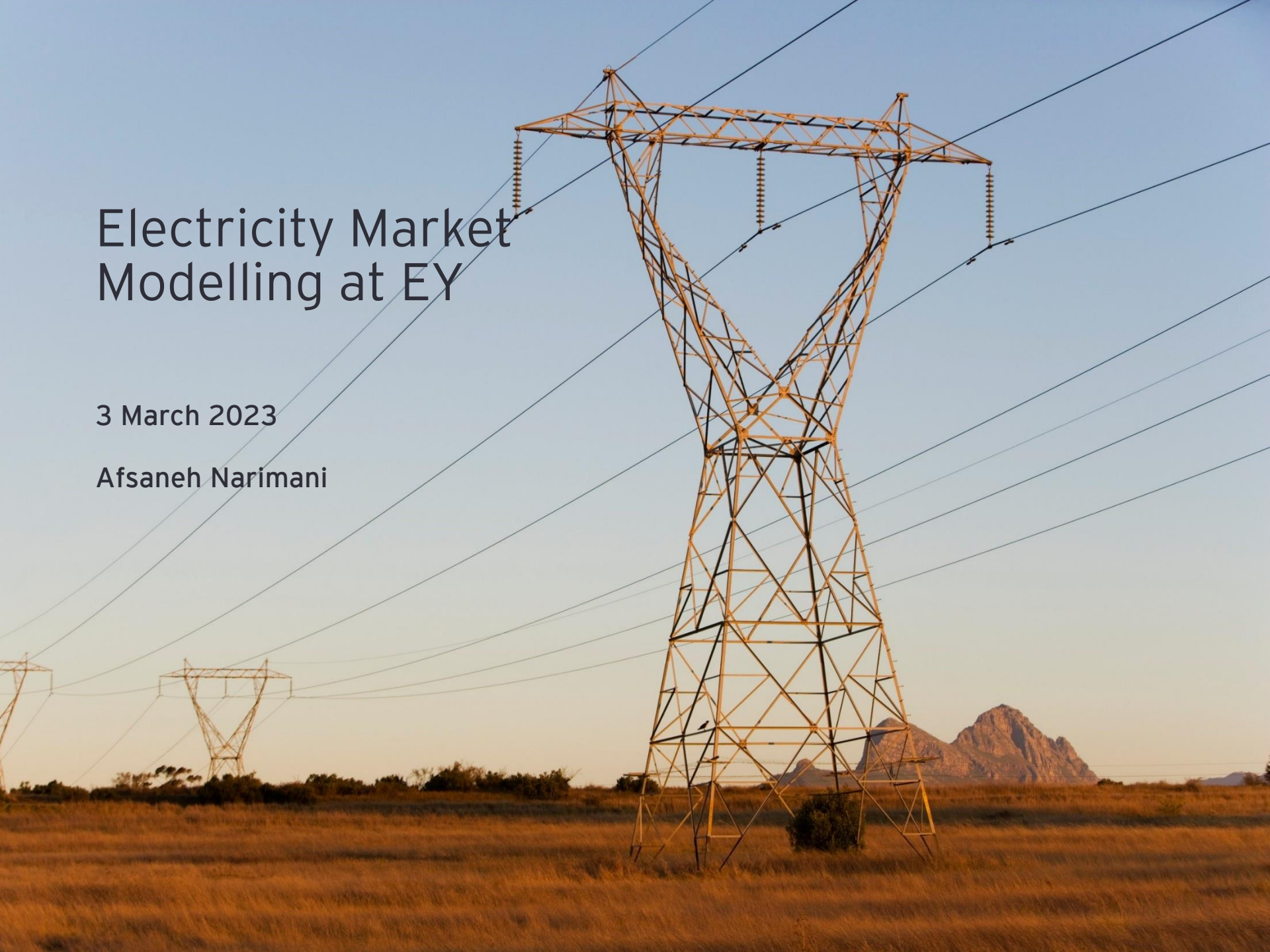


Electricity Market Modelling at EY

3 March 2023

Afsaneh Narimani

Who am I?

- A IUT Electrical Engineer graduate (2000)
- A Electrical Design and Lead Engineer in mining industry till 2012
- A QUT PhD graduate (Electrical Engineering 2017)
- A energy industry consultant since 2017

Views expressed represent my own and not those of EY.

Overview

- Energy transition
- The NEM
  - Today and the future
- EY ROAM
- How to model the NEM
- The challenges ahead
- Career
- Other opportunities at EY

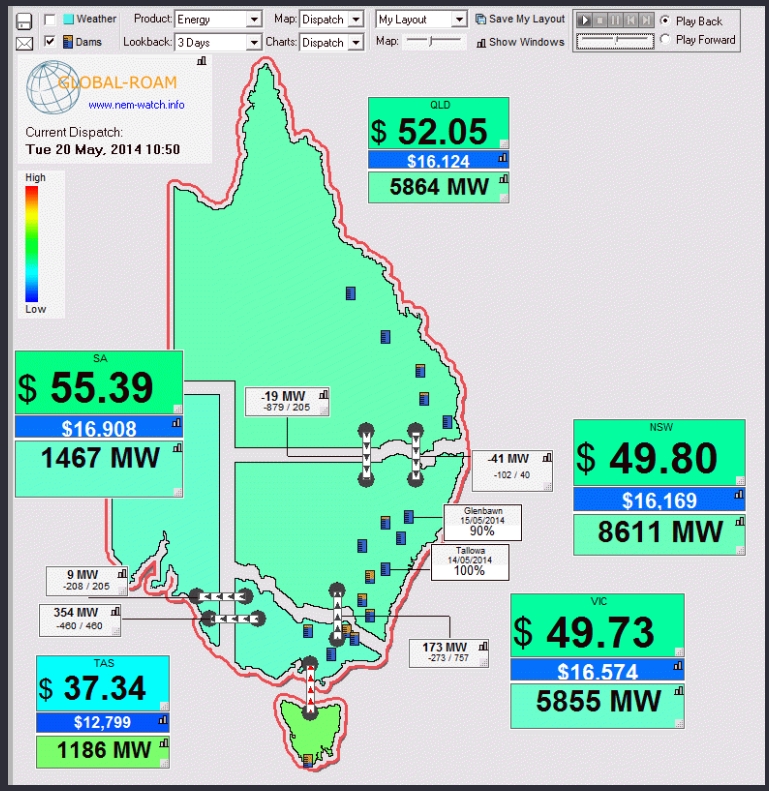
Energy transition

- The energy sector is decarbonising
  - Coal-fired power stations reaching end of life or becoming unprofitable
  - State-based renewable energy schemes driving replacement capacity
- Electricity consumers are changing their behaviours
  - Rooftop PV, household batteries and electric vehicles
- Traditional business models are being challenged
  - New bespoke retail options
  - Renewable energy zones and microgrids
- New technologies are being developed and implemented
  - Smart metering
  - Aggregation of household solar and batteries into virtual power plants
  - Peer to peer trading facilitating customer to customer interaction
  - Improved forecasting algorithms
  - Using machine learning to develop power station auto-trading software
  - Grid-forming inverters
  - Hydrogen industry
- All of this is happening very rapidly!

What is the NEM?

