Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

The future Australian National Electricity Market: how affordable, secure and sustainable? …and how renewable, distributed and competitive?

Iain MacGill

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

ZHAW School of Management and Law Seminar

Zurich, 6 June 2019

Centre for Energy and Environmental Markets

Australian NEM

- Although not actually National
- And not primarily a Market, but a power system

Participating jurisdictions	Qld, NSW, Vic, SA, Tas, ACT
NEM regions	Qld, NSW, Vic, SA, Tas
NEM installed capacity (including rooftop solar PV)	55 590 MW
Number of large generating units	240
Number of customers	9.7 million
NEM turnover 2017–18	$17 billion
Total electricity demand 2017–18[1]	203 TWh
National maximum demand 2017–18[2]	32 469 MW

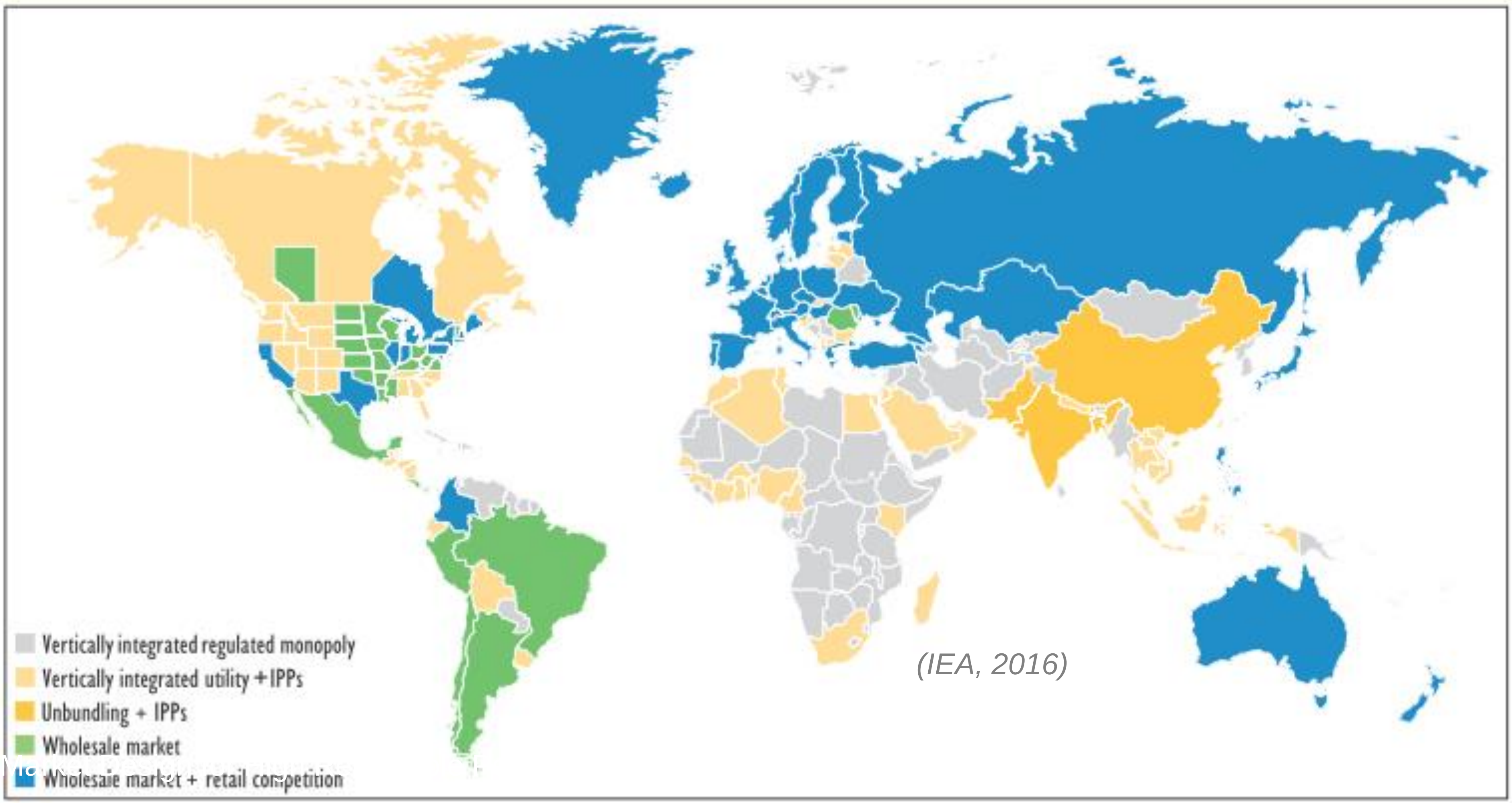
Sources: AEMO; AER.

(AER, State of the Energy Market, 2018)

Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

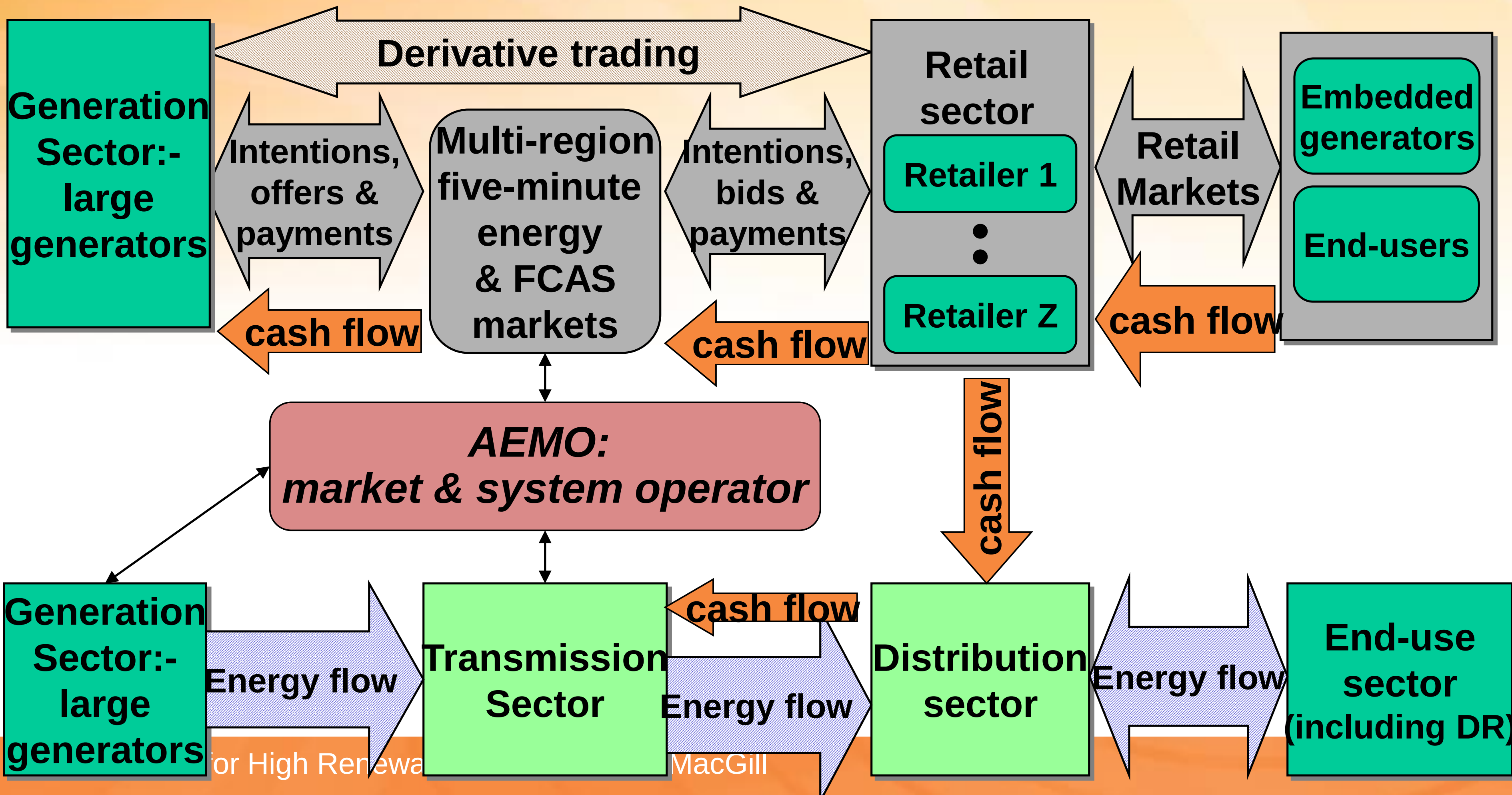
Still, NEM a leading global example of a highly restructured electricity sector



