Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA



The future Australian National Electricity Market – how renewable, how distributed, how synchronous, and how much storage?

Iain MacGill

Associate Professor, School of Electrical Engineering and Telecommunications
Joint Director (Engineering), CEEM

Machines2018 – 19th Annual Conference

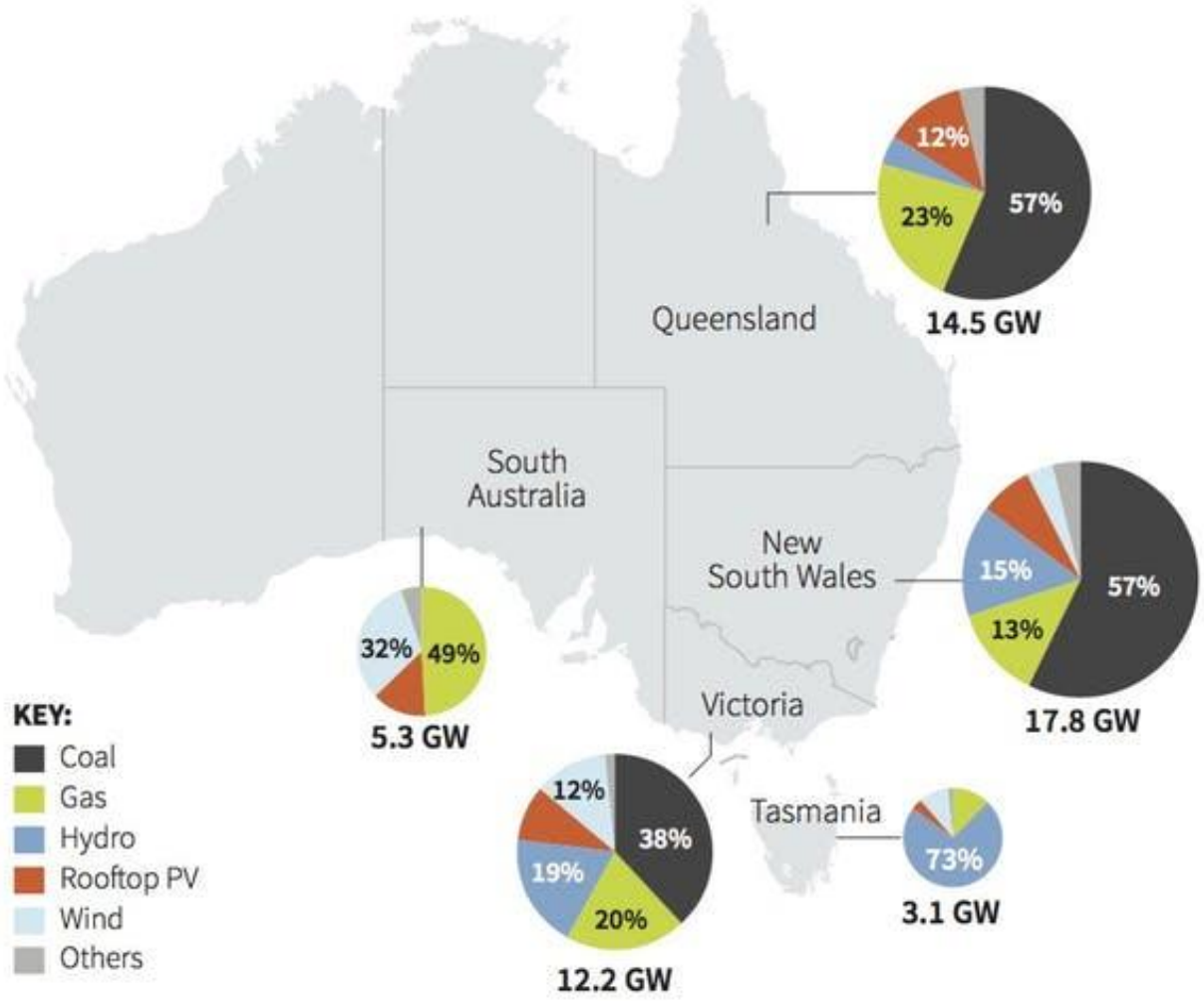
Coogee, 29/10 – 1/11/2018

Australia's National Electricity Market

The National Electricity Market (NEM) covers eastern Australia, from Queensland to Tasmania.

POWER GENERATION BY SOURCE

NEM total: **52.8 GW**



Source: NEM. Data as of June 14, 2017

J. Wu, C. Inton, 14/06/2017

REUTERS

A destination – shaped by energy trilemma

Choose any two?

Balancing the 'Energy Trilemma'

Energy Security
The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand.

Energy Equity
Accessibility and affordability of energy supply across the population.

Environmental Sustainability
Encompasses the achievement of supply and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.

ENERGY SECURITY

"To promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to –

- *price, quality, safety, reliability, and security of supply of electricity; and*
- *the reliability, safety and security of the national electricity system."*

National Electricity Law (Schedule to the National Electricity (South Australia) Act 1996), s.7

ENERGY EQUITY

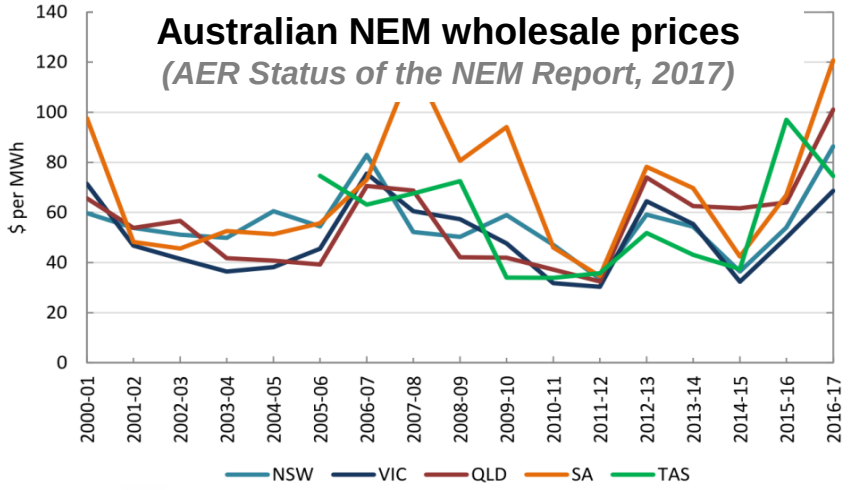
(World Energy Council, 2016)

ENVIRONMENTAL SUSTAINABILITY

Might get none…currently high NEM wholesale & retail prices, emissions, *although now improving*

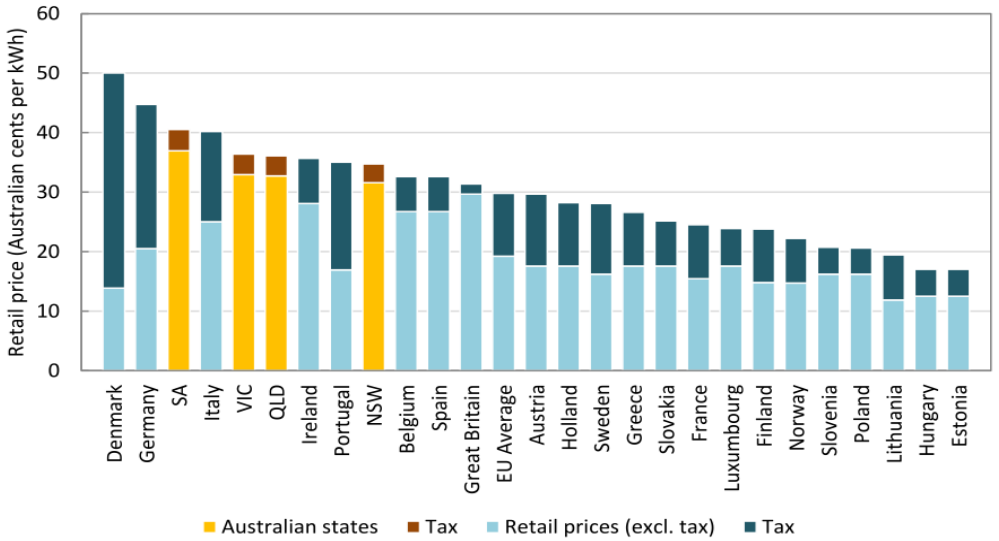
Australian NEM wholesale prices

(AER Status of the NEM Report, 2017)



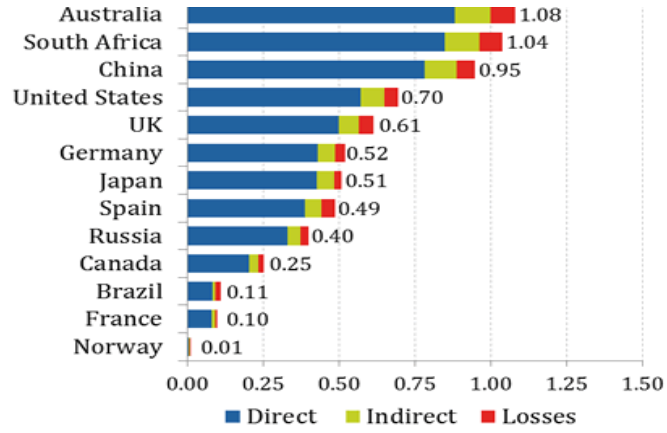
International retail electricity price comparison

(ACCC Retail Price Competition Inquiry, 2017)



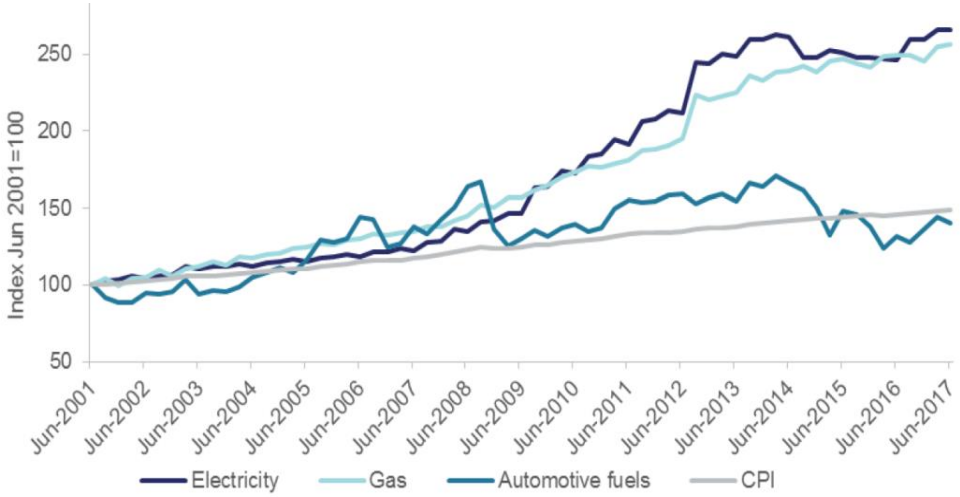
Electricity emissions intensity comparison

(shrink that footprint)

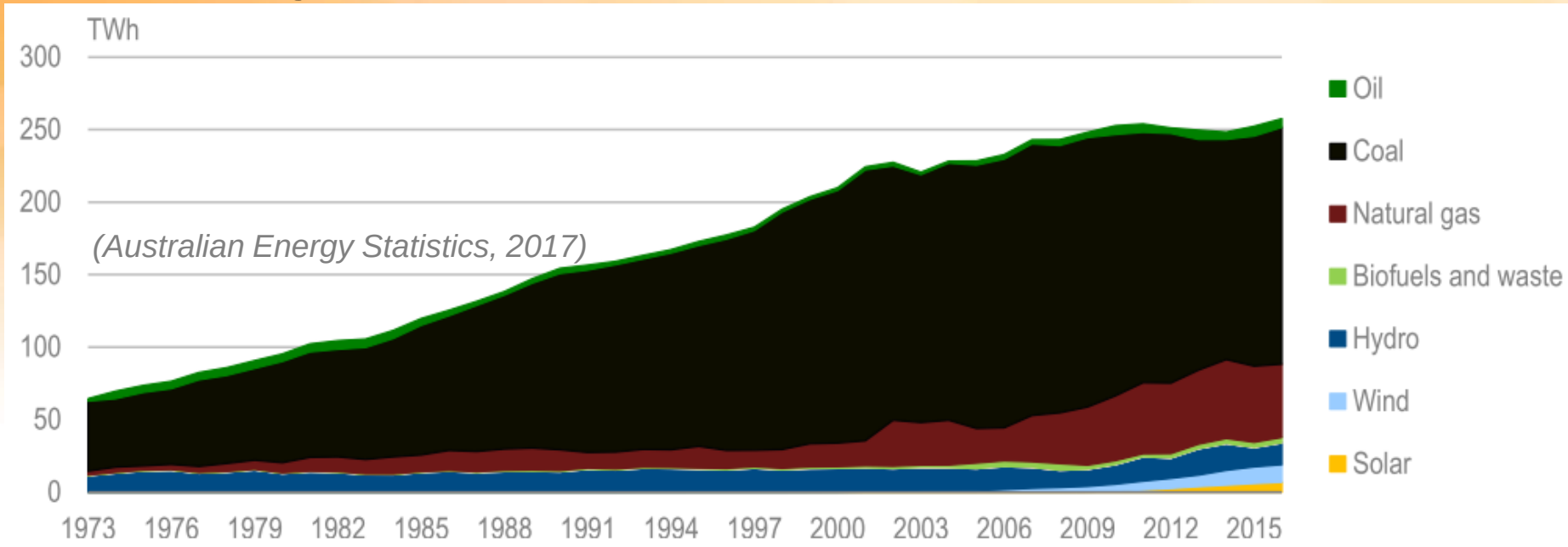


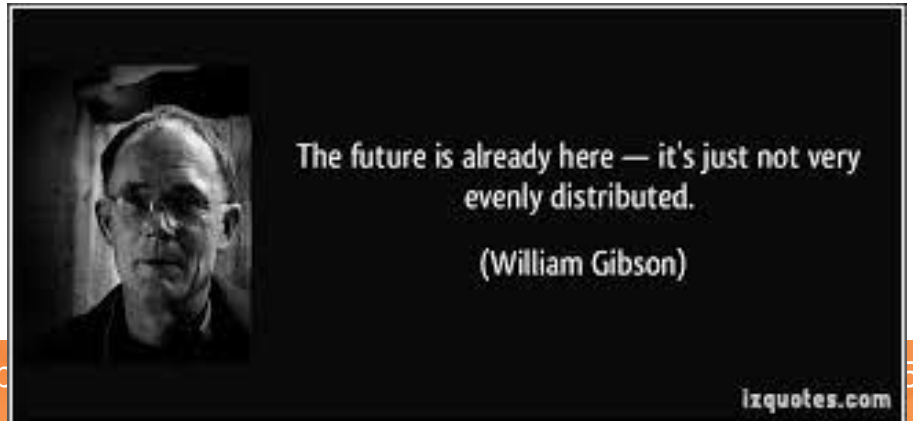
Australian residential energy prices index

(Australian Energy Statistics Update 2017)

