Navigating the energy mid-transition

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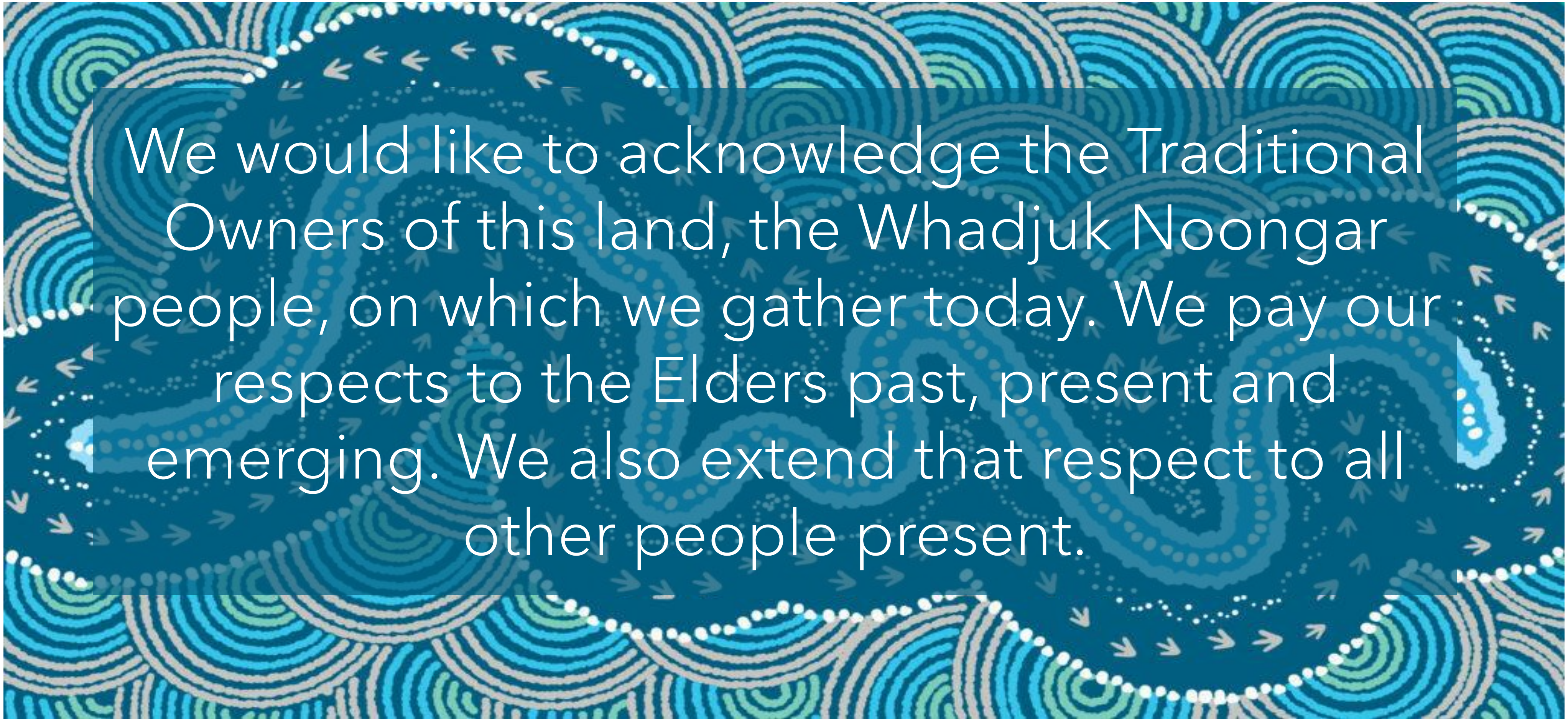
4 April 2023

Acknowledgment of Country



We would like to acknowledge the Traditional Owners of this land, the Whadjuk Noongar people, on which we gather today. We pay our respects to the Elders past, present and emerging. We also extend that respect to all other people present.

Artwork by Dylan Sarra

The Churchill Fellowship

Winston Churchill Trust
Learn globally, inspire locally.

- From the Winston Churchill Trust website:

  "Churchill Fellowships offer a diverse range of people from all walks of life an opportunity to travel overseas for four to eight weeks to explore a topic or issue that they are passionate about.

  No qualifications are required in order to apply for a Churchill Fellowship, and the topic of your proposed project is limitless, provided a benefit to Australia and willingness to share your findings with the Australian community is evident."