(IEA, 2016)

The Australian National Electricity Market (NEM)

(adapted from Outhred, 2010)



The future NEM

- How affordable?
- How secure?
- How sutainable?

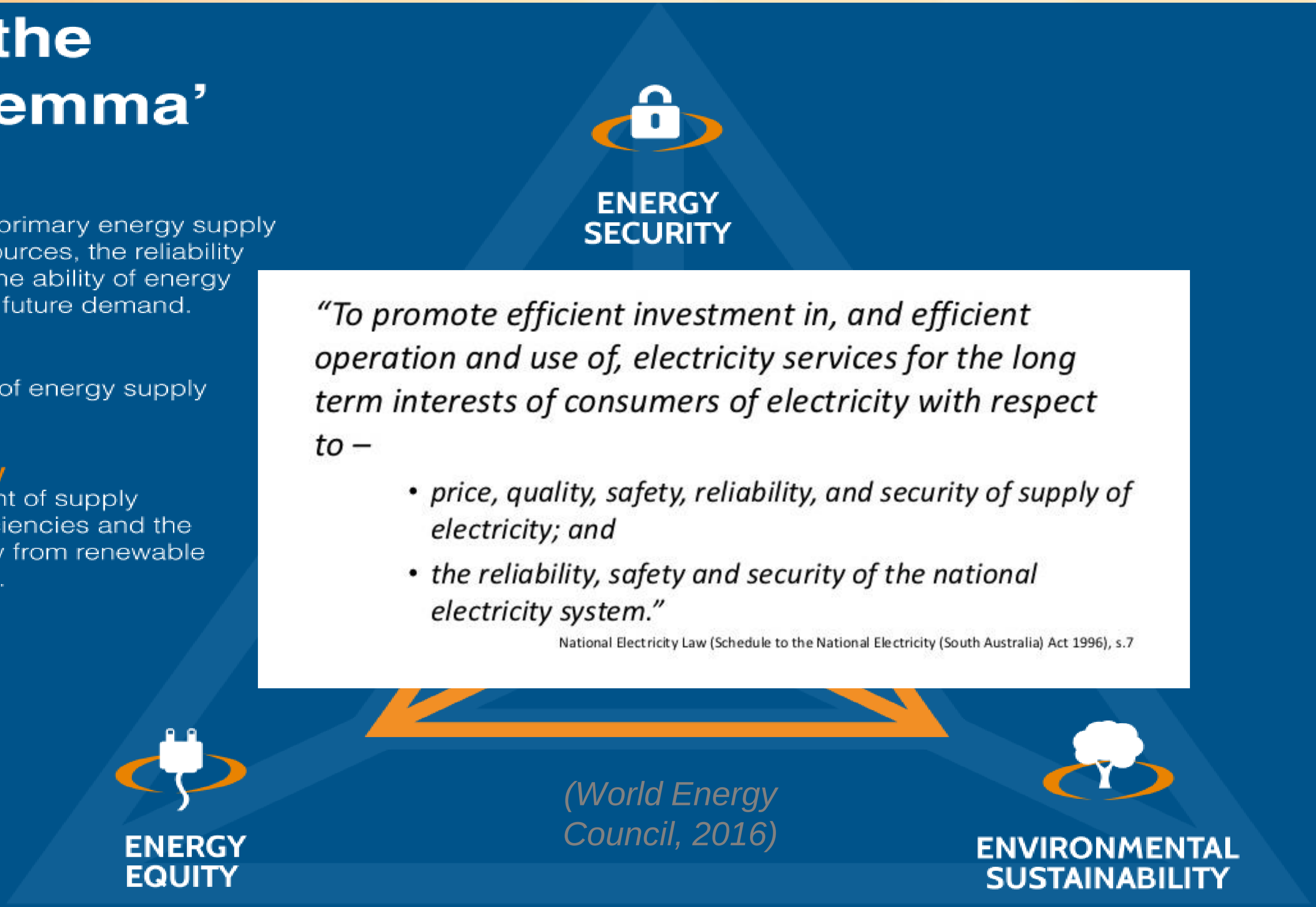
Represents possible destination: our long-term interests *difficult decisions seem required – choose any two?*

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.



"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 –

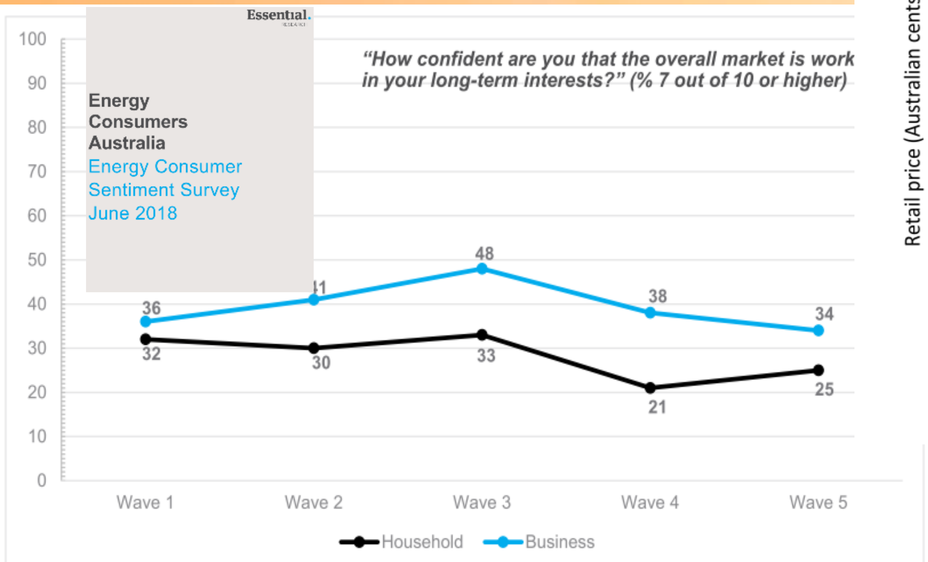
- *price, quality, safety, reliability, and security of supply of electricity; and*
- *the reliability, safety and security of the national electricity system."*

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

(World Energy Council, 2016)