- Australia's biggest grid, the National Electricity Market
  - Interconnected power system comprising the eastern states.
- ~40,000 km of transmission lines and cables.
- ~11 million customers.
- ~200 TWh of electricity supplied to businesses and households each year.
- $11.5b traded in FY 2020-21.

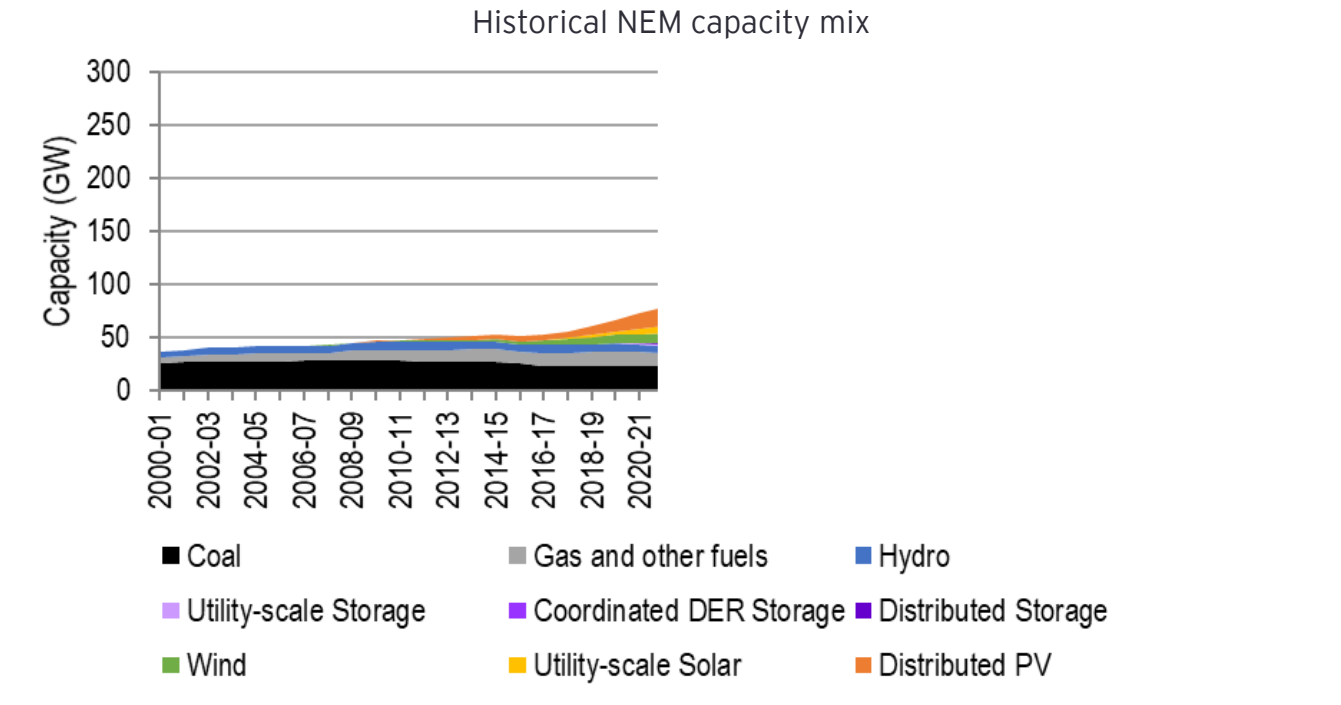
Prices vary between -1,000 $/MWh to 15,500 $/MWh every 5 minutes, depending on supply and demand.



Sources: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM & http://www.nem-watch.info/

The NEM today

- 65 GW of installed capacity, including 23 GW coal, 14 GW distributed solar.
  - Most grid-scale renewables built in the last 5 years.
- Currently get 50% of our energy from coal.
- Coal generators are getting old. 35% of capacity will retire in the next 10 years, 70% in next 20-years based on age.

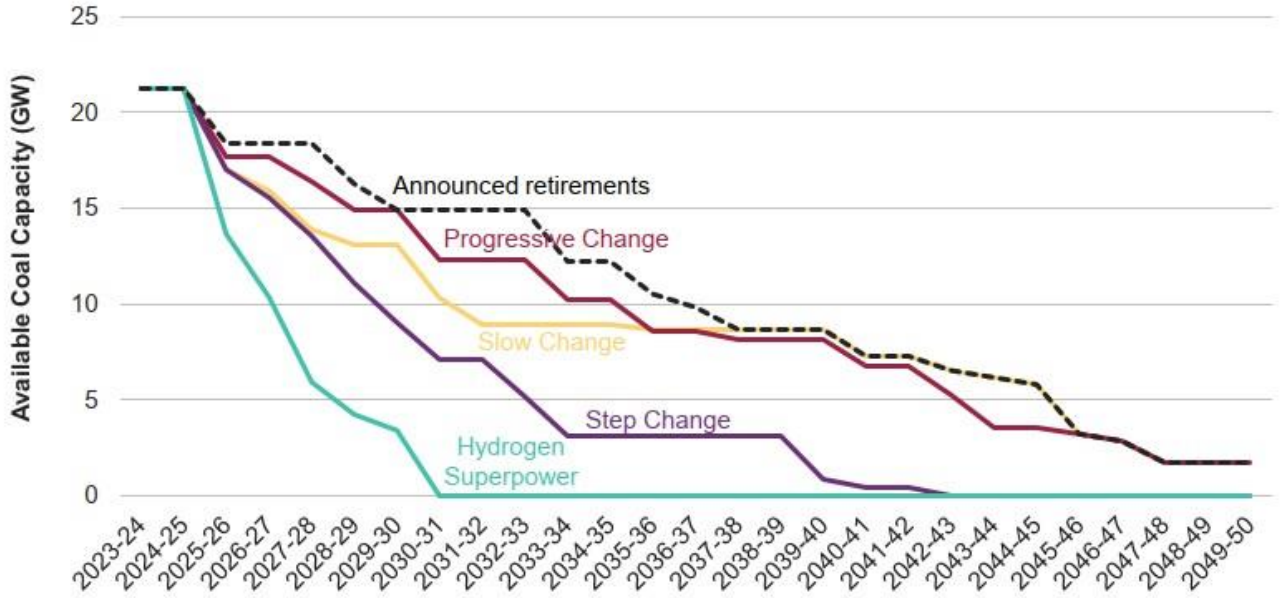


Sources
Historical: AEMC, https://www.aemc.gov.au/news-centre/data-portal/annual-market-performance-review/2020/nem-generation-capacity-installed-megawatts-fuel-type-2001-2020

The NEM of the future: accelerating coal withdrawals

- Recent announcements by AGL and Queensland Government are bringing announcements closer in line with forecast Step Change outcome (and emissions consistent with 1.8°C).

