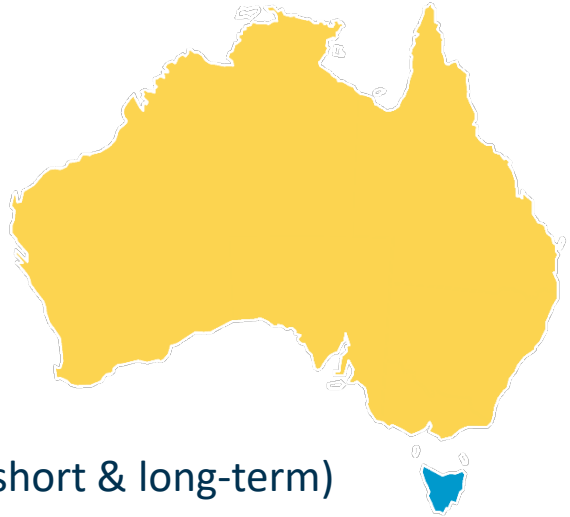
Improving hydro scheduling in a high non-synchronous penetration power system

an Australian experience

Tasmania

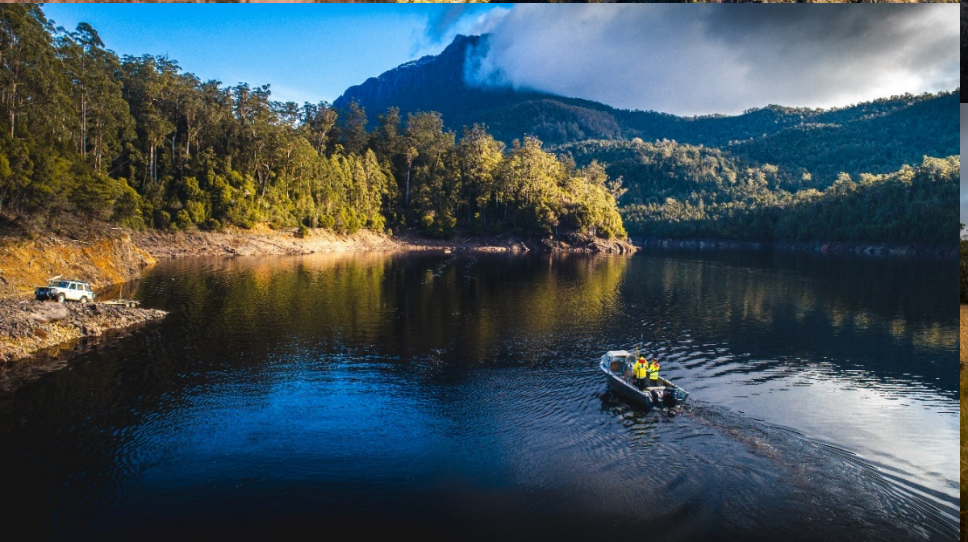
- Island state of Australia
- Connected to mainland via ~500 MW DC link
- 1200 MW average electricity demand
- Generation 82% hydro, 15% wind, 2% rooftop solar, 1% gas*
- Hydroelectric generation owned & operated by Hydro Tasmania