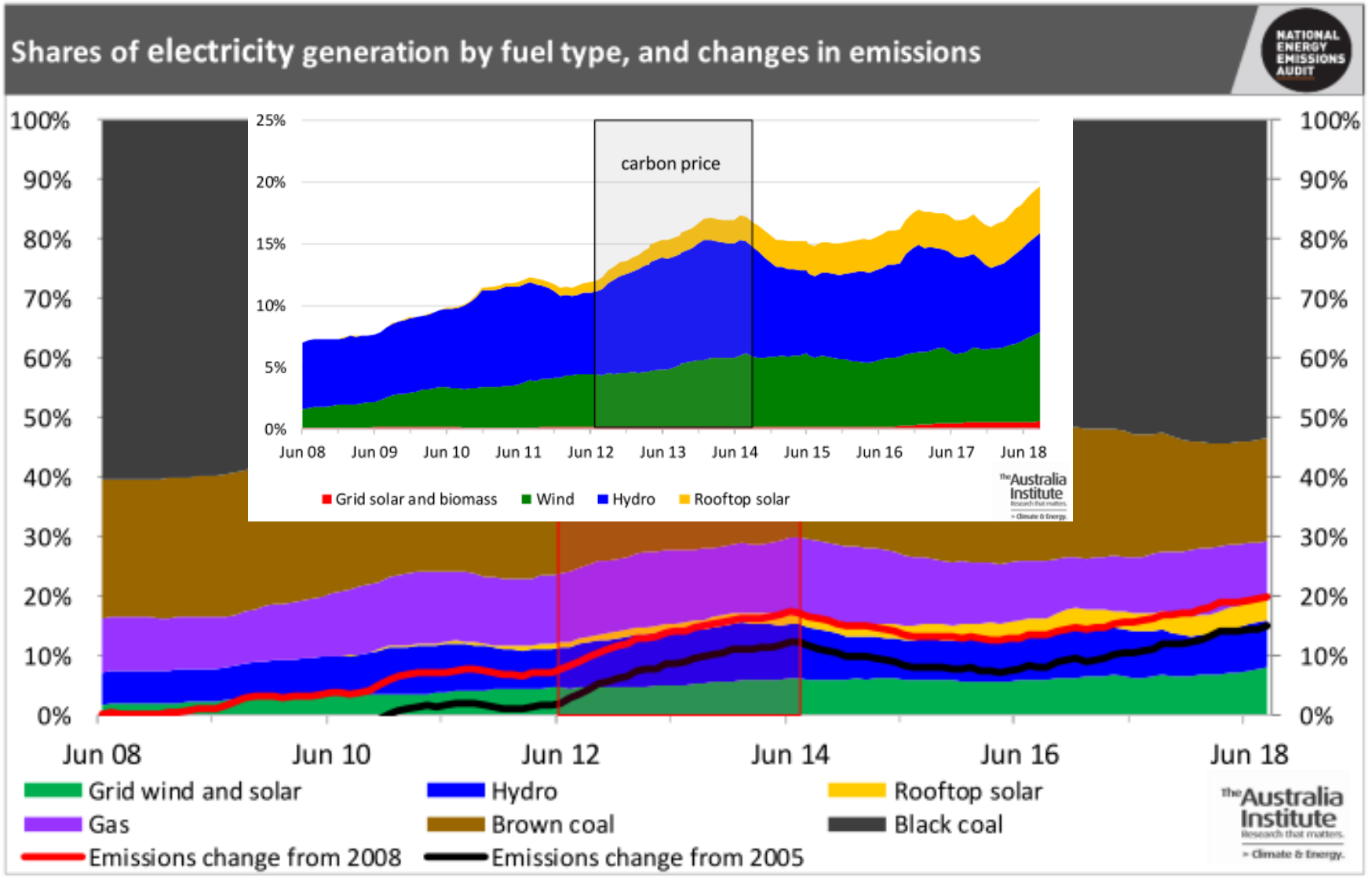


If trend is destiny for the Australian electricity sector

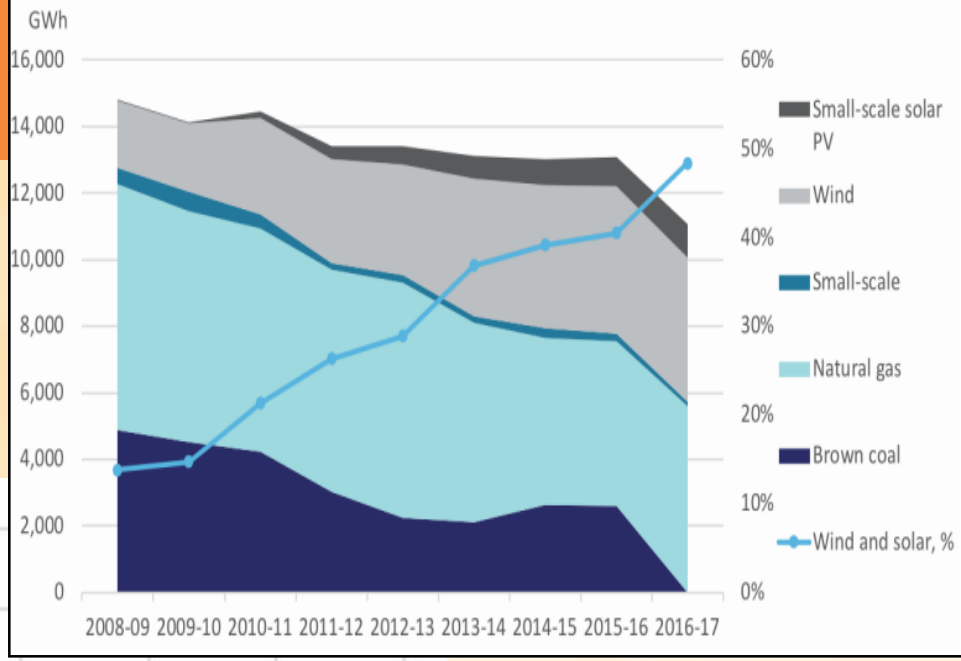




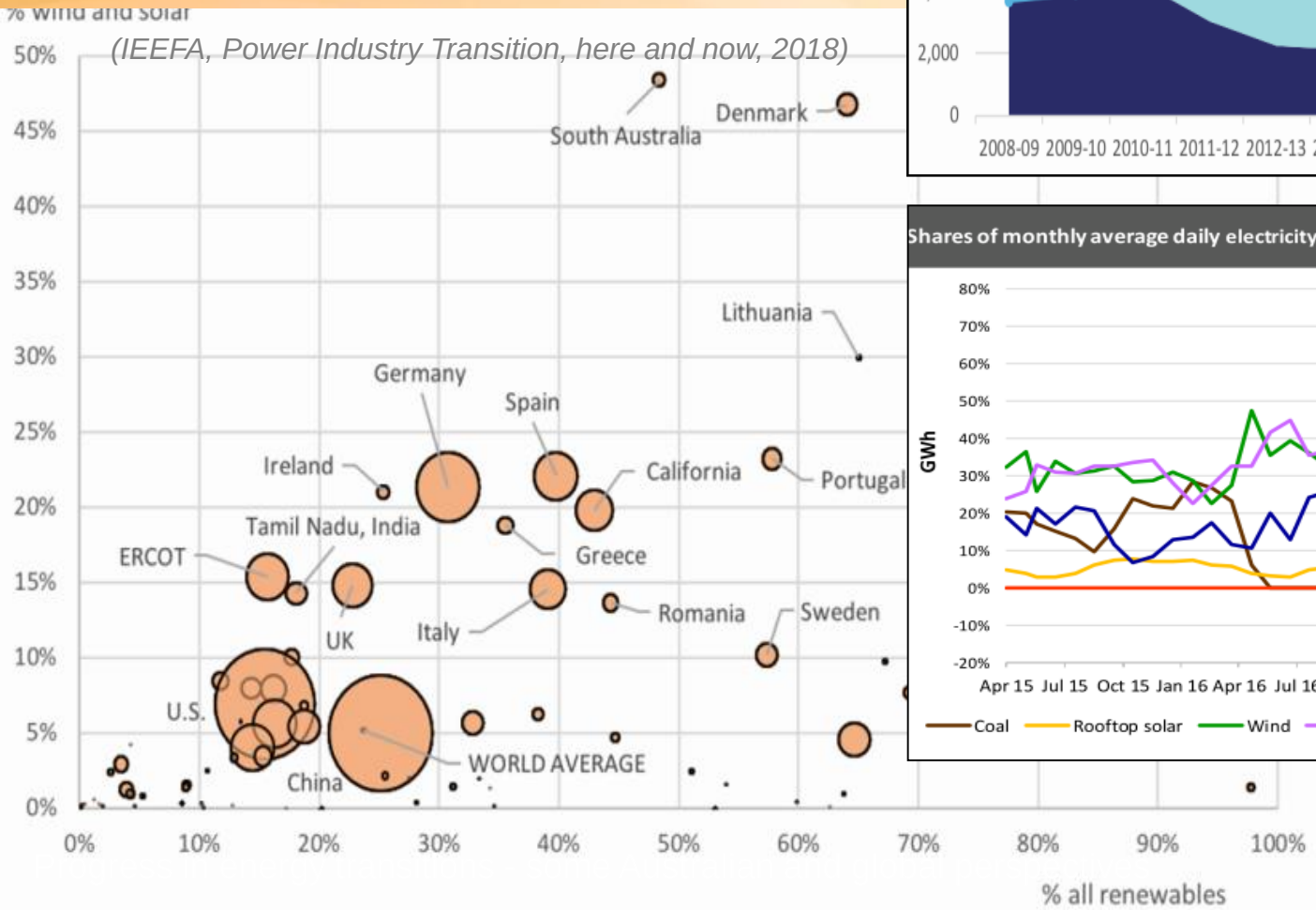
More recently, RE penetrations growing

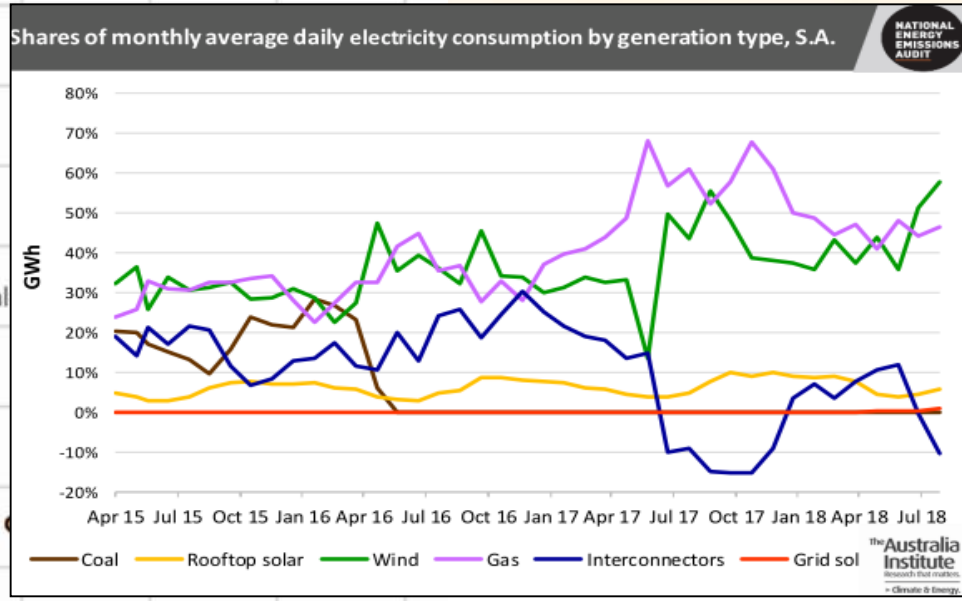


.. while in South Australia

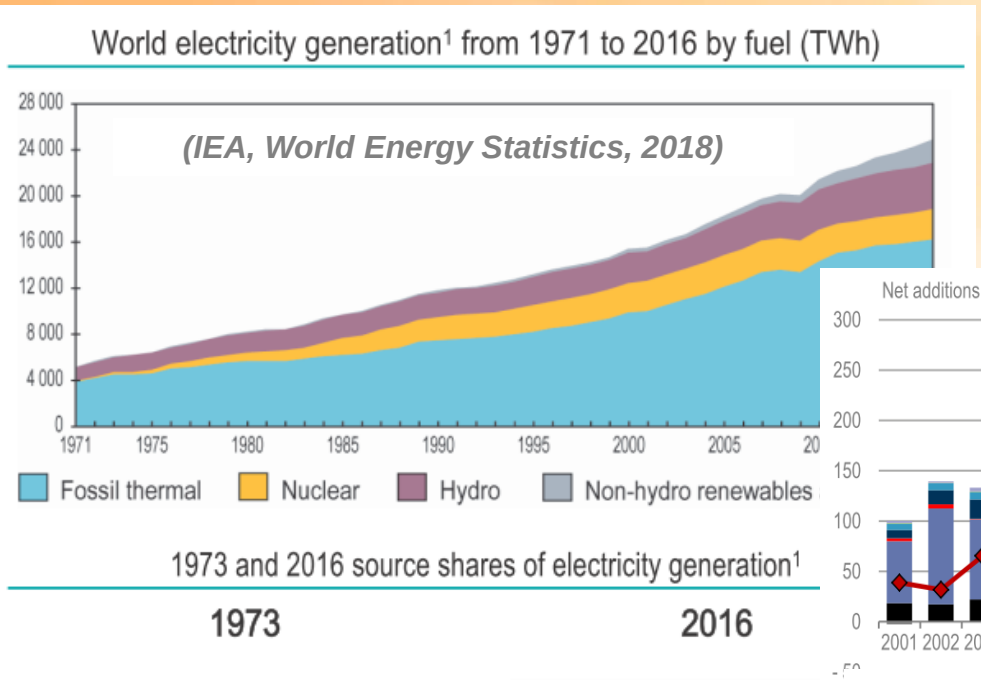


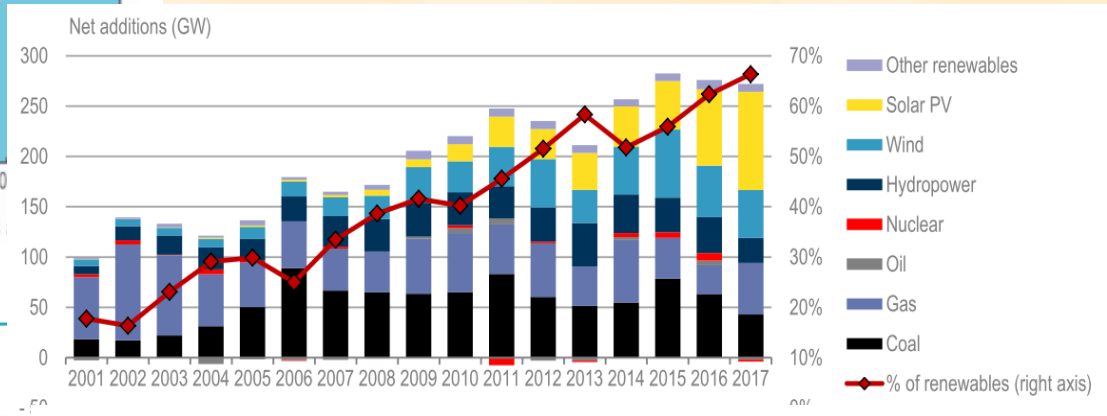
(IEEFA, Power Industry Transition, here and now, 2018)



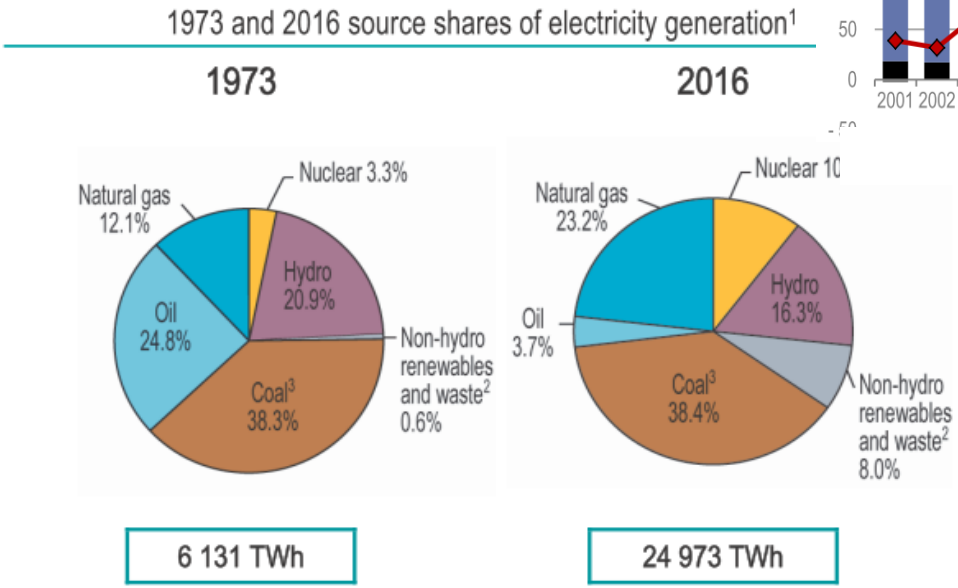


Globally

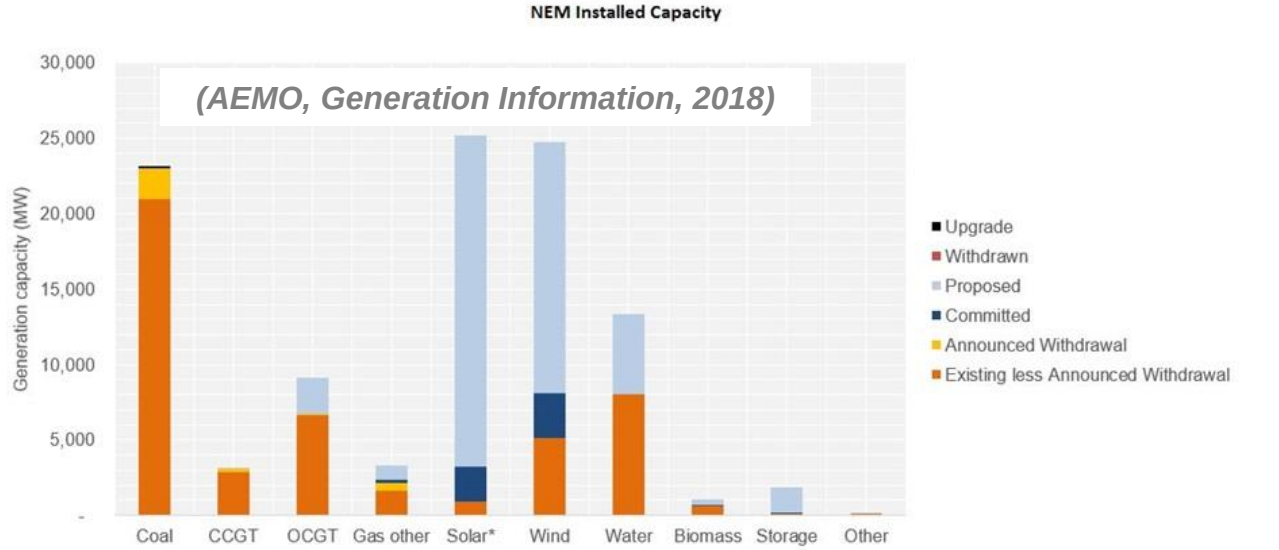




(IEA, World Energy Investment, 2018)

