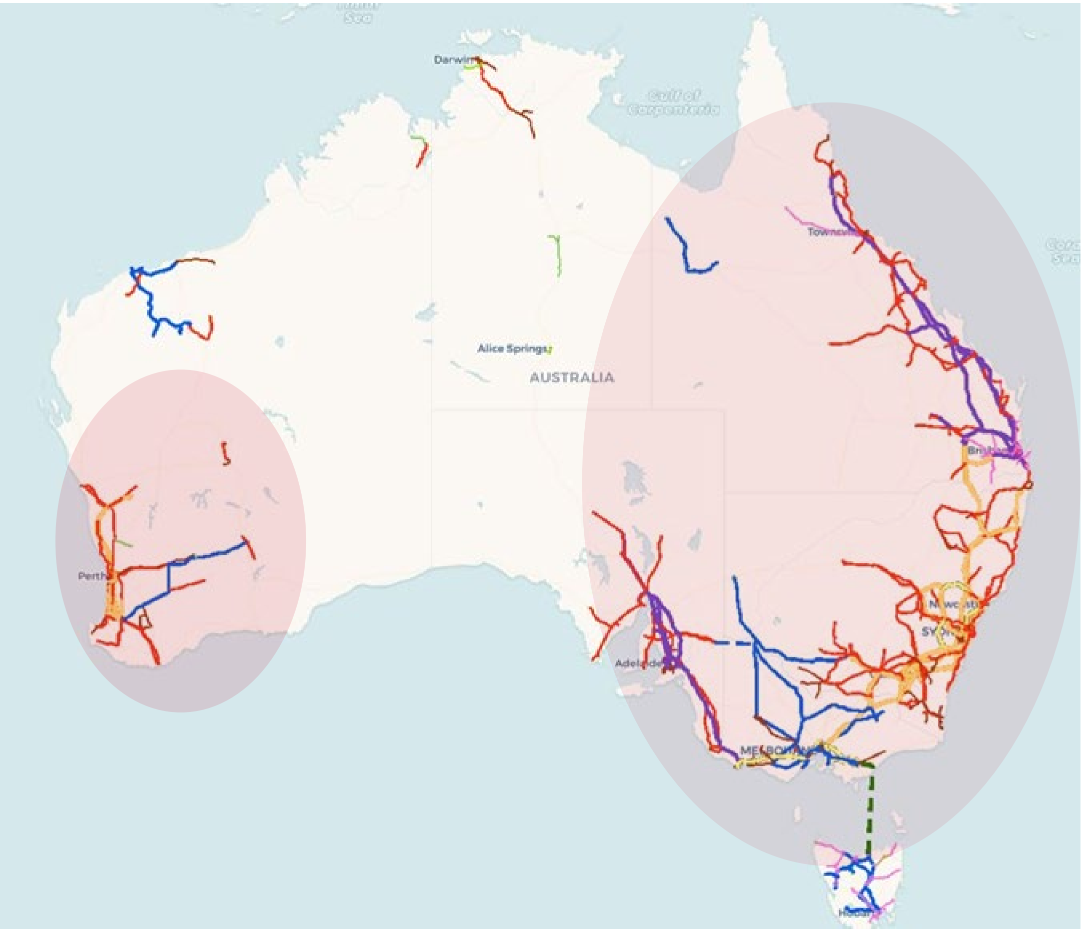
Energy storage in the National Electricity Market

Agenda

1. A market in transition
2. Role of storage in the NEM
3. Future market design
4. Conclusions

Western Electricity Market
Two settlement gross pool
Reserve Capacity Mechanism

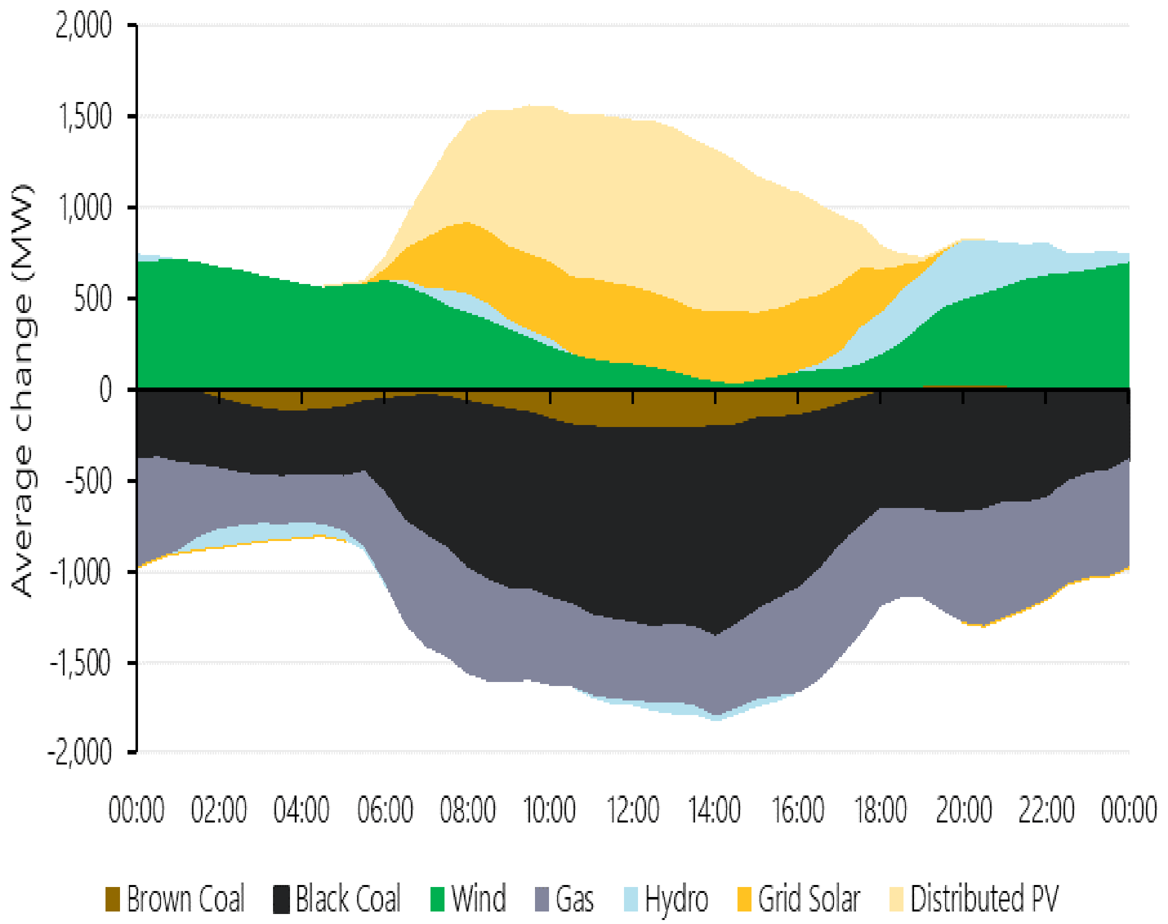
National Electricity Market
Energy only gross pool
Energy + 8 FCAS