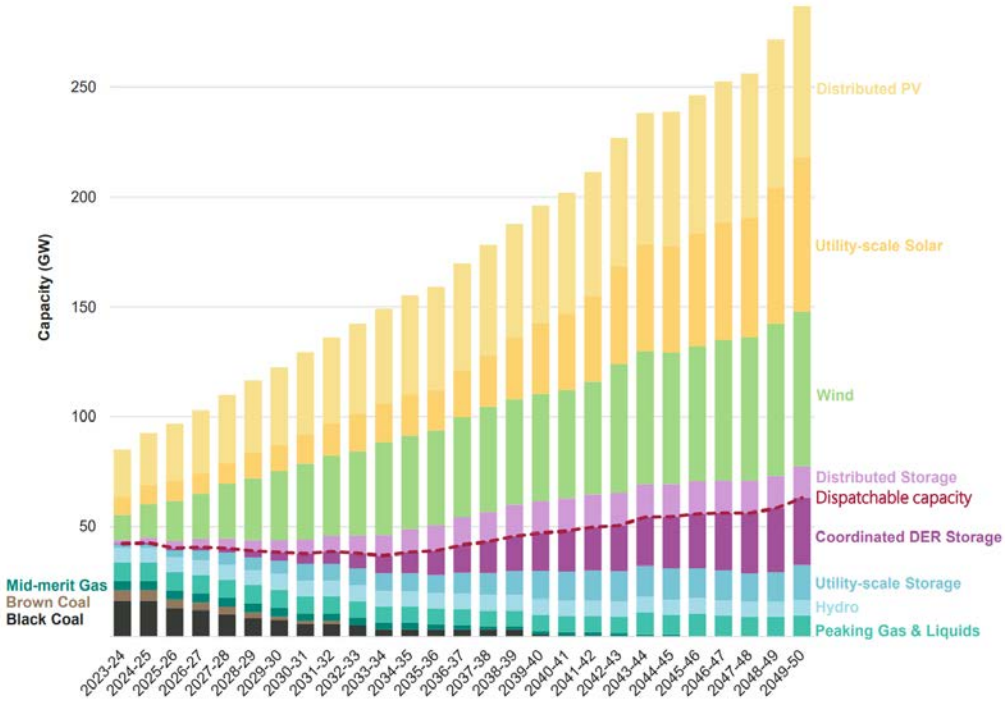
- Hydro historically managed using heuristic-based models (both short & long-term)
  - Since 2021, implementing MILP & SDDP optimisation models

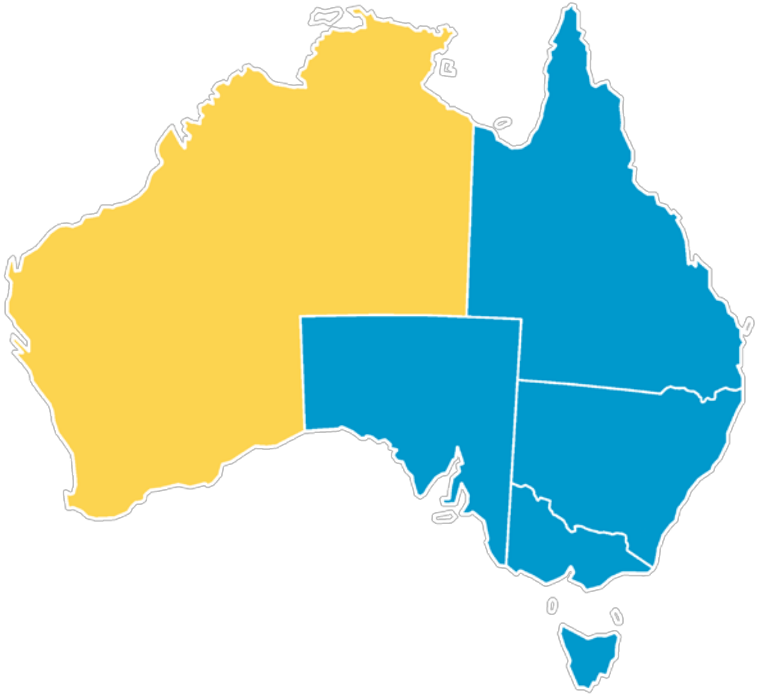
* Since newest wind farms commissioned in 2020