- I was the recipient of a Churchill Fellowship in 2020 with the project "To optimally operate a low inertia electricity grid with high penetration of renewable energy"

My Fellowship itinerary (28 October – 13 December 2022)

Places Visited

- Sydney
- Los Angeles
- Folsom
- Austin
- Washington
- London
- Wokingham
- Warwick
- Manchester
- Exeter
- Dublin

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I went to visit grids that are in “mid-transition”

“[Z]ero-carbon and emitting fossil fuel systems co-exist at scales where each imposes operationally relevant constraints on the other […]

During the mid-transition, neither the zero-carbon nor carbon-emitting infrastructure can fully support all energy services on its own, and the overall system is not optimised for either infrastructure’s sociotechnical particularities […]

Risks of maladaptions, overlooked opportunities for synergies, and uncoordinated decision-making are high during the mid-transition, particularly as infrastructures encounter simultaneous climate, technology, and societal dynamics that are not well characterised by past experience.” [1]

I sought out jurisdictions that were quite advanced in the energy transition and were transforming from a fossil fuel generation capacity base:

- California (CAISO)
- Texas (ERCOT)
- Great Britain
- Ireland (I-SEM)

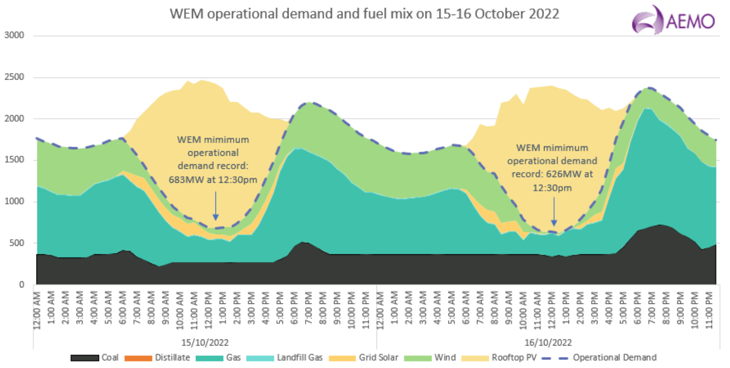
[1] Grubert, E., & Hastings-Simon, S. (2022), “Designing the mid-transition: A review of medium-term challenges for coordinated decarbonization in the United States”, WIREs Climate Change, 13(3), e768. https://doi.org/10.1002/wcc.768

High level comparison of power systems

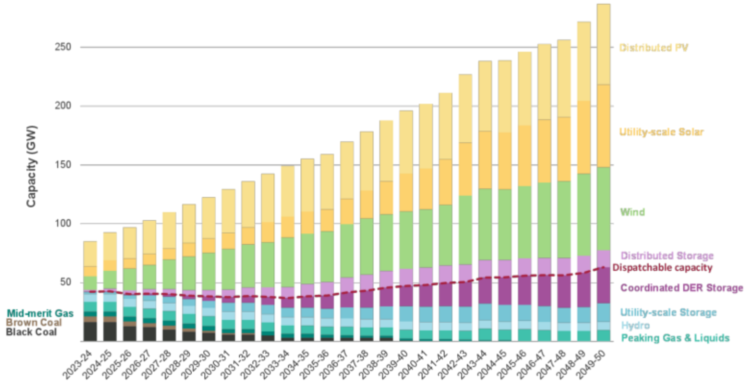
	NEM	WEM	CAISO	ERCOT	GB	I-SEM
Historical peak demand (GW)	33.8	4.0	52.1	80.0	60.1	6.9
Installed generation capacity (GW)	59.7	5.8	75.8	>92	63.1	15.7
Cross-border interconnector capacity (GW)	None	None	16.1 (import)	1.25 (HVDC)	7.4 (HVDC)	0.95 (HVDC)
Renewable installed capacity (GW)	~24.4	1.2	27.3	~47.2	17.9	6.9
Renewable % of installed generation capacity	41%	21%	52%	51%	28%	44%
Max instantaneous renewables (% of demand served)	69%	84%	103.5%	71.3%	71.1%	~96%
Maximum System Non-Synchronous Penetration (%)	~65% (mainland) ~92% (Tasmania) ~92% (South Aus)	~70%	~67%	~71%	N/A	~75%
Distributed PV capacity (GW)	14.4	1.9	~12.5	2.1	8.0	~0.3
DPV % of installed generation capacity	24%	33%	16%	2%	13%	2%
Electric vehicles (excluding hybrids)	65,600		563,070	80,900	660,000	34,977
Electric vehicles per 1,000 people	~2.6		~14.3	~2.7	~9.8	~6.9