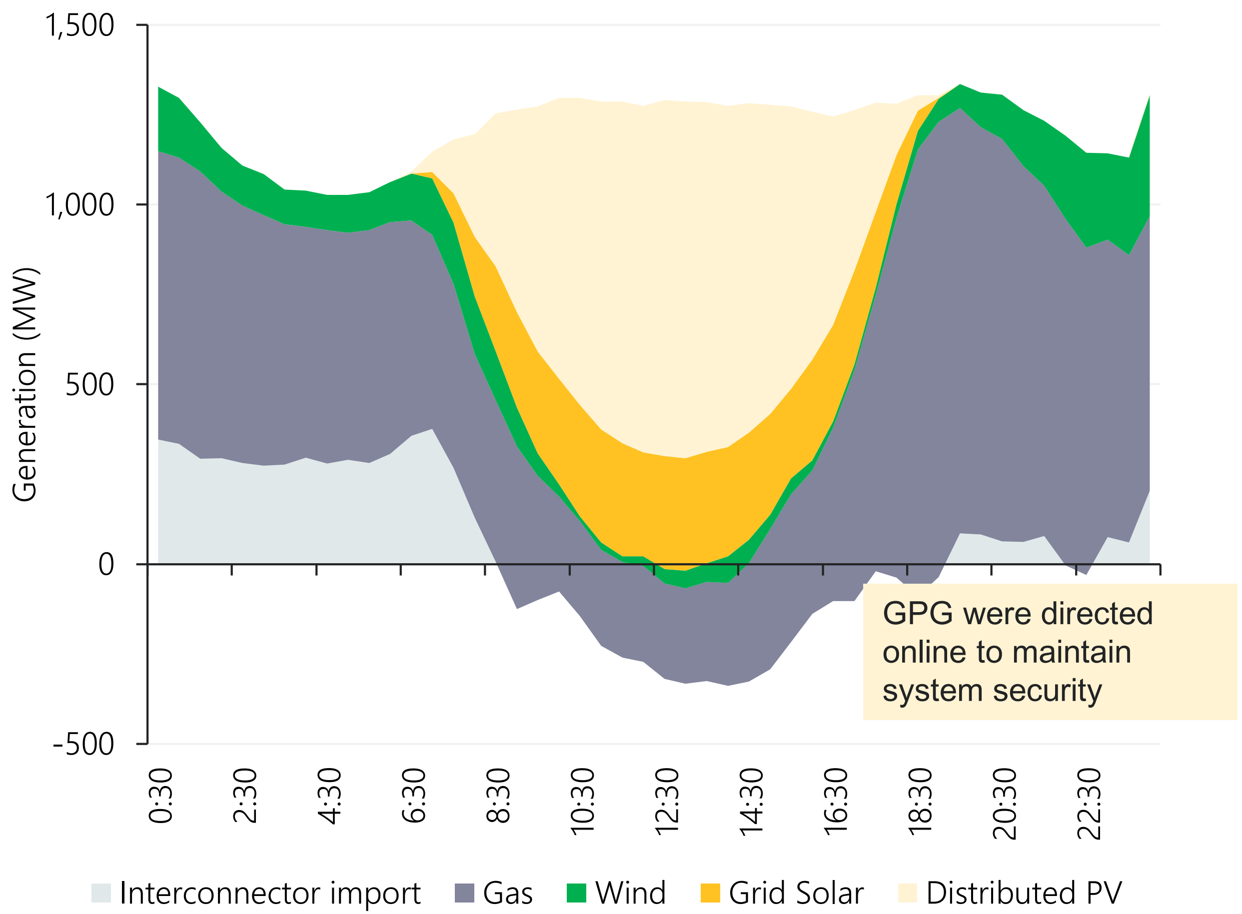
Transformational shifts in demand and supply …

