THE AUSTRALIAN EXPERIENCE IN THE GLOBAL CONTEXT

Australian National University

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ANU Grand Challenge: Zero-Carbon Energy for the Asia-Pacific

Motivating Energy Change:

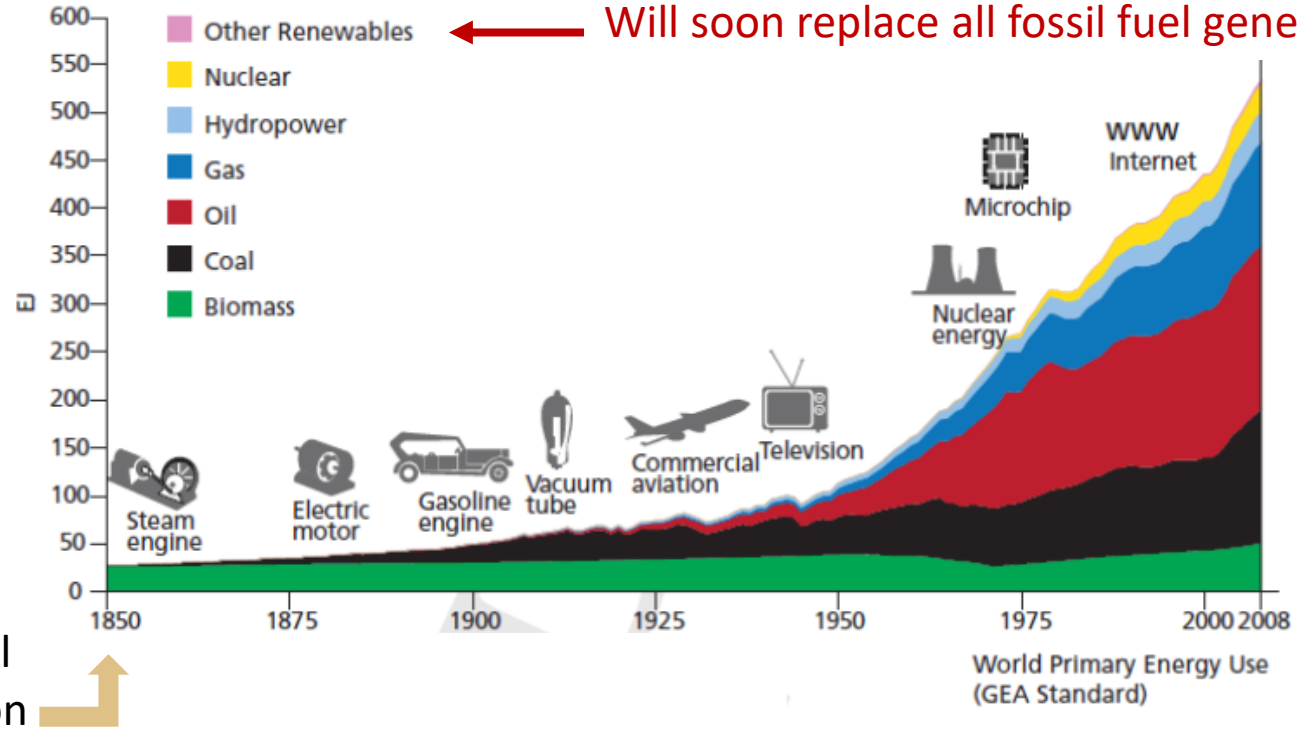
- Climate change
- Energy *and* security
- Energy access
- Energy productivity

Take-home message:

There is a massive transformation taking place in the world's energy supply that will affect everything – and in particular –

Energy and Security

Global energy consumption



Source: International Institute for Applied Systems Analysis (IIASA) 2012, Global Energy Assessment Technical Summary

Compare to the Industrial Revolution

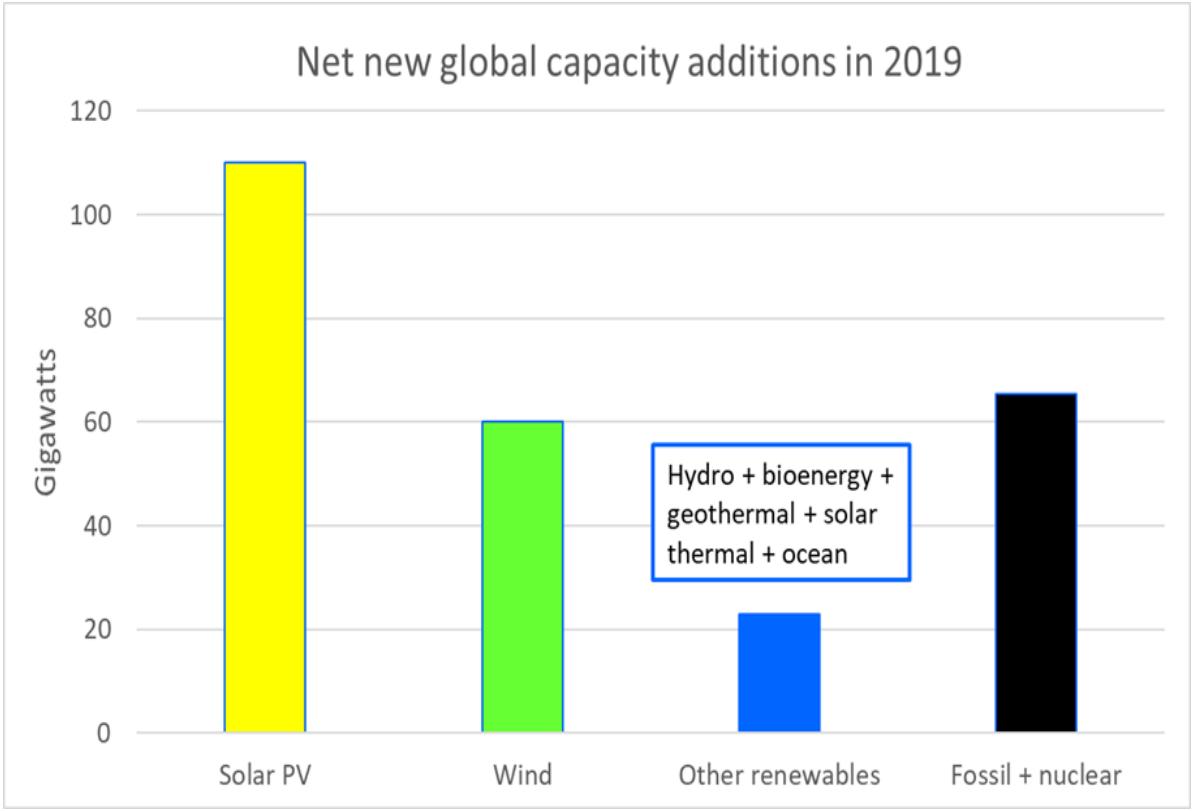
The Industrial Revolution:

- Driven by technology
- Unplanned and unforeseen
- Caused huge social and economic dislocation
- Government went missing, resulting in chaos

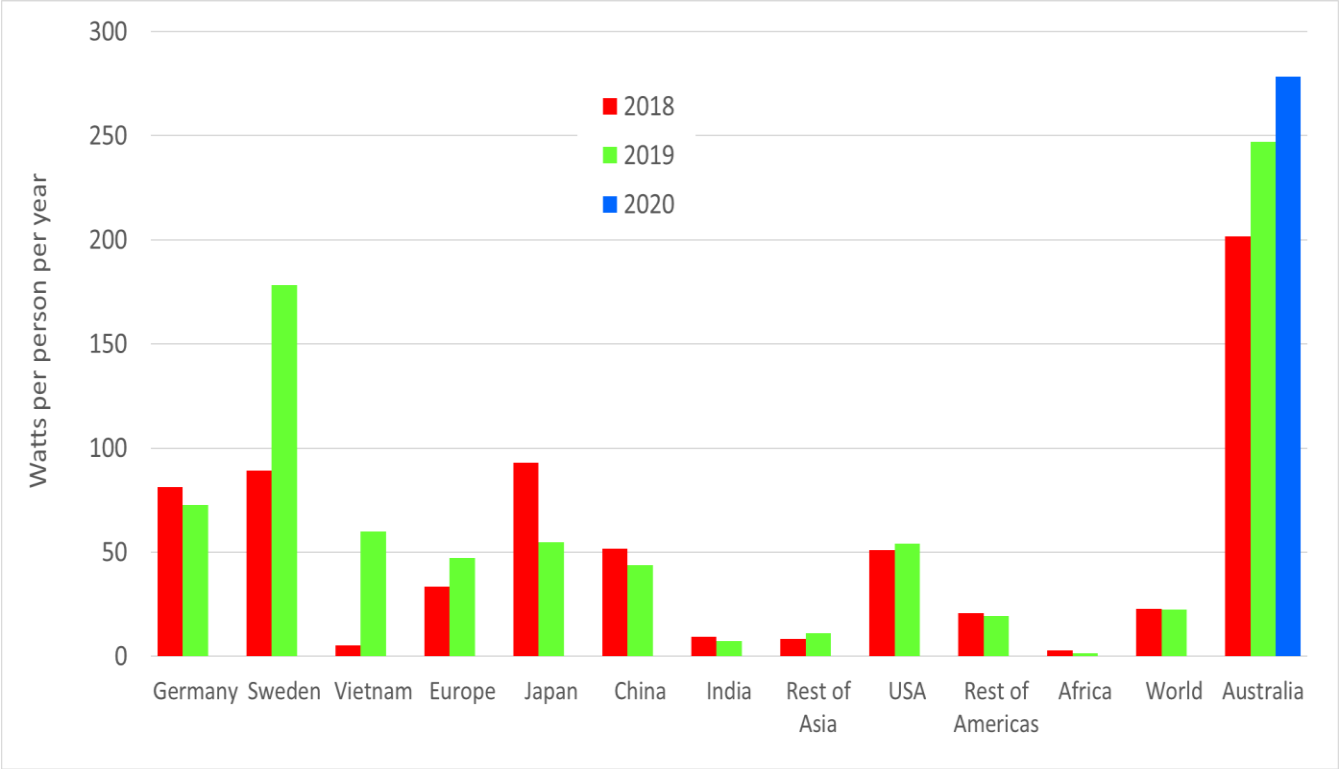
The Energy Transition:

- Similar in scope and magnitude
- Driven mainly by climate change
- Facilitated by (fortuitous?) advances in technology
- Was completely foreseen and could be planned
- Should avoid social and economic dislocation
- Government has a key role

Global generation installations 2019



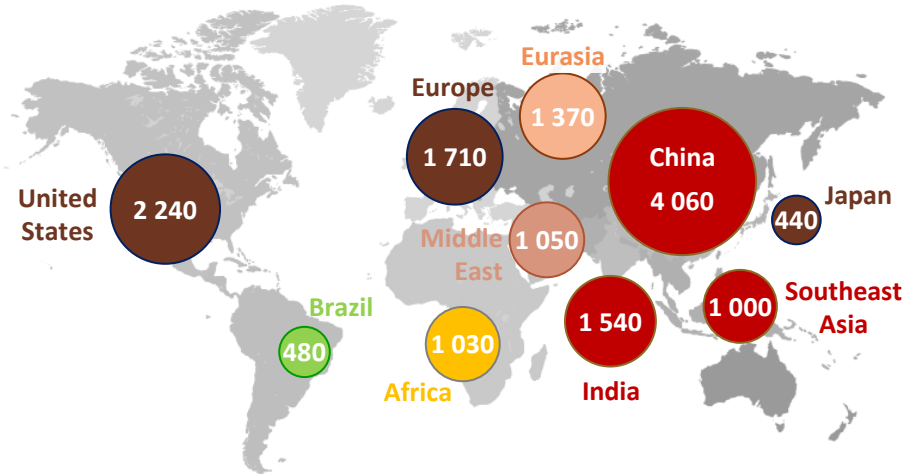
Global annual per capita RE installation



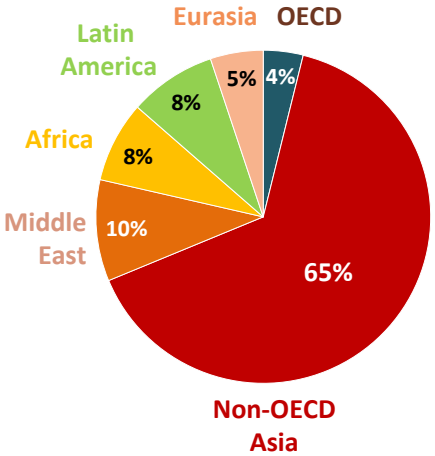
Australia leads the world: >250W per capita p.a. RE installation rate

Energy growth shifts to Asia

Primary energy demand, 2035 (Mtoe)



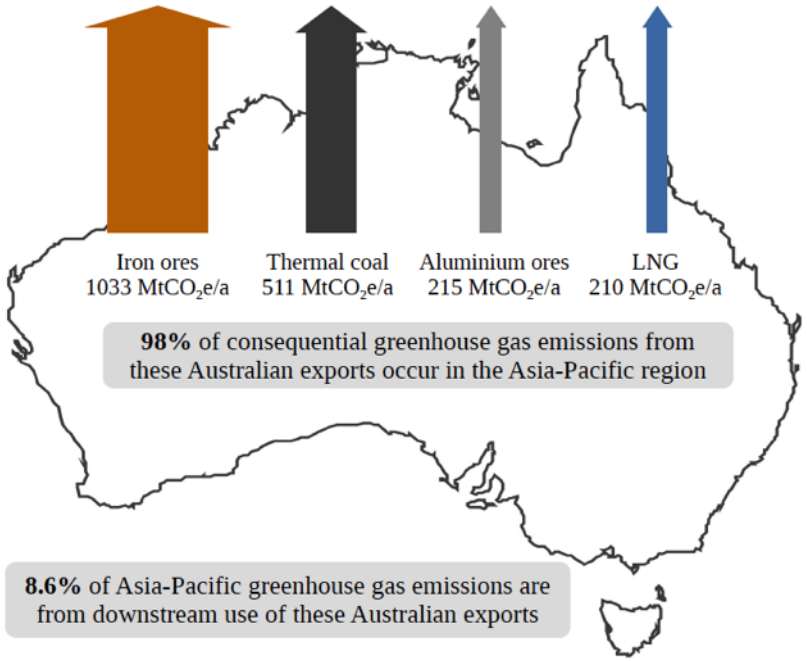
Share of global growth 2012-2035



"China is the main driver of increasing energy demand in the current decade, but India takes over in the 2020s as the principal source of growth"

Source: International Energy Agency World Energy Outlook 2013

ANU Grand Challenge:
Zero-Carbon Energy for the Asia-Pacific



Total emissions = 1,969 $MtCO_2e/y$

~ 3.7 x Australia's domestic emissions

A future Australian export scenario

Export the same amount of energy as now:

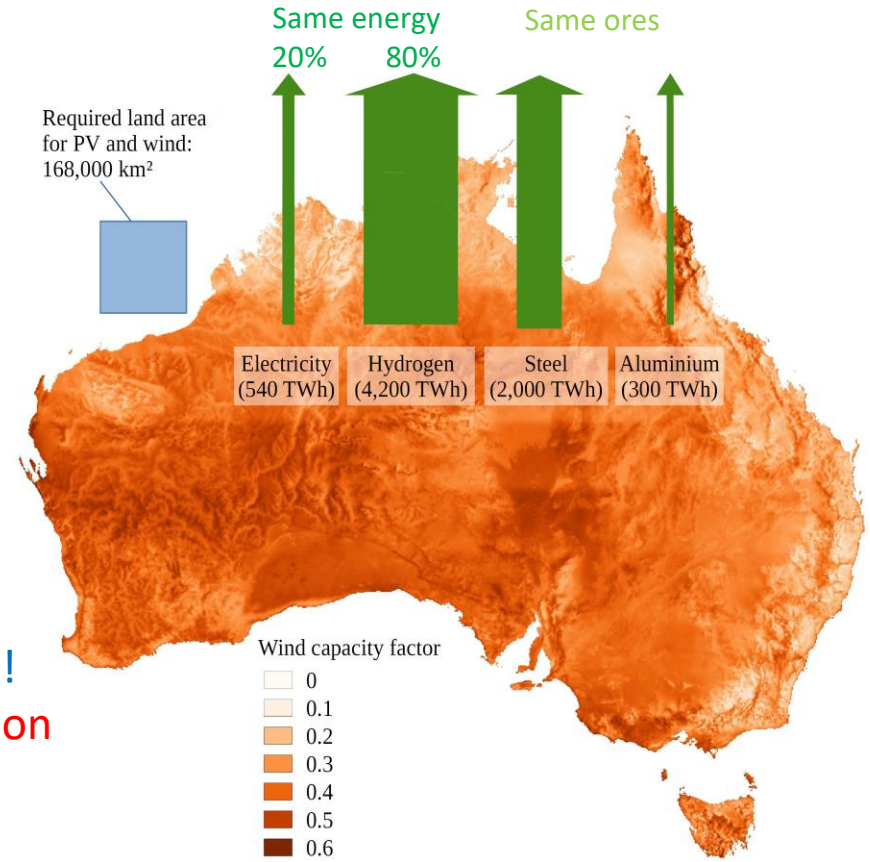
- 80% as hydrogen (65 Mt/year)
- 20% renewable electricity (540 TWH/y)

Mine the same amount of ore and export:

- 510 Mt/y as green steel (6 Mt/y steel now)
- 18 Mt/y as green aluminium (2 Mt/y Al now)

Total renewable electricity required

- 7,040 TWh/y
- 27 x Australia's present electricity generation!
- Add 100% domestic RE + 200% in electrification
  = 2,700 + 100 + 200 = 3,000% renewables!