Centre for Energy and Environmental Markets

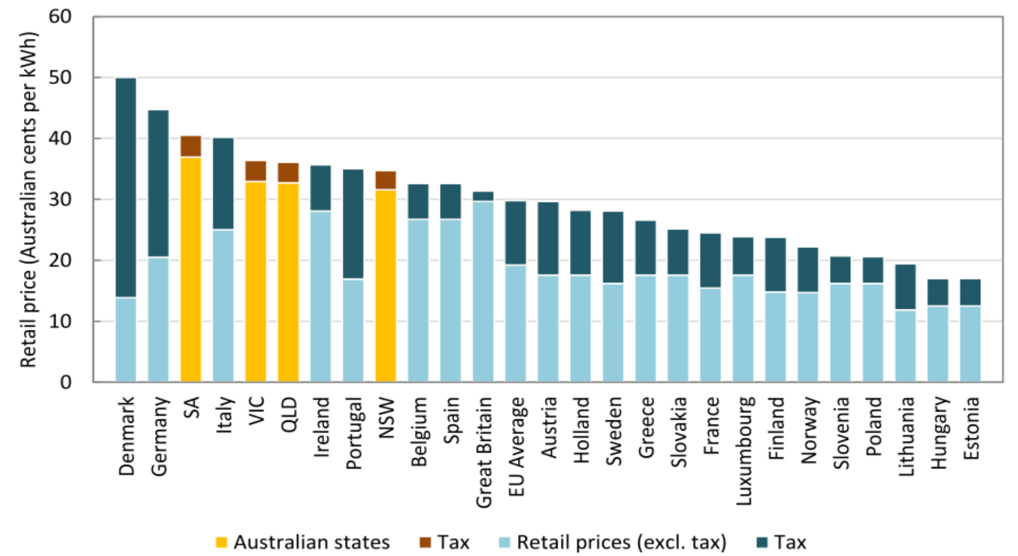
..but may get none



International retail electricity price comparison

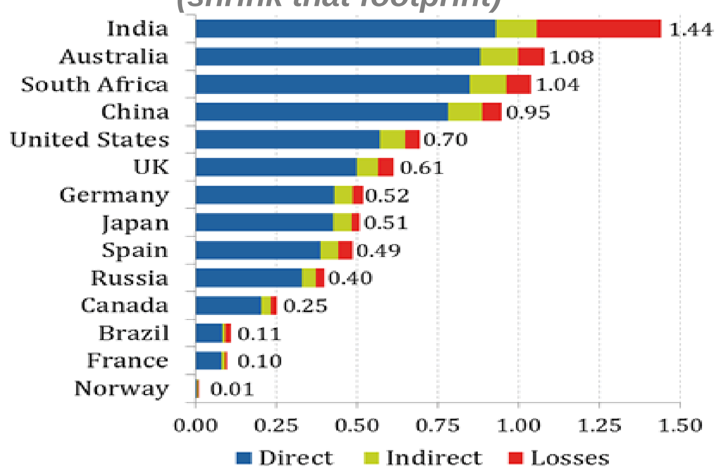
(ACCC Retail Price Competition Inquiry, 2017)

Figure 1.9: Comparison of residential electricity prices (before and after tax) (Australian cents per kWh) (May 2017 prices in Australia, 2015 prices in European countries)[62]



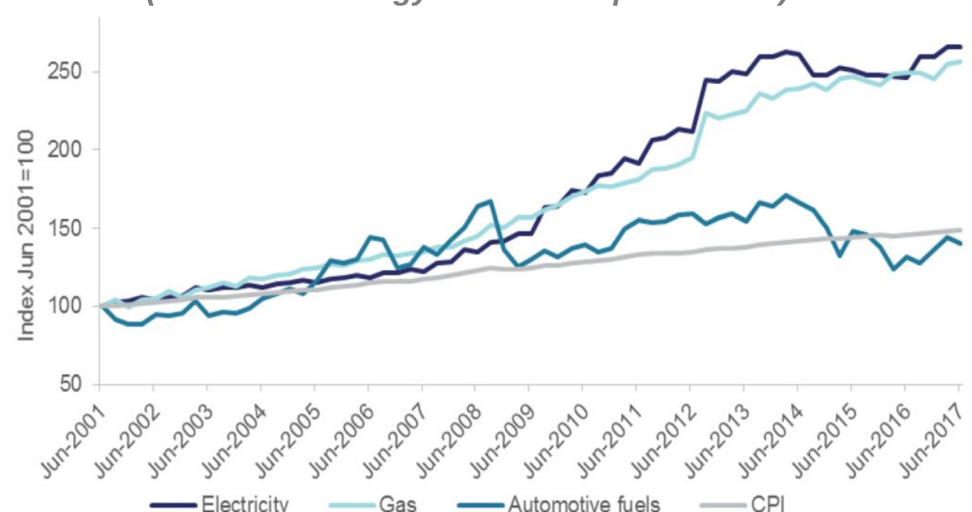
Electricity emissions intensity comparison

(shrink that footprint)



Australian residential energy prices index

(Australian Energy Statistics Update 2017)



Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

Including growing security and reliability challenges

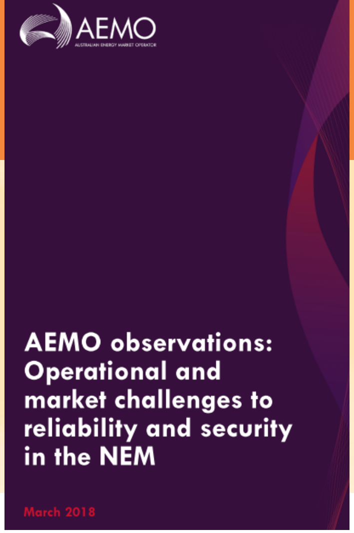


Table 1 Key system changes and operational challenges

Issue	What we are seeing	Operational implications	Potential avenues to address
Changing supply mix	• More variable renewable energy • Less dispatchable generation • Older resources	• Increased variability and uncertainty in the resource mix • Increased reliance on directions	• Forecasting improvements • Valuing flexible performance • Strategic reserves • Day-ahead markets • Integrated system planning
Changing electricity demand	• Higher ramps for peaks • Lower minimum demand • More active consumers • More distributed energy resources (DER)	• Increased variability and uncertainty in demand • Erosion of baseload • Increased ramping requirement	• Forecasting improvements • Use of DER • Valuing flexible performance • Strategic reserves • Day-ahead markets • Integrated system planning
Changing impact of weather	• Temperature changes • Extremity of weather events	• Increased demand • Increased stress on system over prolonged heat periods • Increased risk of disruption • Increased uncertainty	• Planning operating standards • Use of DER • Optimising utilisation of demand side response – for reserves to manage uncertainty and support greater system resilience • Forecasting improvements