Transition away from fossil to renewables…

Change in supply – Q4 2020 versus Q4 2019 by time of day

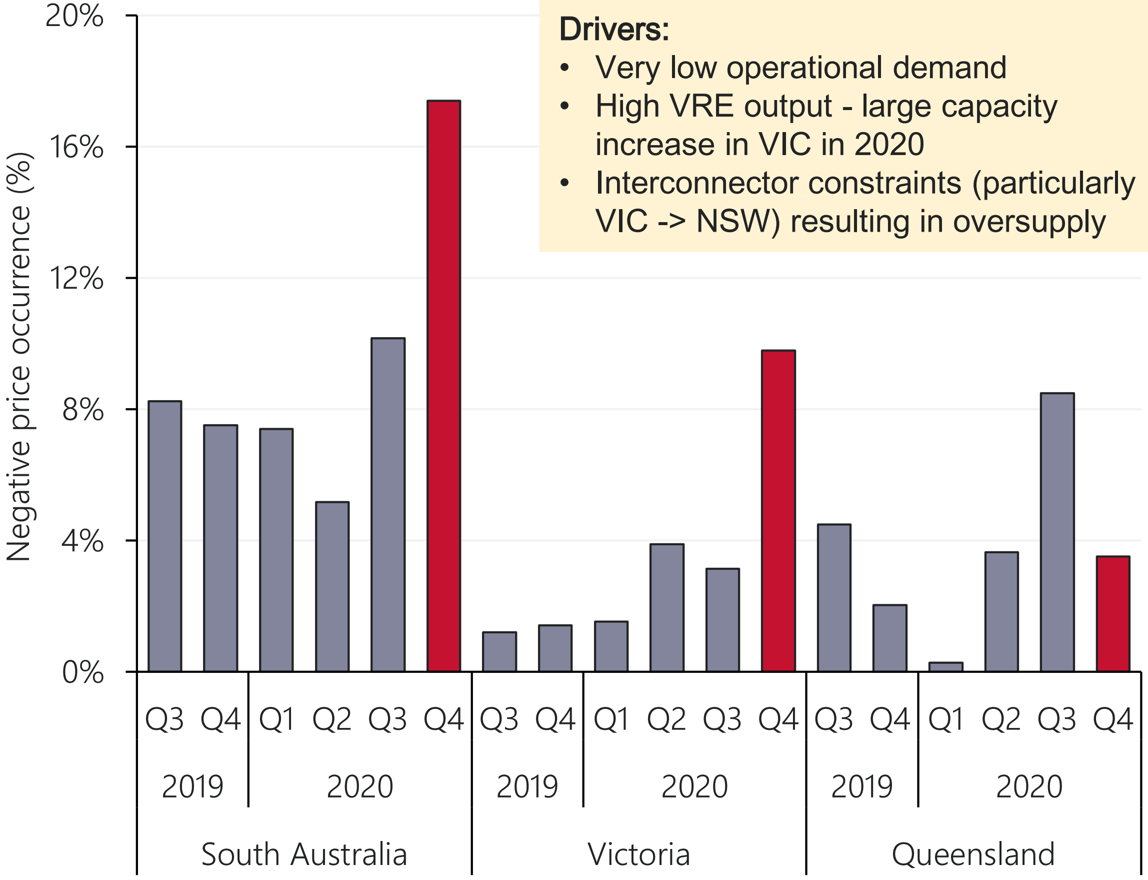


SA solar meets 100% of demand for the first time



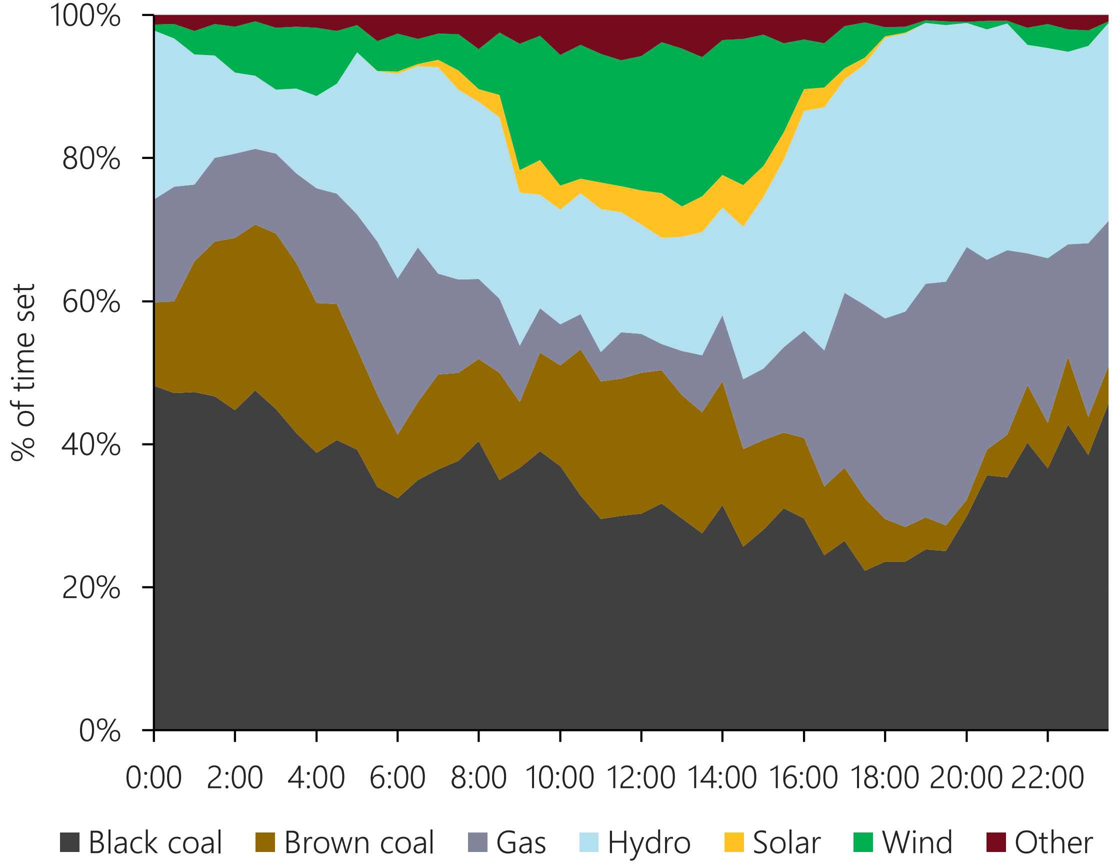
..driving dynamic pricing outcomes.

SA prices negative 17% of the time in Q420..



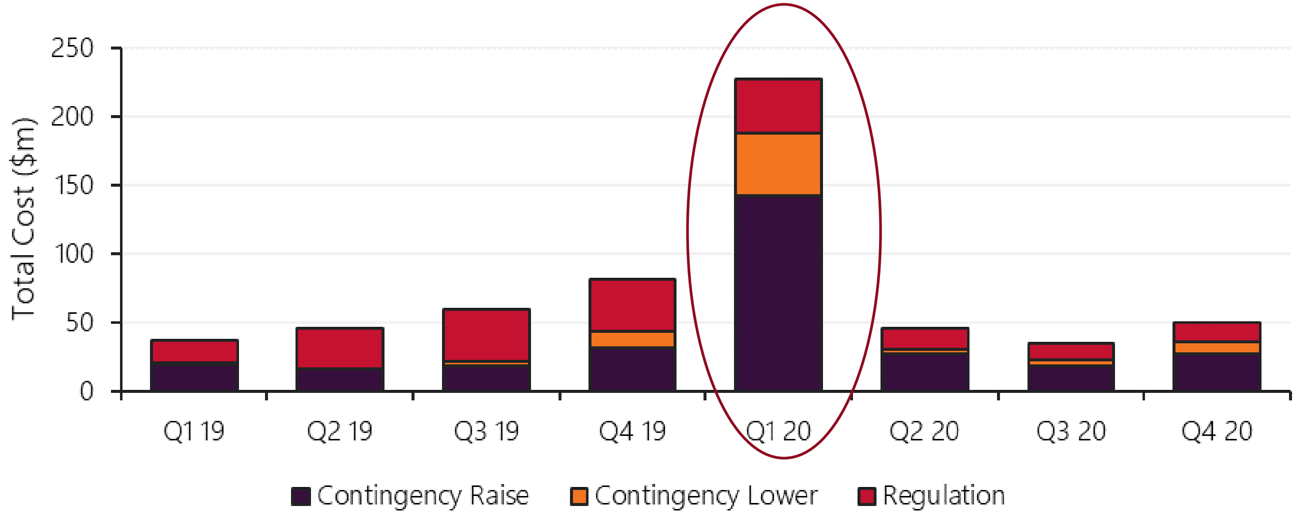
Drivers:
- Very low operational demand
- High VRE output - large capacity increase in VIC in 2020
- Interconnector constraints (particularly VIC -> NSW) resulting in oversupply