“National” Electricity Market



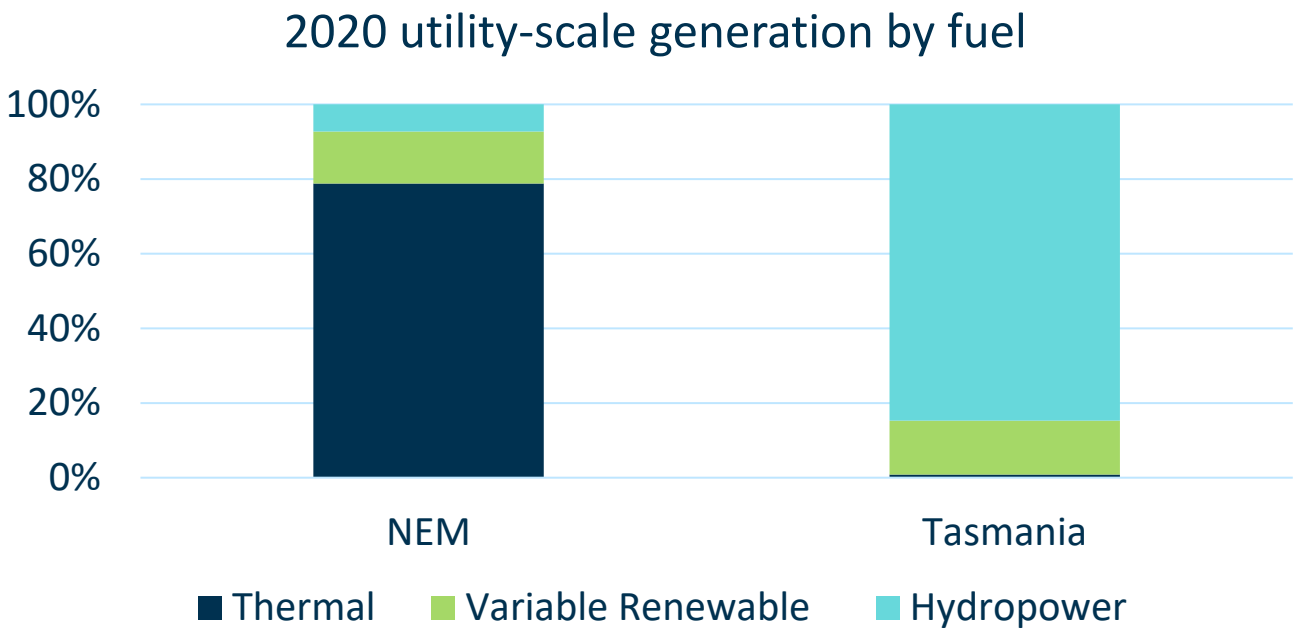


“National” Electricity Market

- Coal dominates – but retiring
  - Significant wind & solar
  - Significant behind-the-meter solar
- 40,000km of transmission
- 10,000,000 customers
- 54,000 MW capacity
- 180,000 GWh annual demand (operational)

- Energy-only spot market
  - Settled every 5 minutes
  - Cap = $15,000/MWh (~100,000 NOK)
  - Floor = -$1000/MWh (~-7000 NOK)
  - 8 frequency control ancillary services markets – co-optimised with energy
  - ALL energy bought & sold on spot market
  - Market participants use financial contracts to manage risks

Hydropower in the NEM



Source: OpenNEM.org

Hydro Tasmania's scheduling models

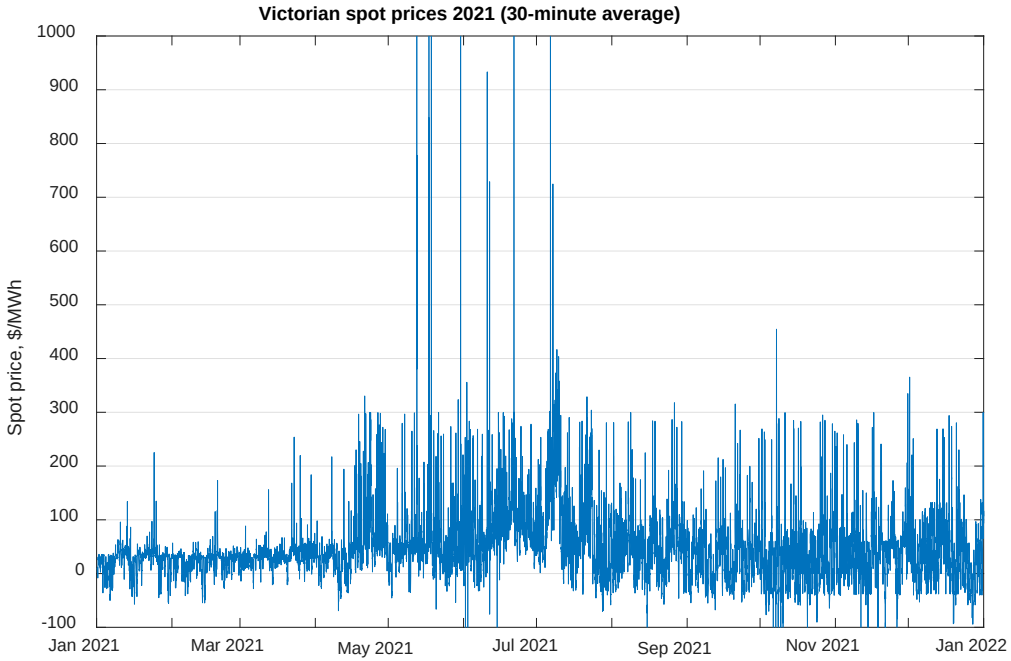
	Existing	New / under development
Short-term (next few days)	In-house heuristic-based "optimisation" (deterministic) In-house hydraulic simulation	NCP short-term optimisation model (PSR) (deterministic)
Long-term (everything else)	In-house heuristic-based simulation (300 replicates) Scenarios used for decision-making	Plexos hydro optimisation model (Energy Exemplar) SDDP hydro optimisation model (PSR)