..yet perhaps can have it all

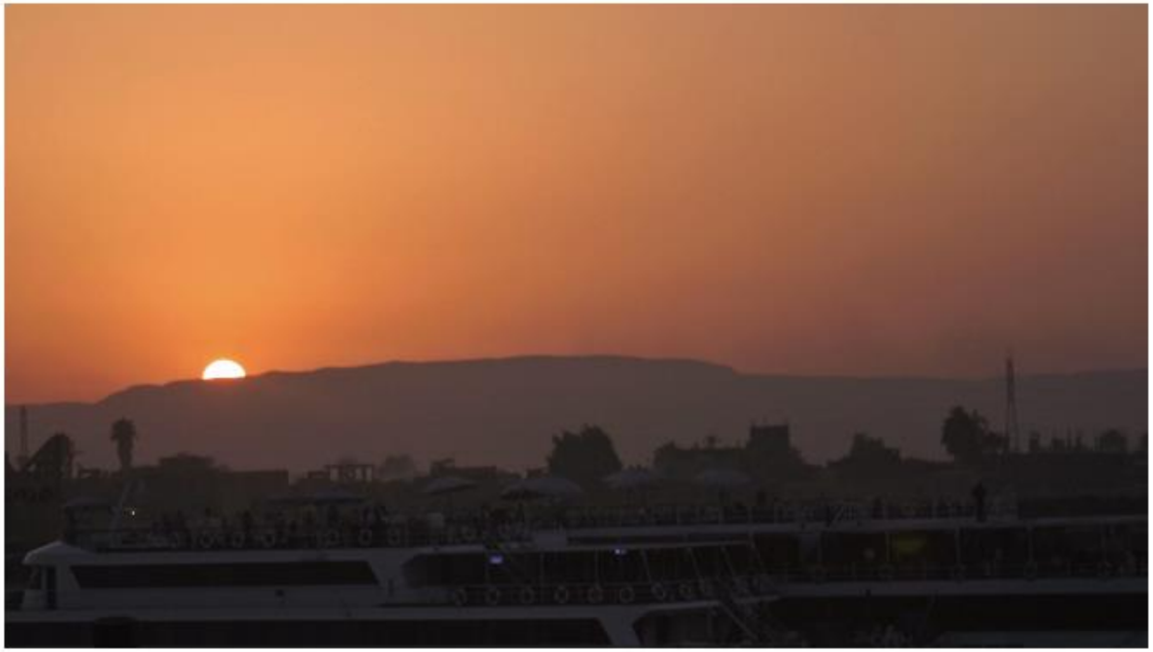
Falling variable renewables costs clearly a game changer

Egypt receives two bids under $0.03/kWh in 200 MW solar tender

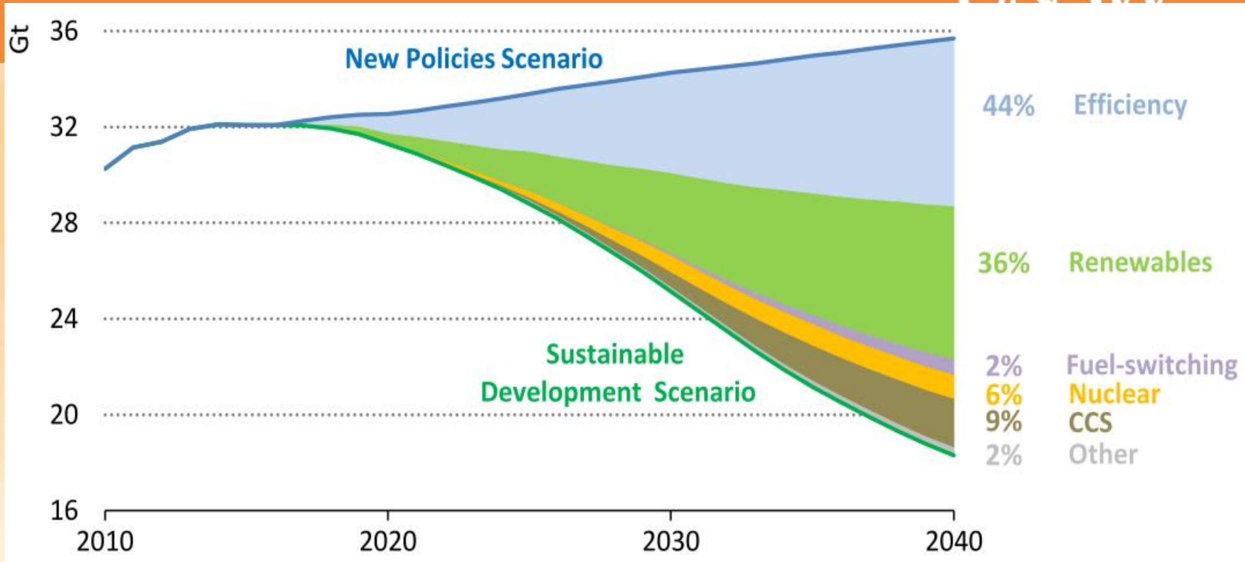
The lowest bid was submitted by Spanish developer Fotowatio, which offered US$0.02791 per kWh. Slightly higher, at $0.02799 per kWh, was the offer of Saudi power company, ACWA.