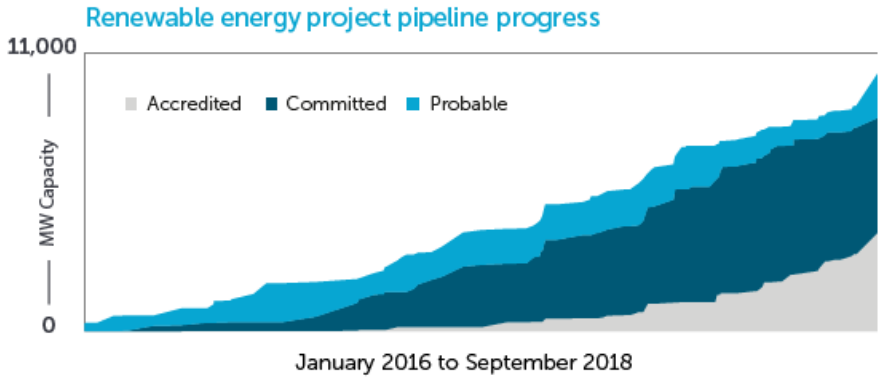


In the short-term for Australia

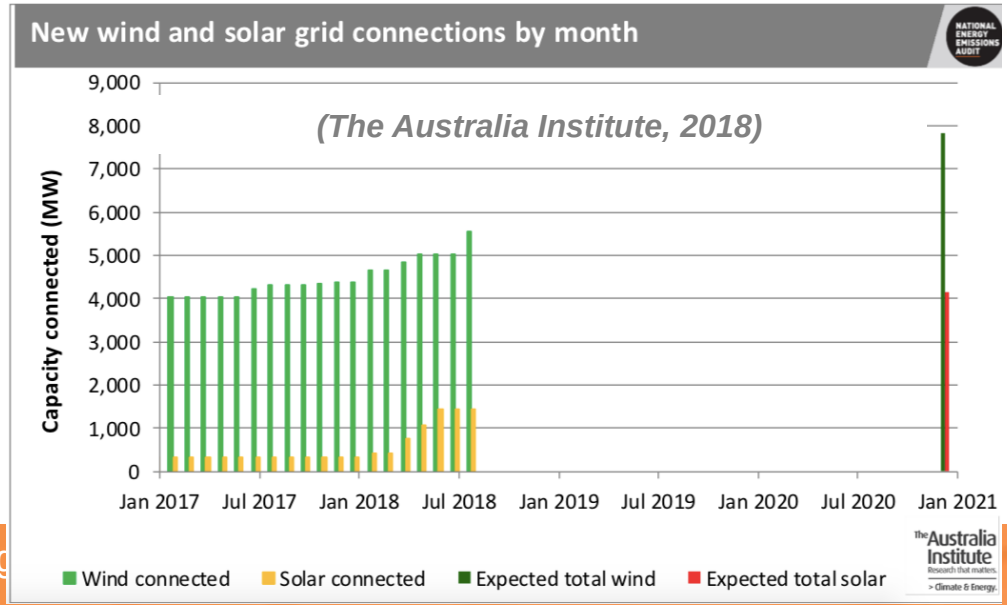


Status	Coal	CCGT	OCGT	Gas other	Solar*	Wind	Water	Biomass	Storage	Other	Total
Existing	23,006	3,093	6,717	2,158	960	5,114	8,021	665	100	155	49,990
Announced Withdrawal	2,000	208	34	480	-	-	-	-	-	-	2,722
Existing less Announced Withdrawal	21,006	2,885	6,683	1,678	960	5,114	8,021	665	100	155	47,268
Upgrade	180	-	-	-	-	-	-	-	-	-	180
Committed	-	-	-	210	2,315	2,992	-	24	107	-	5,648
Proposed	-	60	2,389	990	21,899	16,643	5,349	385	1,688	59	49,462
Withdrawn	-	-	-	-	-	-	-	-	-	-	-

Note: Existing includes Announced Withdrawal. This data is current as at 1 July 2018.



(Clean Energy Regulator, Project database 2018)



Wind + PV projects getting larger, cheaper

Innogy breaks ground on 349 MWp Australian Limondale solar farm

Germany's innogy is all set to deliver its first utility-scale solar PV project in Australia. Preparation works and pre-pilling tests are currently underway, and main works are expected to commence this October.

SEPTEMBER 27, 2018 MARIJA MAISCH

UTILITY-SCALE PV AUSTRALIA

Belectric was key to the innogy project acquisitions in Australia.

Image: Belectric

Share

From pv magazine Australia

Germany's innogy SE has confirmed it has taken the final investment decision for the Limondale solar farm in New South Wales (NSW). At 349 MWp, Limondale is expected to be Australia's largest solar power plant once completed.

Origin stuns industry with record low price for 530MW wind farm

28

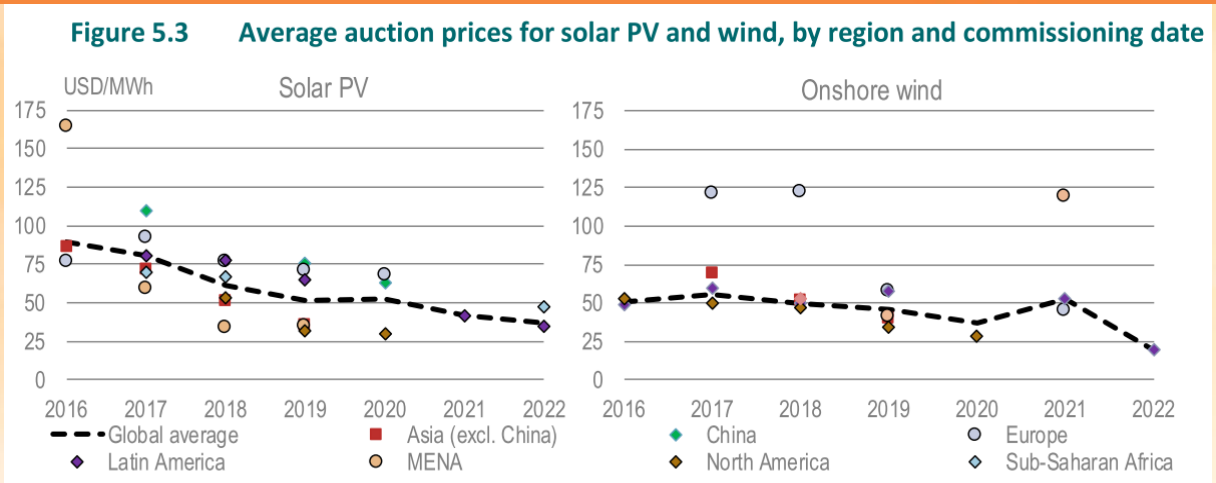
By Sophie Vorrath & Giles Parkinson on 8 May 2017

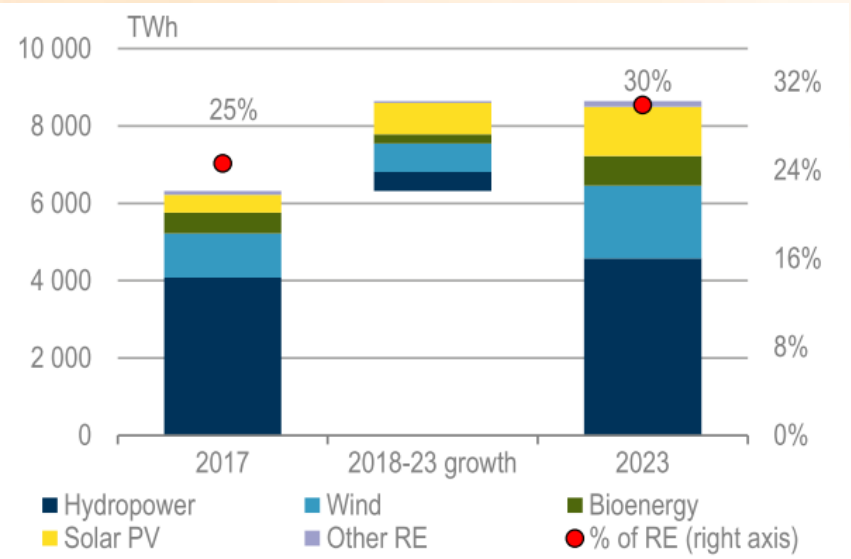
Print

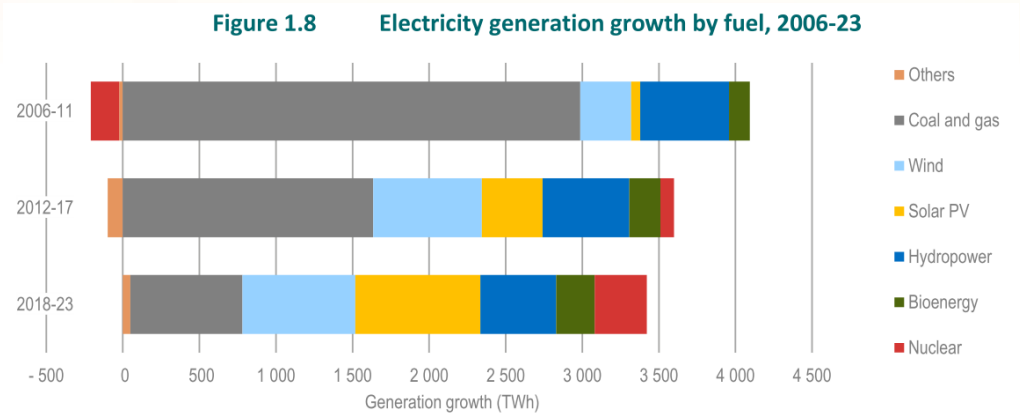
Origin Energy has set a stunning new benchmark for renewable energy off-take deals in Australia – and sounded the alarm for energy incumbents – after committing to a long-term power purchase agreement of below $60/MWh for the 530MW Stockyard Hill Wind Farm in

And globally..

according to the IEA



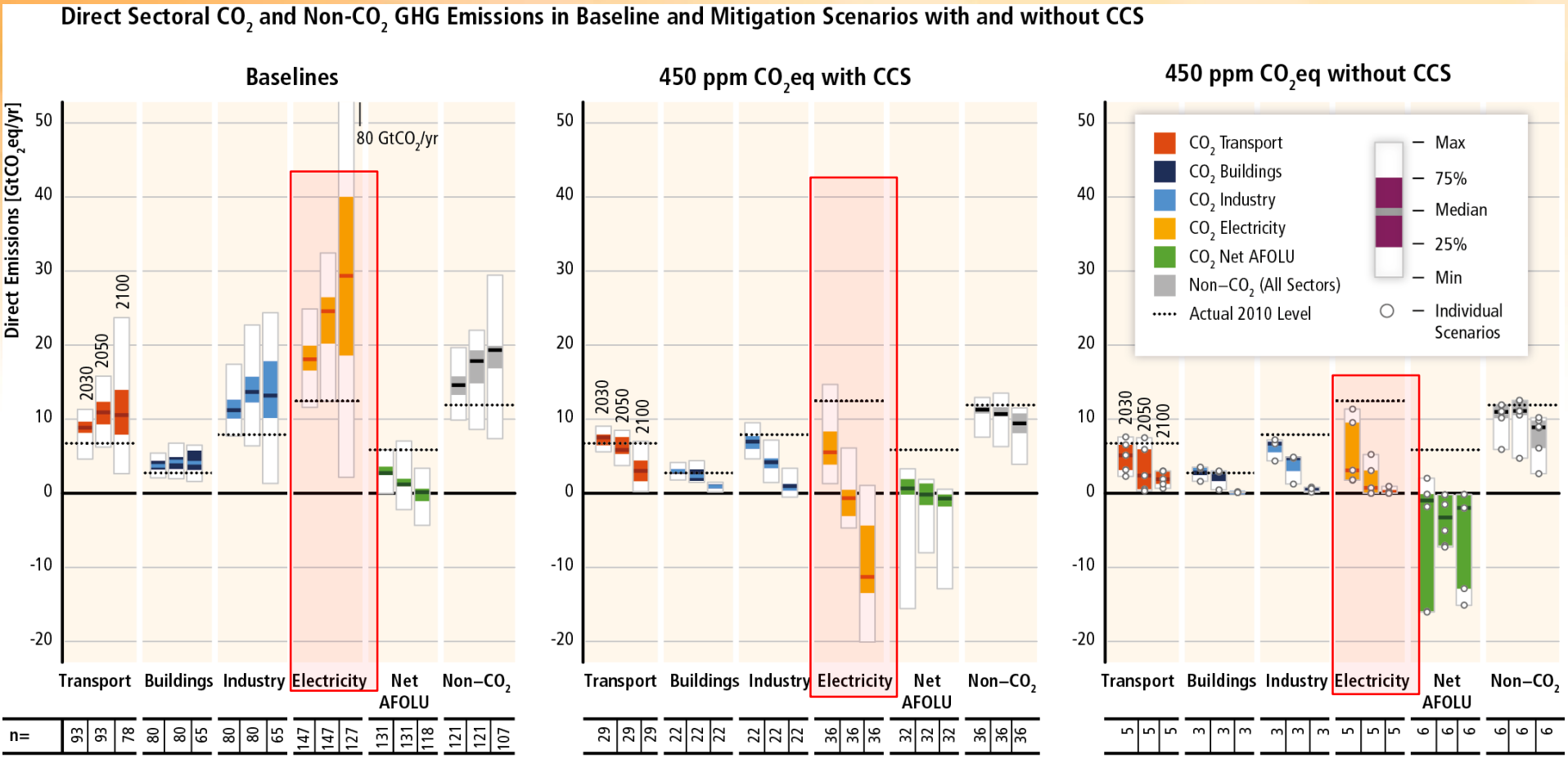




(IEA, Renewables 2018)

In the longer term, it depends

IPCC scenarios for avoiding dangerous climate change



(IPCC, Fifth Assessment Report, 2015)

In the longer term? Quick Poll – Q1

- What generation mix do you see as more likely for the Australian NEM in 2040?
  - Approaching 80-100% renewables (RE)
  - Around 50% RE, 50% coal and gas without Carbon Capture and Storage (CCS)
  - Around 50% RE, 50% coal and gas with CCS
  - Around 25% RE, 75% coal and gas without CCS

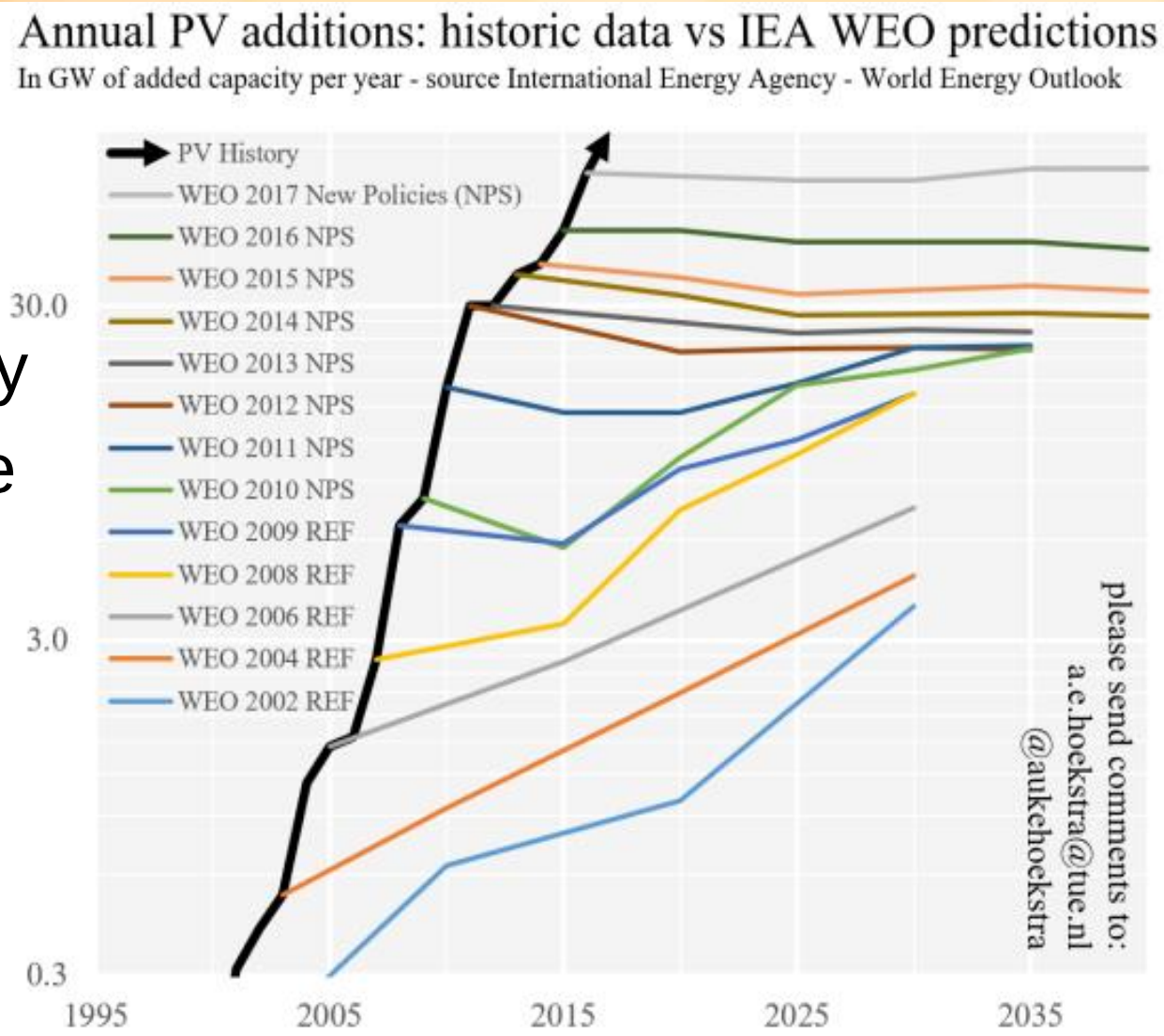
Tools for exploring the future

- Projections
  - Project from current data and historical trends into the future
- Forecasts / predictions
  - Add judgements – eg related trends
- Scenarios
  - Hypothetical alternative futures to help explore decision making