Australia is at the pointy end of the energy transition

- All the power systems I visited are seeing techno-economic problems arising from the energy transition, e.g. declining inertia, low system strength, "duck curve" effects from DER, large short-term forecast errors due to weather variability, retiring synchronous generation, etc
- In most systems, there are typically ≤3 issues that are of concern
  - Some systems benefit from being part of larger interconnections (e.g. California) or have significant amounts of cross-border interconnector capacity (e.g. Great Britain)
- However, Australia has nearly all of the problems, with large-scale electric vehicle integration being the sole exception (but this is coming in the future)
- Other jurisdictions are looking at Australia on what (or not) to do to navigate the energy transition



[Source: AEMO]



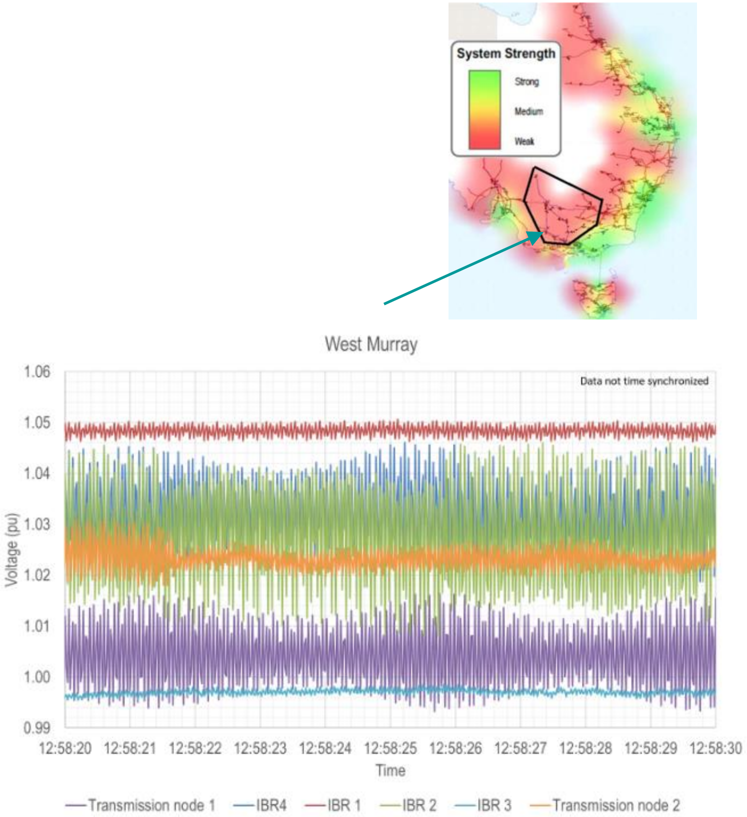
[Source: AEMO]

Market design shapes the scope of feasible solutions

- Different market designs emphasise different things, for example:
  - The NEM design is focused on co-optimised real-time outcomes with as few distortions to the real-time price signal as possible
  - The Great Britain design follows a more European approach of emphasising day-ahead outcomes, where balancing in real-time is a side issue left to the system operator to sort out
  - The standard FERC market design has both financially binding ahead markets and real-time (security constrained) co-optimisation, but still allows for a fair amount of operator discretion
  - The WEM design started off more like Great Britain, but is gradually lurching towards a more NEM design
- The feasible set of system security solutions is influenced by market design and the underlying philosophy behind it, for example:
  - In the UK, the industry's acceptance of National Grid ESO's operational opaqueness, as well as an established culture of innovation, allows National Grid ESO to freely experiment with different overlapping products and services
  - In Texas, ERCOT has market mechanisms to procure large volumes of operating reserves (recently increased to ~6.5 GW) to manage forecast uncertainty, which can paper over many system security issues