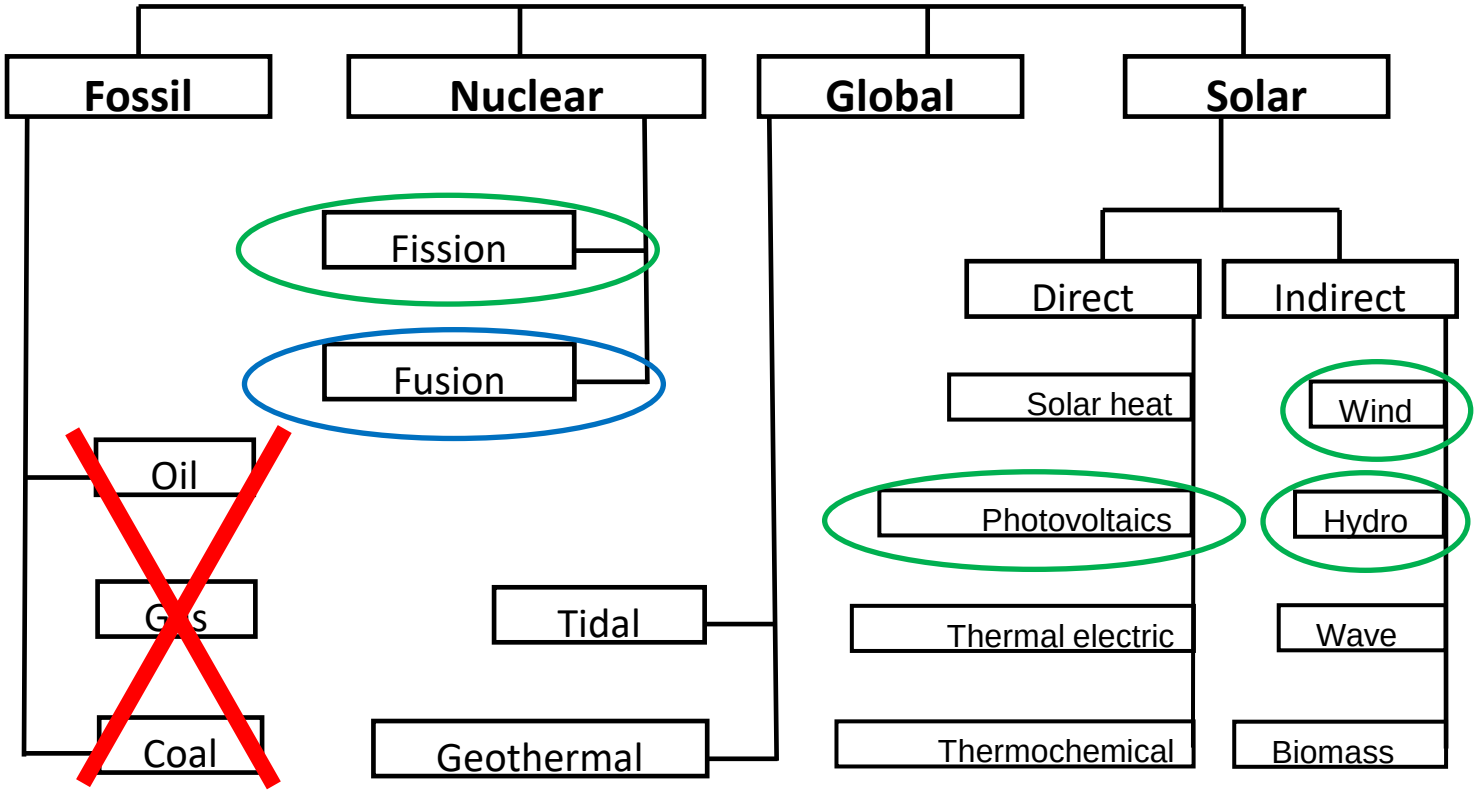


Question break

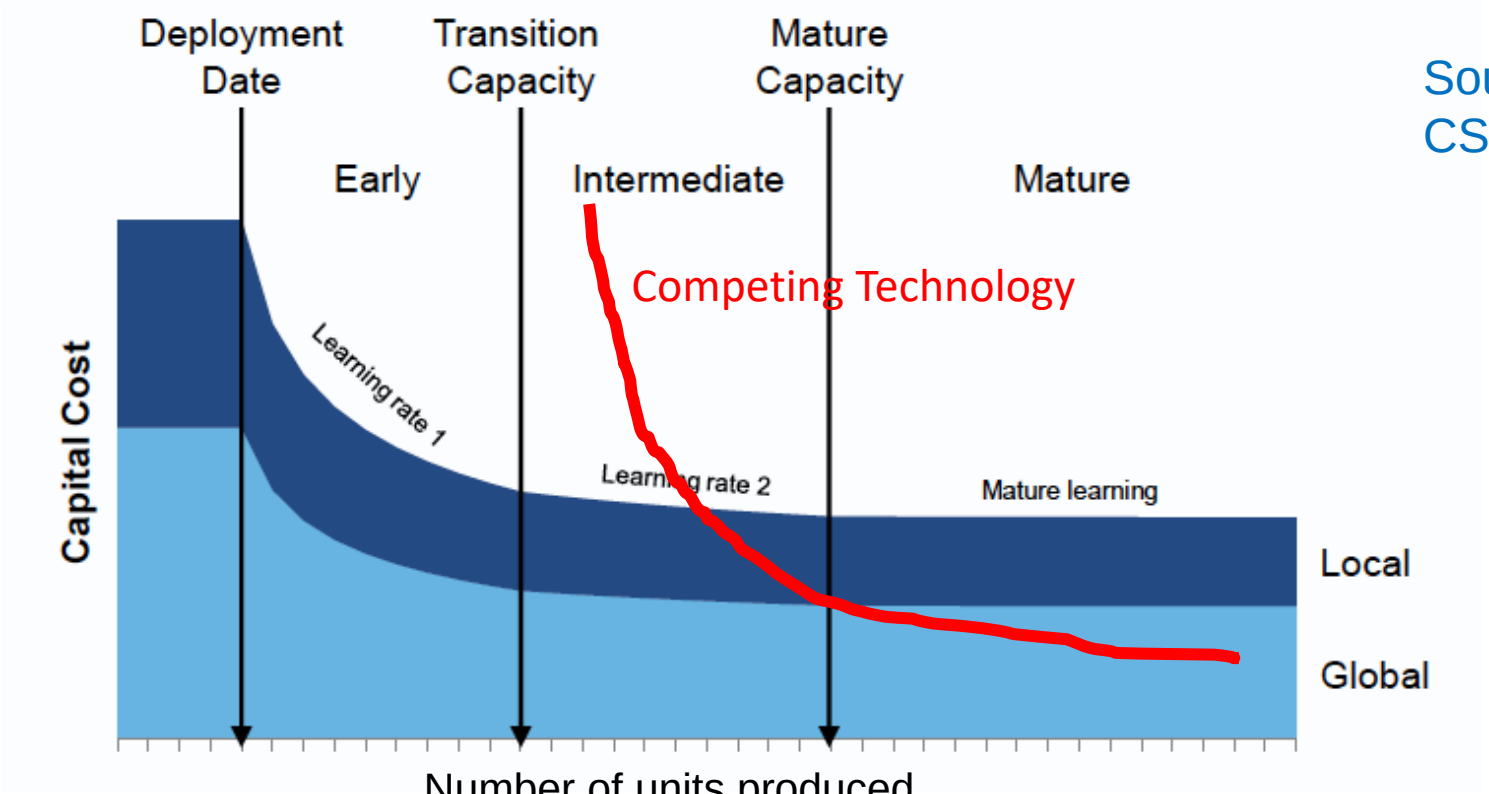
- Any questions?
- Select “raise hand” to ask a question
- Select “lower hand” to remove it

Technology

Energy generation sources



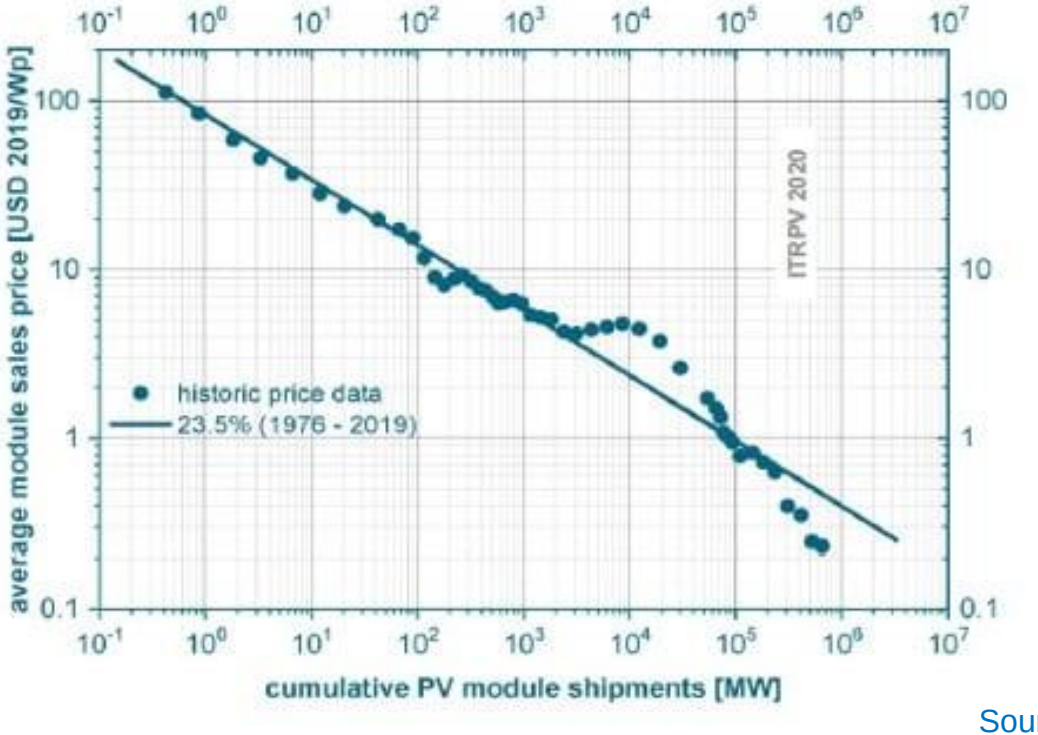
Learning rates



Source: CSIRO

Technology learning rates: solar PV

1/500th price per module!