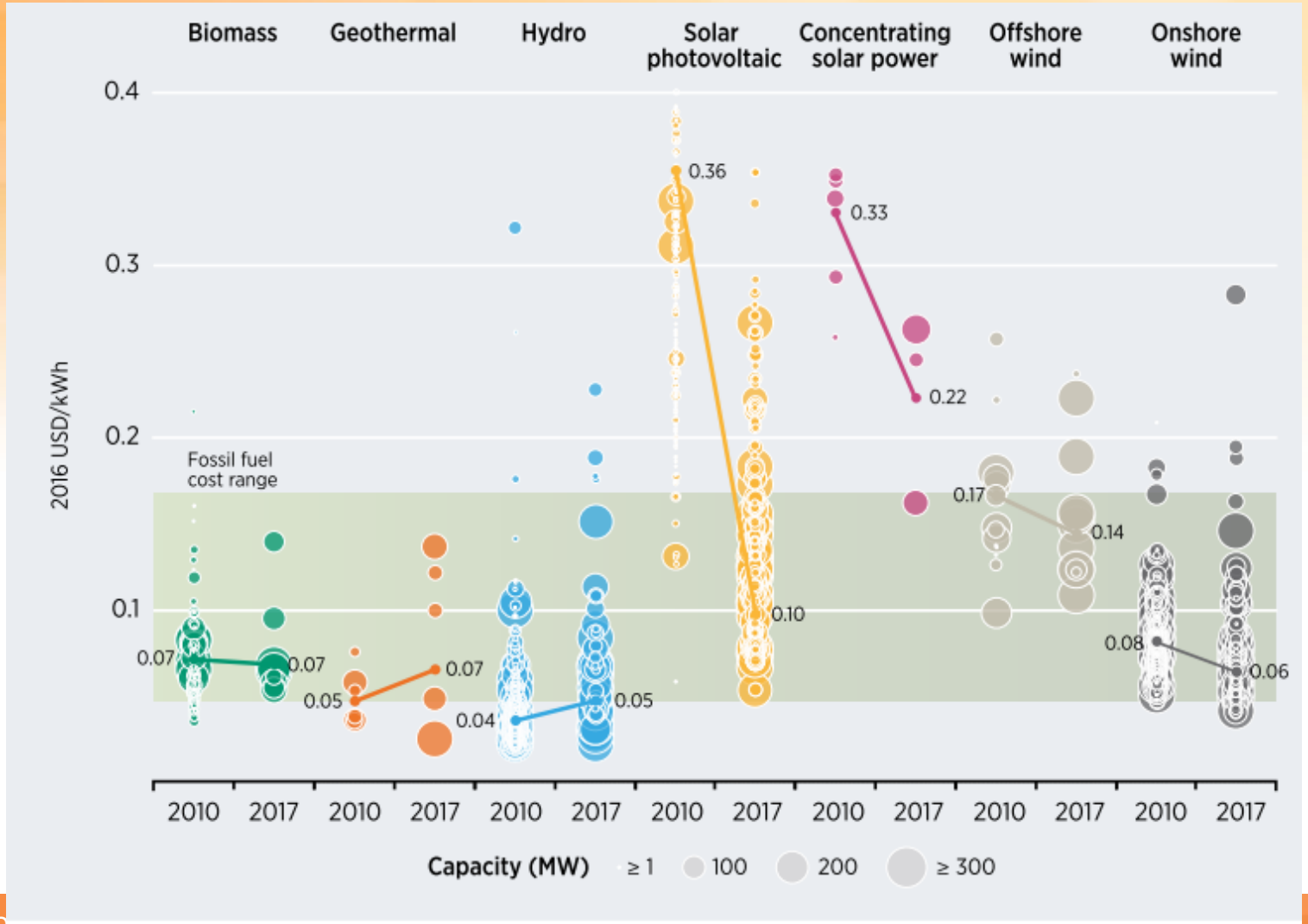
Take care with projections + forecasts

Trend is not destiny

Neither is expertise



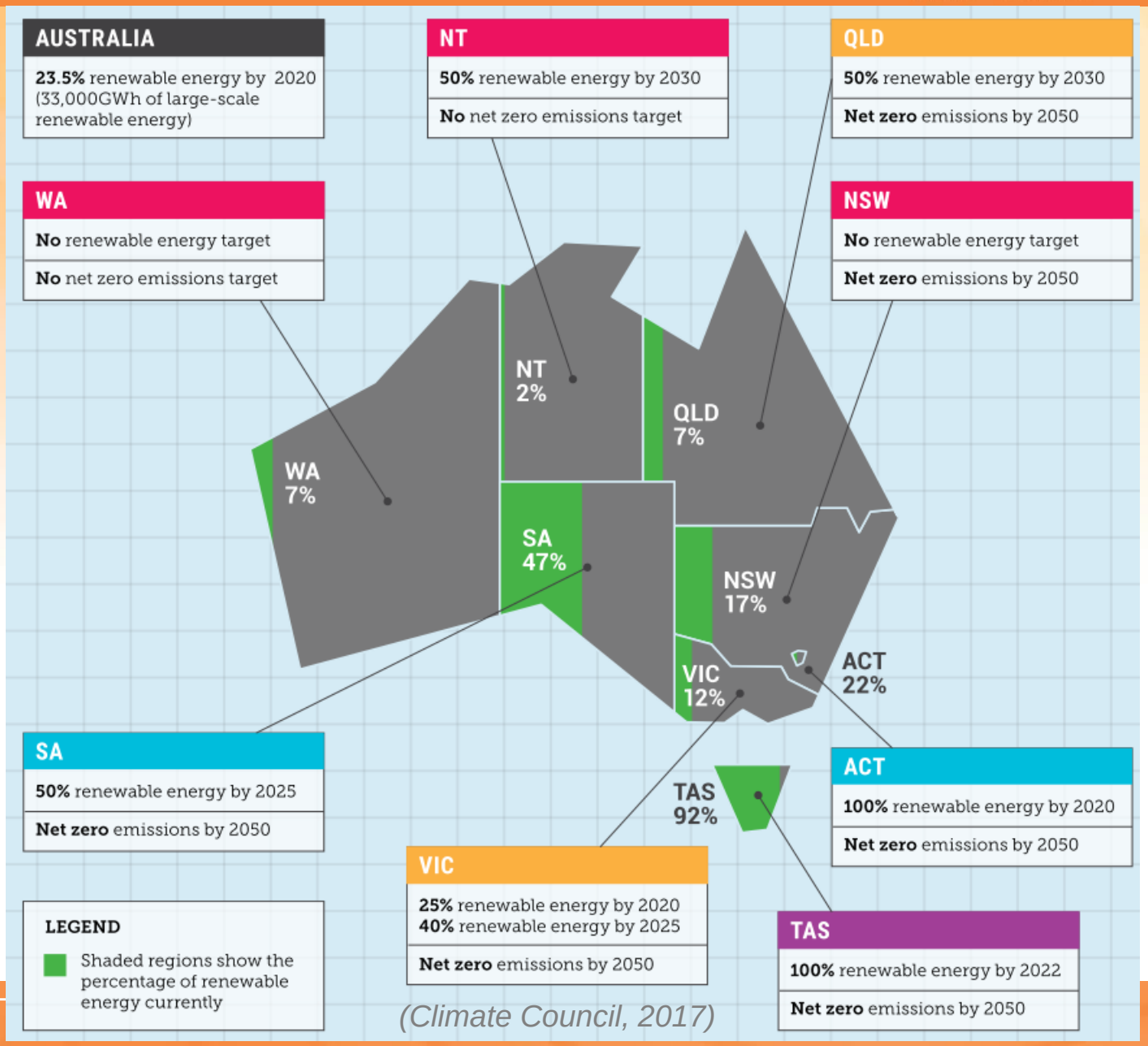
What we know keeps changing…



Source: IRENA Renewable Cost Database.

(IRENA, 2017)

State RE targets in the NEM



(Climate Council, 2017)

Corporate renewable PPAs also a driver

EXCLUSIVE BUSINESS THE ECONOMY ENERGY

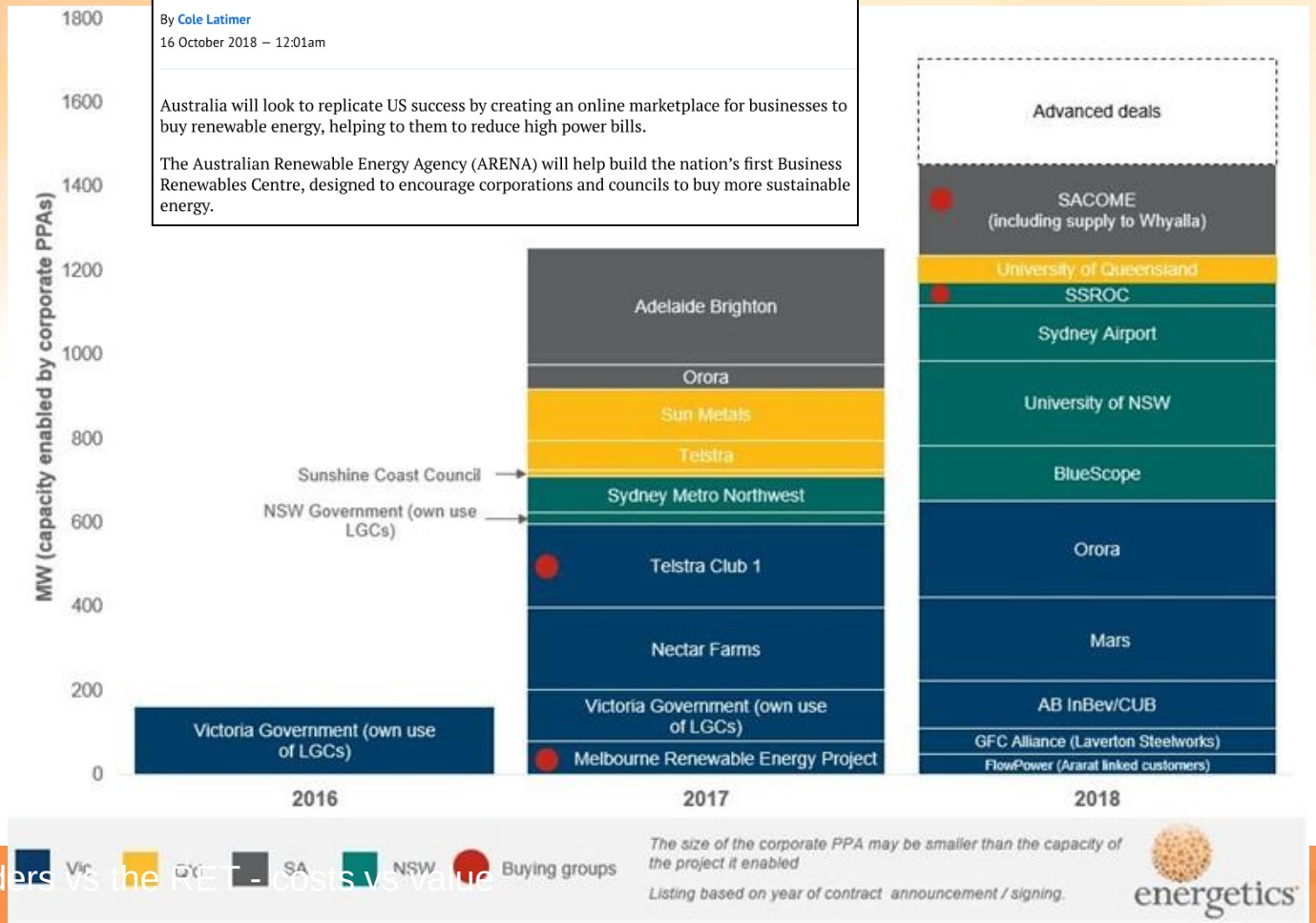
Online renewable marketplace aims to help business cut power bills

By Cole Latimer

16 October 2018 — 12:01am

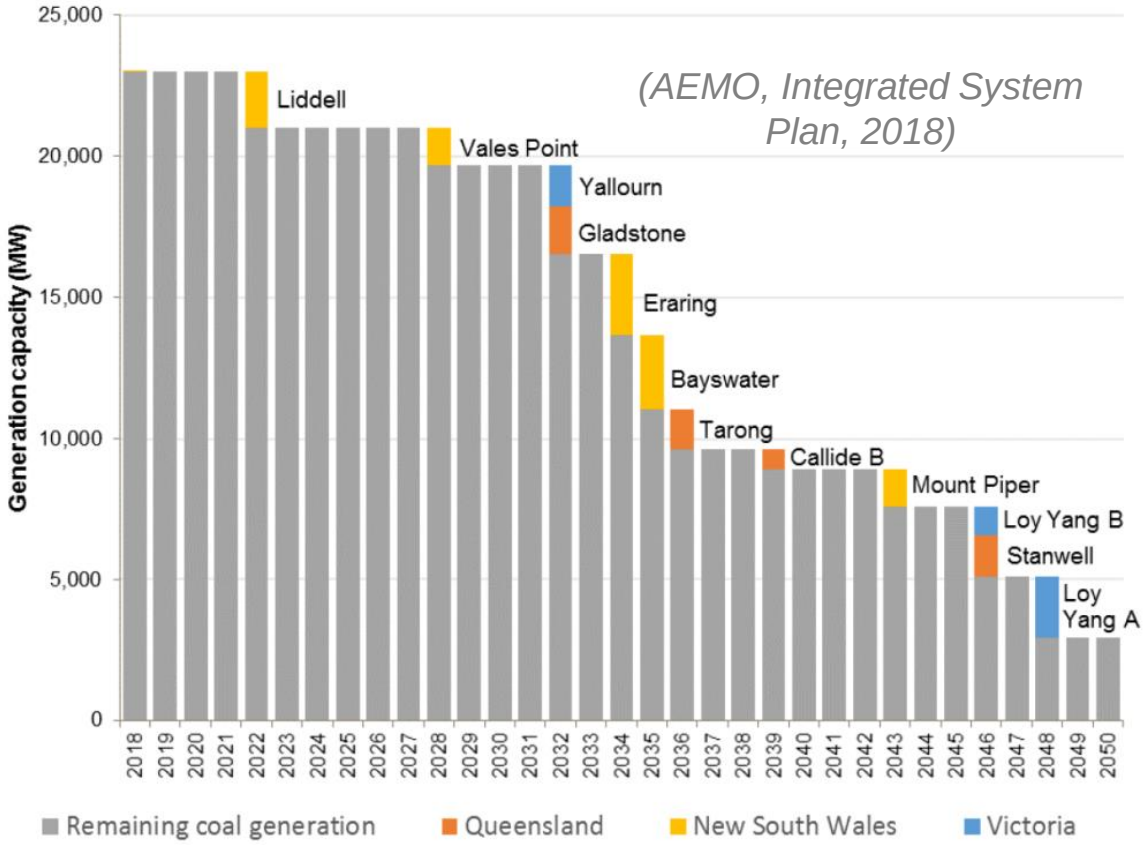
Australia will look to replicate US success by creating an online marketplace for businesses to buy renewable energy, helping to them to reduce high power bills.

The Australian Renewable Energy Agency (ARENA) will help build the nation's first Business Renewables Centre, designed to encourage corporations and councils to buy more sustainable energy.



..and what happens with existing coal fleet?

Figure 4 **NEM coal generation fleet operating life to 2050, by 50th year from full operation or announced retirement**

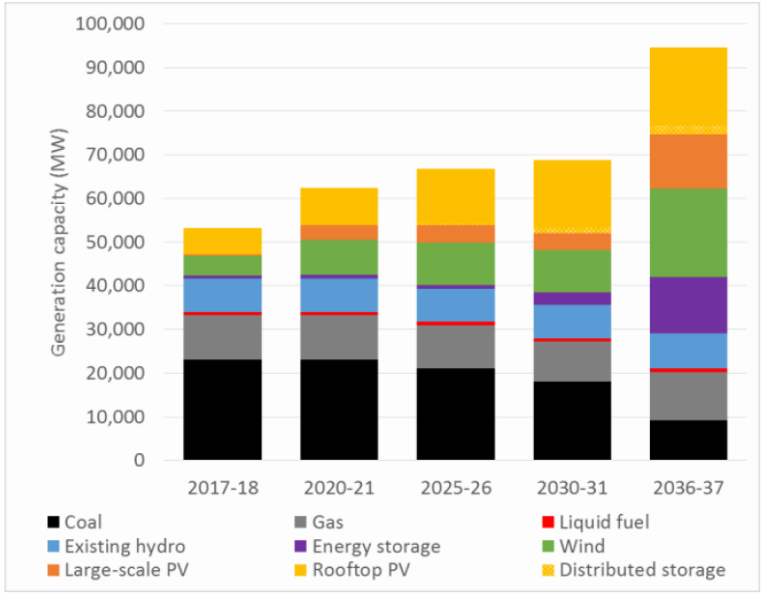


(AEMO, Integrated System Plan, 2018)

Scenarios for NEM

- A wide range to choose from
- AEMO ISP likely the most useful

Figure 9 Preliminary projections of NEM generation capacity (left) and generation output (right), Neutral scenario