..wind farms setting spot prices 8% of the time in SA



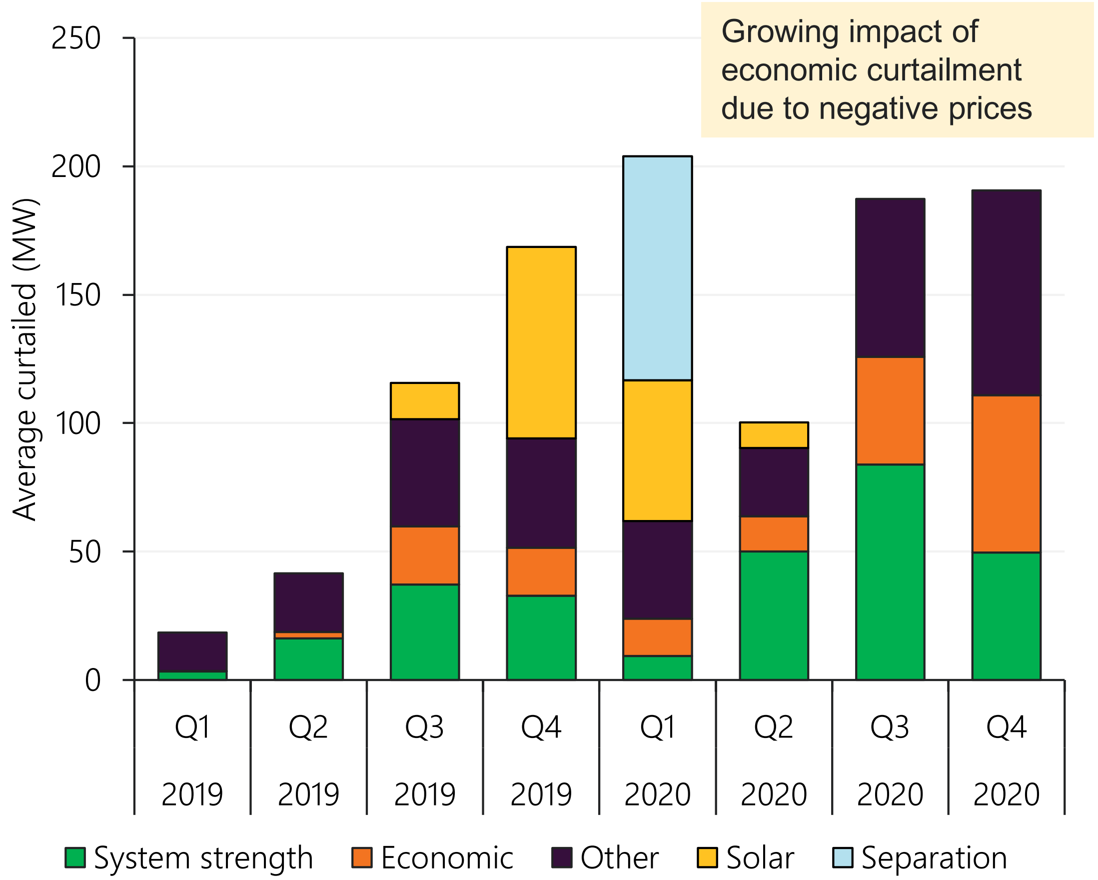
Record ancillary services and curtailment

Record high ancillary service costs…



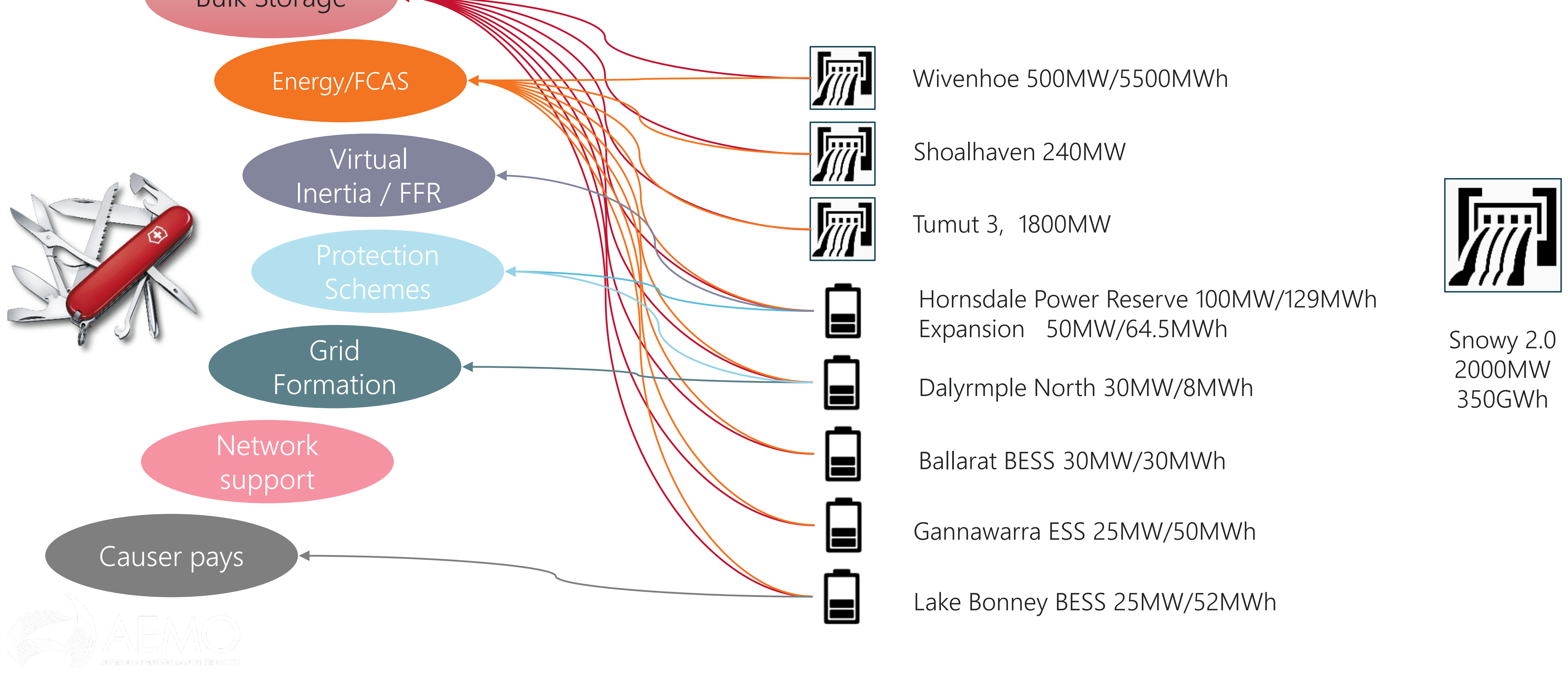
…driven by regional separation events.