Tasmanian hydrology

- Entirely rainfall-driven inflows
- Very seasonal - negative summer inflows
- Historical records to 1924
- Impact of climate change on seasonal patterns
  - Dryer autumns & summers
  - Timing of inflows hugely material to operational decision-making

- Range of storage sizes – 1/2hr to 3+ years
- 2 largest storages driven by different weather patterns

Negative market prices



Percent of half-hour intervals when the regional spot price was negative, Cal 2021

NSW	QLD	SA	TAS	VIC
4%	7%	23%	13%	19%

- Price caps +$15 000 to -$1 000
  - (+100,000 to -7000 NOK)
- Coal / inflexible generators want to avoid start/stop cost
- Renewable generators get renewable energy credits

Negative market prices

- For long- and short-term scheduling

- Linearisation techniques which assume positive price
  - E.g. pumped storage or battery incentivised to store and discharge at the same time
  - E.g. series of linear “>=” inequalities for losses

Synchronous condenser operation

- Very high inverter-based energy resources in Tasmania
  - DC interconnector ≈ 500 MW
  - Wind capacity = 568 MW
  - Solar (utility) capacity = 225 MW
  - Total **> 1200 MW**
- Operational demand
  - Min 900 MW
  - Average **1100 MW**
  - Max 1700 MW

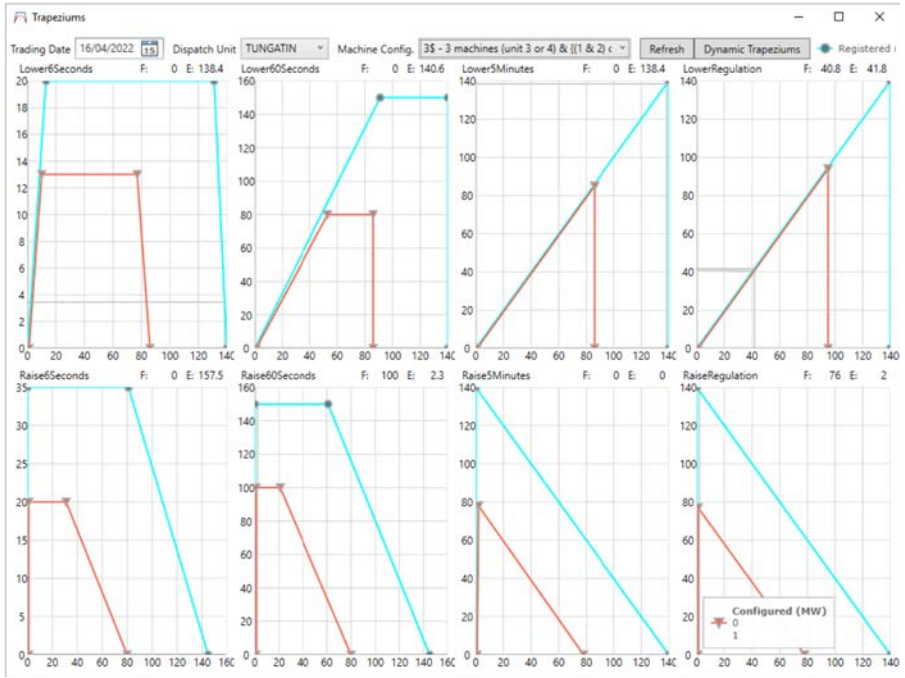
- Record 91.6% non-synchronous penetration (16 January 2021)
- Working towards 100% instantaneous penetration
- Support with synch con & low-load running of hydro generators (& gas)