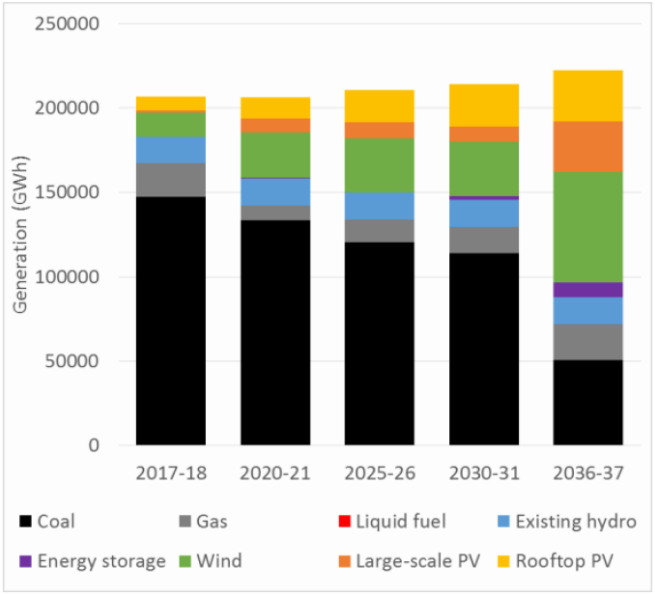
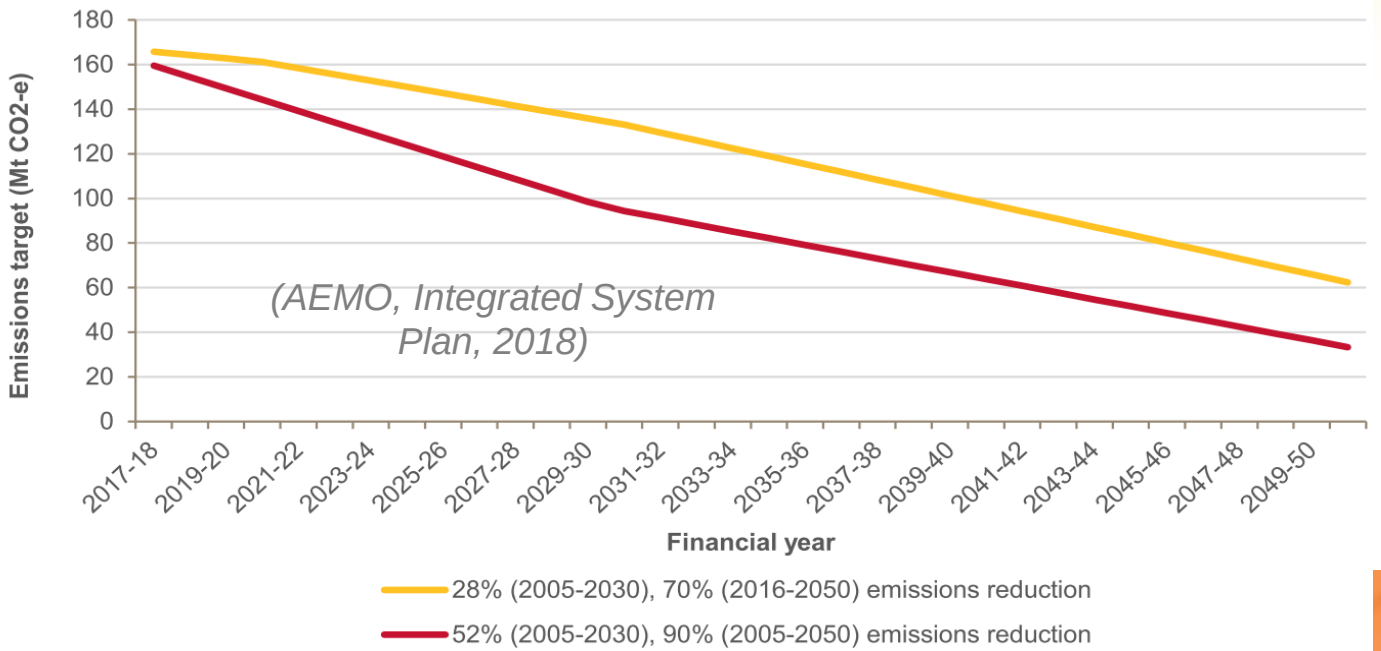
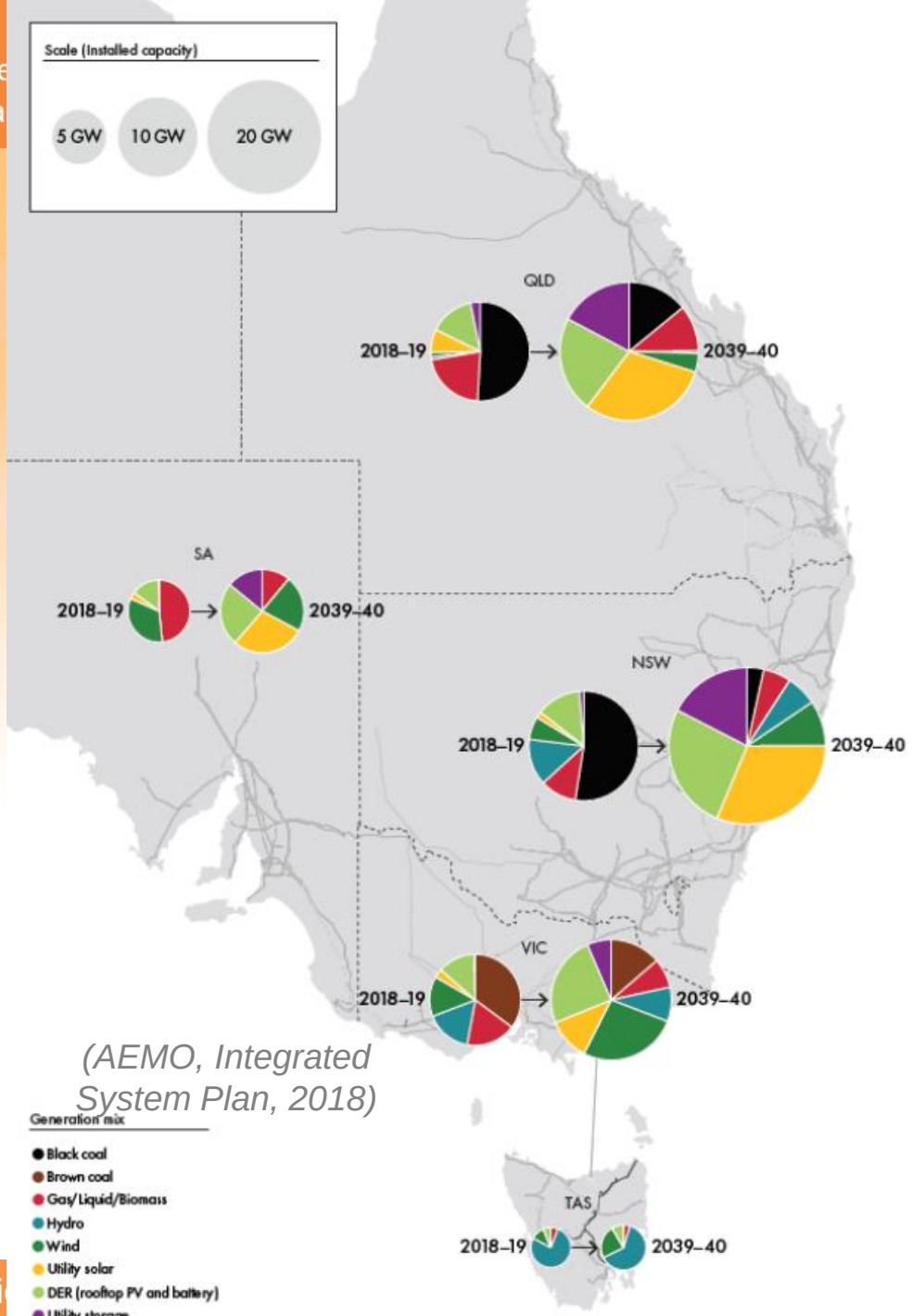


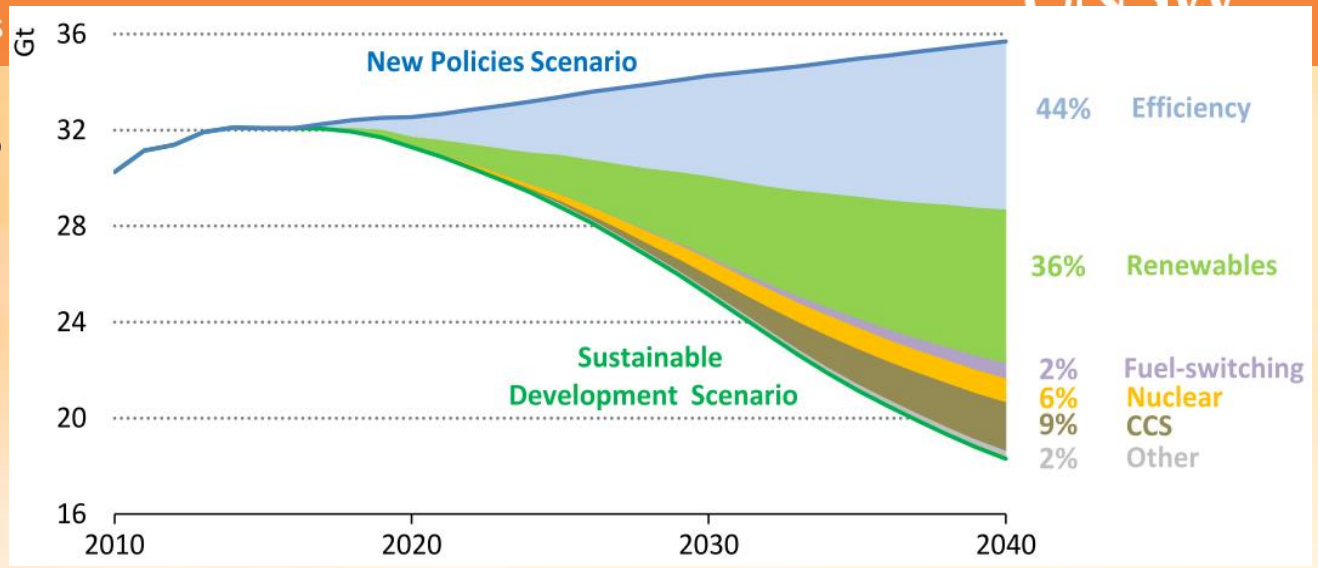
Figure 5 Proposed NEM emissions reduction trajectories to be examined in ISP scenarios



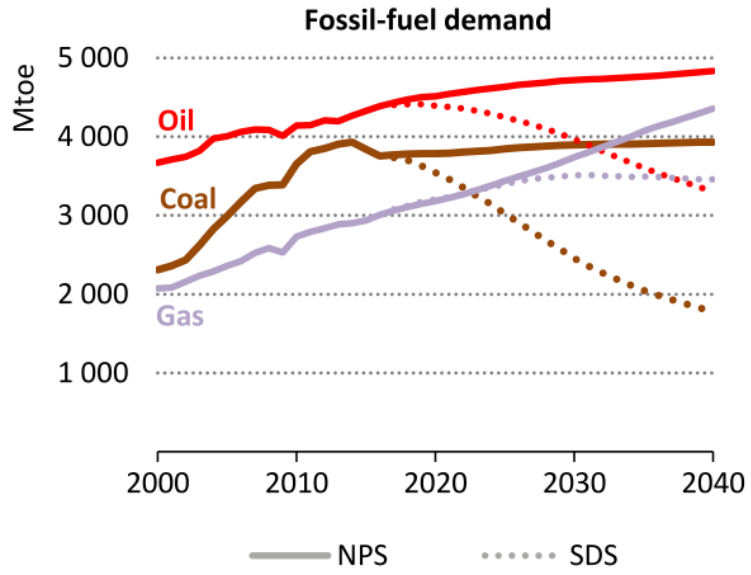


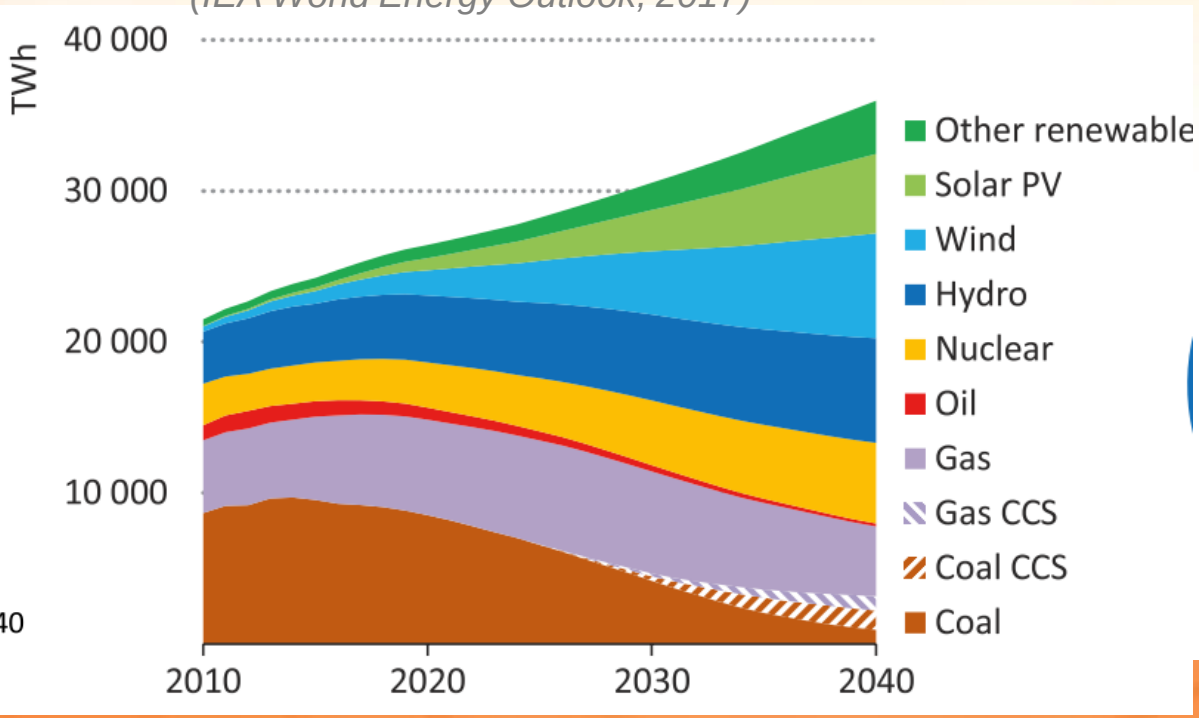
(AEMO, Integrated System Plan, 2018)

IEA pathways

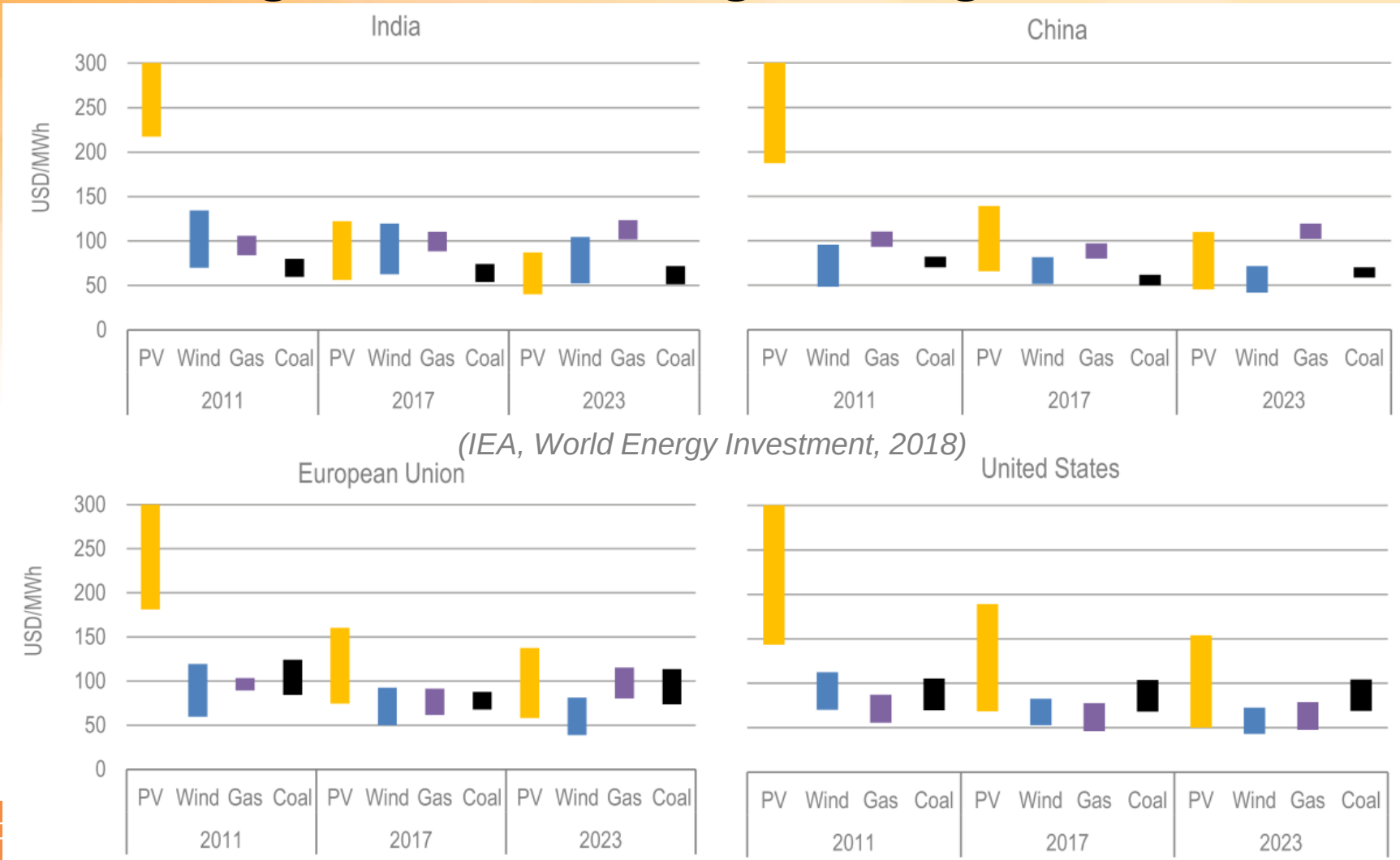


(IEA World Energy Outlook, 2017)





Policy still required…
but falling RE costs a growing driver



(IEA, World Energy Investment, 2018)