VRE output limited by record high curtailment



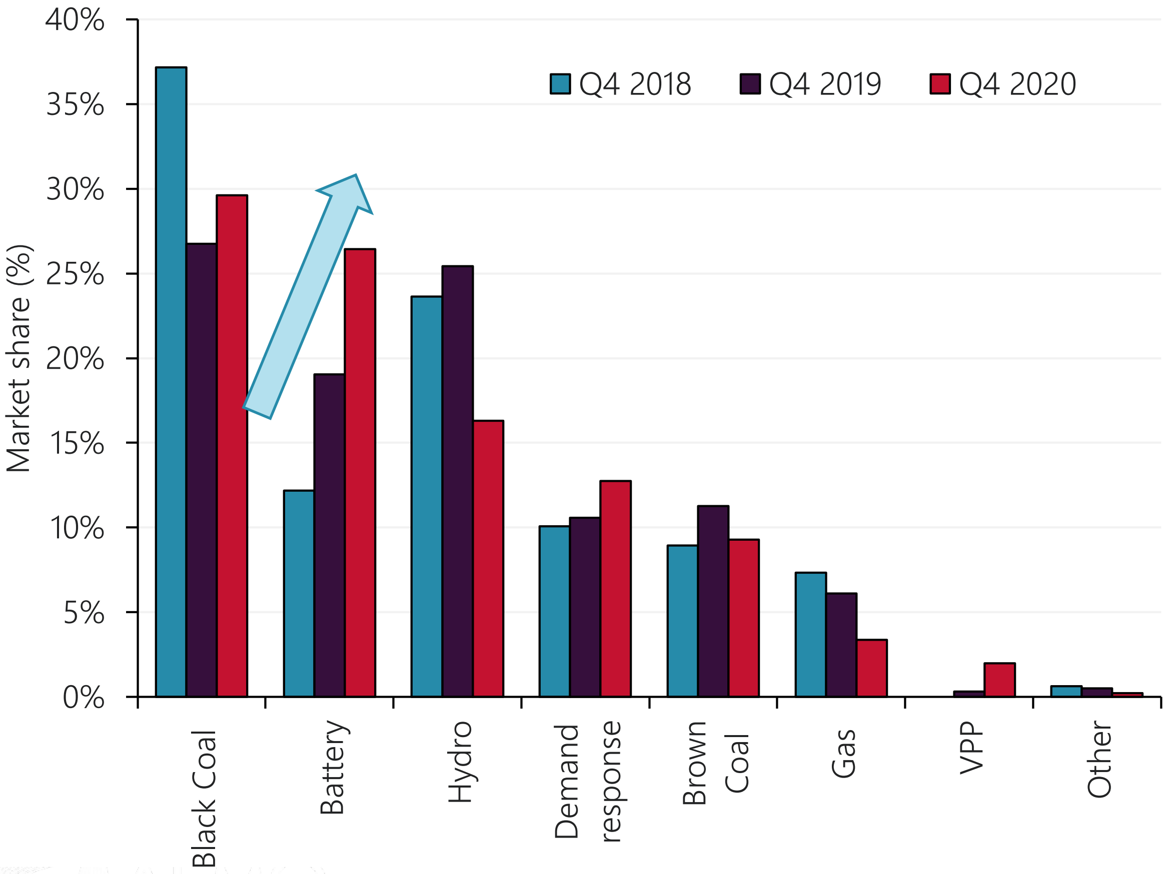
Grid scale storage in the NEM

Realisation of value stacking opportunity beyond spot.