Synchronous condenser operation

- For short-term scheduling only
- Third “binary” generator state (on, sc, off)
- Partial start-up costs
- System strength and/or inertia contribution (applies when “on” or “sc”)
  - Contributes to multi-machine constraints

Frequency Control Ancillary Services

- Australian NEM's regulation & contingency services
- 8 (10) markets:
  - Regulation raise/lower
  - (1 second raise/lower - 2023)
  - 6 second raise/lower
  - 60 second raise/lower
  - 5 minute raise/lower
  - Anything longer than this is "energy" (5-minute spot market)
- Capability defined as trapezium



Frequency Control Ancillary Services

- 8 (10) frequency markets co-optimised with energy
- Trapezium defined as series of linear inequalities
- Initially optimising for minimum availability
  - Optimising bids later – shallow market

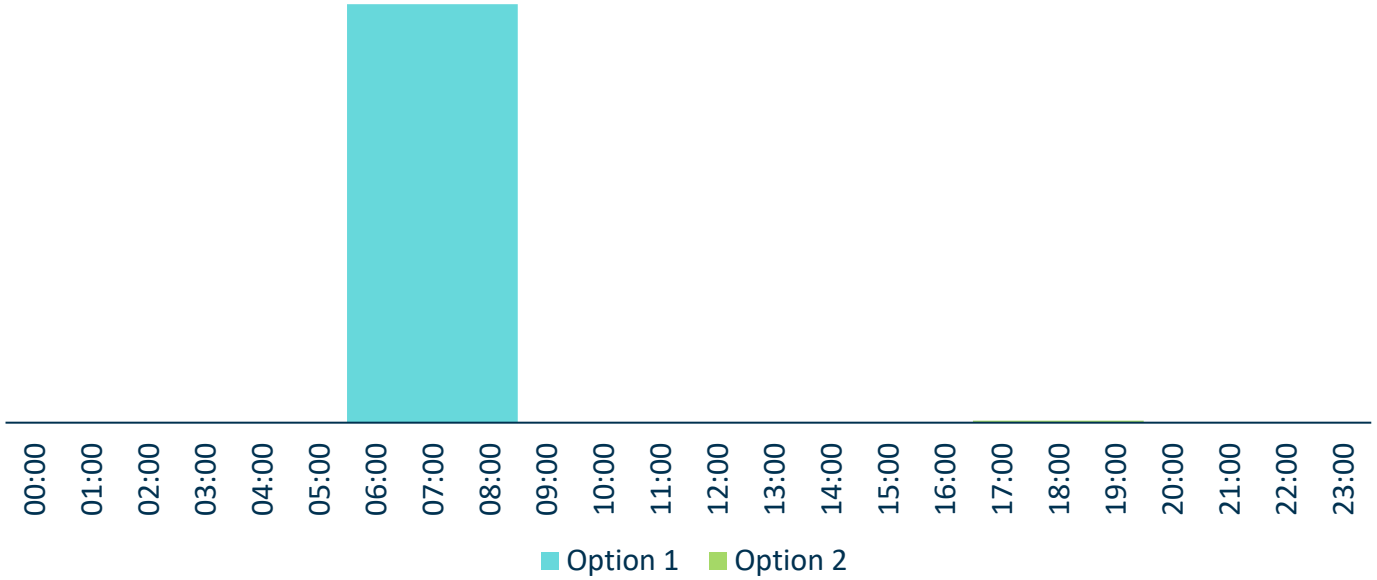
Update materiality

- 5-minute market
- Energy & FCAS offers updated any time
  - IF changes in demand, price, dispatch, plant condition