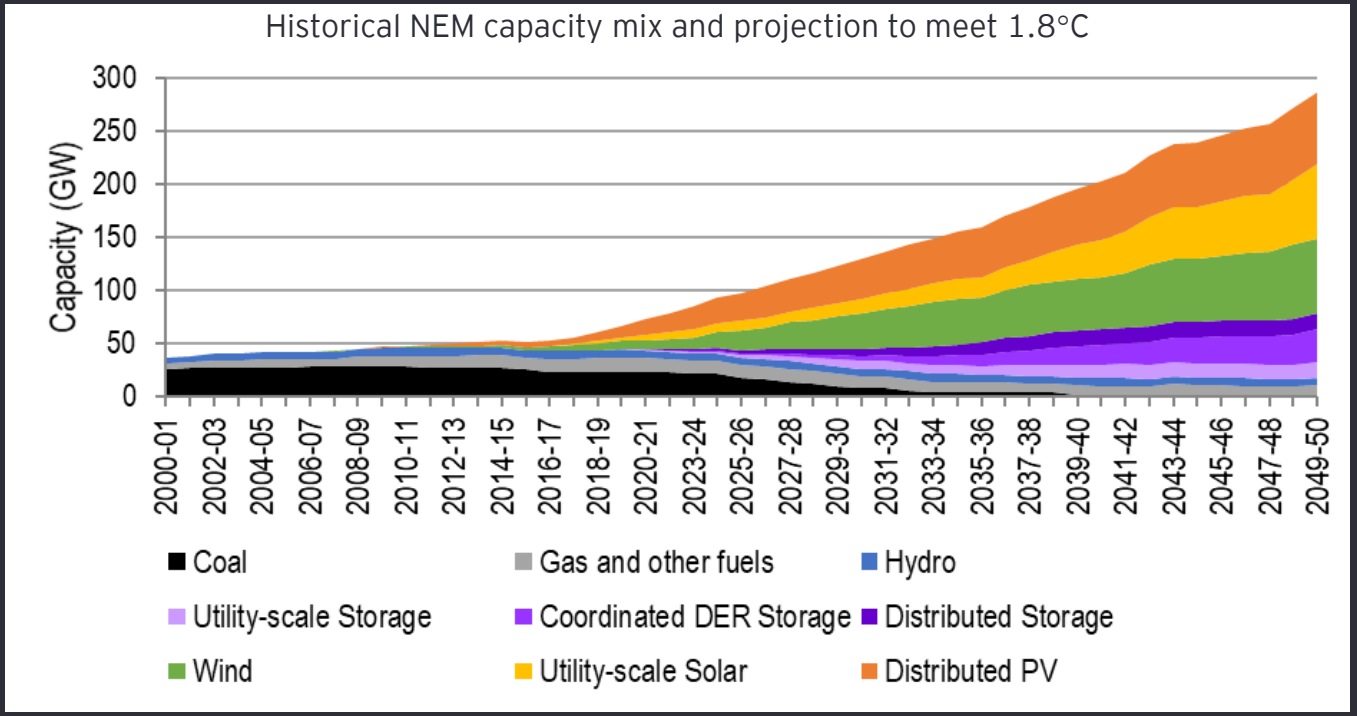
Forecast coal retirements, various modelled scenarios versus announced retirements in June 2022



Sources
Projection: Australian Energy Market Operator, June 2022, *2022 Integrated System Plan, Step Change scenario.* Available at: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

The NEM of the future

- Coal exit needs to be faster to limit climate change to 2°C or less.
- Replaced with
  - Energy from wind, solar
  - Firming capacity from storage and gas



Sources
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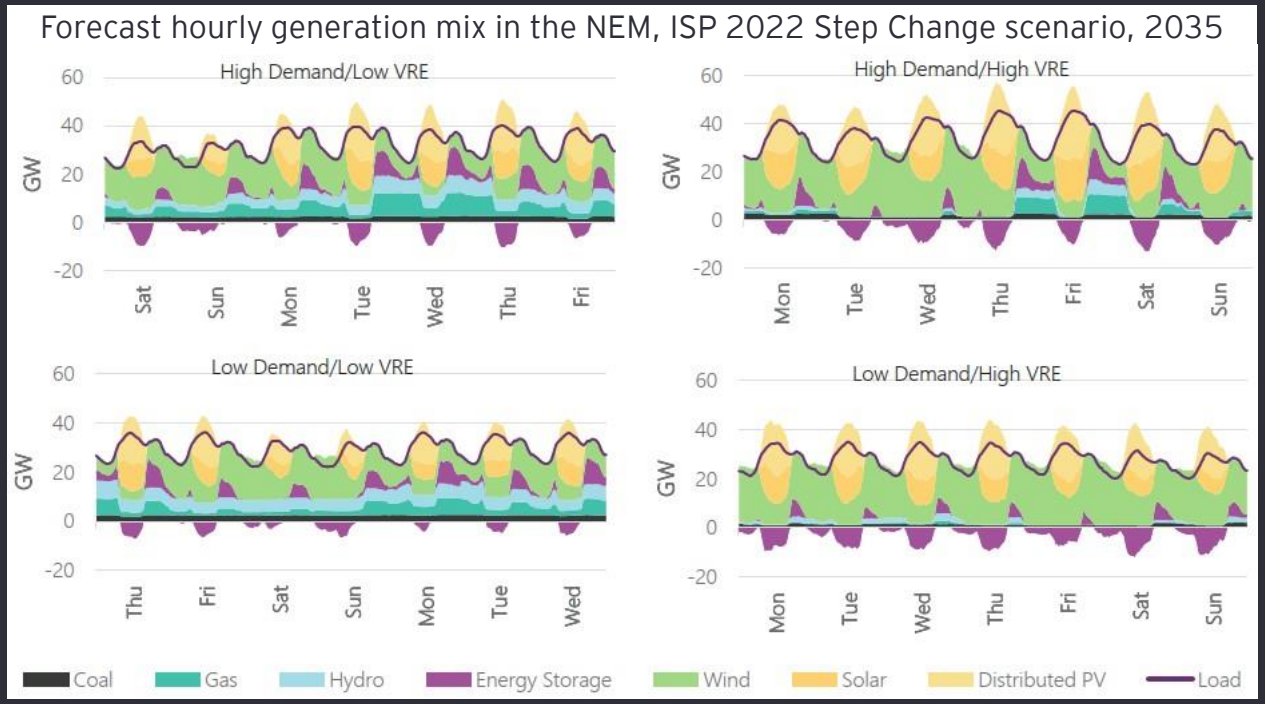
Projection: Australian Energy Market Operator, June 2022, *2022 Integrated System Plan, Step Change scenario.* Available at: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