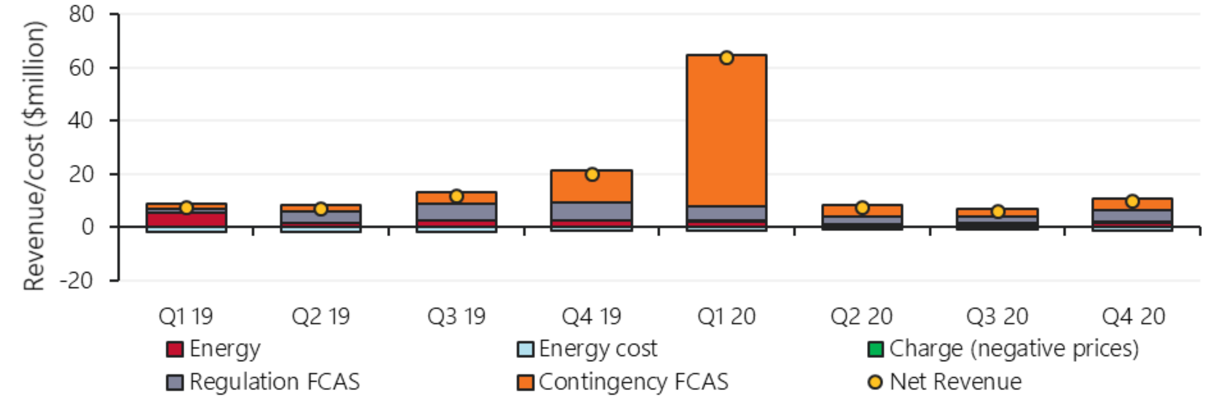


Battery displaces traditional FCAS providers

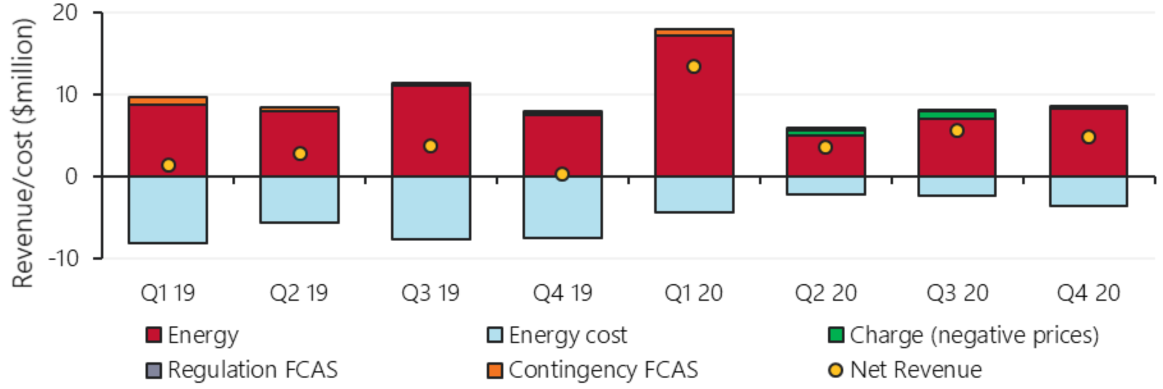
Battery FCAS market share more than doubled to 26% in Q4 2020



Battery net revenue in spot markets



Pumped hydro net revenue in spot markets



[1]*Mass implementation of mandatory Primary Frequency Response (PFR) began from 30 September 2020*

Future market design

Design imperatives

- New markets – system services
- Realisation of storage value
- Removal of barriers
- Level playing field
- Flexibility

AEMC Rule Determinations

Agreed

- Five minute settlement

In consideration

- Registration and participation
- Two-sided trader / services model
- Storage scheduling and dispatch
- Hybrid, DC-coupled systems

ENERGY SECURITY BOARD

POST 2025

ELECTRICITY MARKET DESIGN

Delivering a stronger, lower emissions power system for Australians

ESB 2025 Market Design Initiative

Consolidated Reform Priorities

Essential system services and ahead mechanisms

Operating and ramping reserves
Fast frequency response
System strength

Resource adequacy

Orderly thermal exit
Retailer Reliability Obligation
Jurisdiction underwriting and investment

Demand side participation

Minimum demand
Two sided markets
Distributed services

Access mechanisms

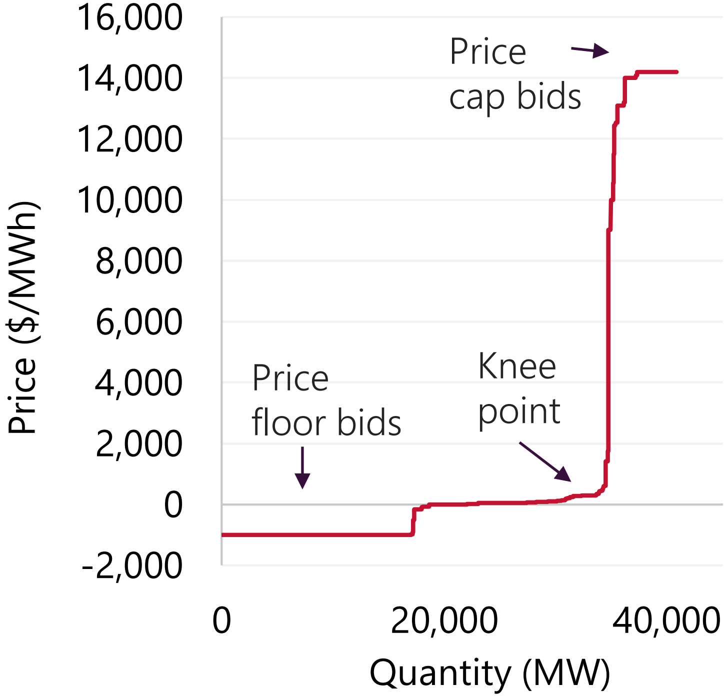
Actioning the Integrated System Plan (ISP)
Enduring locational price signals and FTRs
Enhancing congestion information