Time →

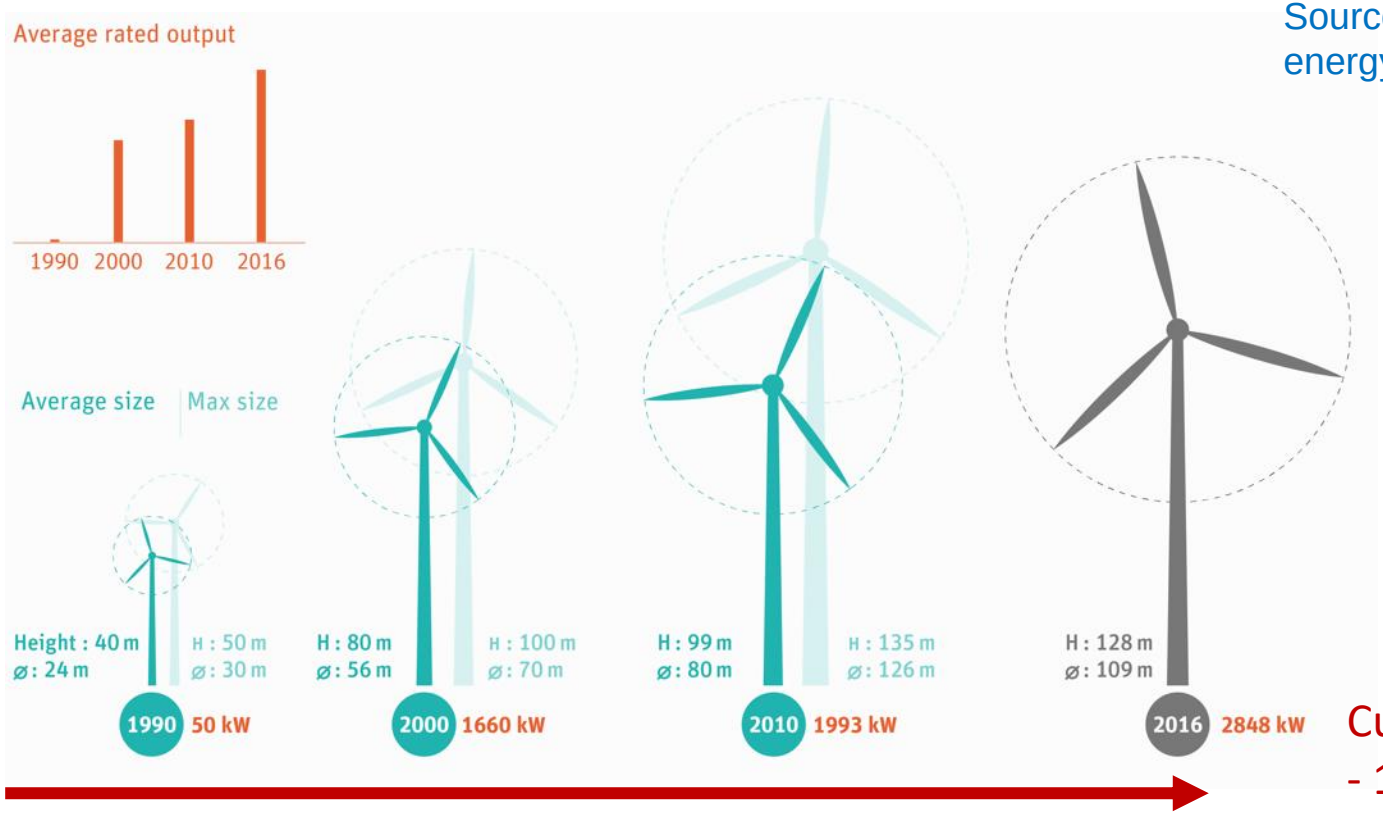
Doubling the units of production decreases the price by 23.5%

This represents a compound annual growth rate (CAGR) of 33% for the last 40+ years!

Source: 11th International Technology Roadmap for PV (2020)

Technology learning rates: wind

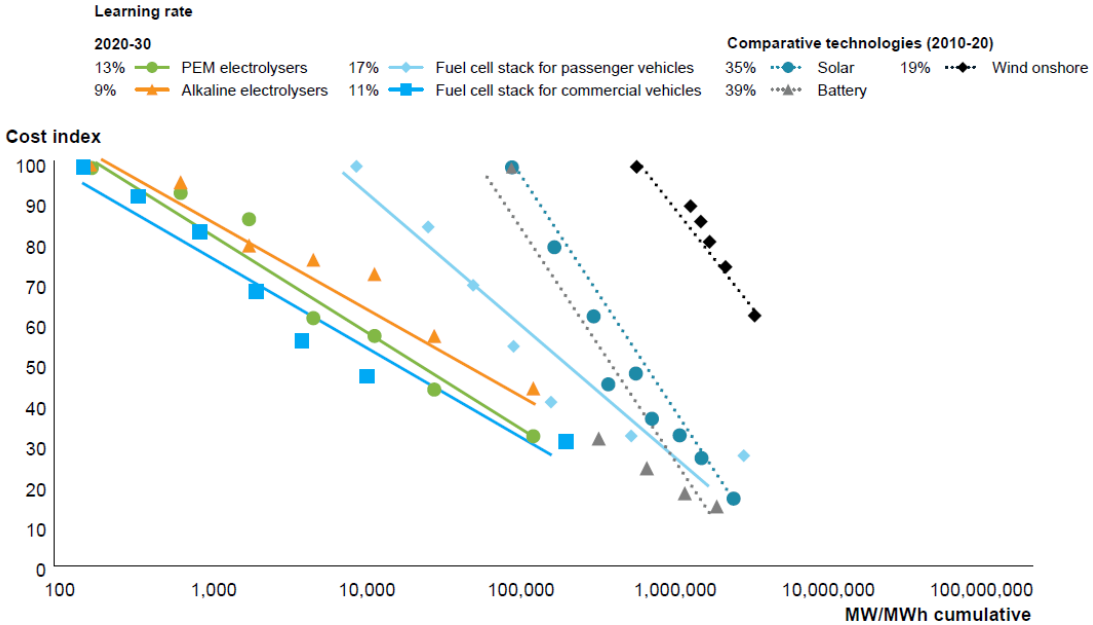
Source: energytransition.org



Currently 5 MW - 100x capacity

Learning rates for various technologies

Capex development of selected technologies over total cumulative production
Indexed to 2020 values (2010 for comparative technologies)[1]



1. Installed base: assuming 50/50 split of electrolysers volume with 50-75% utilisation; assuming 115 kW for PV, 250 kW for buses and 300 kW for trucks; LCOE used for solar cost; batteries in MWh

SOURCE: McKinsey; IRENA; BNEF; Ruffini & Wei (2018) (learning rates); DoE

Levelised cost of electricity (LCOE)

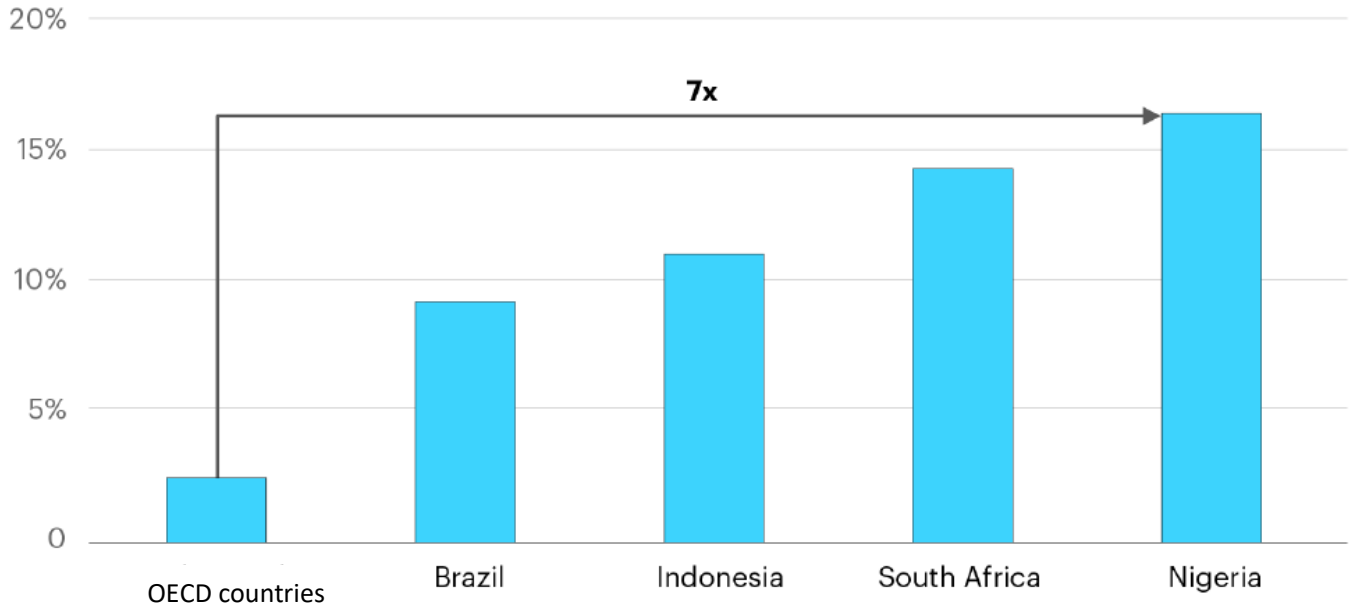
$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Caution: assumes plug-and-play !