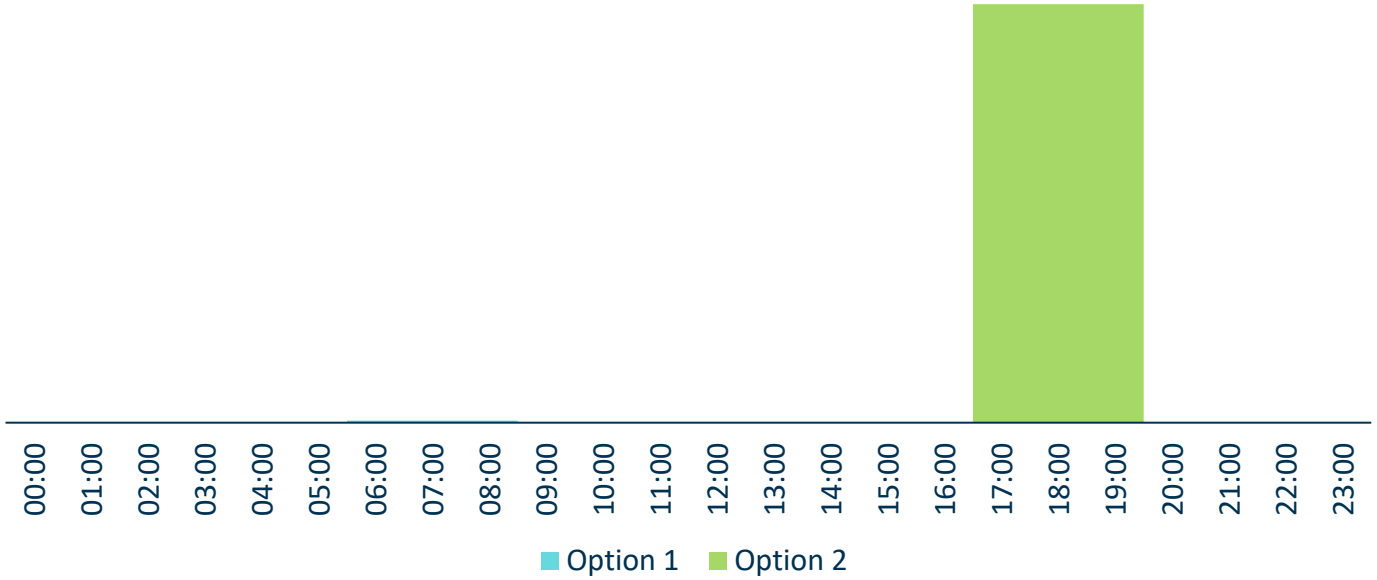
- Optimisation re-calculated at least every 5 minutes

- Provide trader with a recommendation – they need to respond
  - Can’t realistically do this for every plant every 5 minutes
  - Not a good look to toggle between similarly optimal options