Appendices

The rationale for BESS in the NEM

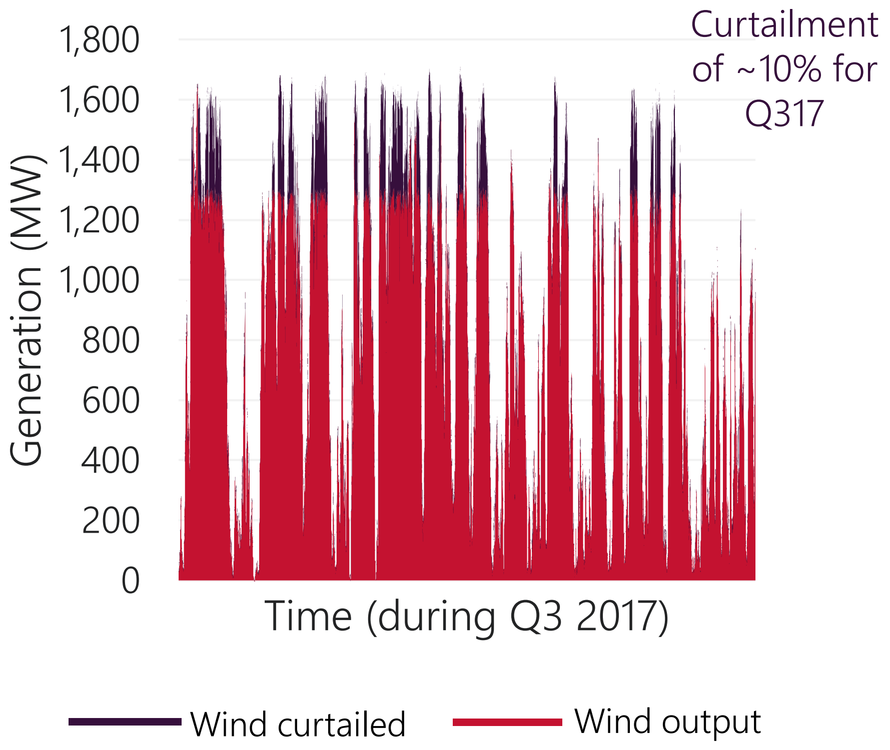
High price cap and low price floor

Sample NEM bid stack for Energy



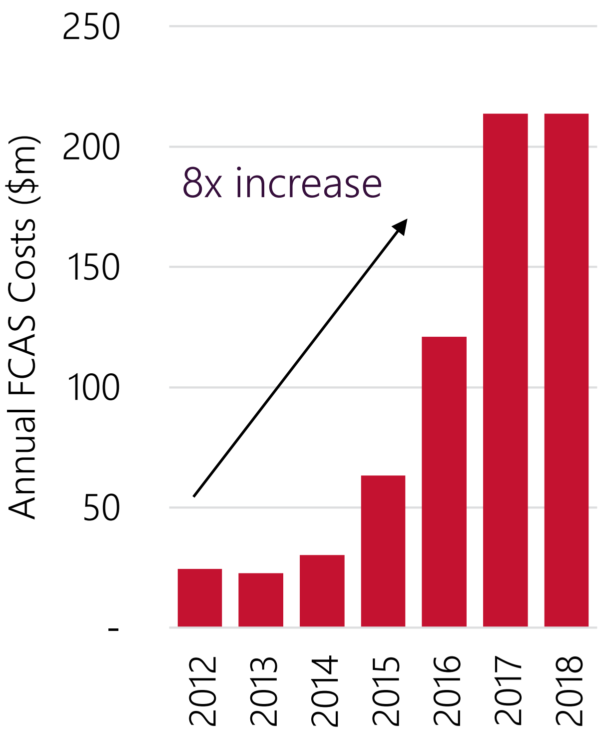
Prevalence of renewable curtailment

SA wind generation and curtailments (Q3-2017)



Growing costs of ancillary services

Annual Costs of Frequency Control Ancillary Services

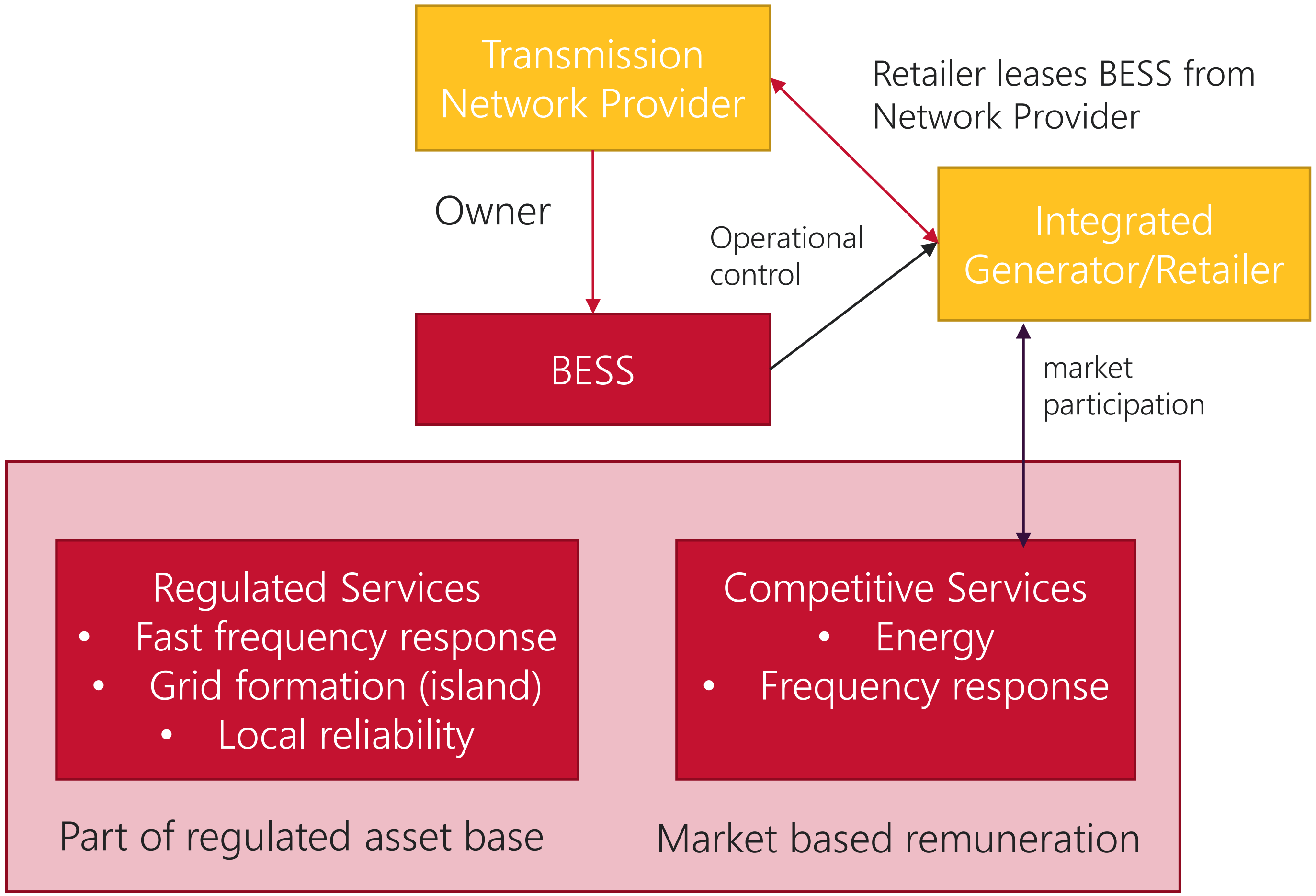


Source: AEMO

Implementing the 'value stack'