AUGUST 7, 2018 EMILIANO BELLINI

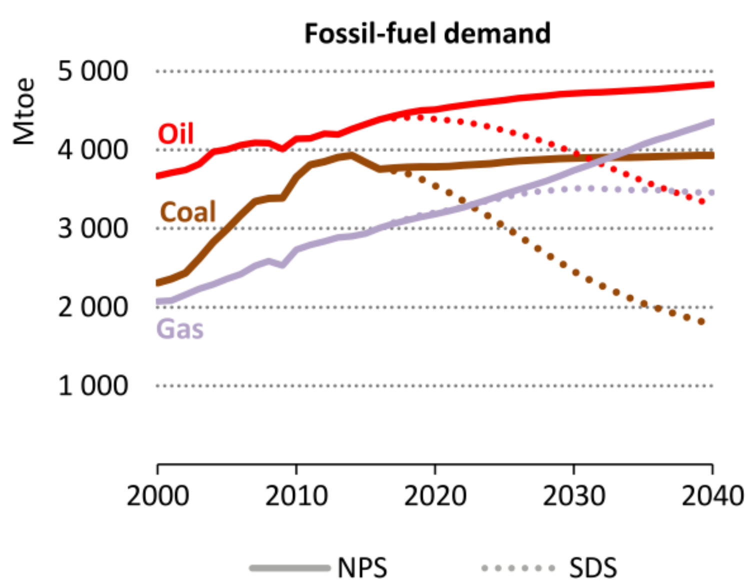
HIGHLIGHTS UTILITY-SCALE PV EGYPT

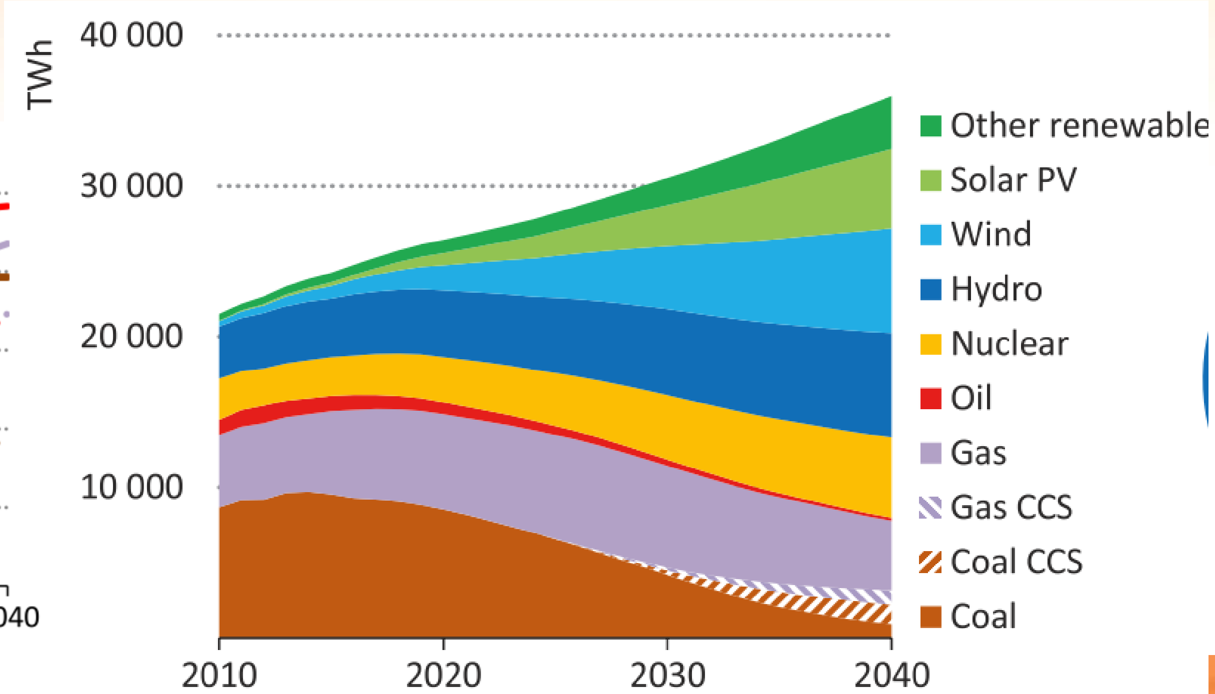


IEA SDS



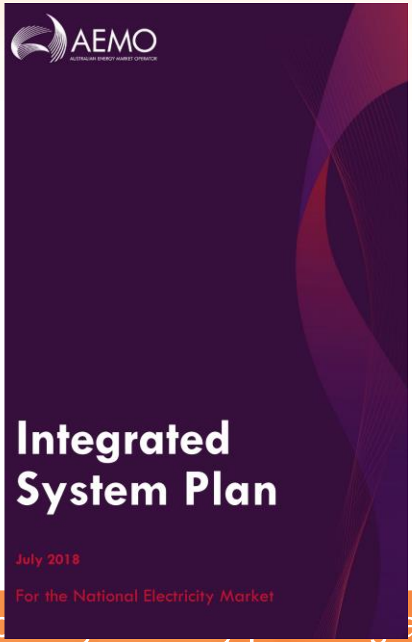
(IEA, World Energy Outlook, 2018)

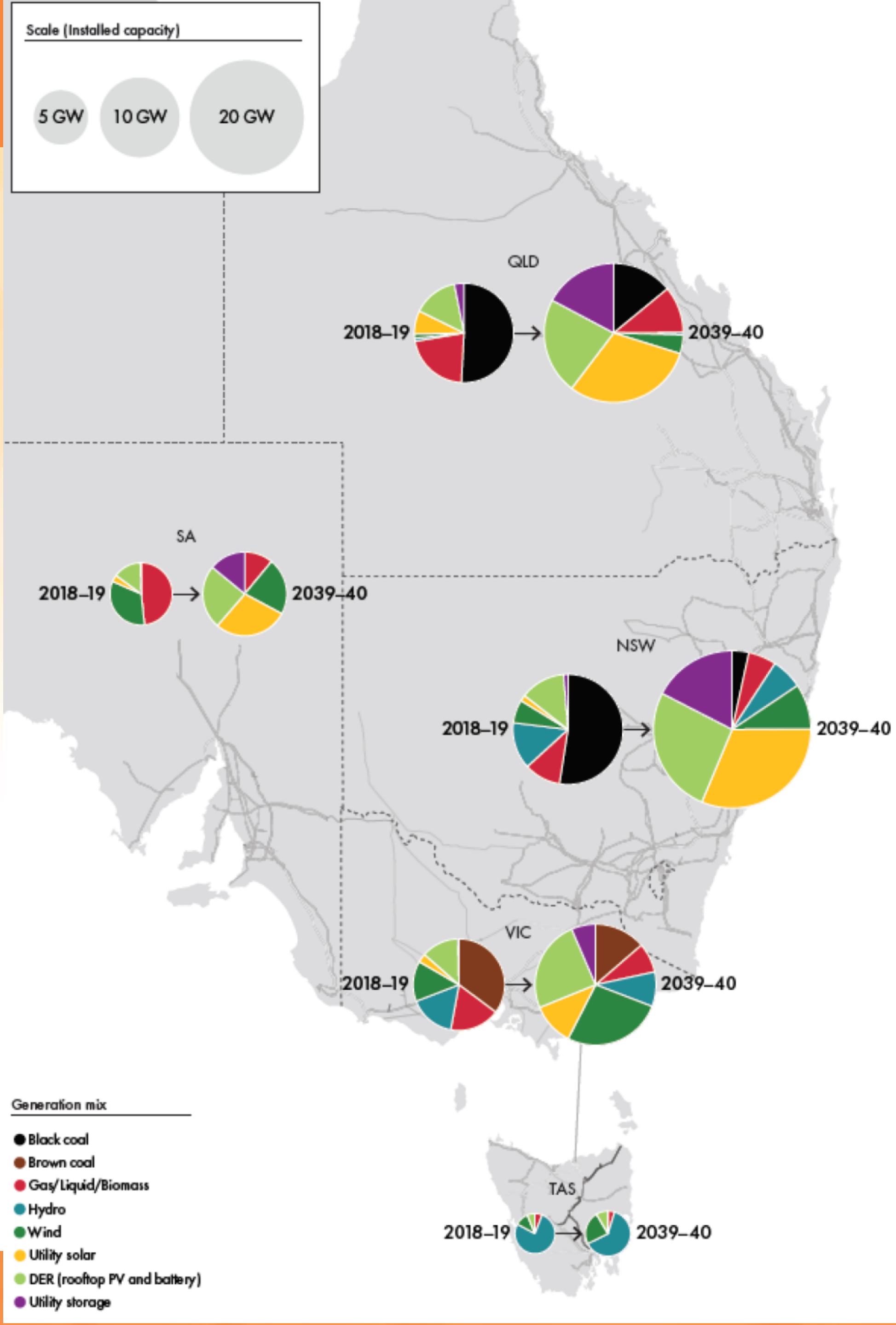




NEM scenarios

No electricity sector plan as such at present… but AEMO National Tx planning provides range of scenarios