The NEM of the future: day-to-day operation

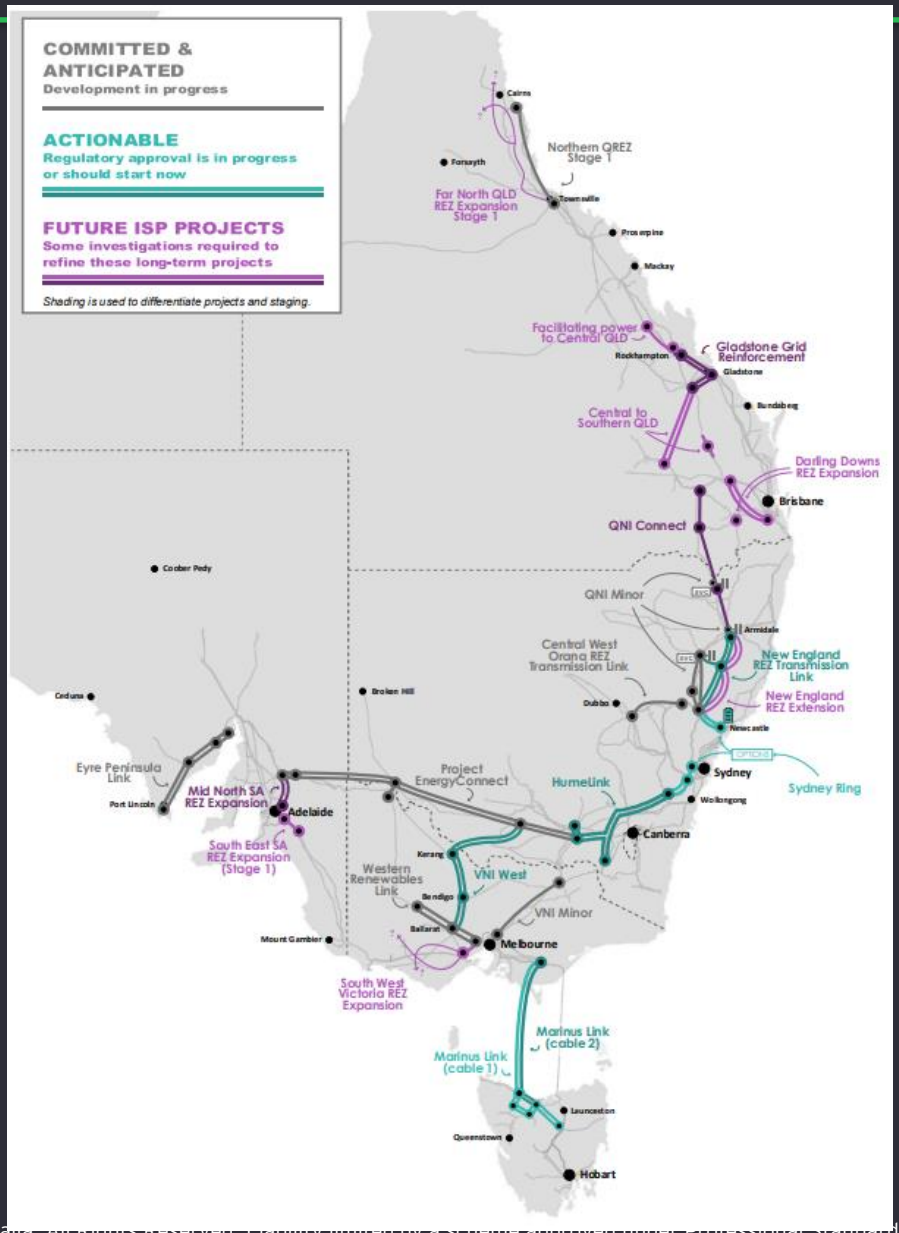
- Will be very dynamic
- Change in shape of grid demand requires different generating technologies
- Technological and geographical diversity are key

Forecast hourly generation mix in the NEM, ISP 2022 Step Change scenario, 2035



Sources
Projection: Australian Energy Market Operator, June 2022, *2022 Integrated System Plan, Step Change scenario.* Available at: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

Network – ISP 2022 Optimal development path



Government ambition

	Ambition	Date of announcement
South Australian Government	100% renewables by 2030	Jun 2019
Tasmanian Government	200% renewables by 2040 Marinus Link by 2028 Battery of the nation (pumped hydro)	Mar 2020
NSW Government	12 GW wind and solar + 2 GW medium storage + transmission by 2030 (50% emissions reduction by 2030, net zero by 2050)	Dec 2020
Commonwealth Government	43% emissions reduction by 2030, net zero by 2050 82% renewables by 2030	Aug 2022
Queensland Government	Coal withdrawals + renewable energy + pumped hydro and transmission 50% emissions reduction by 2030, 90% by 2035, net zero by 2050 50% renewable by 2030, 70% by 2032, 80% by 2035	Sep 2022
Commonwealth, Victorian and Tasmanian Governments	Transmission - Marinus Link and VNI West by 2028	Oct 2022
Victorian Government	75-80% emissions reduction by 2035, net zero by 2045 65% renewable by 2030, 95% by 2035	Oct 2022

QLD Energy and Jobs Plan

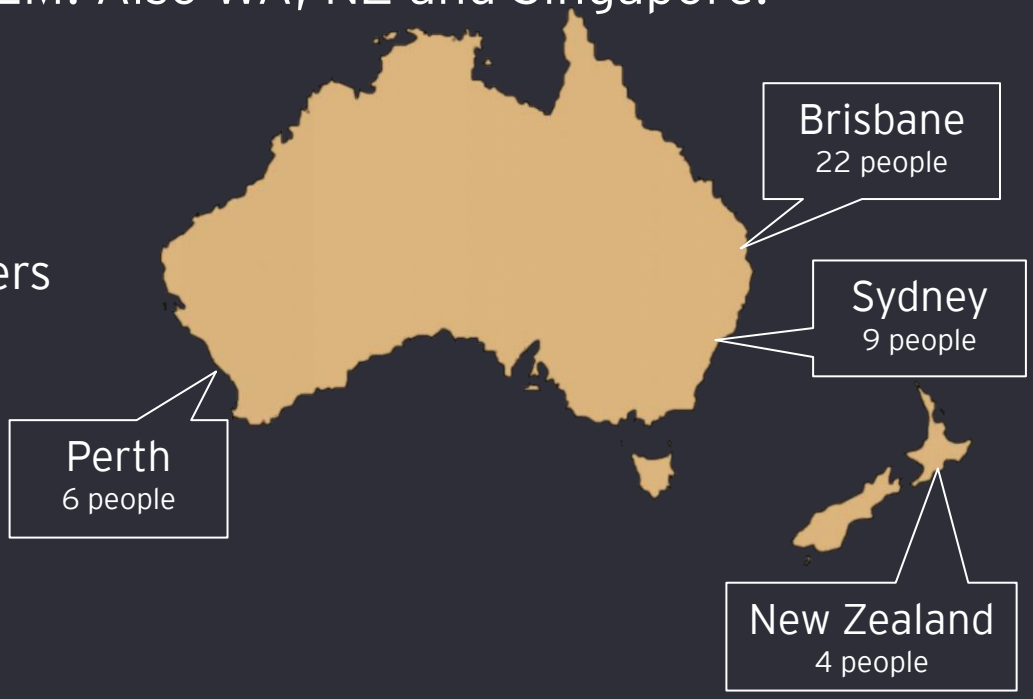
- Expansion of the Queensland Renewable Energy Target (QRET) to 50% renewable energy by 2030, 70% by 2032 and 80% by 2035.
- Development of the Borumba Dam (2 GW/24 hr) and Pioneer-Burdekin (up to 5 GW/24 hr) pumped hydro energy storage (PHES) projects, between 2030 and 2035.
- Hydrogen-ready gas developments, including a 200 MW peaking project at Kogan Creek.
- Establishment of QREZ.
- Emission reduction target of 50% lower on 2050 levels by 2030, 90% lower on 2005 levels by 2036 and net zero by 2050.
- Transmission investments, at up to 500 kV, to build new backbone transmission connecting energy storage and renewables to load centres, including connections to Borumba PHES and Pioneer-Burdekin PHES, expanding the connection of Southern Queensland to Central Queensland, and connecting Hughenden and Townsville, unlocking more renewable generation.