I_t = Investment in year t
M_t = Operations and maintenance
F_t = Fuel expenditure
E_t = Electricity generation
r = Discount rate
n = Life of system (amortisation)

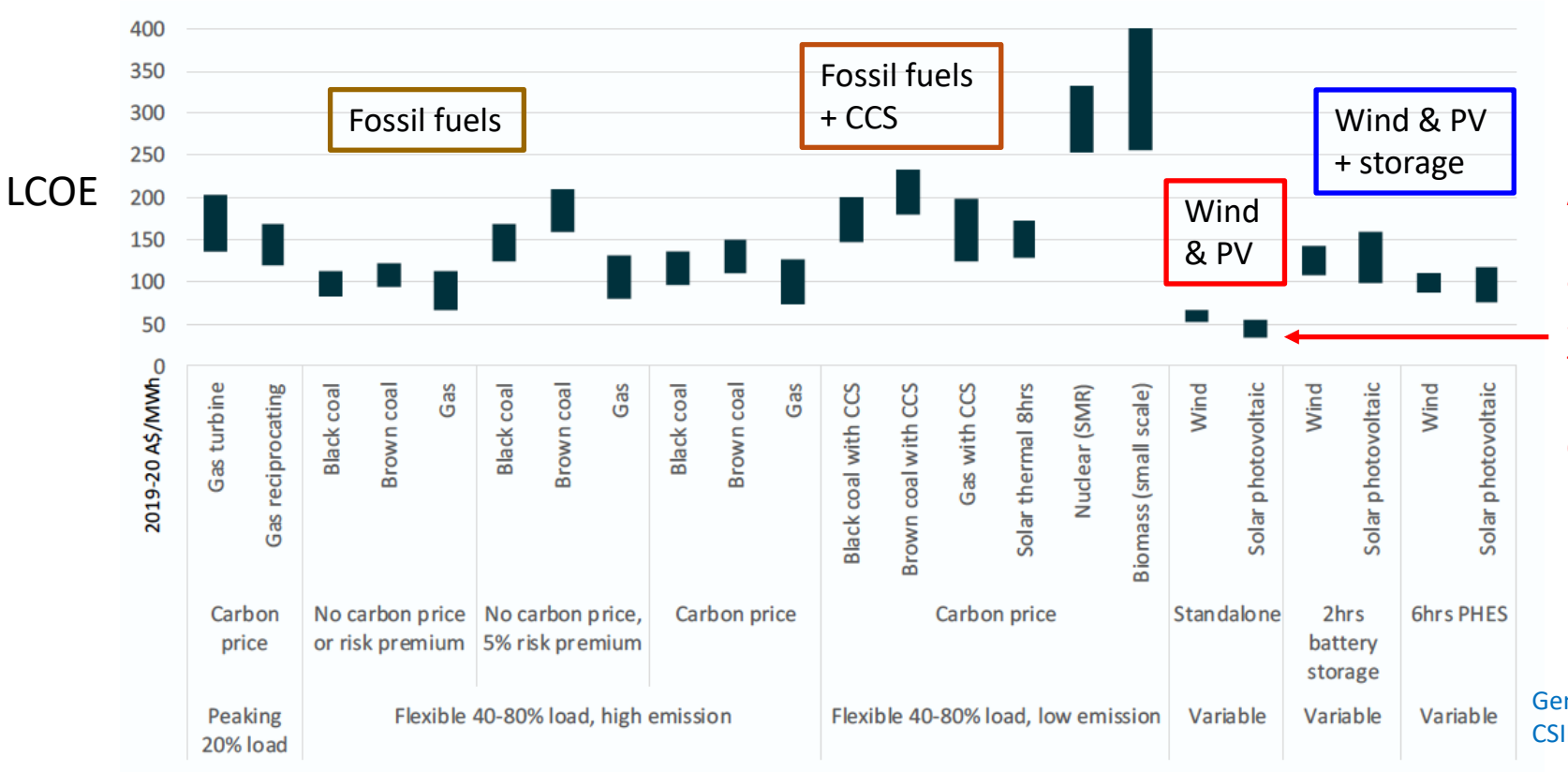
Cost of capital by location

Indicative cost of capital by economy (nominal base rates plus market risk premium), 2020
Financing Clean Energy Transitions in Emerging and Developing Economies



International Energy Agency

Australia: solar and wind now cheaper than coal



ACT 2020 reverse auction $45/MWh fixed price ($35-37 in constant $)

GenCost 2019/20
CSIRO & AEMO

Question break

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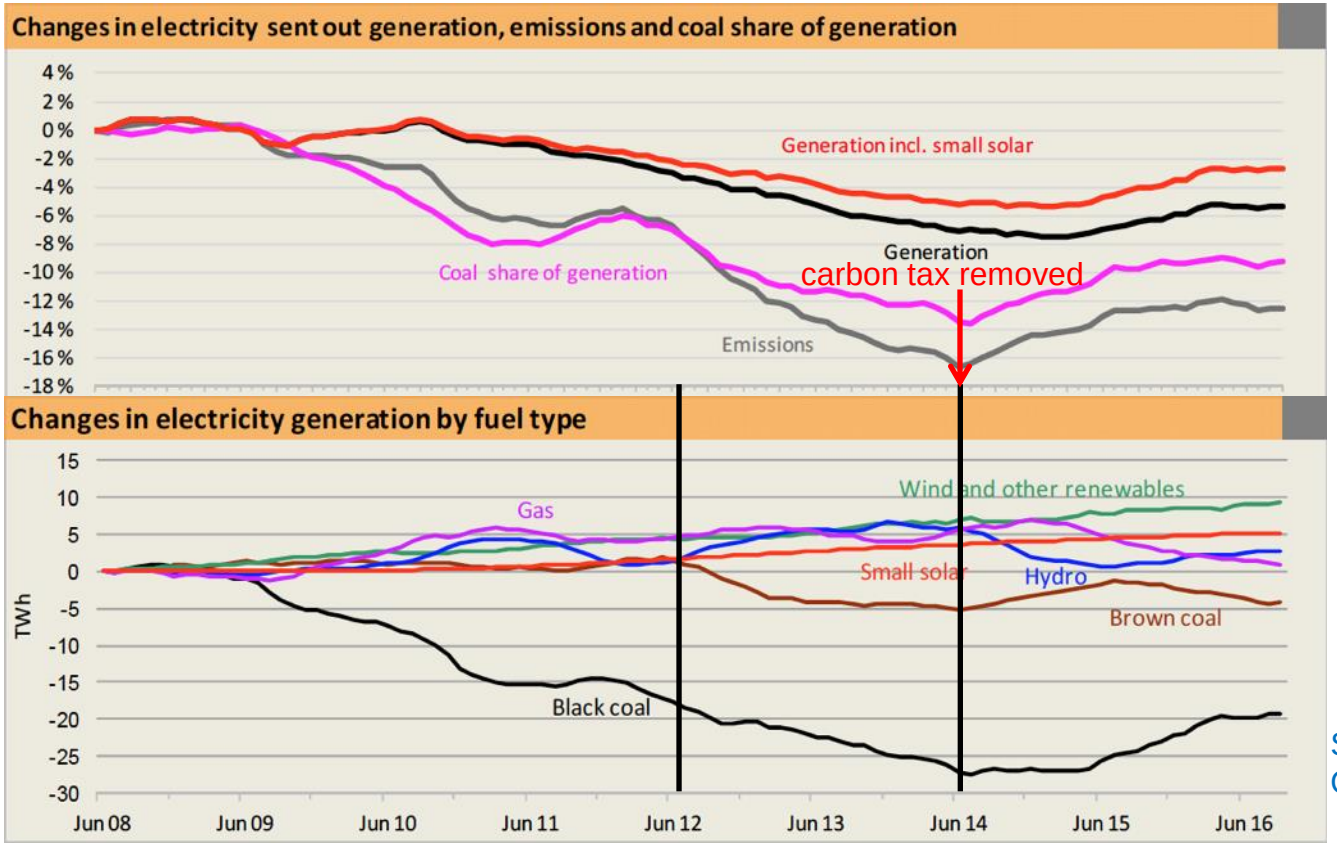
Policy

Electricity demand and sources



Source: Pitt and Sherry, October 2016

The Finkel Review of the NEM

Argues that consistent, long term measures are needed to address climate change and to provide industry certainty:

- ~~Carbon pricing scheme~~
- ~~Emissions Intensity Scheme~~
- ~~Clean Energy Target~~
- ~~National Energy Guarantee~~

= ruled out by Coalition Party Room

Why does policy certainty matter?