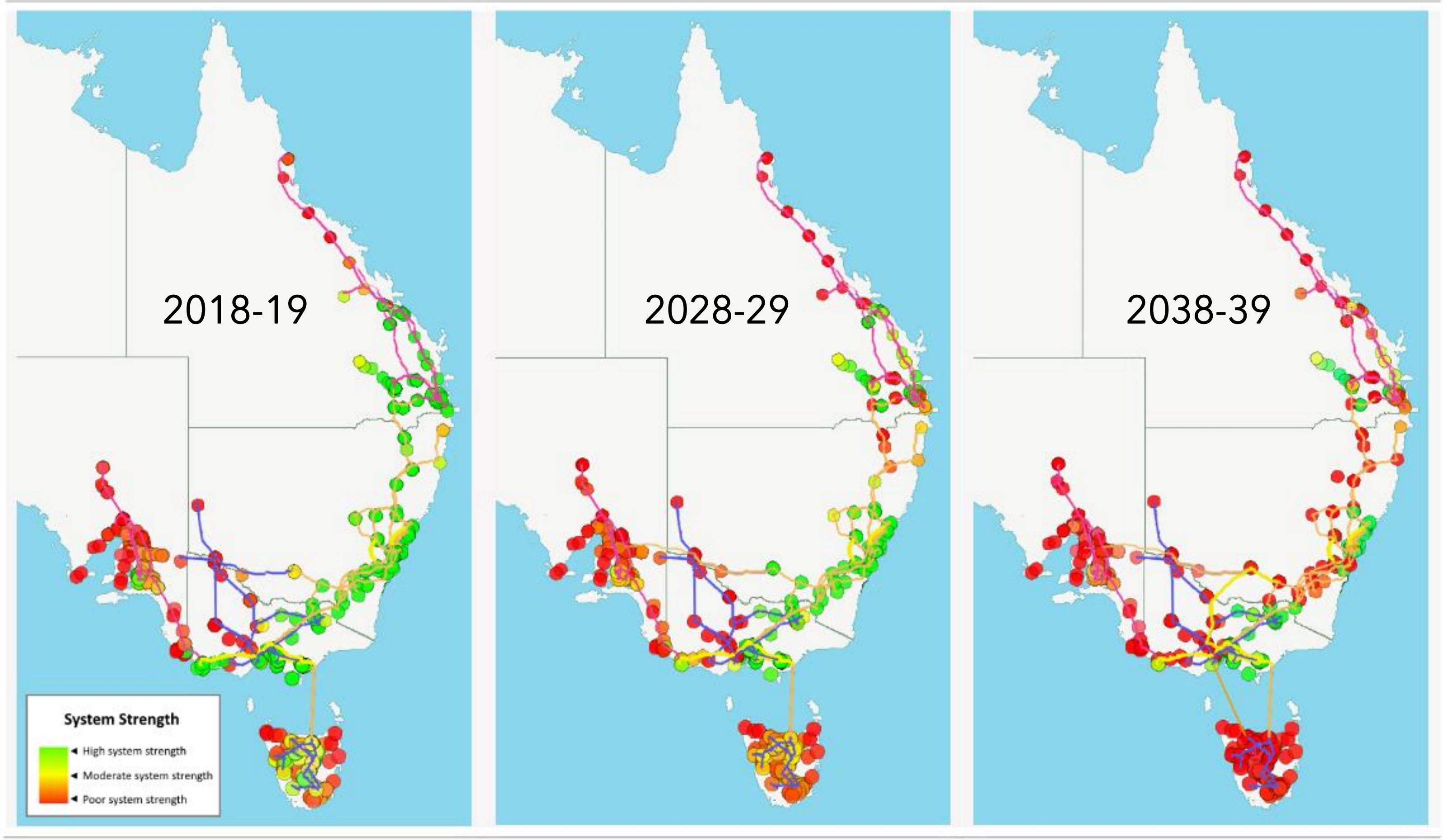
Technical risks will emerge as we get closer to 100% IBR penetration

- IBR dominated low (or zero) inertia systems have been deployed operationally and successfully proven in small-scale systems, but there are still questions and gaps in our engineering knowledge when it comes to large, complex, multi-gigawatt scale systems operating at >90% IBR penetration for extended periods of time.
- As a result, there are technical risks that we will need to manage as instantaneous IBR penetrations creep up towards 100%, such as:
    - New unexpected issues that only begin to arise at high IBR penetrations, emerge non-linearly and have mechanisms that we don’t fully understand
    - Lack of appropriate theoretical frameworks and analysis tools to predict and mitigate any technical issues in the planning stage
    - Insufficient visibility and monitoring systems to identify and detect issues in real-time before they arise or become material problems



Oscillations occurring on 2 September 2020 with no known disturbance trigger [Source: AEMO]

The risks will no longer be isolated to certain areas, but widespread



Projected system strength (fault levels) across the NEM from 2018/19 to 2038/39 [Source: AEMO]

At the same time, there is a desire to speed up the energy transition

U.S. forum calls for countries to speed up energy transition

Fast transition to renewables will save the world $18 trillion, says Oxford study

World's emissions targets at risk if pace of change doesn't pick up: Rio Tinto

Climate Advisor Slams UK For Energy Transition Tardiness

DAVOS 2023

It's time to tackle humanity's greatest challenge by speeding up the green energy transition

Green energy drive must gather pace

Next first minister urged to 'pick up the pace' in tackling climate change

German Science Academy urges speed and cooperation in Europe's energy transition

Electricity transition in India's renewable-rich states needs to accelerate, says study

But keeping costs under control is still important

- We want to manage technical risks and quickly get on with the energy transition, but not at any cost, especially for consumers who are already suffering from cost of living pressures.