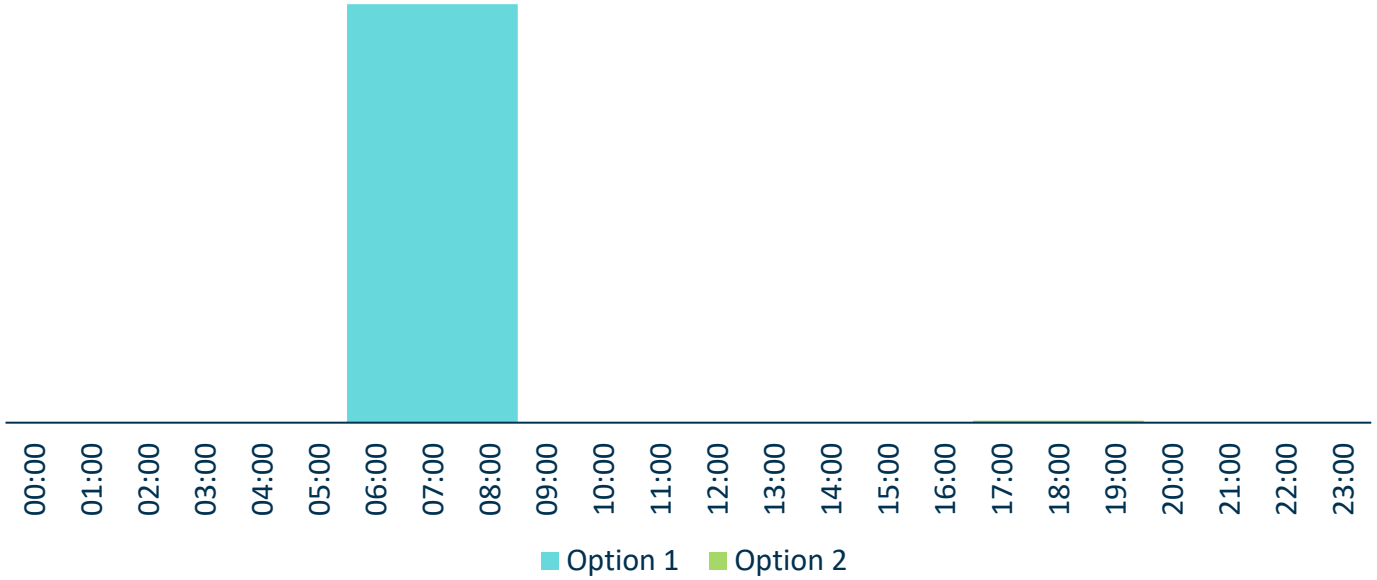
Update materiality



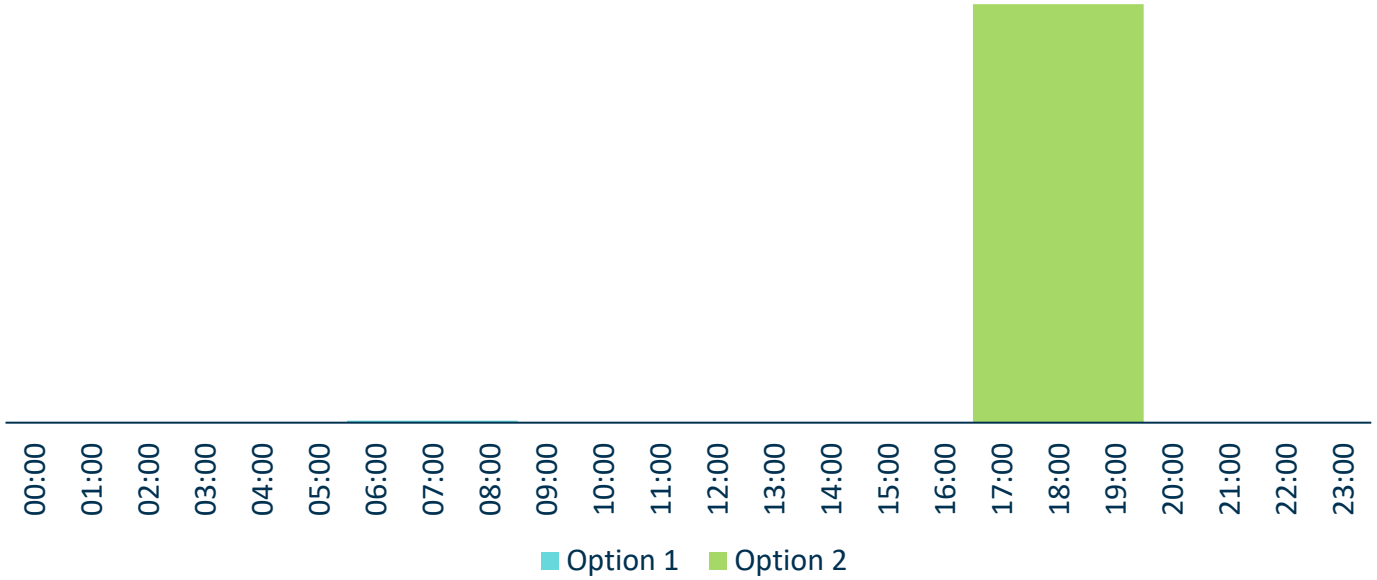
Update materiality



Update materiality



Update materiality



Update materiality

- Only alert trader of material changes
  - Materiality ≠ magnitude
- Apply materiality/magnitude test to input assumptions
  - Very simple
- Apply small penalty for deviations from last accepted solution
  - More complicated, guarantees materiality
- Post-processing comparison of objective function
  - Only applies at system level

Bid discretisation & smoothing

- 10 price bands per “dispatch unit” per day
- Set the day before
- Can update volumes per price band at any time

- HT storage durations from < 1 hr to > 3 years
- Small storage marginal water value (opportunity cost) varies throughout day

- Cannot accurately dispatch these units (and meet water management requirements) with marginal price bids alone

Bid discretisation & smoothing

- NEM spot market is pay-as-cleared
- Bid small storages at low price to “guarantee” their dispatch at forecast optimal times
- Smooth generation (ΔMW penalty) to avoid over-optimising (forecast accuracy)
  - Also reduces wear and tear

Thankyou

To my colleagues at Hydro Tasmania & PSR

www.hydro.com.au

Pippa.Williams@hydro.com.au