QEJP and Draft AEMO IASR 2023 – Dec 2022


EY ROAM

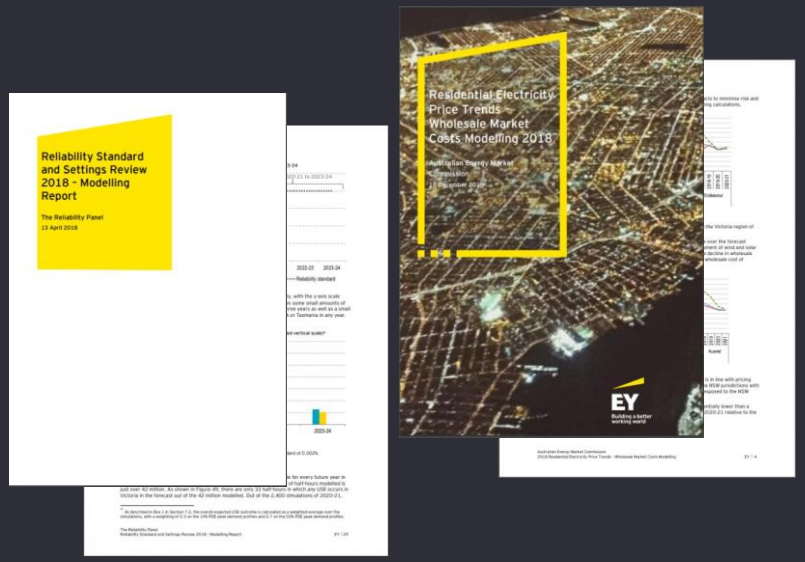
Who is EY-ROAM?

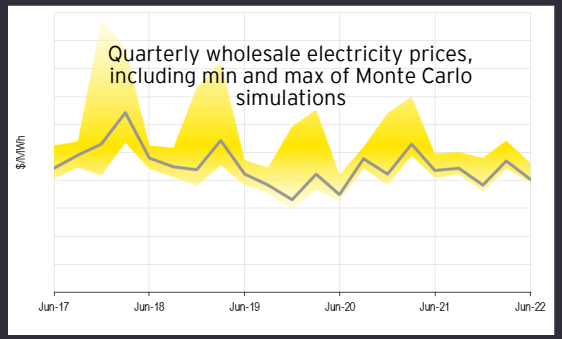
- EY-ROAM is a leading provider of electricity market modelling services in Australia.
- We enable our clients to make informed decisions about the future by providing them with evidence-based insights.
- Our modelling suite has been developed in-house for over 20 years, since the start of the NEM. Also WA, NZ and Singapore.
- We work with:
  - renewable developers
  - energy sector investors
  - network service providers
  - energy retailers
  - regulators
  - governments
  - government agencies



What we do

- Energy policy development
- Whole of system planning studies
- Studies for new entrant generators and generators being transacted
  - Wholesale market price forecasts
  - Marginal loss factor assessments
  - Network curtailment risk assessments
- Transmission developments & upgrades
- Market design research and review





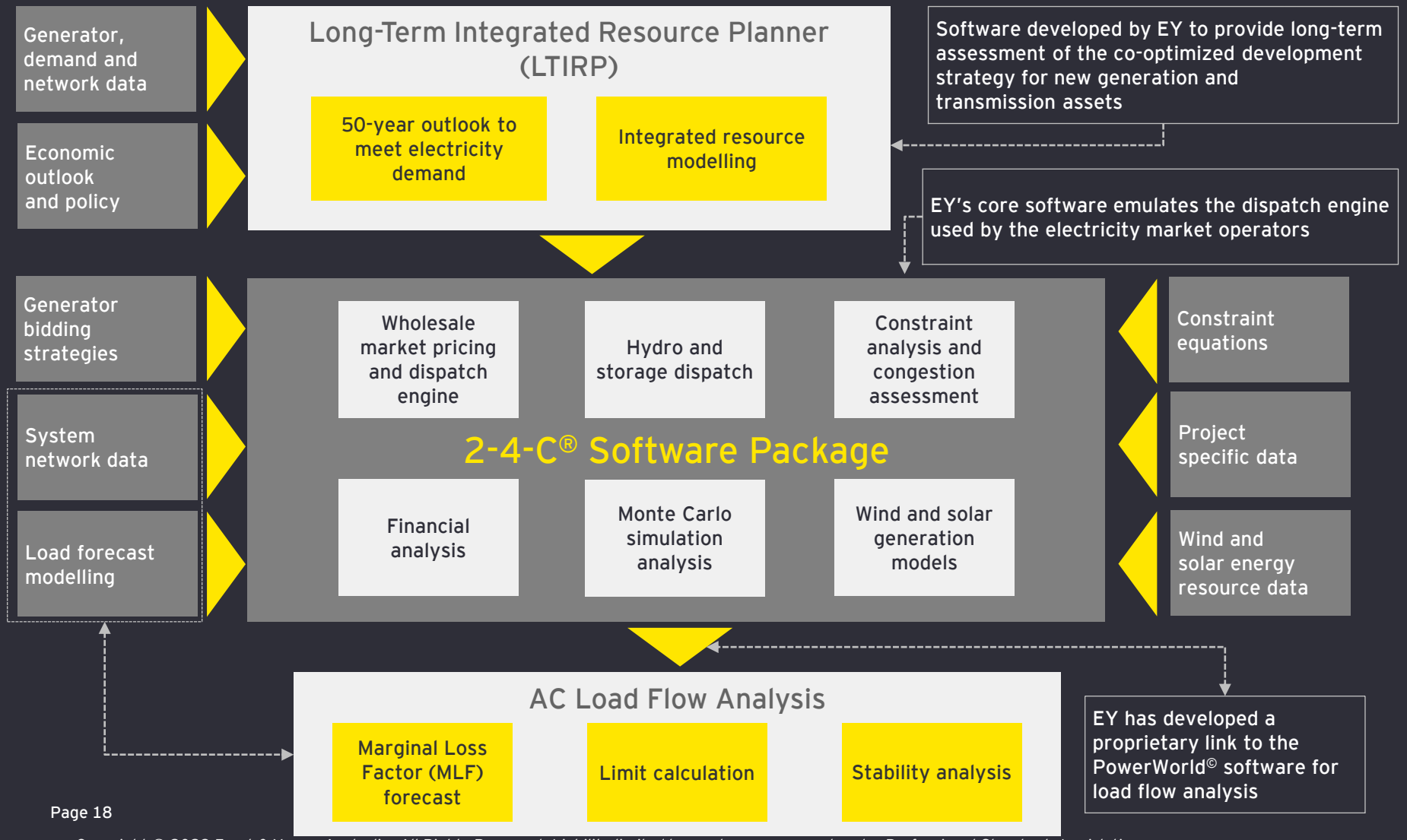
Market modelling at EY ROAM

Modelling the NEM of the future

- Linear and mixed integer programming.
- Compute projection of least-cost supply to meet demand subject to constraints
  - Physical
    - Limits on flows on transmission lines
    - Solar and wind availability
    - Charging and discharging of storage
  - Policy
    - Renewable energy targets
    - Carbon emissions multi-year budgets or trajectories
- Large simulations (hours to days), large data sets.