Policy certainty

= de-risks investment planning

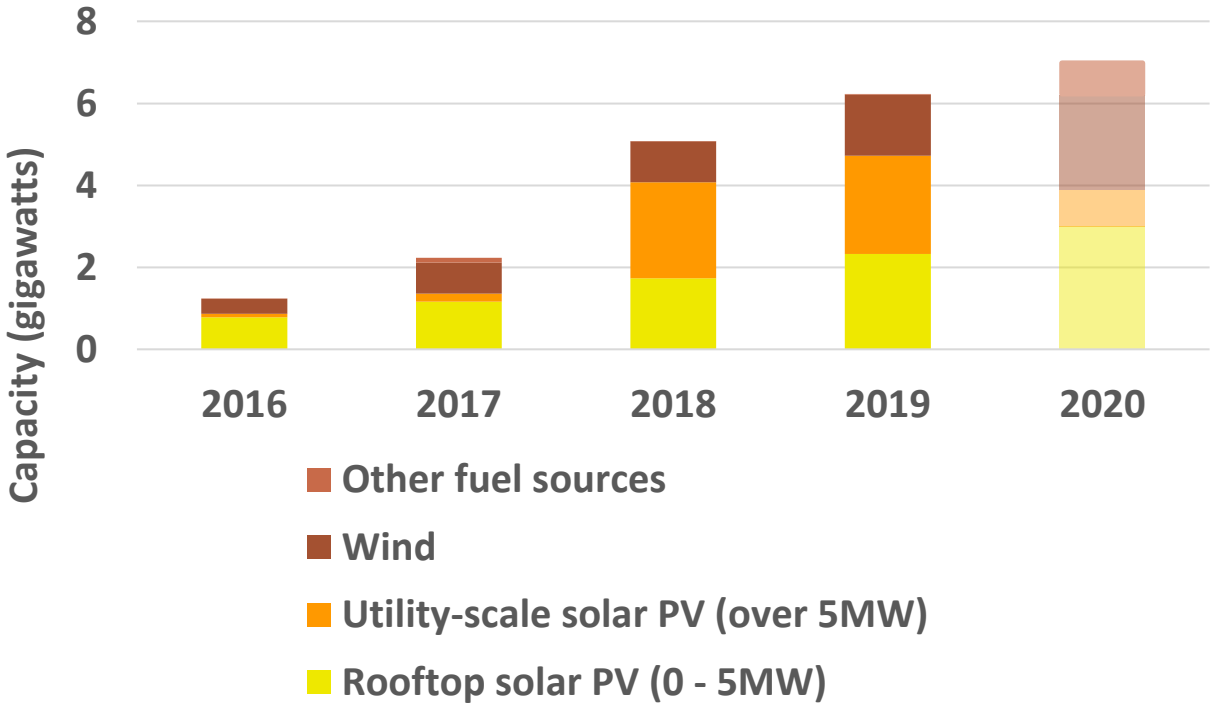
= lowers the cost of finance

= makes the energy transition cheaper

= “keeps electricity prices down”

Australian Renewable Energy Pipeline

Source:
Clean Energy Regulator



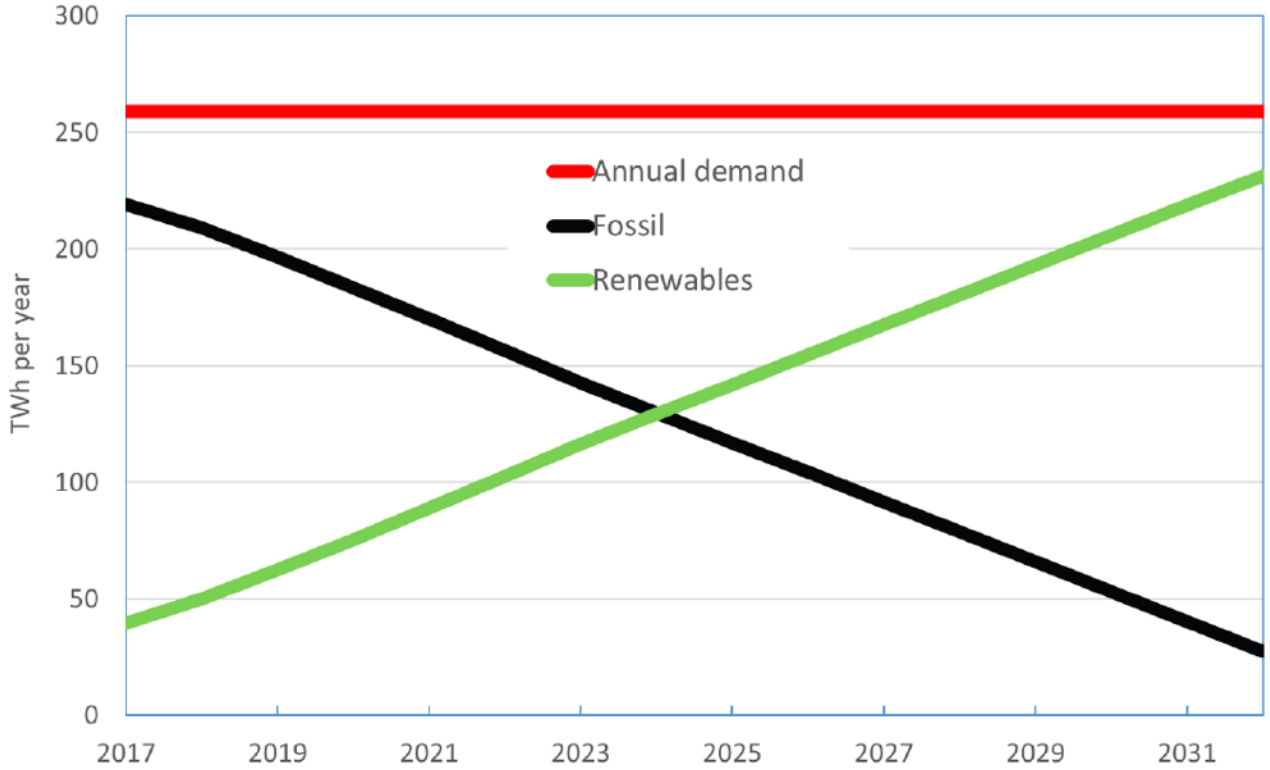
Low large-scale investment <2016 because of govt. policy uncertainty

2020 Large-scale renewable energy capacity installation rate: ~ 4.1 GW p.a.
2020 Small-scale renewable energy capacity installation rate: ~ 3.0 GW p.a.

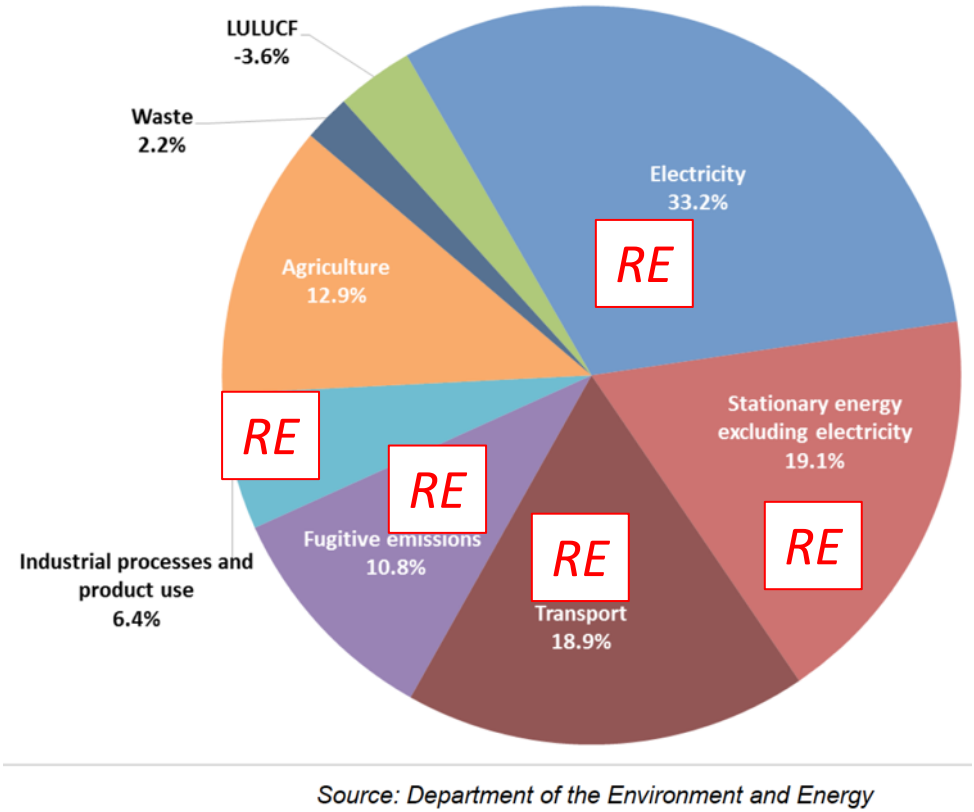
} ~7.1 GW p.a.

Do you have solar on your roof?