The West Australian

WA wholesale electricity price spikes to record heights

The wholesale electricity price in WA spiked to record heights in the December quarter as the State used more gas amid coal shortages,...

25 Jan 2023

AFR

Energy affordability exposes brutal divide between rich and poor

Wealthy Australians are ordering electric cars and buying solar panels, but poor people are locked out of the benefits, a new study has...

ABC

Energy price rise to bite for low-income Australians, advocates say

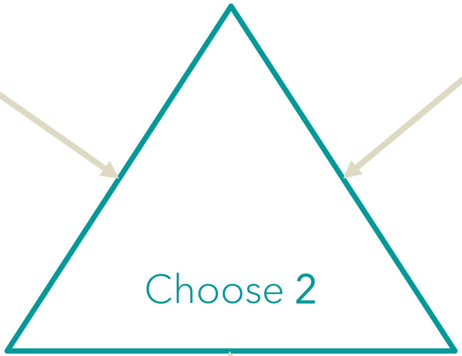
Brooke Mawson and her family love footy, fishing, and going for a family drive, but the rising cost of electricity is forcing them to...

- Ideally, we'd want to prudently:
  - Limit the downside risks of over-investment and stranded assets, e.g. an over-build of synchronous condensers
  - Provide sufficient investment signals for solutions to enter the market
  - Allow new technological innovations to flourish, e.g. grid-forming inverters, new analysis and mitigation techniques, etc

Balancing technical risk, speed of transition and economic efficiency

A low risk and economically efficient transition would seek to find optimal techno-economic solutions, but would be slow as it will take time to understand and mitigate all the technical risks.

A low risk and fast transition would be engineering-led, using conservative tried and tested solutions to pre-emptively mitigate risks before they emerge, e.g. a large coordinated buildout of synchronous condensers to replace synchronous generators.



An economically efficient and fast transition is possible, but we'd probably have to accept a higher level of technical risk, e.g. unbundled spot markets for all essential system services and allowing new technologies to participate without spending the time to fully understand all the interactions and implications.

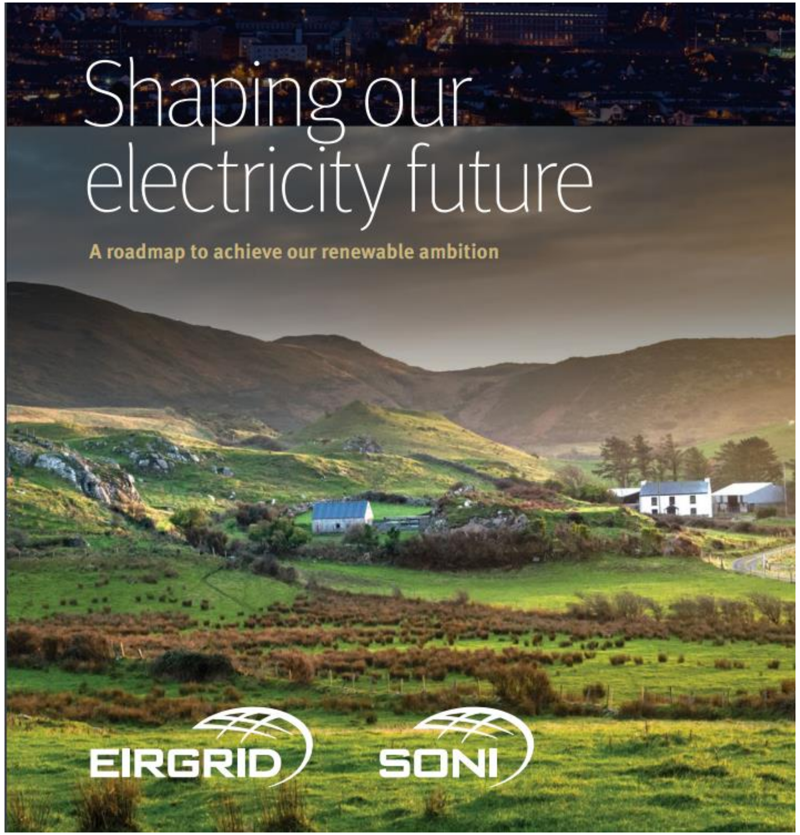
We need to start thinking about coordinated transition strategies