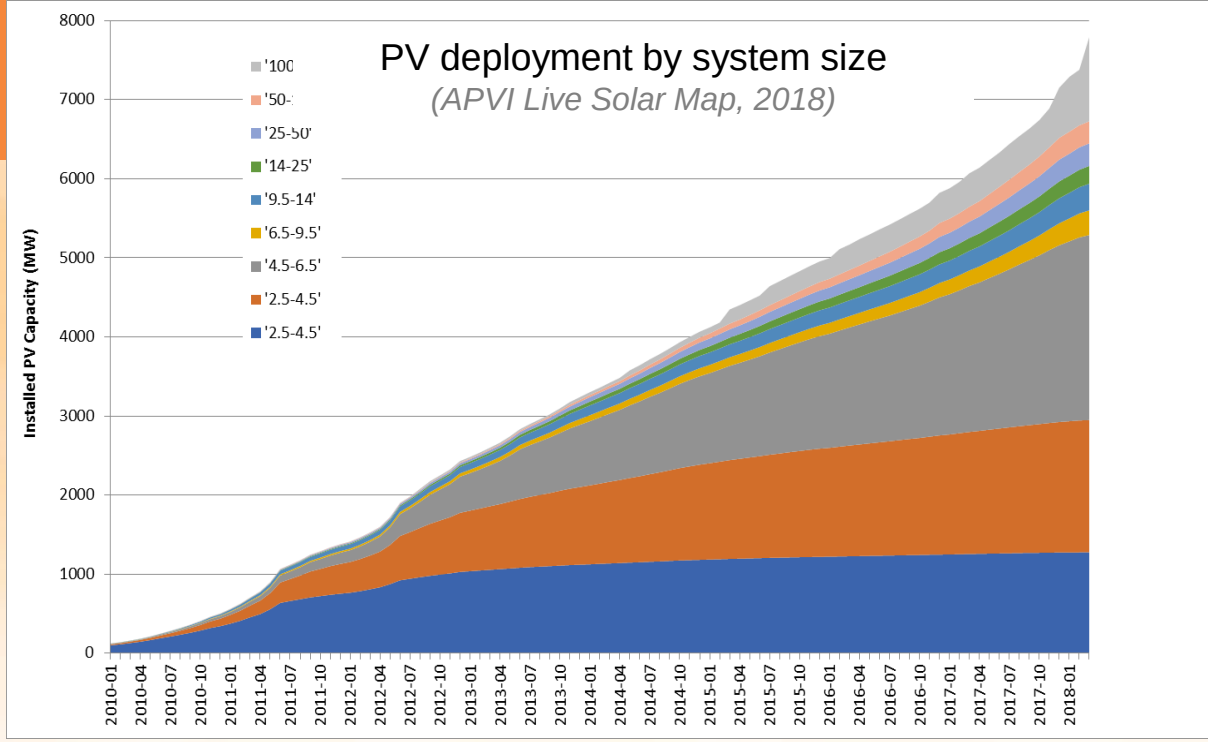
PV's ultimate scalability

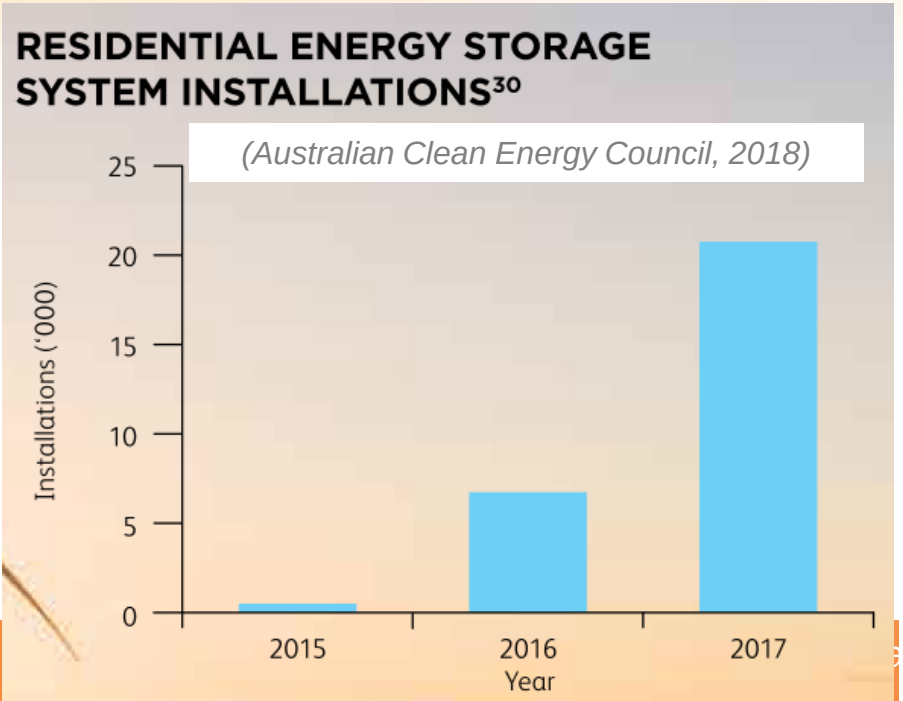
.. and battery storage too

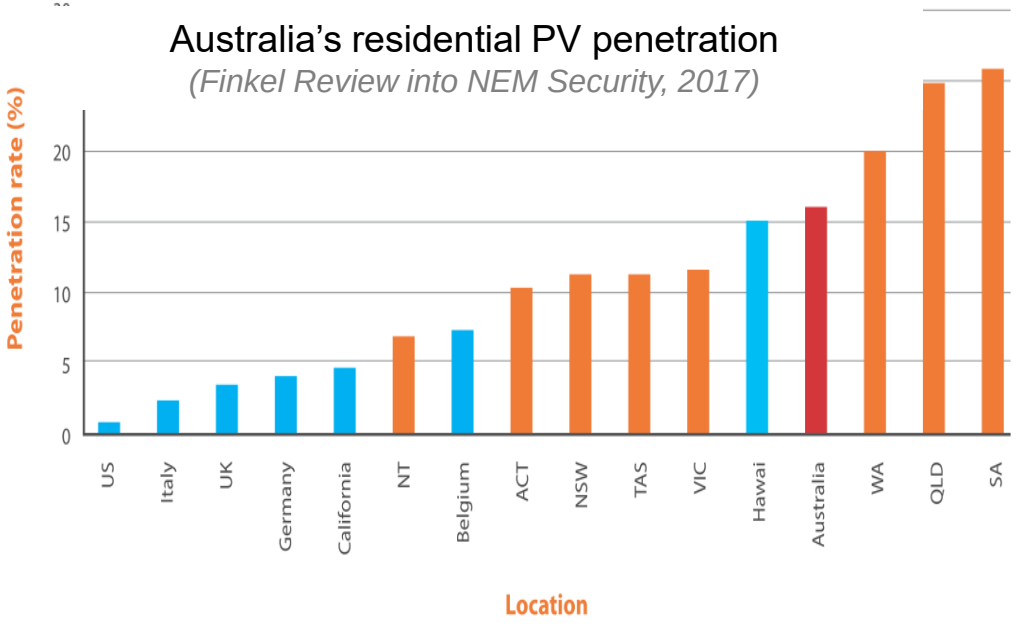
Centre for Energy and Environmental Markets

Australian PV

- Over 80% is ‘rooftop’ PV
- World leading residential PV penetration
- ~15% new Residential PV includes energy storage







Quick Poll – Q2

- What mix of centralised vs distributed generation do you see as most likely for the NEM in 2040?
  - Significantly >50% distributed
  - Around 50% distributed
  - Around 25% distributed
  - Around 10% distributed

Key question – where are prices going?

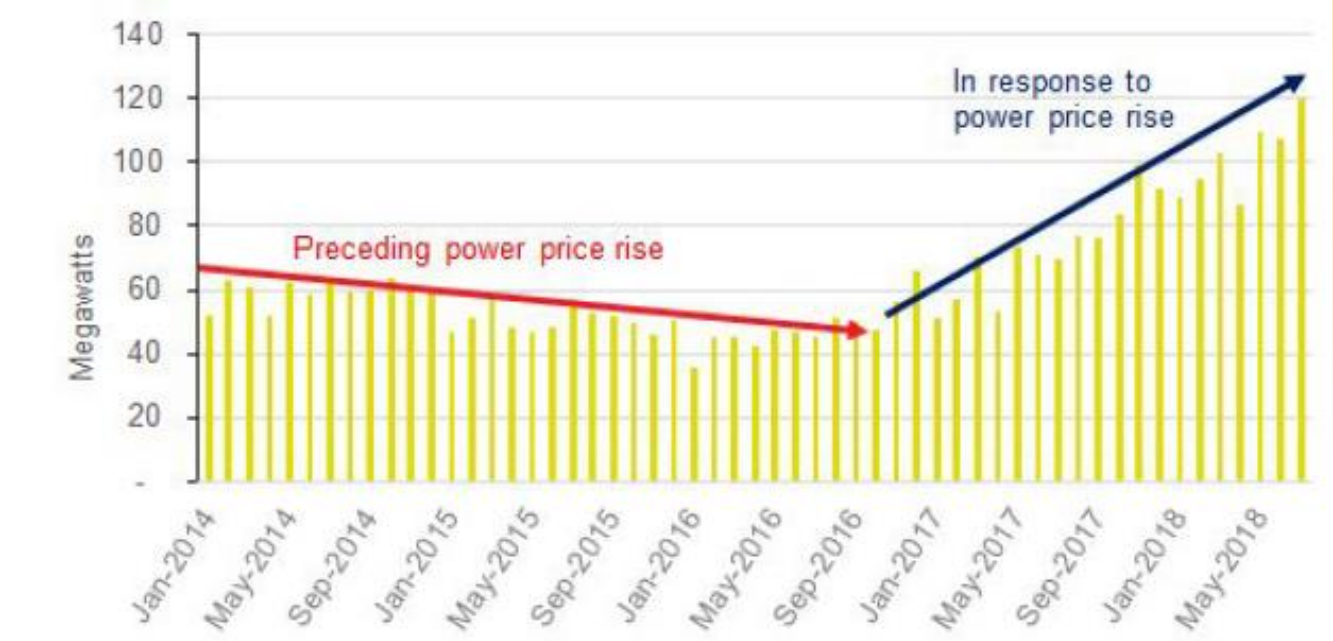
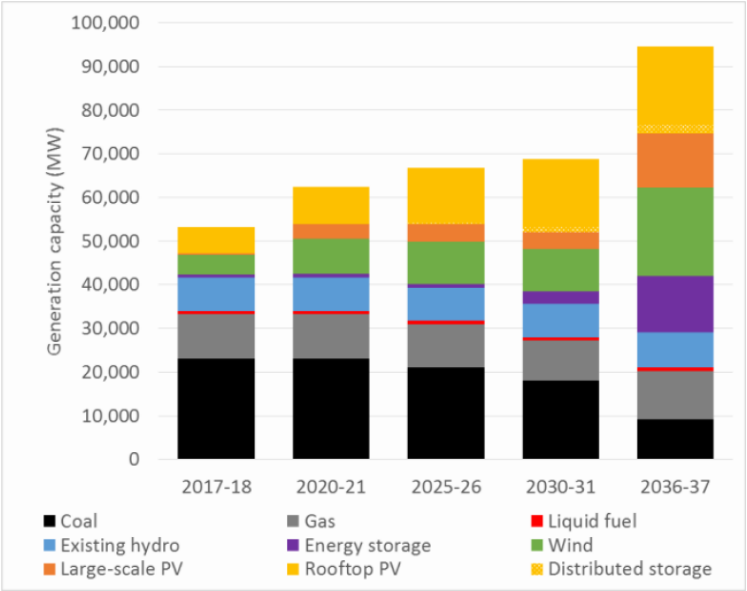


Figure 3: Rooftop solar PV capacity installed by month in NEM states

Scenarios for NEM

- Neutral has only modest dx generation
- …but do have a high DER scenario

Figure 9 **Preliminary projections of NEM generation capacity (left) and generation output (right), Neutral scenario**



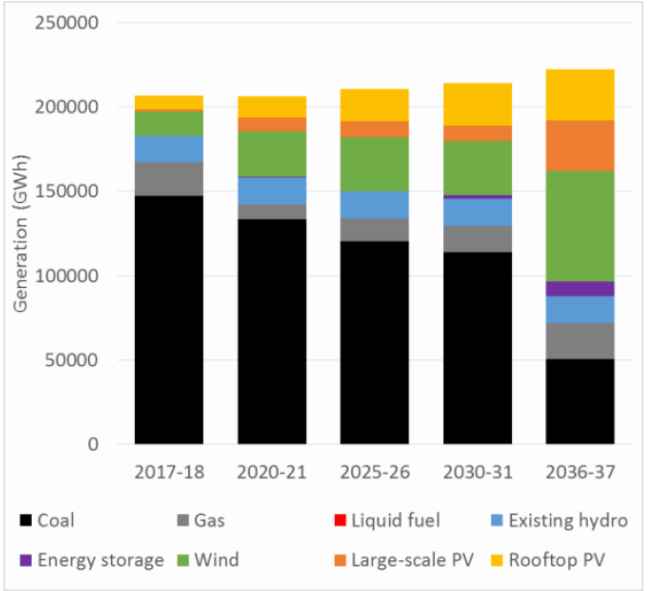
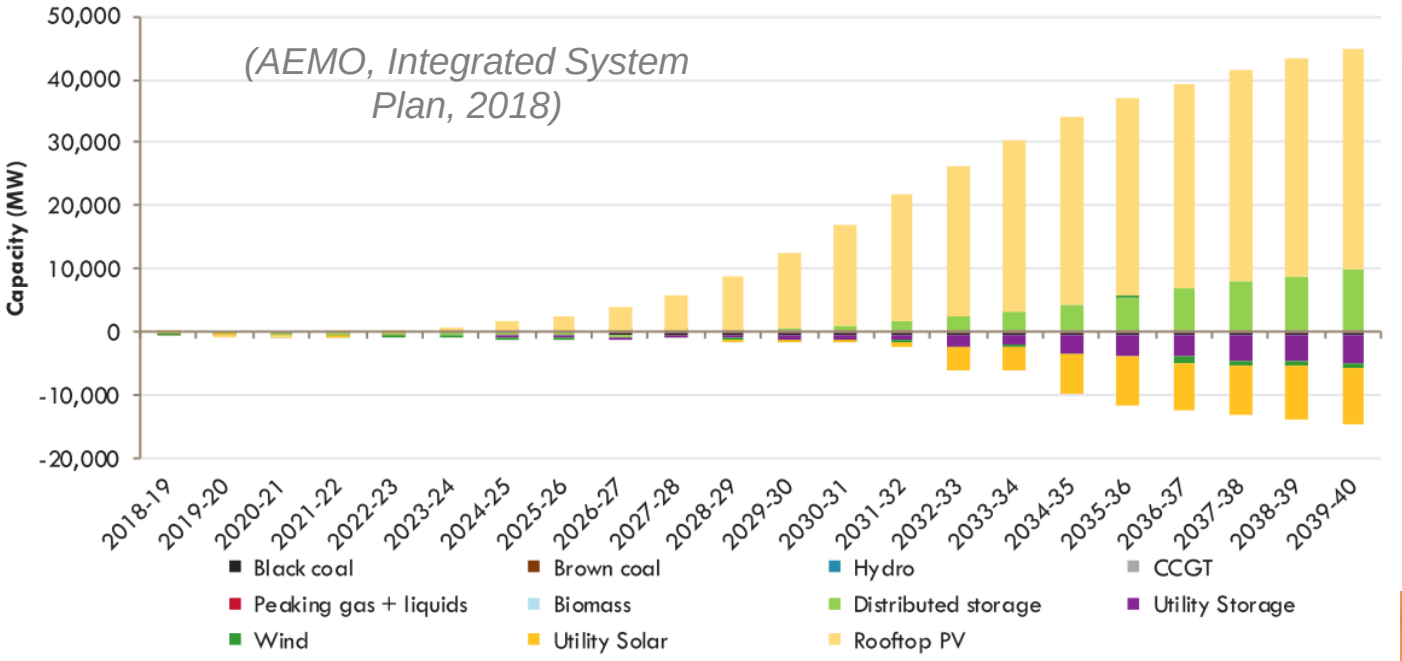
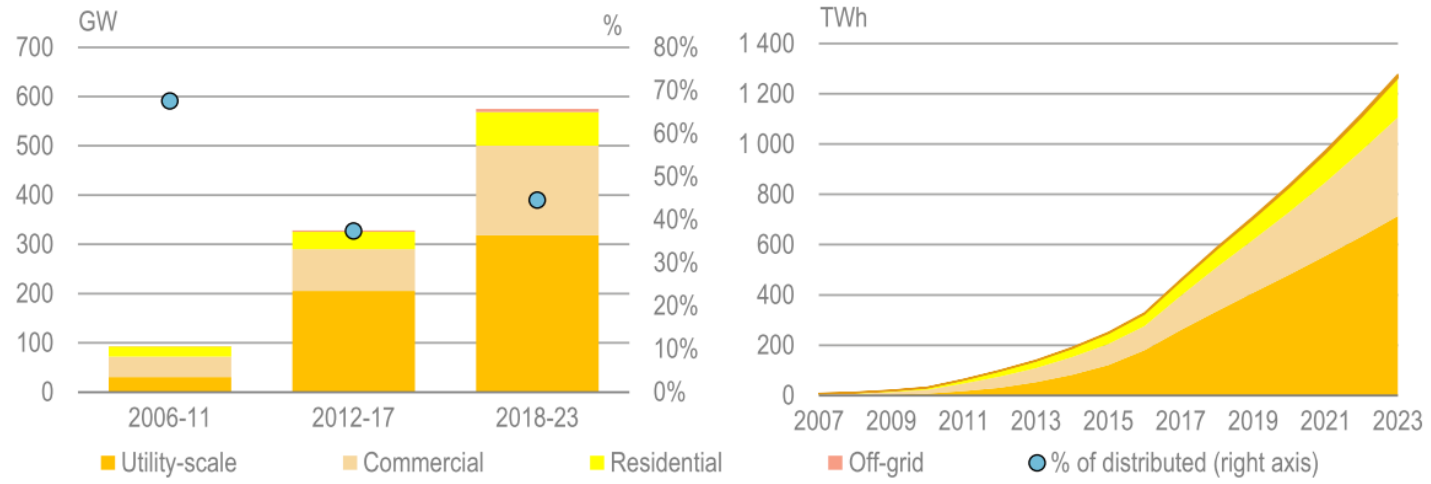