EY ROAM modelling tools

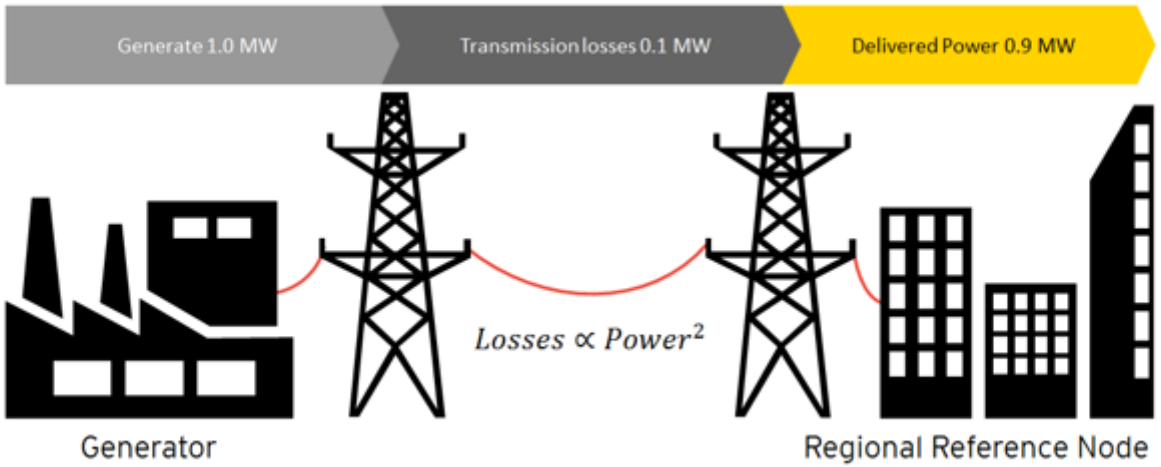
EY's electricity market modelling tools have been developed in-house and are robust and adaptable to any electricity system around the world.



Marginal Loss Factor

MLF theory

MLFs provide the marginal increase (or rate of change) in losses for an incremental change in generation from a generator with respect to a reference node (or bus). This means that if generation at one bus increases by 1.0 MW the hypothetical change at the reference node may be 0.9 MW. The reduction of 0.1 MW is losses and is proportional to the square of the power injection. For example if the power injection doubles, losses will quadruple.



Network congestion assessment

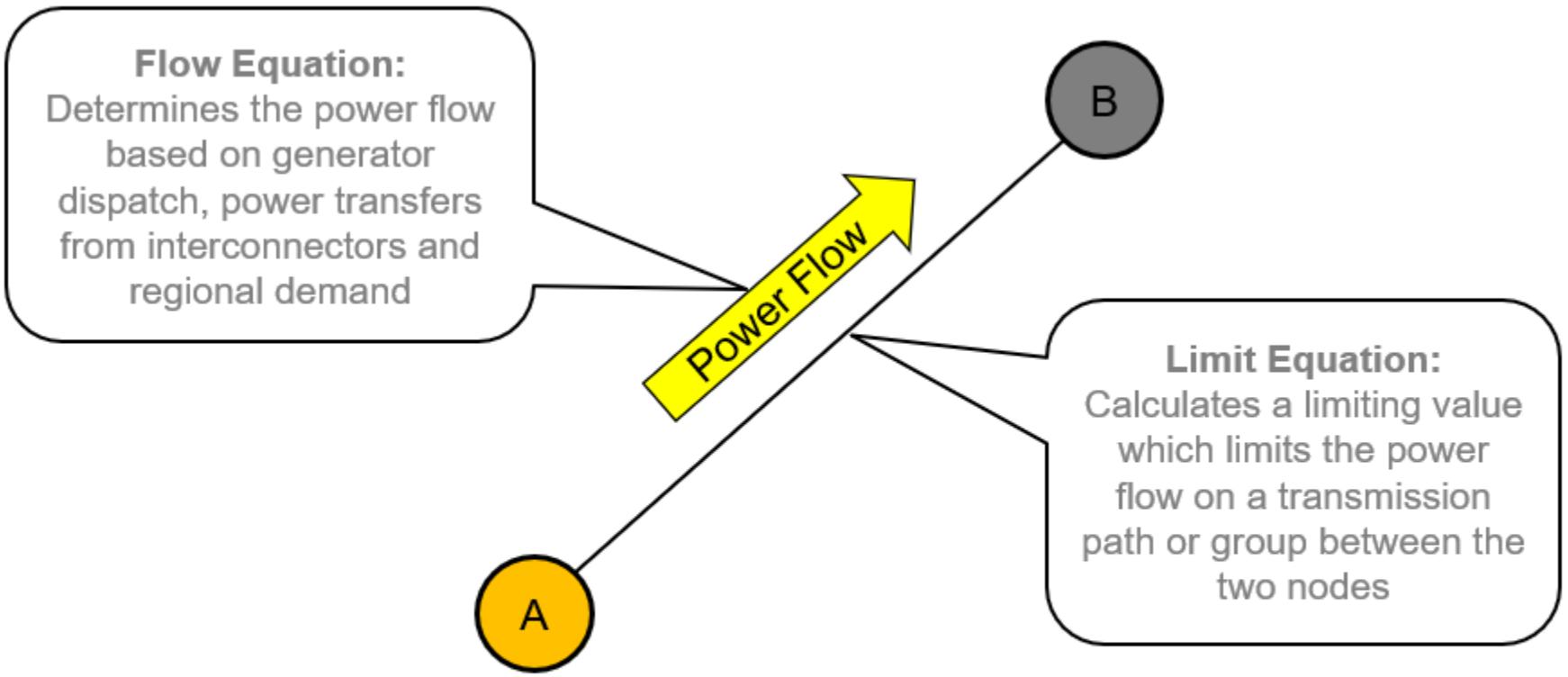
Network congestion

- NEMDE (National Electricity Market Dispatch Engine) produces least cost dispatch of market participants subject to the constraints.
- Constraint equations represent the physical limitations of the network.
- If a constraint is binding, it means that the market dispatch has been affected and therefore no longer least cost dispatch
- Three main ways congestion can affect generator's revenue:
  1. Project is constrained off
  2. Inter regional constraints cause price separation
  3. Project is constrained on (causing it to generate at a price lower than SRMC)
- Multiple types of constraints:
  - Network, Frequency, Other (e.g. rate of change, non-conformance, etc.)

Thermal constraints

- Simplest kind are N constraints
  - These simply prevent the thermal limit of a transmission line from being exceeded
- The majority of the NEM is operated with N-1 constraints enabled
  - This means that the network will remain stable in the event of any contingency (line outage)
  - More onerous than N constraints

Thermal constraints



The purpose of a **constraint equation** is to make sure that the flow does not exceed the limit. i.e.