Renewable / fossil replacement rate



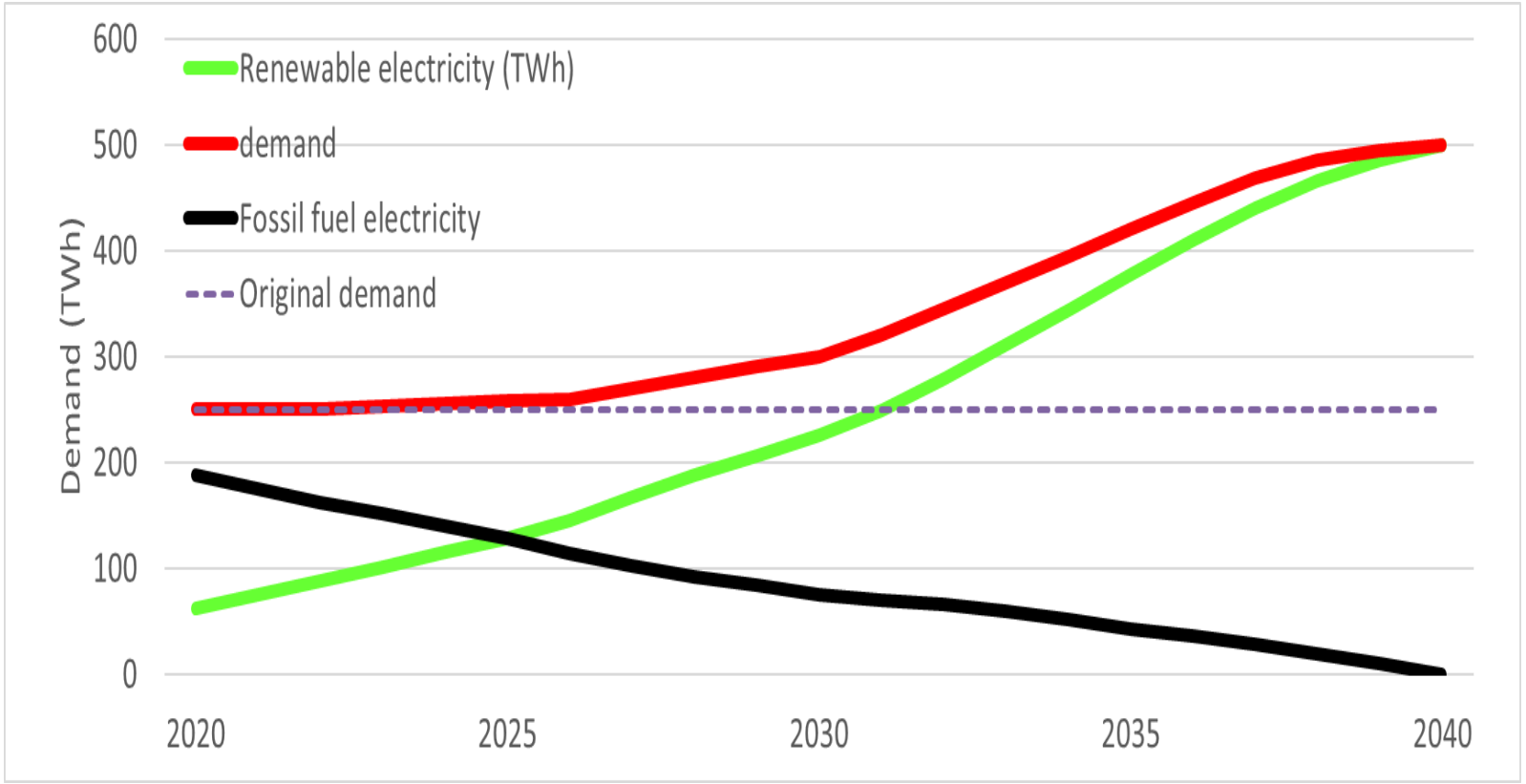
Electrification of all energy use



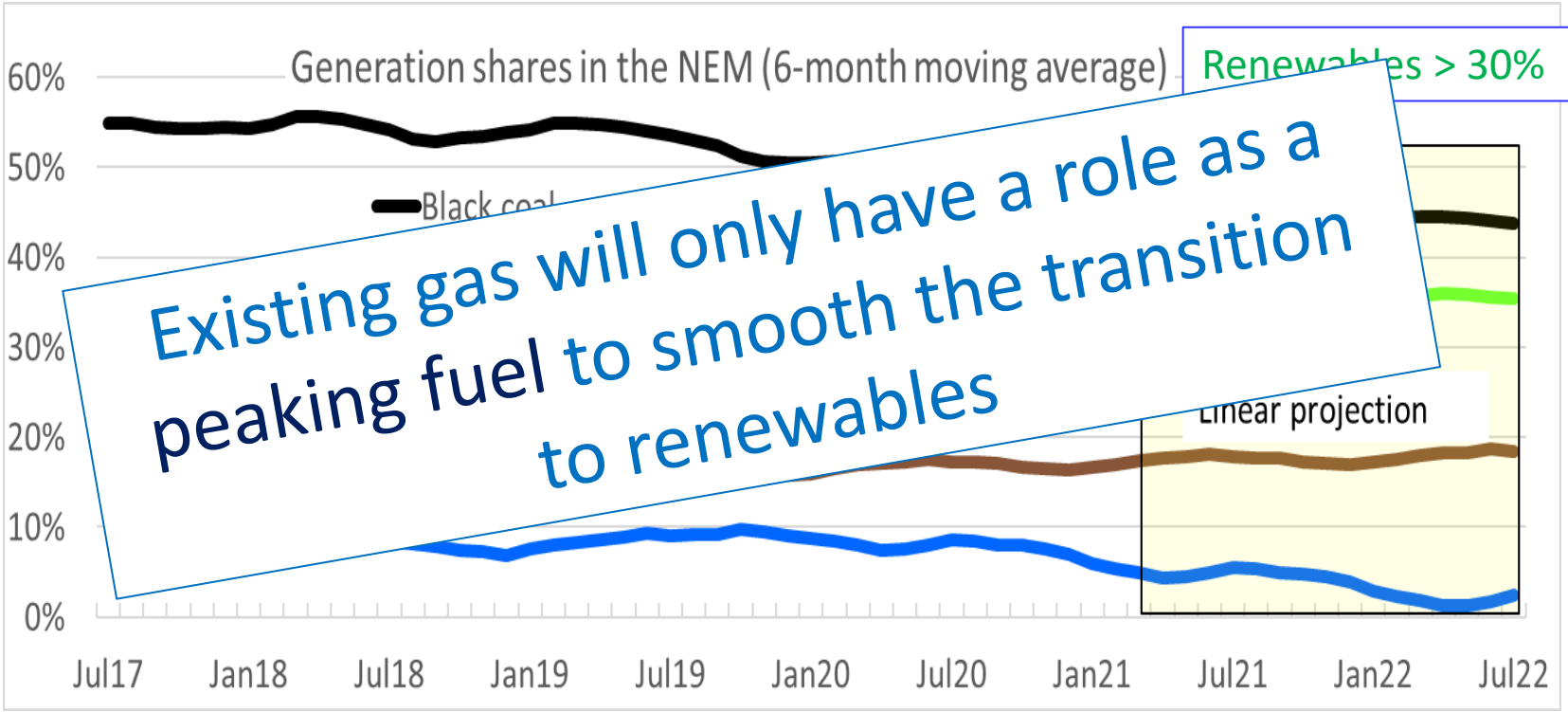
Source: Department of the Environment and Energy

IF the electricity sector provides the best opportunity to make the most rapid impact, then this requires >>28% GHG emissions reductions by 2030 given that the other sectors are harder to address.

Renewable/fossil replacement with electrification



National Electricity Market Generation



Renewables > 30%

Existing gas will only have a role as a peaking fuel to smooth the transition to renewables

Gas ~ 5%

Hydrogen in Australia – will it replace gas?

- Electricity generation (gas)
- Low temp. heating (gas)
- [illegible] (gas)
- Fuel cell EVs

- No – renewables cheaper
- [illegible] e.g. solar thermal
- Partly e.g. ammonia
- Yes – long range transport

Exports will dominate domestic hydrogen consumption

How high can renewables go?

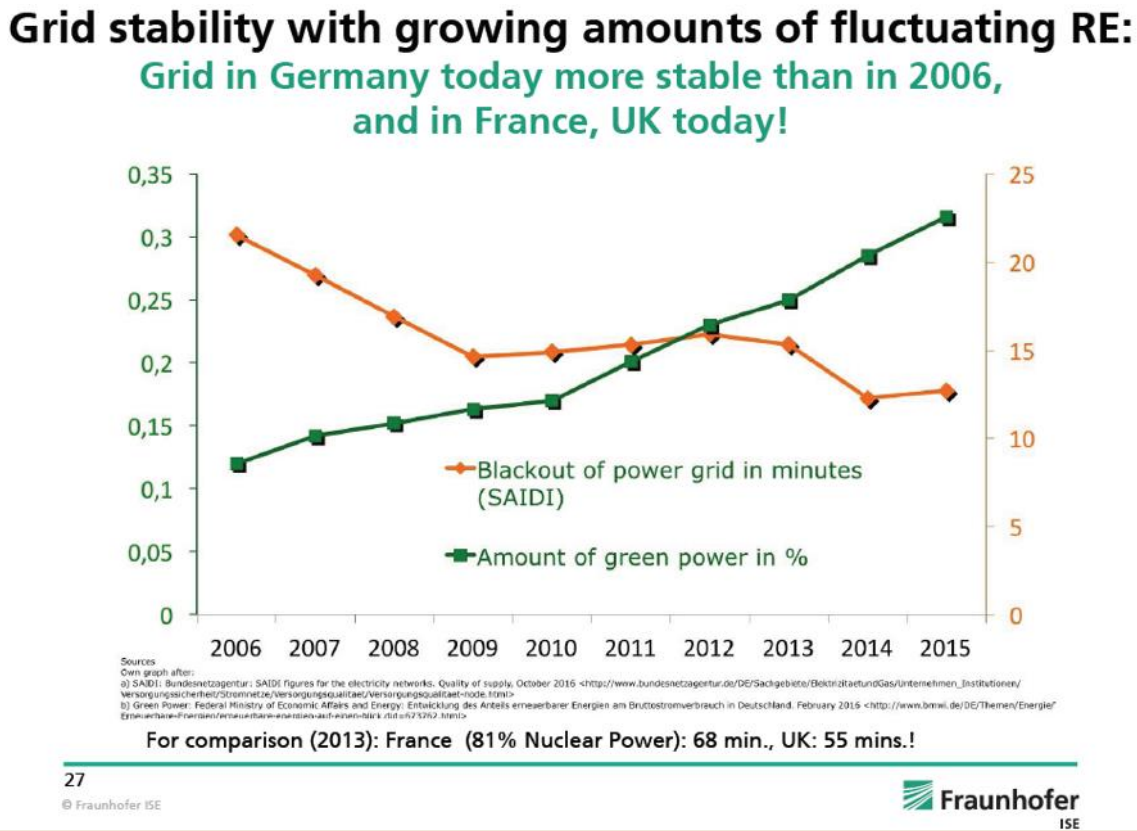
- The higher the penetration (>50 %), the higher the cost to cover intermittency:
  - Overbuild supply
  - Build additional storage capability
  - Build additional network infrastructure

} Adds 50% to LCOE but still cheaper than coal

- Will this provide the same level of *reliability* of supply? Yes – perhaps better
- Will this provide the same level of *security* e.g. increasing extreme weather events? Maybe

Grid stability in Germany

Source:
Prof. Eicke Weber
Fraunhofer ISE



Renewable Generation

Question on notice:

What is the fraction of renewable electricity in your country?