Figure 20 **Projected installed capacity, High DER scenario relative to Neutral case**

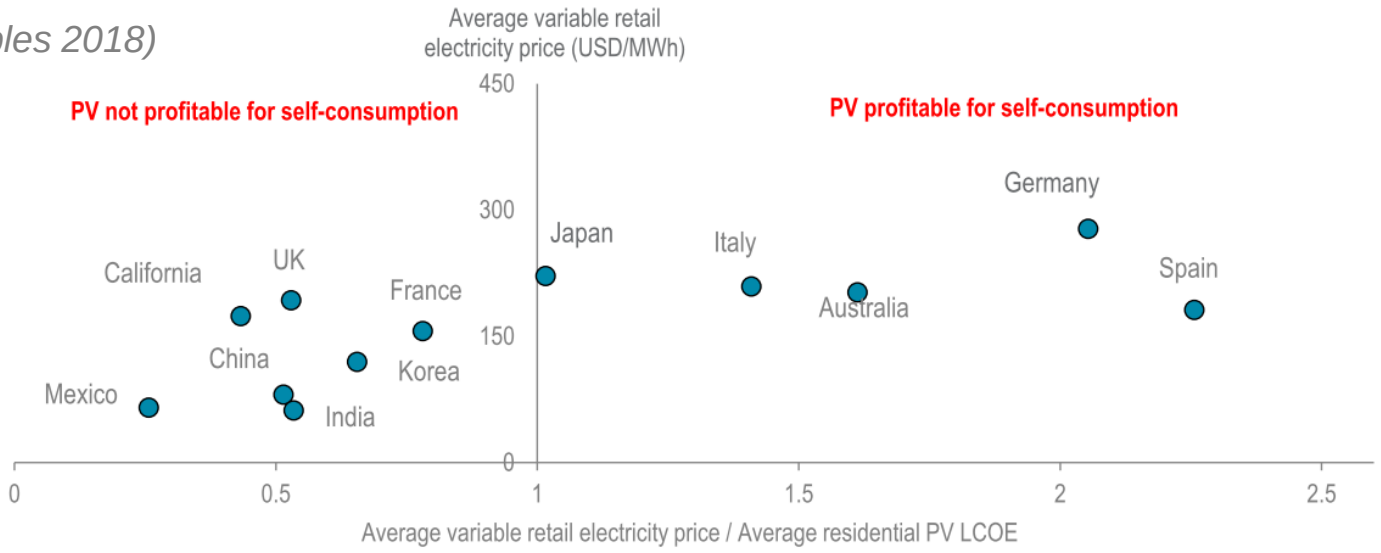


Global perspectives

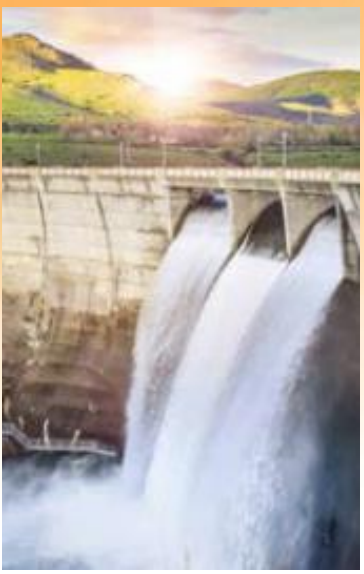
Figure 5.6 Solar PV capacity growth and total generation, 2006-23

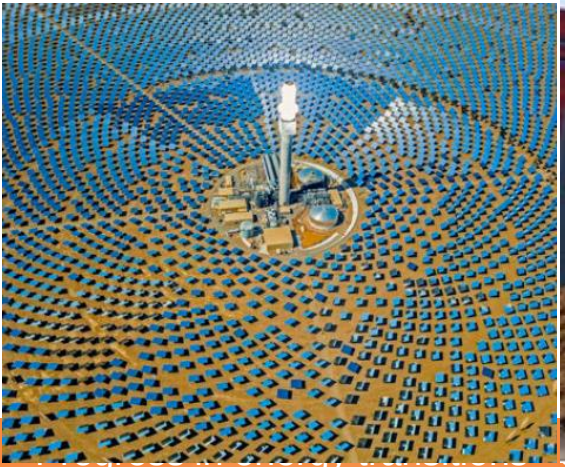


(IEA, Renewables 2018)



Renewable – inherent storage vs variable

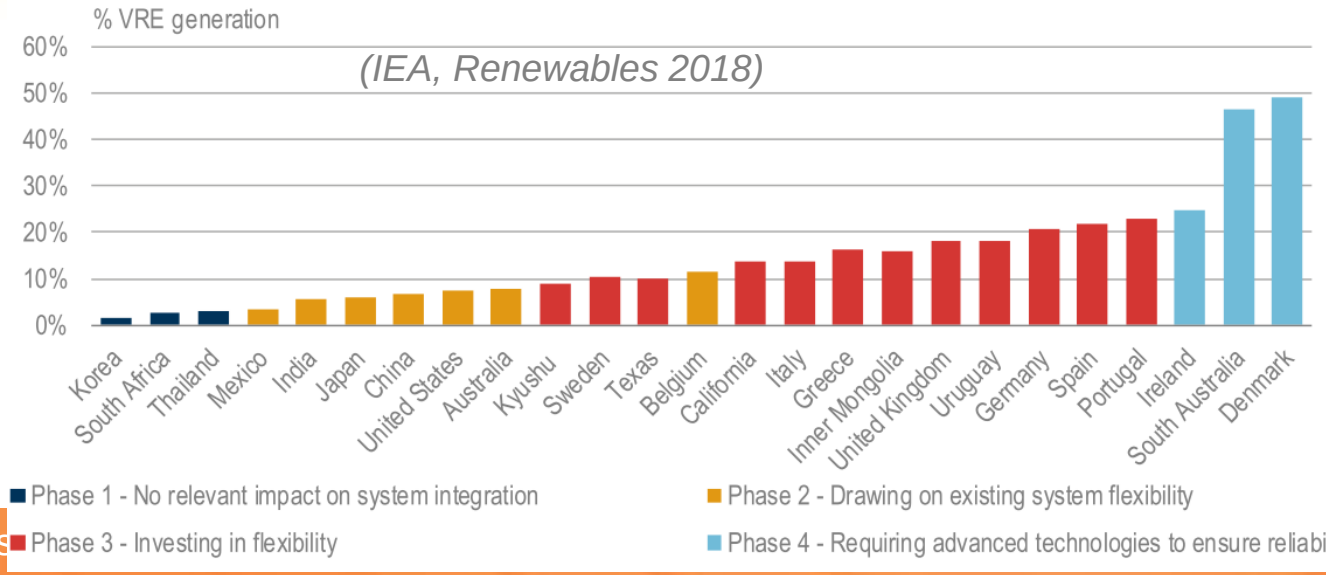




Variable RE integration challenges

Figure 5.11 System integration phases, transition challenges and flexibility measures

Phase characteristics from a system perspective	Key transition challenges	Flexibility options to enable transition
Phase 4 The system experiences periods in which VRE makes up almost all generation	Ensuring robust power supply during periods of high VRE generation	Advanced technology to increase stability, digitalization and smart grid technologies, energy storage, DSR, flexibility from VRE
Phase 3 VRE generation determines the operation pattern of the system	Accommodating greater variability of net load and changes in power flow patterns on the grids	Plant retrofits for flexibility, improved grid infrastructure, interconnections, effective short-term wholesale markets,
Phase 2 VRE has a minor to moderate impact on system operation	Minor changes to operating patterns of existing power systems	Improve VRE forecasting, economic dispatch
Phase 1 VRE has no noticeable impact on the system		



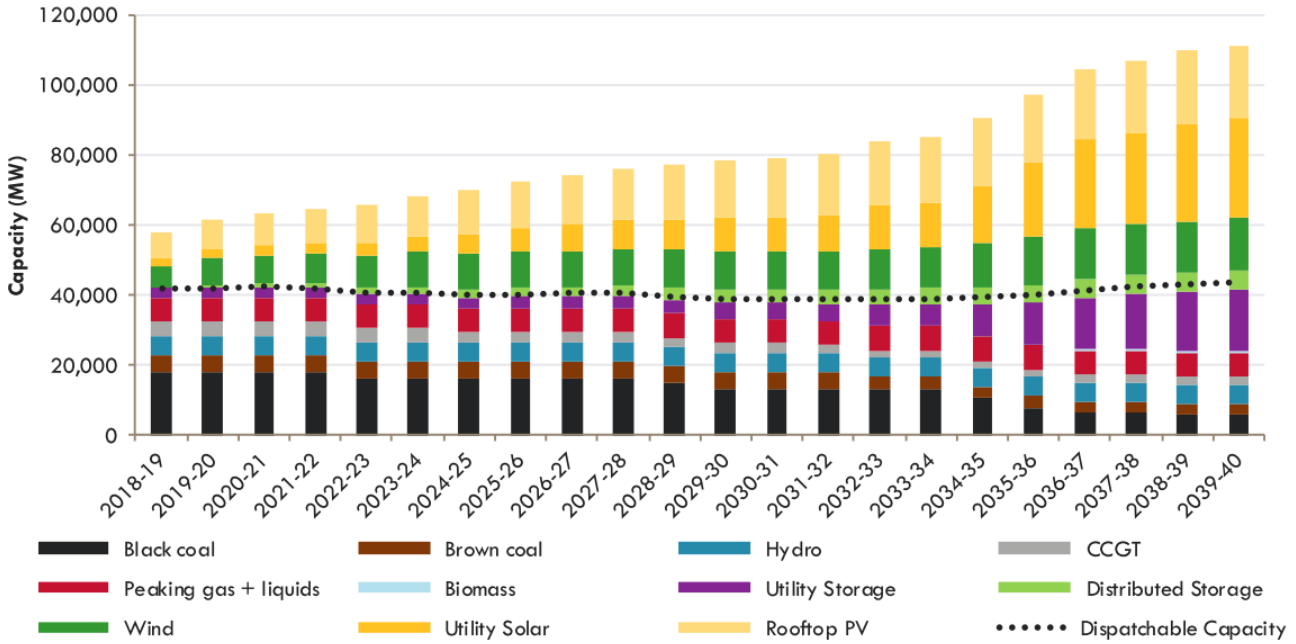
Quick Poll – Q3

- Where will the key energy storage reside in the NEM in 2040?
  - As now, coal stockpiles and gas pipelines
  - Lots of pumped hydro
  - Lots of battery storage
  - Stored renewables, concentrating solar power, biomass, hydro
  - All of the above

Scenarios for NEM

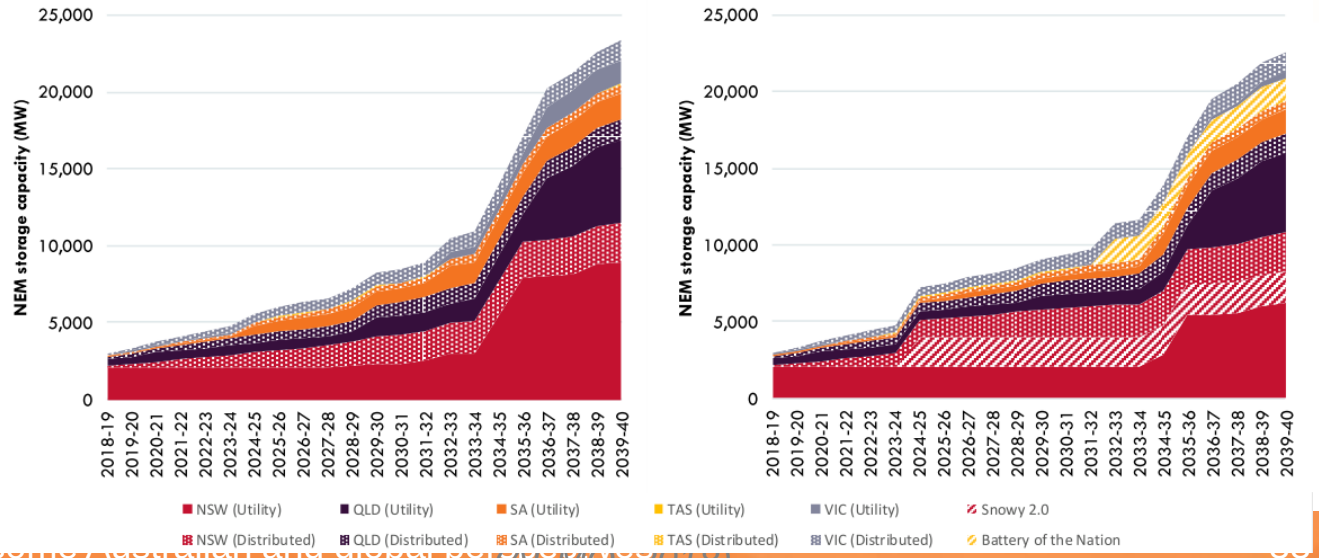
- Neutral has key role for utility + distrib. storage

Figure 9 **Forecast NEM generation capacity in the Neutral case**



(AEMO, Integrated System Plan, 2018)

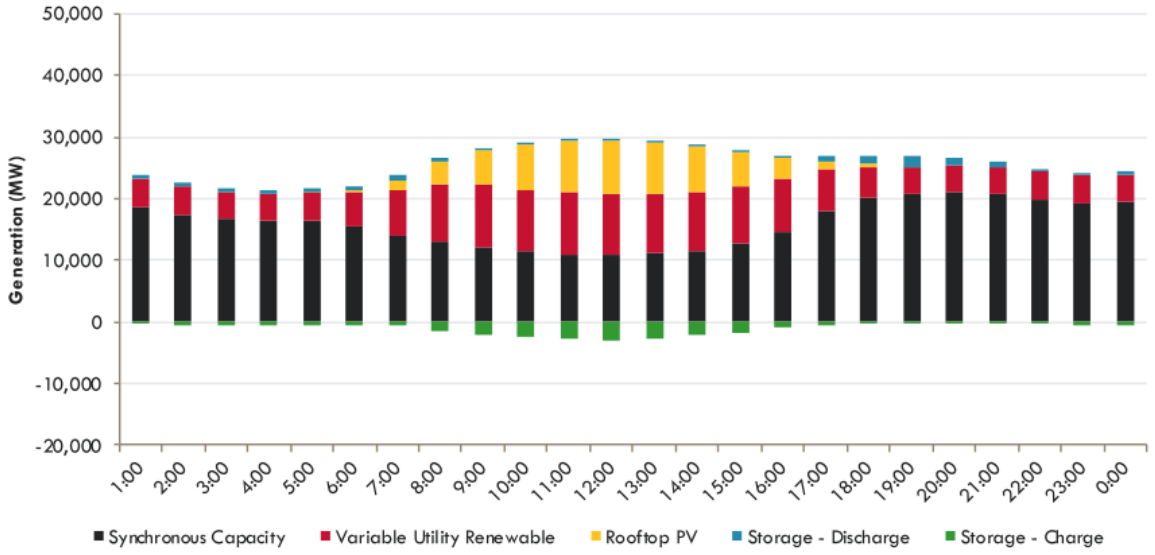
Figure 31 **Projected build of storage for Neutral (left) and Neutral with storage initiatives (right)**



(AEMO, 2018)

Storage to have a key dispatch role

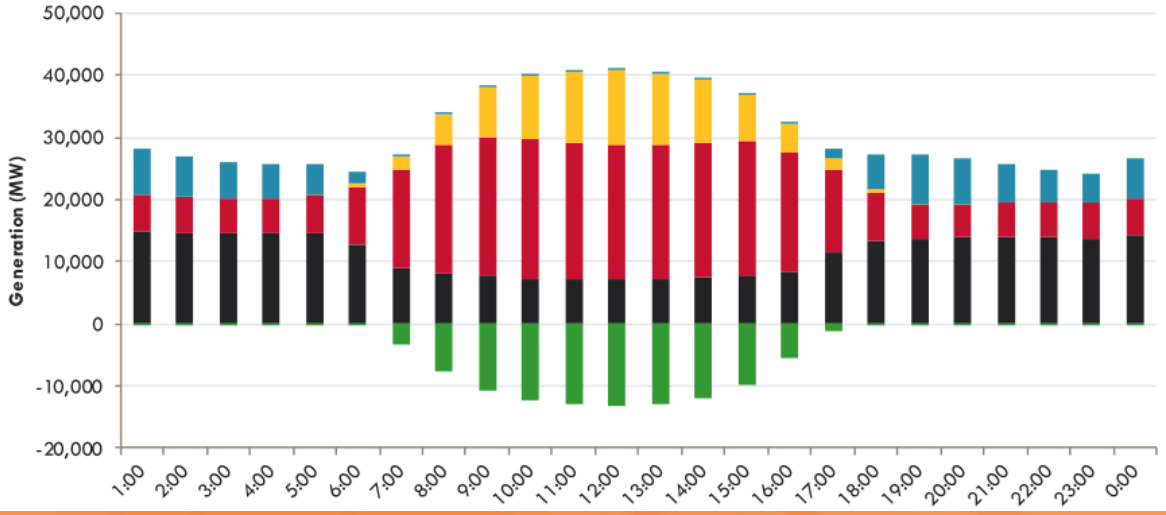
Medium renewable share



- Increasing role for utility-scale variable renewable energy.
- Emerging energy storage role.
- Reduced need for synchronous plant during high renewable generation times, given higher operational costs.