Power Flow ≤ Flow Limit

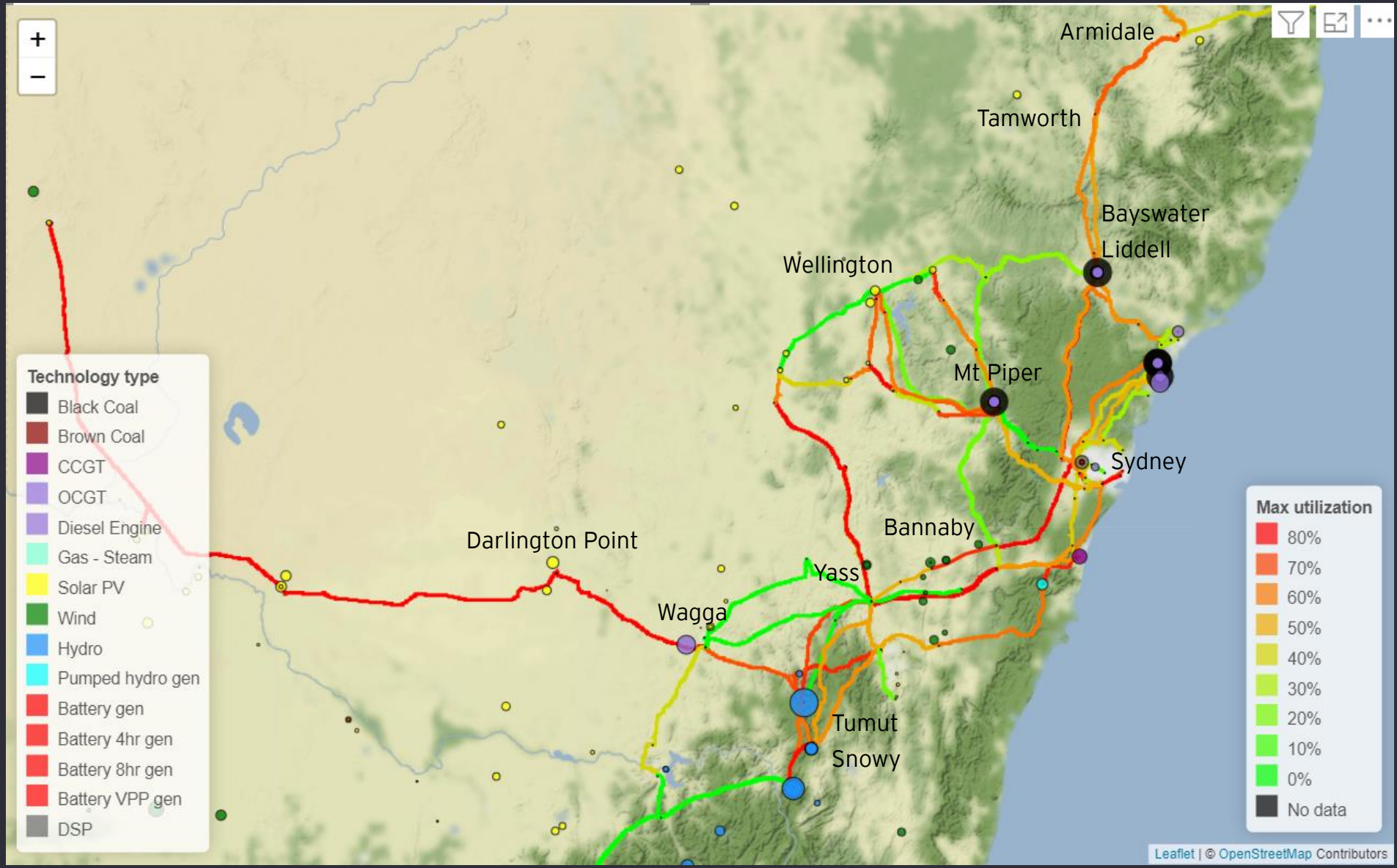
What do constraint equations generally look like?

- Constraint equations have three main parts:
  - Left hand side (LHS)
  - Operator
  - Right hand side (RHS)