- To technically operate the grid securely at 100% renewable energy will be a challenge as we need to practically "*rebuild the plane while it is still in flight*" in order to operate without large synchronous generators propping up the system
- Doing so in an orderly manner will likely require a high-level coordinated and system-wide strategy to guide long-term investment and planning decisions, e.g. for investments such as synchronous condensers, stronger transmission links, new technologies such as grid-forming inverters, etc
- Such a strategy would describe:
    - What is the right mix of investments?
    - When and where should they be deployed?
    - Who should invest in them?
    - How should they be procured?

[Source: Ayden Creative]

There may be value in having a single planner (and buyer)

- In WA, system security and transmission planning (and procurement) responsibilities are dispersed (between AEMO and Western Power)
- Internationally, this planning (and procurement) function often just sits with the system operator:
    - **US FERC jurisdictions:** the RTO/ISO (e.g. CAISO, ERCOT) is generally responsible
    - **Great Britain:** National Grid ESO
    - **Ireland:** EirGrid/SONI
- This allows the system operator to centrally plan and procure a coordinated mix of services, and develop a single, unified strategy, e.g. Ireland's roadmap



[Source: EirGrid]

The share of DER is becoming significant in a few systems

Australia, California, Hawai'i and Great Britain are leading the world when it comes to DER uptake and integration:

	NEM	WEM	CAISO	Hawai'i (Oahu)	Great Britain
DPV capacity (GW)	14.4	1.9	~12.5	~0.62	8.0
DPV % of installed generation capacity	24%	33%	16%	36%	12.6%
DPV % of historical peak demand	43%	48%	24%	50%	13.3%
Electric vehicles (excluding hybrids)	65,600		563,070	15,964	660,000
Electric vehicles per 1,000 people	~2.6		~14.3	~15.7	~9.8

But harnessing DER at scale is still quite immature worldwide

- DER is still mostly treated like an uncontrolled nuisance to be managed by the system operator, even in grids that have a large share of DER (like Australia)
- However, there are efforts to harness DER for the good of the system, mainly in one of three ways:

  1. **DER export pricing:** to incentivise decentralised price-responsive behaviour, e.g. by setting a time-of-use feed-in tariff that is lower during daylight hours (WA, Hawai'i, CAISO) or by levying time-dependent export tariff / compensation (NEM).
  2. **Aggregated DER system services:** providing services such as frequency control (NEM), demand response / flexibility (UK Power Networks, CAISO, WA) and constraint management (National Grid ESO). Probably seen most success, but quite a fragmented market.
  3. **Aggregated DER wholesale market participation:** integration of DER in energy market scheduling, e.g. Project Symphony (WA), Project EDGE (NEM) and FERC Order 2222 (US)
     - California ISO basically implemented FERC Order 2222 in 2016, but noted that uptake has been virtually non-existent due to existing DER incentives (e.g. net energy metering)

Everyone is grappling with the same set of non-technical challenges

- Skilled labour bottlenecks: there is a squeeze for skilled technical professionals, along with a gradual hollowing out of electric utility and system operator expertise as people get lured away by private sector developers and consultancies. Meanwhile, the pool of experienced professionals is not growing.
- Handling large volumes of grid connection applications: the boom in renewable energy generation has led to a commensurate ballooning of connection applications that all jurisdictions are now grappling with, e.g. as connection applications were cheap at one point, one developer submitted >100 applications.
- Building out transmission is difficult: for basically all the same reasons it is hard in Australia, e.g. regulatory approval framework, social license, financing, etc. Regional politics can also come into play (e.g. cheap hydro from Quebec could be exported to Massachusetts via Maine, but the people of Maine blocked the project in a referendum).

Final thoughts

- During and after my Fellowship trip, two nagging questions kept coming up as ones that we don't really have good answers for in Australia:
    1. Who is providing the **strategic oversight** to steer the energy transition away from going down chaotic and painful pathways?
    2. How do we approach the **trade-offs** between technical risks, the speed of transition and economic efficiency?
- Energy Policy WA has made some attempts to answer these questions through its Energy Transformation Strategy, but in my view, there is still more work that needs to be done.
- Part of this work is purely technical (i.e. power systems analysis), and with the skilled labour bottlenecks affecting the industry, I see a lot of value in engaging and enabling as many technical experts within industry, academia and the public more broadly to contribute to this work. However, this would require the disclosure of more technical information about the power system.