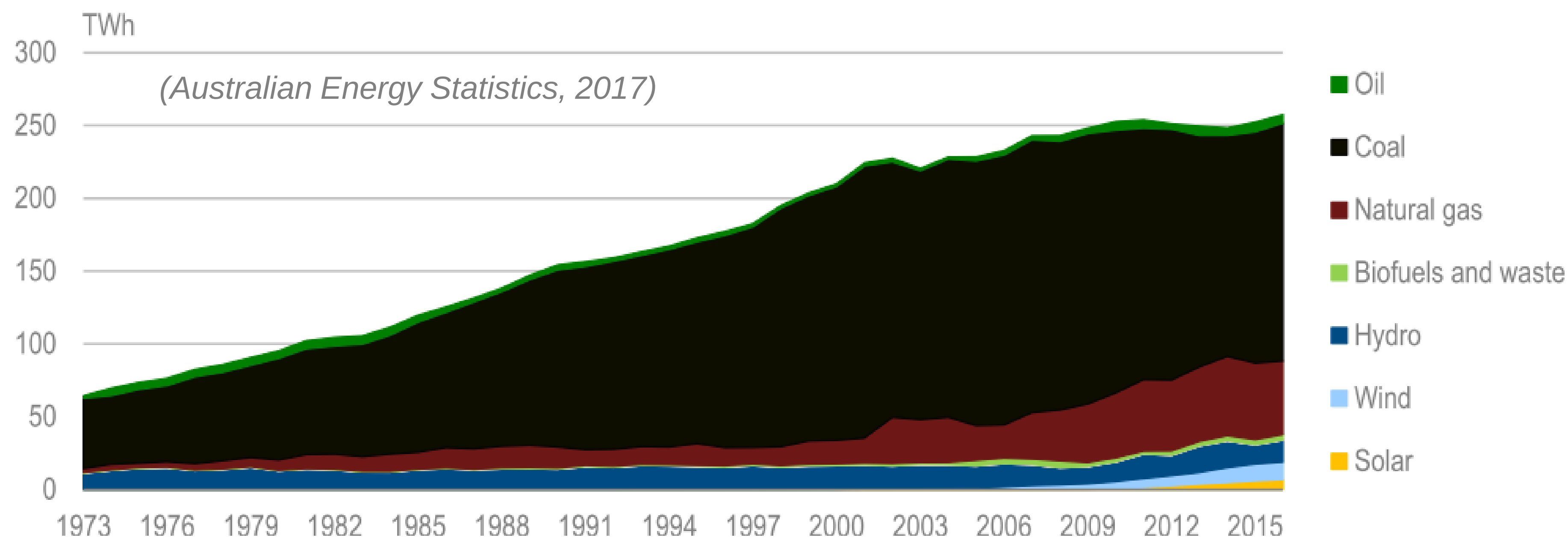


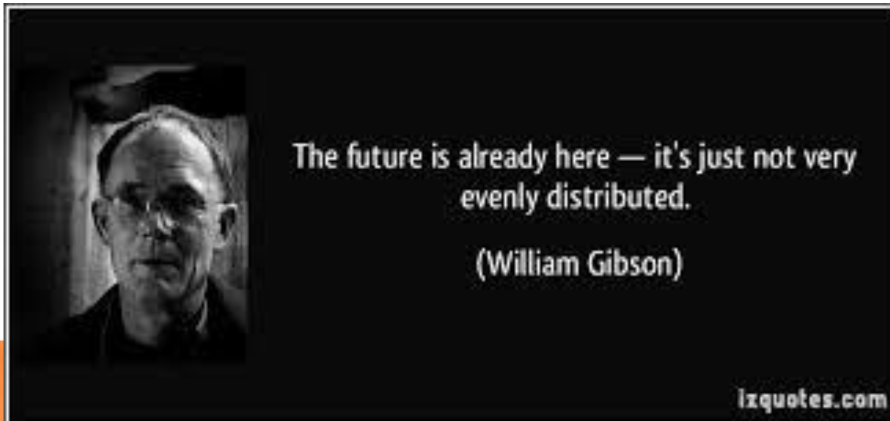


The future NEM

- **How renewable?**
- How distributed?
- How competitive?

To date for Australia's electricity sector





Recently, greater NEM-wide RE deployment

- South Australia has one of world's highest regional penetrations of variable renewables

year ending February 2019 were:

total NEM	21.2%,
New South Wales	12.0%
Queensland	8.4%
Victoria	20.8%
South Australia	52.8%
Tasmania	97.1%

Figure 6

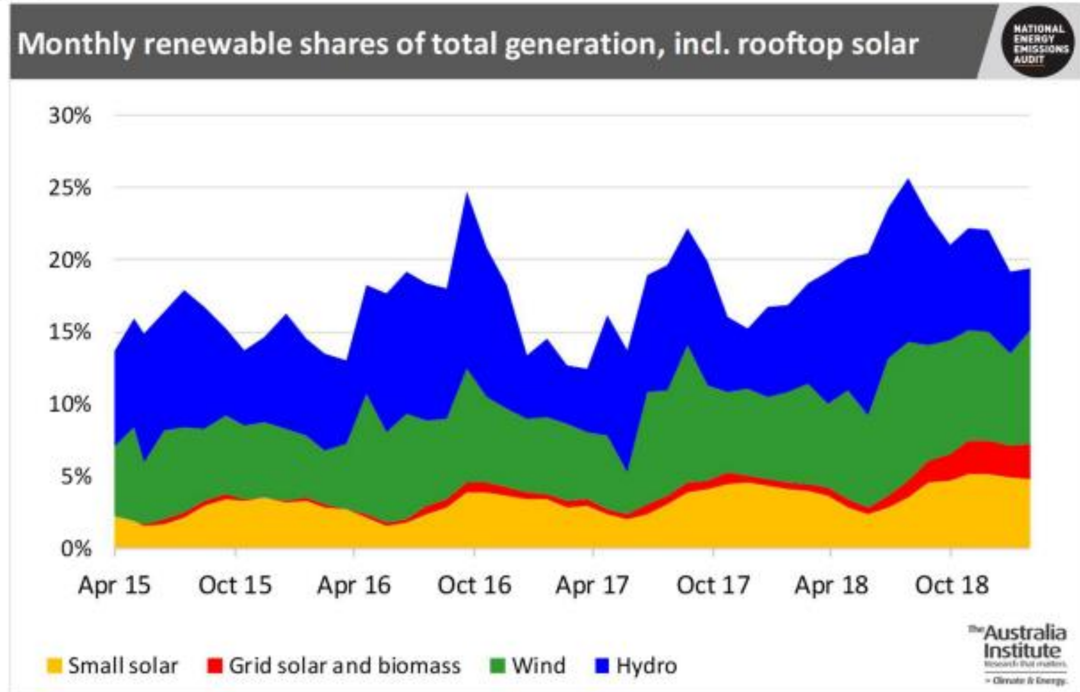
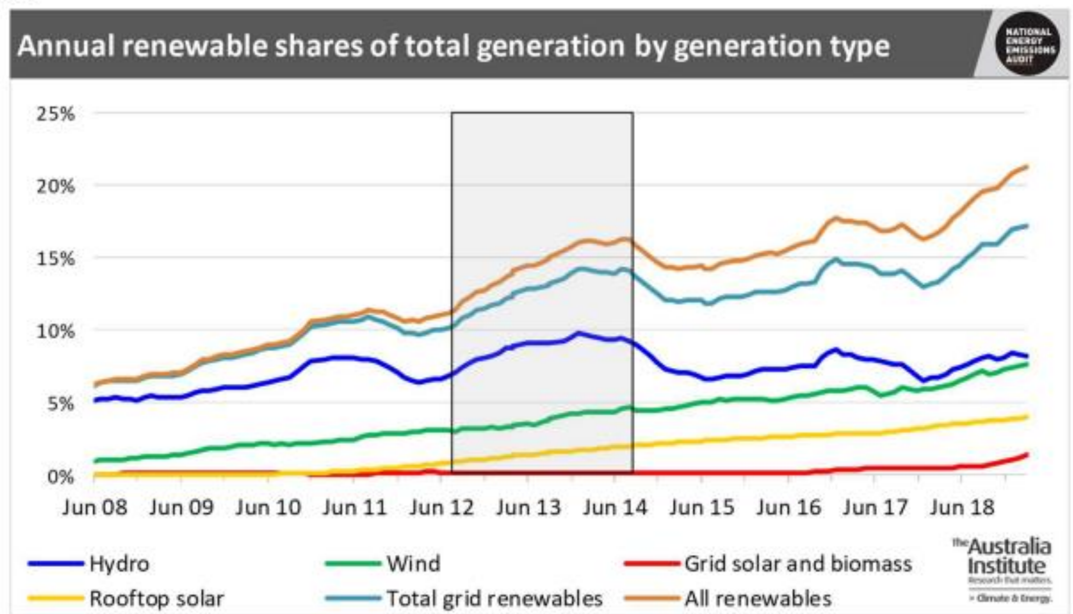