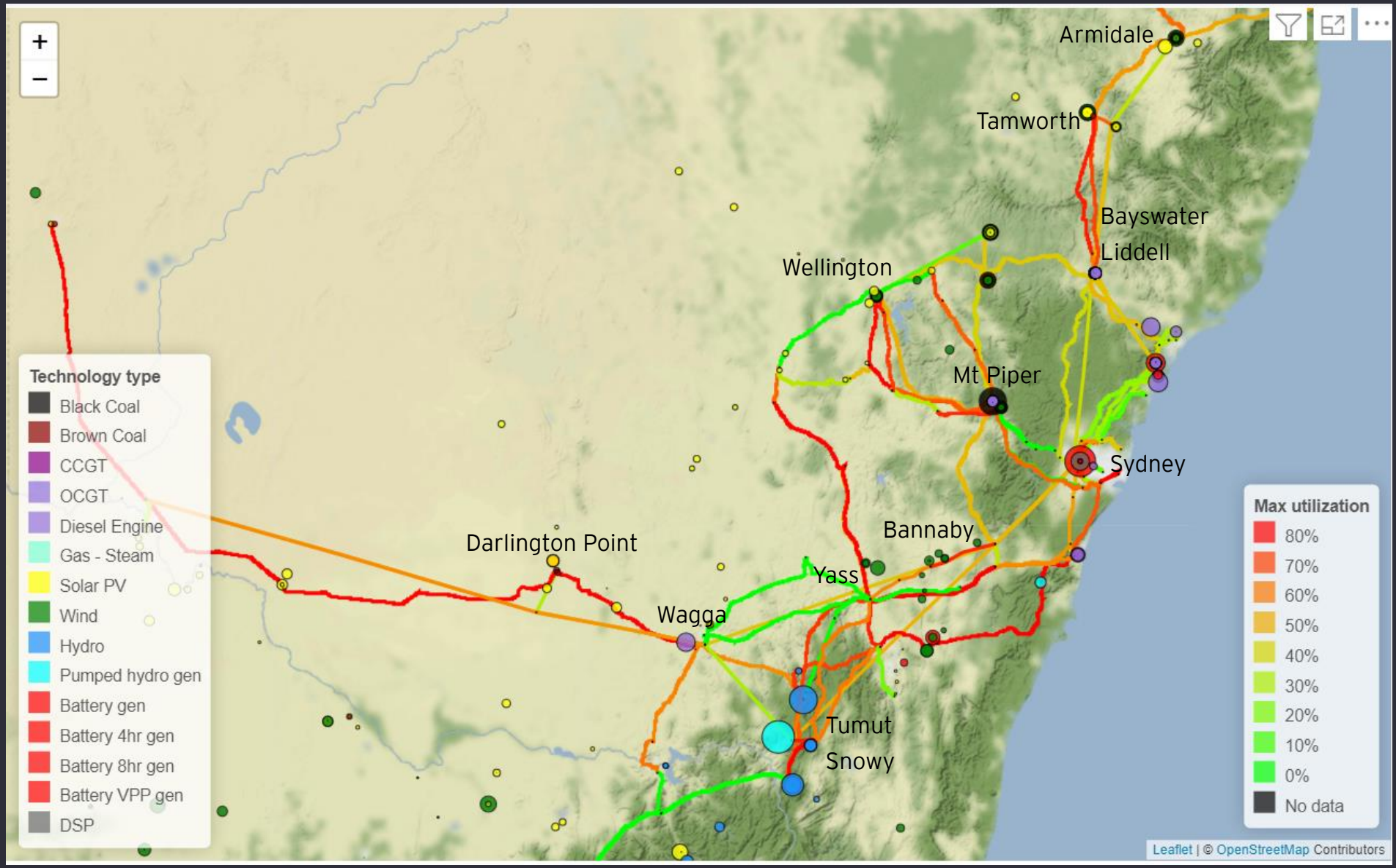
$$LHS \leq RHS$$

- LHS ➔ controllable variables
- RHS ➔ non-controllable variables

Maximum transmission line utilization – FYE 2023



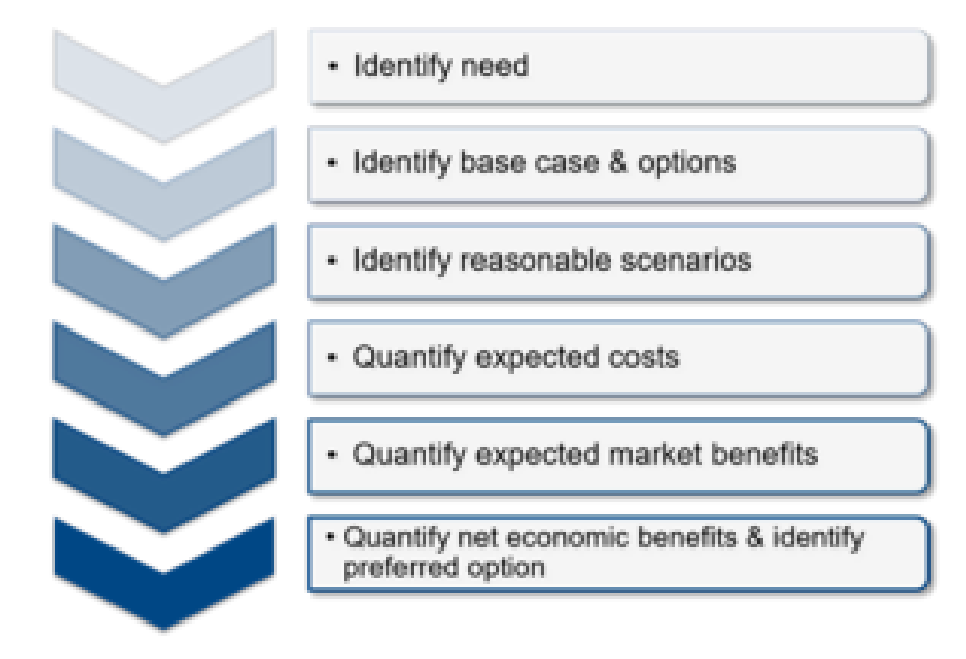
Maximum transmission line utilization – FYE 2032



Long term integrated resource planning

Long term resource planning

LTIRP Software developed by EY to provide long-term assessment of the co-optimized development strategy for new generation and transmission assets



The challenges ahead

The challenges ahead

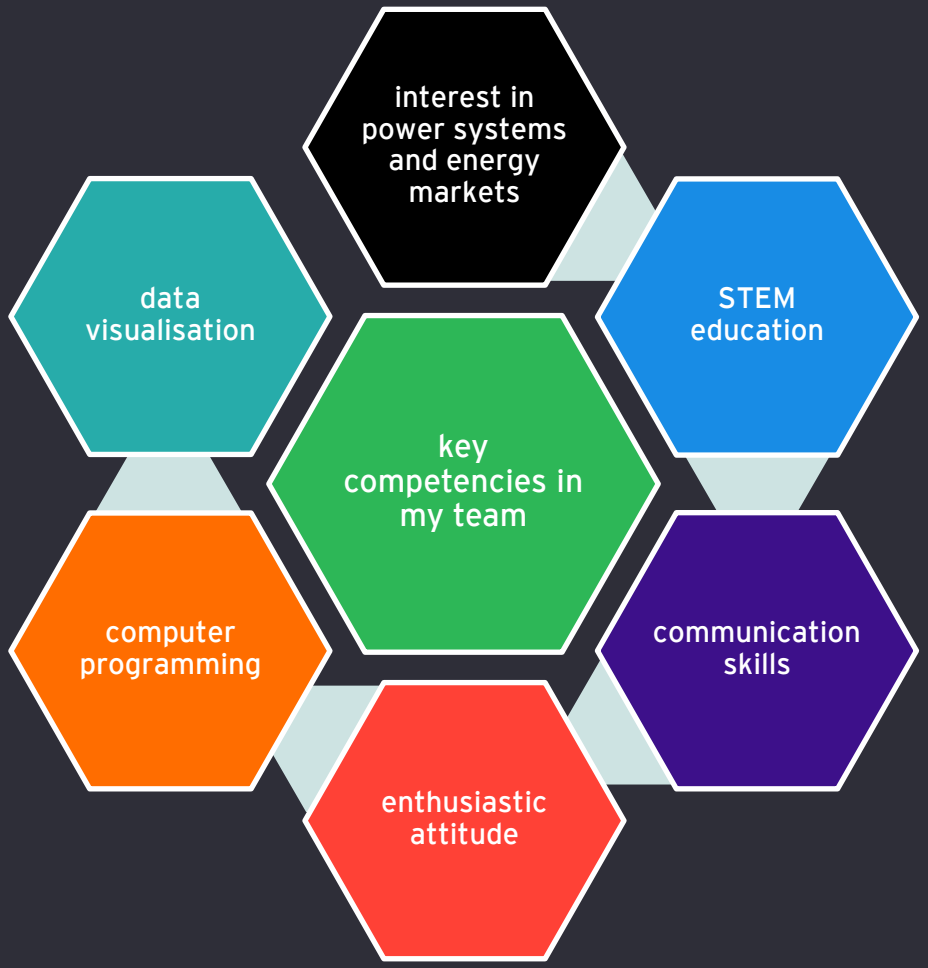
- Technical challenges
  - Grid not configured for where we build wind and solar
    - Transmission losses and congestion
    - Need new transmission
    - Distribution designed for one-way flow
  - Inertia and system strength
    - Frequency and voltage control becoming more difficult.
    - How to manage lots of asynchronous inverter controlled generators?
  - Storage coordination
  - Uncontrollable rooftop solar and minimum grid demand
  - Increasing dependence on weather-dependent energy sources, in changing environment.
- Political and regulatory challenges
  - Heavily regulated industry means change is slow
  - Lack of consistent federal energy policy
- Community acceptance challenges
  - Land use
  - Cost, particularly for last few percent emissions
- Supply chain challenges: knowledge, labor, materials
  - Lead time to order HV cables 5+ years
  - Grid-scale batteries from 6 months in 2018 (Hornsdale BESS) to 2+ years today.

- Faster electrification will increase the challenge
- Australia and the NEM are at the leading edge of these challenges globally.

Opportunities at EY

Electricity sector careers

- My team are:
  - Engineers: power systems, electrical, mechanical, software
  - Physical scientists: physicists, mathematicians, statisticians, data scientists
  - Economists
  - A few dual degrees with finance
- We are people who enjoy playing with data, tackling challenging multi-disciplinary problems, and working with purpose towards a cleaner energy future with a secure and reliable grid.
- These are skills needed across the electricity sector!



Internship and research opportunities

- Research for publication in Cigre symposium
- Final year undergraduate project
- Internship and vacation student opportunity
- ROAM scholarship
- Work placement opportunity for Master degree students

Thank you!