Value stack	Services
Energy	Merchant arbitrage Contracts
Ancillary Services	Frequency response (FCAS) Fast frequency response Voltage control System restart
System	Control schemes Grid formation
Network	Local reliability Network voltage control Avoided/deferred investment
Other	Causer-pays mitigation
Consumer	Retail charge avoidance Virtual power plant

Case study: Dalrymple Battery Project

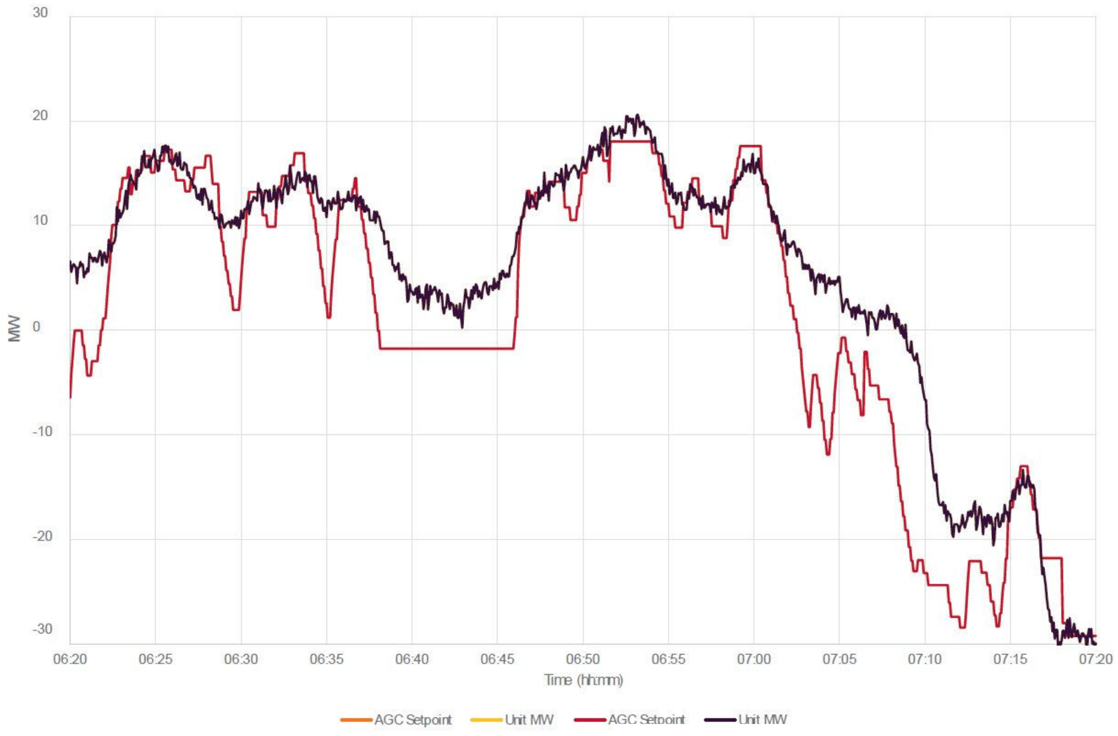


Source: Electranet

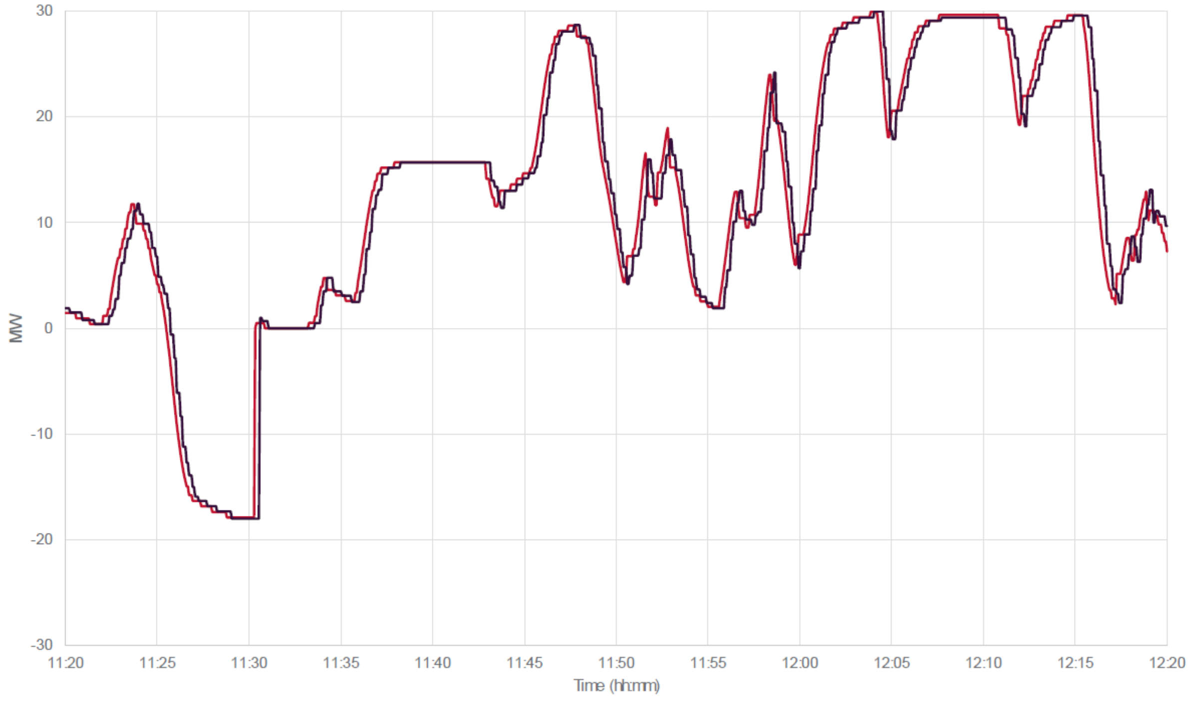
Quality of regulation delivery

Accuracy and speed of regulation FCAS response

Large conventional steam turbine



Hornsdale Power Reserve battery



AGC setpoint Unit MW

Interaction with Panel

- Please use the "Chat" feature
- The Moderator will monitor for questions/comments