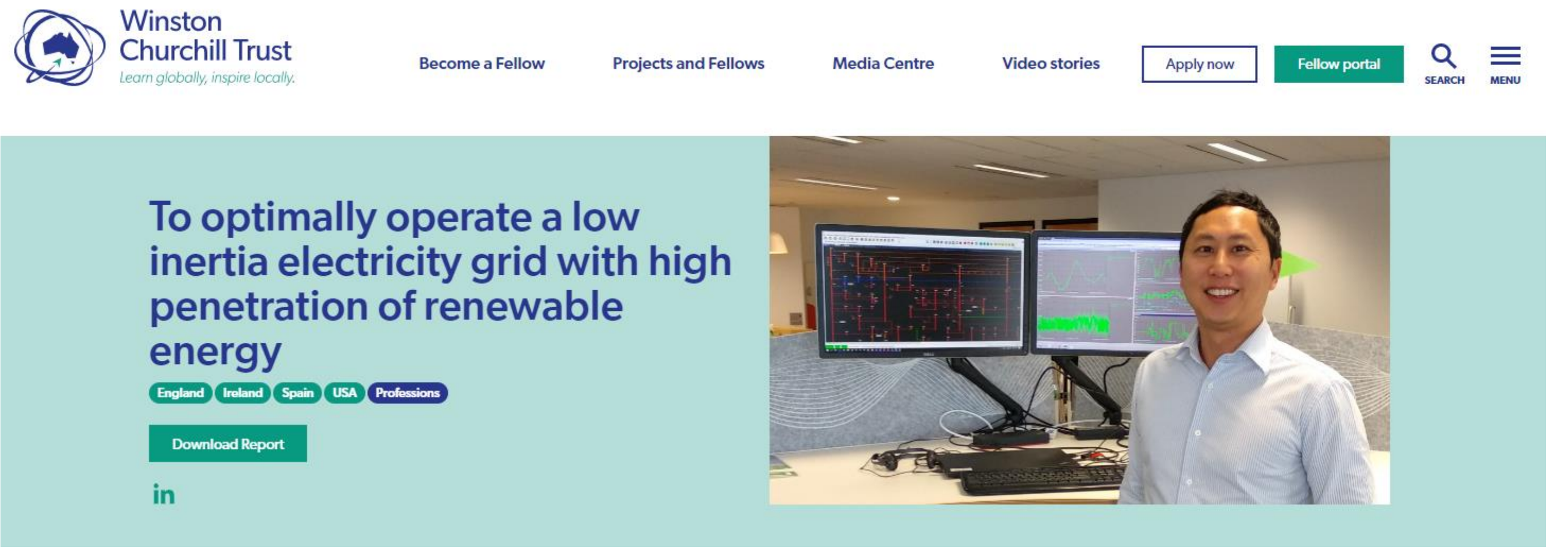
Recommendations

1. Government (including market bodies), in conjunction with industry, should start developing a framework for guiding decision making around the trade-offs between technical risks, the speed of transition and economic efficiency (which could also include the explicit pricing of technical risk).
2. Establish an independent technical advisory group, perhaps similar to the Australian Technical Advisory Group on Immunisation (ATAGI), that can provide independent strategic and system-wide advice to government and the market bodies on the technical direction of power systems in Australia.
3. Encourage Transmission Network Service Providers (TNSPs) and AEMO to provide more transparency over power system data and network models so that academic and industry researchers can independently study the power system (similar to the way New Zealand's Electricity Authority makes these datasets available freely to the public).

More information

You can download my Fellowship report from the Winston Churchill Trust website:

https://www.churchilltrust.com.au/project/to-optimally-operate-a-low-inertia-electricity-grid-with-high-penetration-of-renewable-energy/