Australia: 31.4% of National Electricity Market in 2021

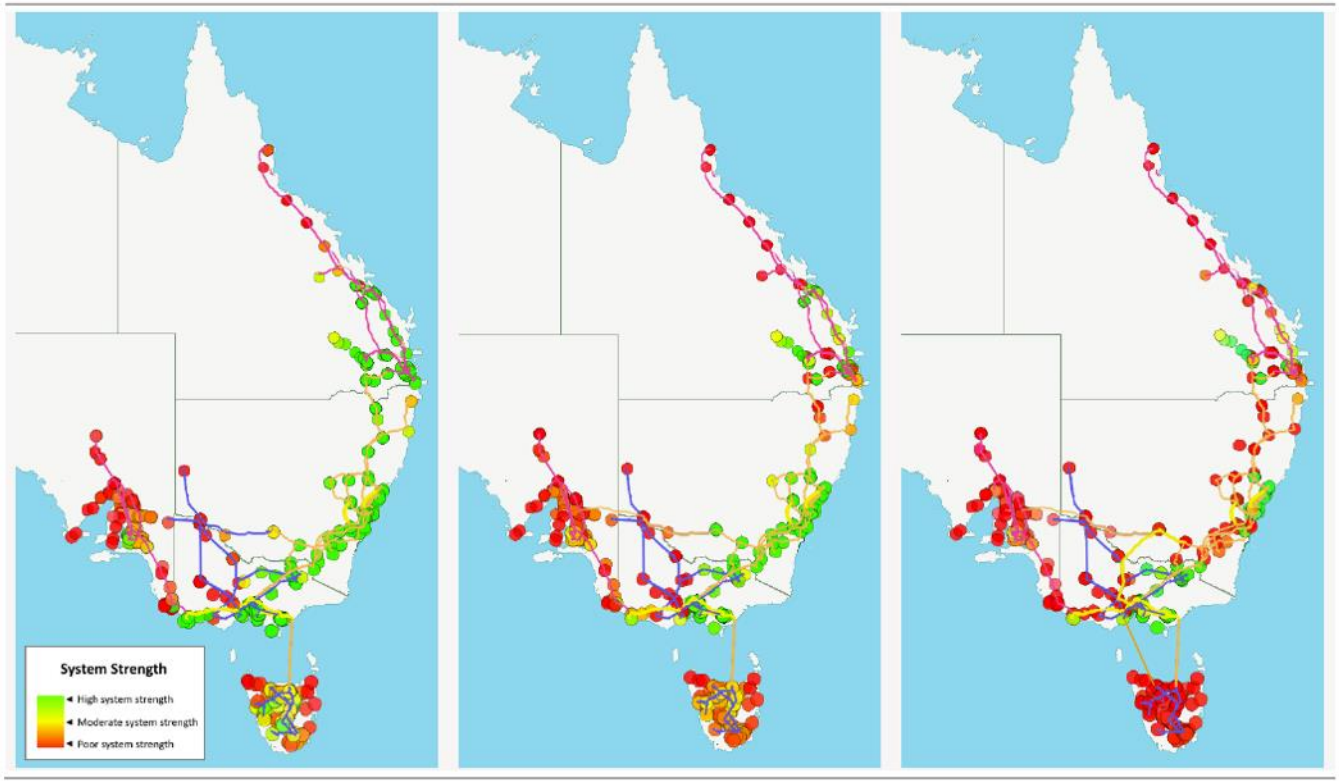
Energy and Security

Australian NEM resilience

The Australian National Electricity Market (NEM) is the world's longest interconnected electricity system – over 5,000 kms end-to-end from Port Douglas in North Queensland to Port Lincoln in South Australia.

Source: AEMO 2018 National Transmission Network Development Plan

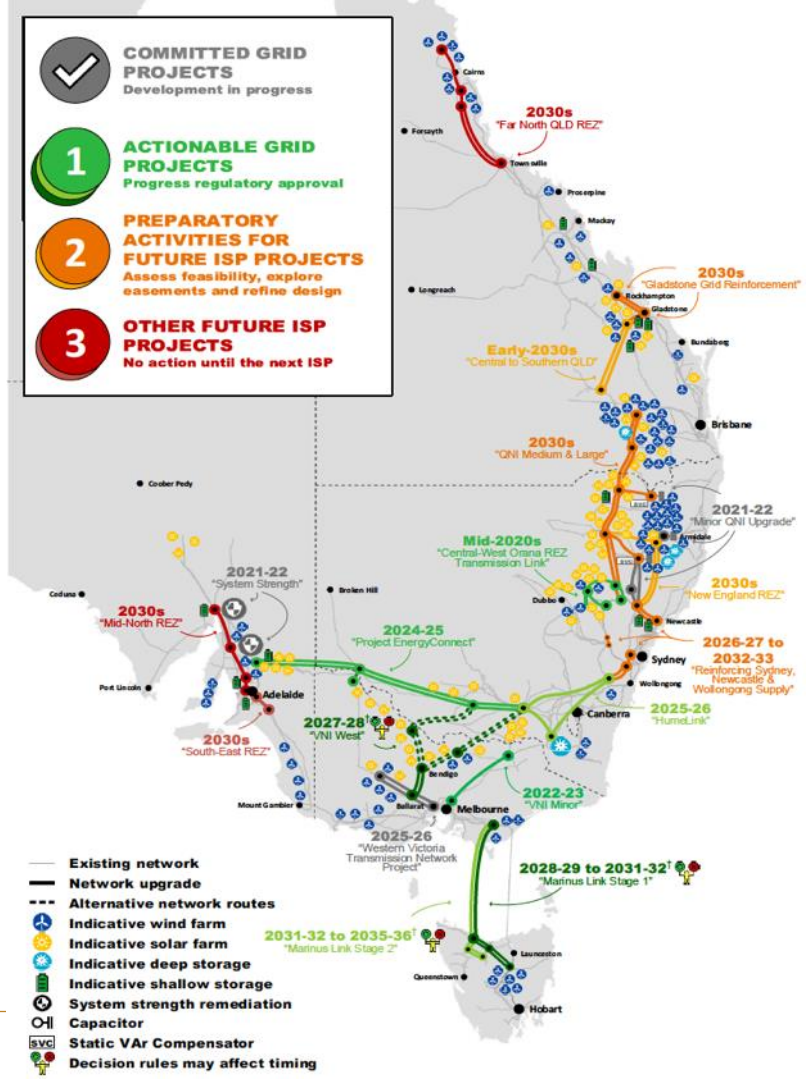
Figure 38 Projected system strength assessments for 2018-19 (left), 2028-29 (middle), and 2038-39 (right)



Integrated System Plan

AEMO – central planning!

- Renewable Energy Zones
- Connected to major demand centres by major HVDC transmission lines
- Backed up by:
  - major storage
  - voltage and frequency control



The ‘Internet of Energy’

- Millions of generators, storage centres and demand response
- Scales from kW to GW, kWh to TWh
- Much greater interconnectivity between nodes
- Robustness from:
  - Multiplicity of key nodes – greater redundancy
  - Multiplicity of transmission pathways – greater redundancy
  - No longer vulnerable to removal of a major thermal power station
- Vulnerability from:
  - More cyber attack entry points – but a centralized system would also be vulnerable

The rise of indigenous energy sources

Trend to national self-sufficiency:

- Domestic renewables – solar and wind
- Domestic gas – coal seam, shale, tight gas
- Domestic liquid fuels – shale oil, biofuel, synthetic fuels
- Electrification – transport, domestic, industry
- Nuclear – small fuel volume, fast neutron reactors

Security implications of Energy Change

- New energy capabilities
- Fewer energy resource wars in the long term
- Less supply chain interdiction
- Potential domestic energy security issues requiring balancing
- Potential nuclear proliferation
- Cybersecurity interdiction of disseminated energy systems
- Resilience from the ‘Internet-of-Energy’

Energy security in your country

Discussion:

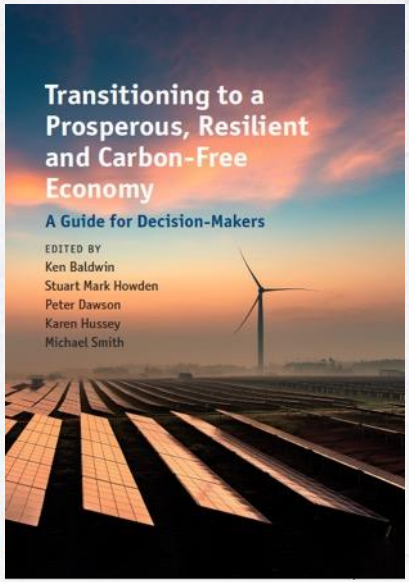
What are some of the key energy security issues in your country?

World-wide trends in energy

- Rapid *decarbonisation* of the energy sector – solar, wind, hydro, nuclear (fusion?)
- Increasing availability of domestic energy sources results in *greater* energy security
- Increased vulnerability to cyber threats
- More disseminated generation, storage and demand response (the ‘Internet-of-Energy’)

Cambridge University Press Book

"This book is a comprehensive manual for decision-makers and policy leaders …… the book presents the tools decision-makers need to achieve rapid decarbonisation, whilst unlocking and maintaining productivity, profit, and growth."



I want this title to be available as an eBook

Transitioning to a Prosperous, Resilient and Carbon-Free Economy

A Guide for Decision Makers

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01 EXTRA ITEMS