Figure 7



THE CONSTRUCTION BOOM FOR LARGE-SCALE RENEWABLE ENERGY PROJECTS

(PROJECTS UNDER CONSTRUCTION OR FINANCIALLY COMMITTED)

(Clean Energy Council, 2019)

395 Megawatts
$945m Investment
500 Jobs

45 Megawatts
$83m Investment
170 Jobs

4941 Megawatts
$10,003m Investment
4681 Jobs

3800 Megawatts
$4714m Investment
2320 Jobs

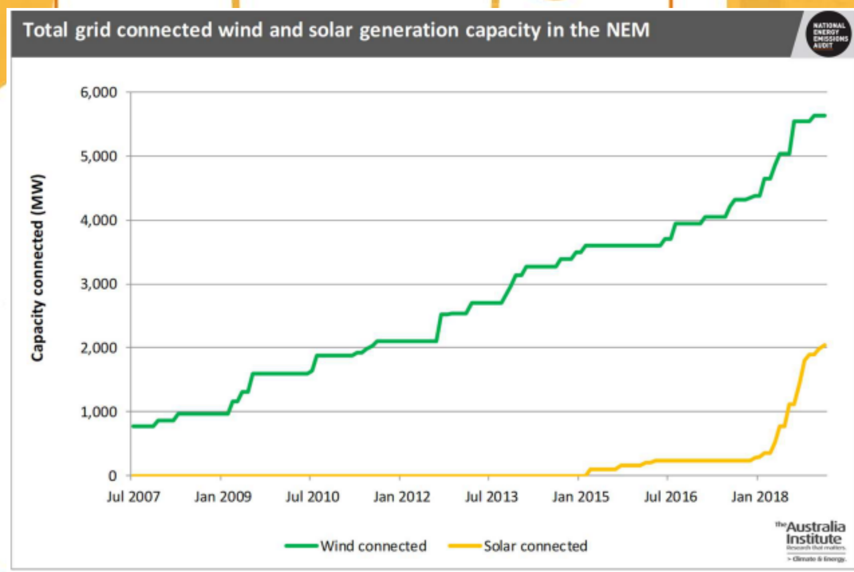
2260 Megawatts
$3119m Investment
2310 Jobs