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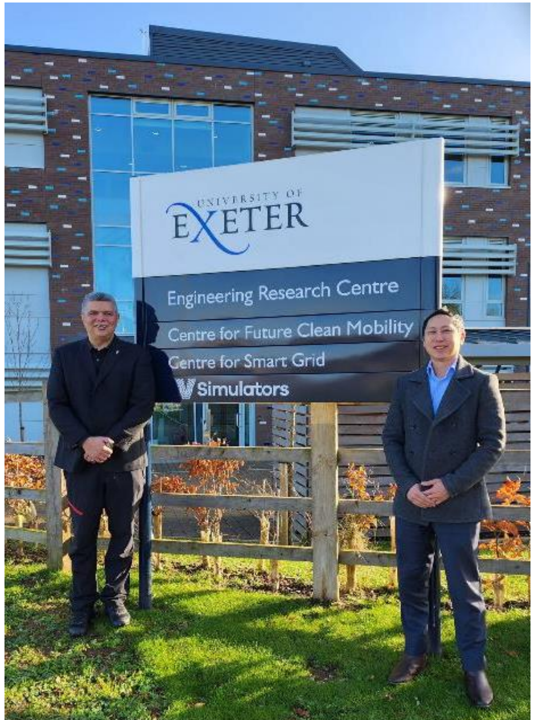
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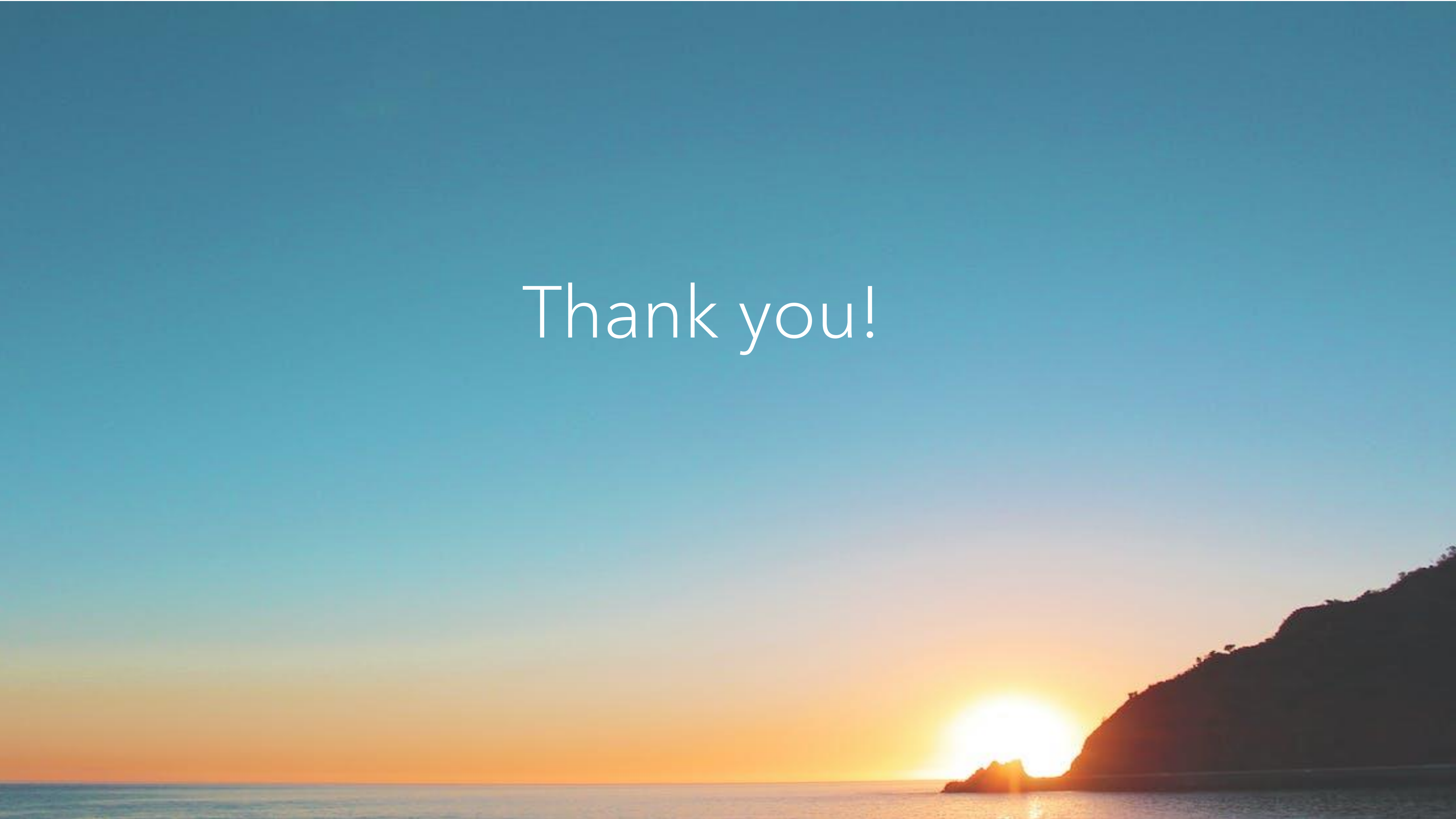
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