(AEMO, Integrated System Plan, 2018)

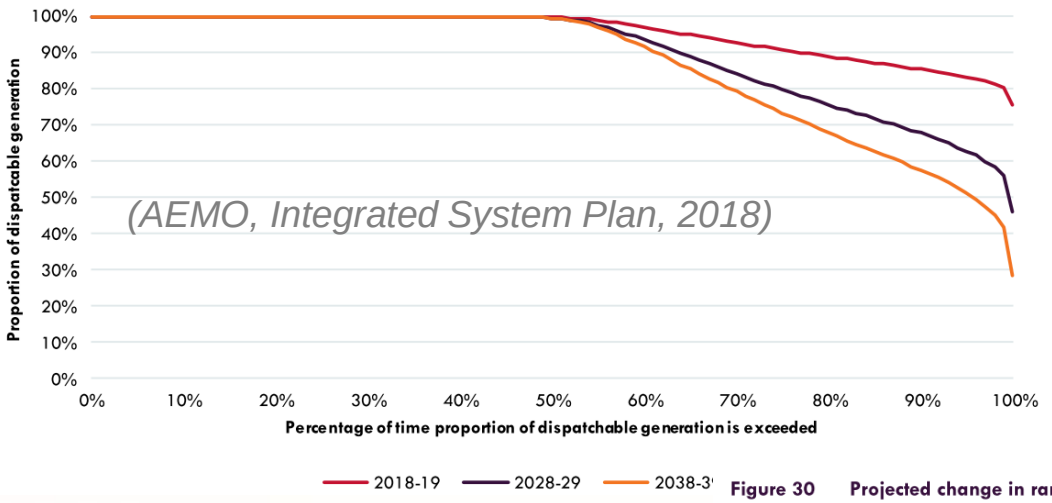
High renewable share



- Large role for energy storage to smooth the production of variable renewable energy.
- Increased flexibility required from synchronous generation to support peak loads and periods of low renewable energy production.

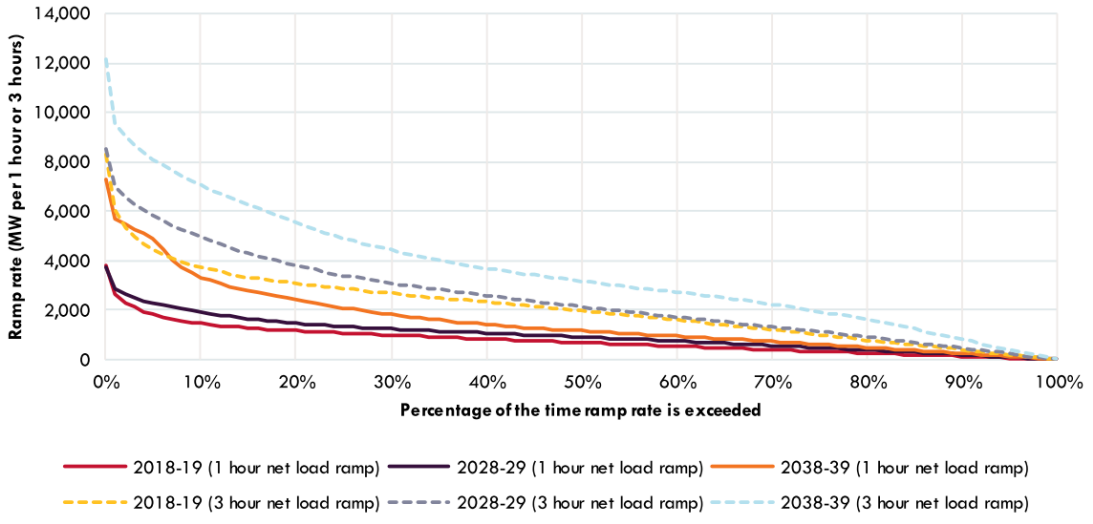
Growing periods of dispatch, ramp challenges

Figure 29 Proportion of conventionally dispatched generation in the NEM, Neutral scenario



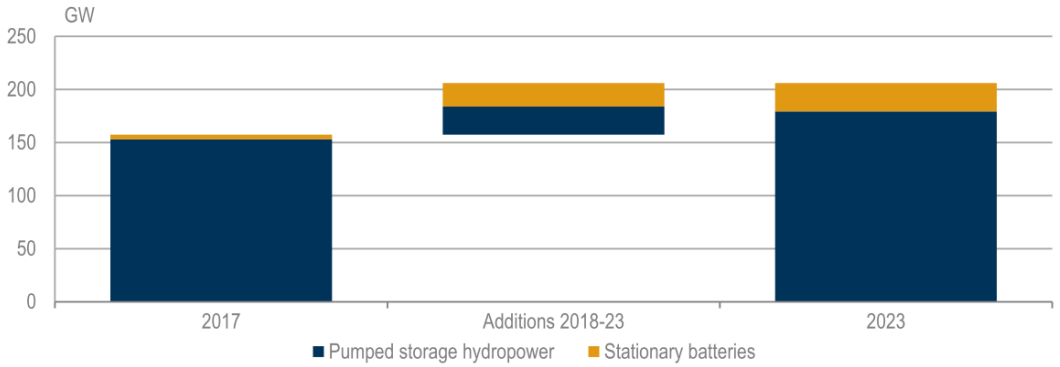
(AEMO, Integrated System Plan, 2018)

Figure 30 Projected change in ramp rate over the next 10 years, Neutral scenario



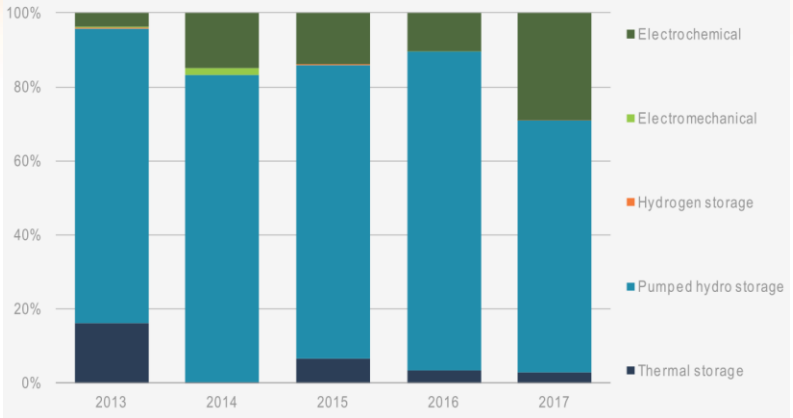
Globally, pumped hydro still dominates but battery role growth

Figure 5.15 Cumulative installed storage capacity (left) and annual additions, 2018-23 (right)



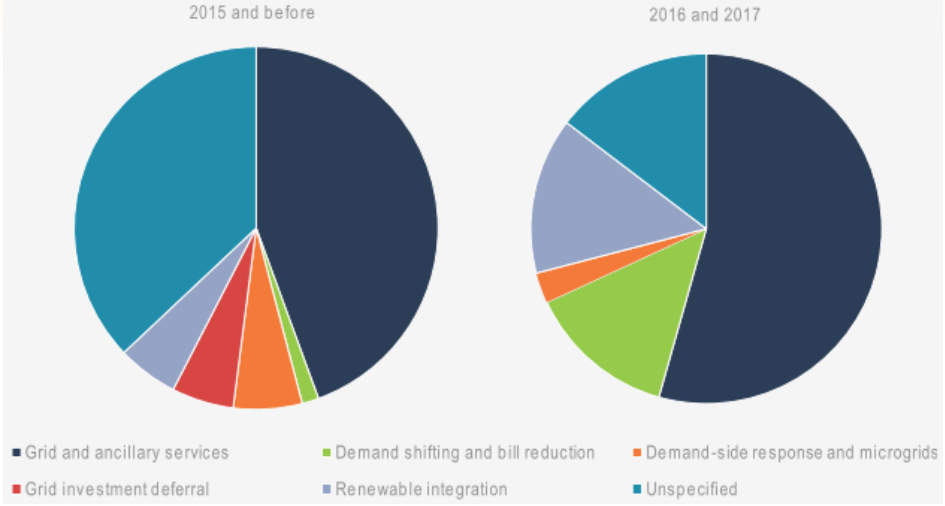
(IEA, Renewables 2018)

Figure 1.23 Share of commissioned grid scale electricity storage projects



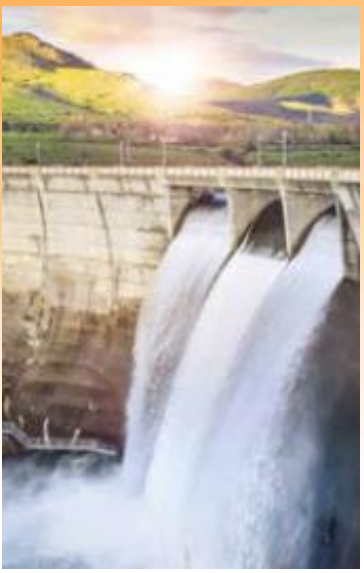
Electro-chemical battery storage comprised nearly 30% of the market for commissioned storage projects in 2017 – benefitting from modularity, fast response capabilities and continuous decreases in costs.

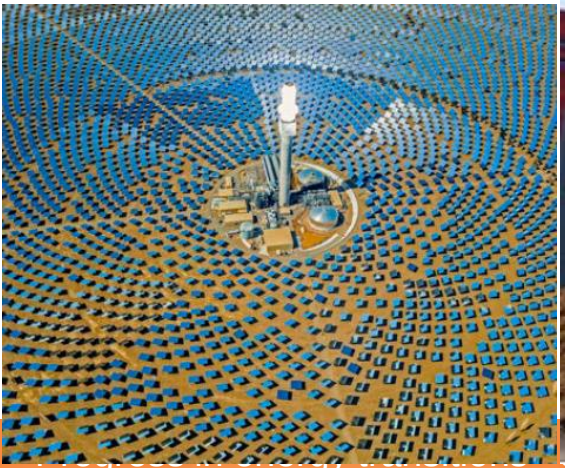
Figure 1.25 Share of global grid-scale battery storage by application (MW)



RE – synchronous machine vs power electronics interface

(photos from Ren21, RE Global Status Report, 2018)



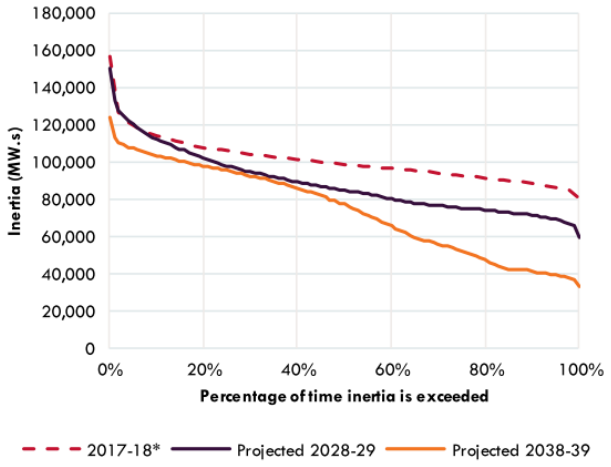


Quick Poll – Q4

- How much generation will have a power electronics grid interface in the NEM in 2040?
  - As at present, around 10% power electronics interface (PEI)
  - Around 25% PEI
  - Around 50% PEI
  - Around 75% PEI
  - Near 100% PEI

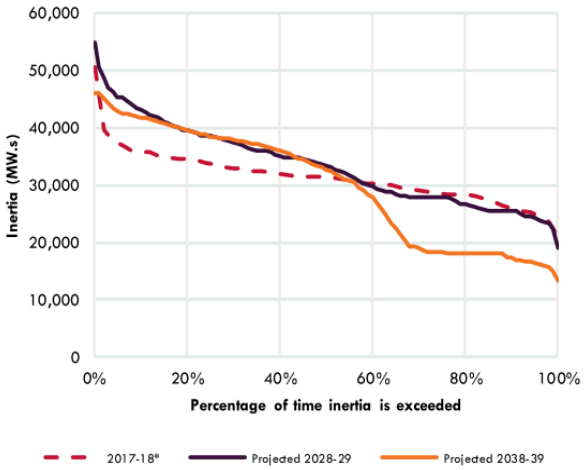
Falling inertia a growing concern

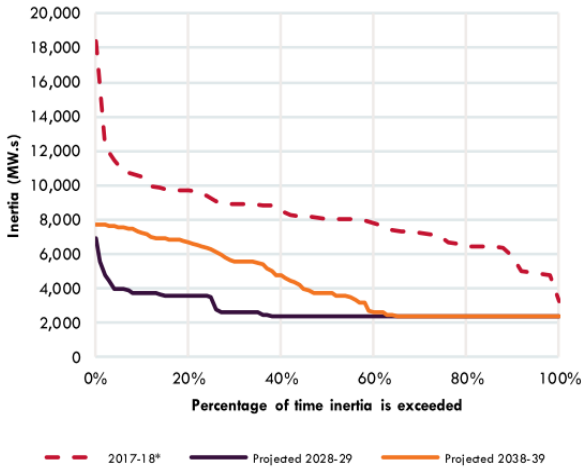
Figure 35 Inertia projections, Neutral scenario, for the NEM



(AEMO, Integrated System Plan, 2018)

Figure 36 Inertia projections, Neutral scenario, for Queensland (left) and South Australia (right)



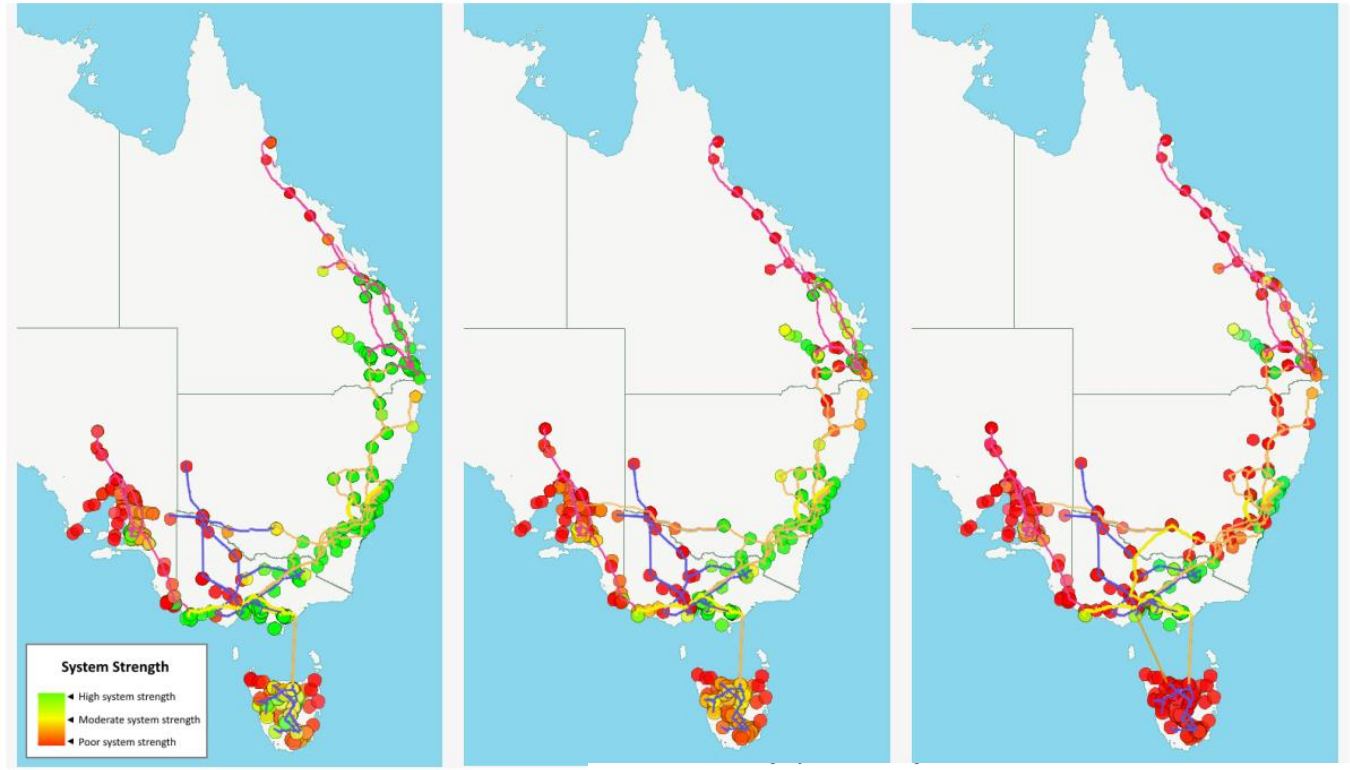


Before 2028-29, South Australia could require remedial action to maintain appropriate levels of inertia within acceptable requirements. The reduction in typical levels of inertia in the South Australia region is as a result of reduced dispatch of synchronous gas plant due to system strength requirements being met by newly installed synchronous condensers[80], and RiverLink enabling access to lower-cost generation in the New South Wales region. While the inertia available in the South Australian region reduces, it should also be noted that the risk of islanding of the South Australian network will be greatly reduced with RiverLink in place. Remedial actions include, but are not limited to:

- Installation of new inertia from synchronous condensers.
- Contracts to provide inertia from synchronous plant that may otherwise not be economically available to generate.
- Increased availability of fast frequency response (FFR).

System strength too

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



(AEMO, Integrated System Plan, 2018)

Since system strength is localised and varies across the network, the exact requirements to improve system strength will depend heavily on the network characteristics at that location. For example, some existing wind farms have been required to install small synchronous condensers to increase local system strength. A coordinated approach that allows renewable generators to contribute towards system strength for a REZ will be more economic than developing system strength solutions at individual wind and solar farms.

As an approximate guide, a 150 MW wind farm connecting in a weak area of the network could require around 30 megavolt amperes reactive (MVAr) of synchronous condenser support, at an approximate cost of $5 million to $10 million. As there are many factors that could influence system strength mitigation requirements and costs, generator proponents should conduct their own due diligence and discuss the topic with the relevant Network Service Provider (NSP) when considering connecting a generator in a low system strength area.

Where next?

"The best way to predict your future is to create it!"

Abraham Lincoln

"Keep calm..

& carry on"

Thoughtful, careful, efforts