262 Megawatts
$580m Investment
358 Jobs

3140 Megawatts
$5034m Investment
2894 Jobs

VIC

TAS



TOTALS

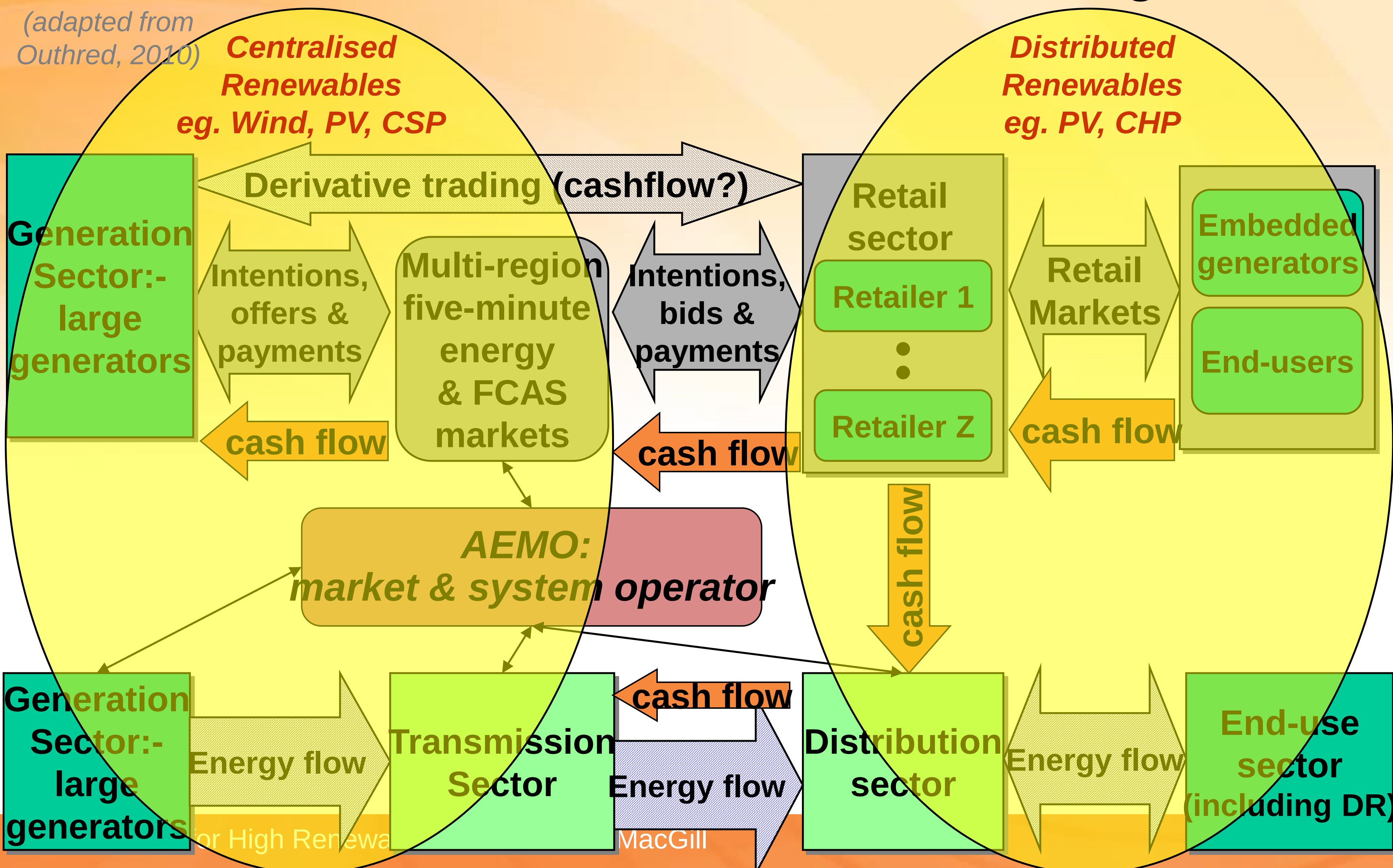
14,841 Megawatt

$24.5b Investmen

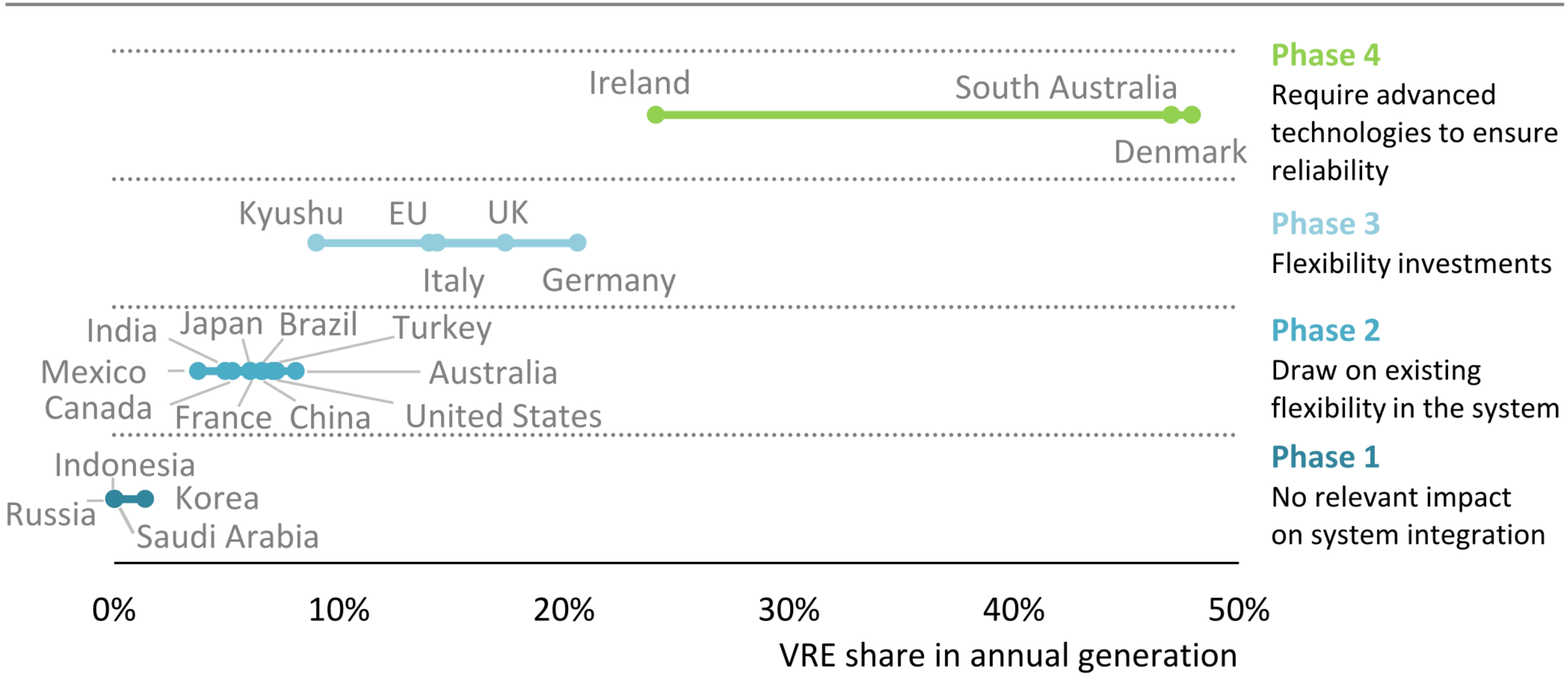
13,23 Jobs

* As at 15 March 2019

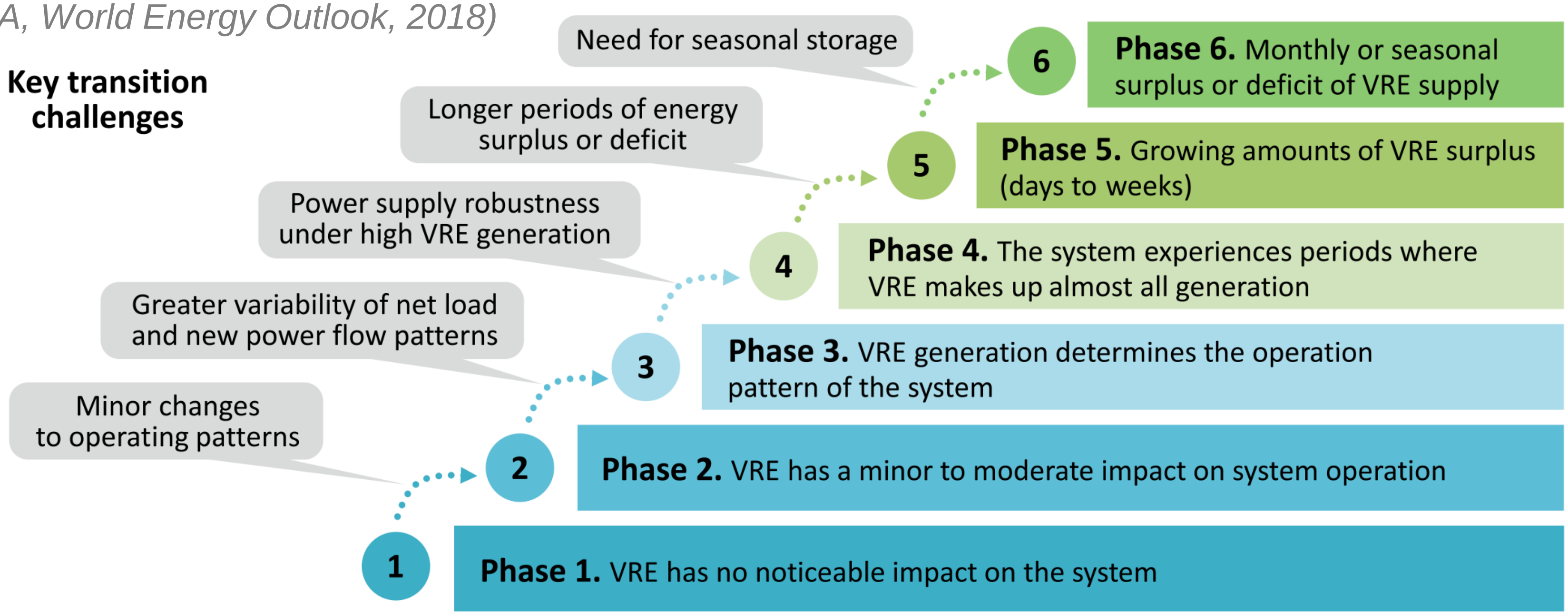
Two market ‘worlds’ for renewables integration



(adapted from Outhred, 2010)



(IEA, World Energy Outlook, 2018)



Elec. Markets for high RE – NEM Status

(IEA, Next Generation Wind and Solar, 2016)

System-friendly strategy	Policy tool	Country example
System service capabilities	Grid codes that require advanced capabilities Advanced design of system services markets	Participation of wind in balancing the grid in Denmark and Spain
Location of deployment	Integrated planning of grid infrastructure and generation	Integrated planning in Brazil
	Locational signals in remuneration schemes	Mexican auction system, differentiation of FIT levels in China
Technology mix	Technology-specific auctions that reflect the value of each technology as determined in long-term planning	South Africa
	SV reflected in multi-technology auctions	Mexico
Economic design criteria	Partial exposure to market prices via premium systems	German and Danish market premium systems, US Tax Credits
Integrated planning, monitoring and revision	An integrated long-term plan for VRE and flexible resources, updated regularly	Integrated system planning in Denmark

NEM reasonably placed but grandfathering of existing plant – RE and conventional – raising issues; need these for Distributed Resources too

NEM reasonably placed although some FCAS issues needing attention; AEMO security review underway, non-synchronous generation penetration limits seem particularly key to high RE

NEM improving ISP but are scenarios sufficiently 'stretched', AEMC Tx framework reporting regime coming; what of possible strategic investment; queues for RE projects growing; Dx integrated planning required too

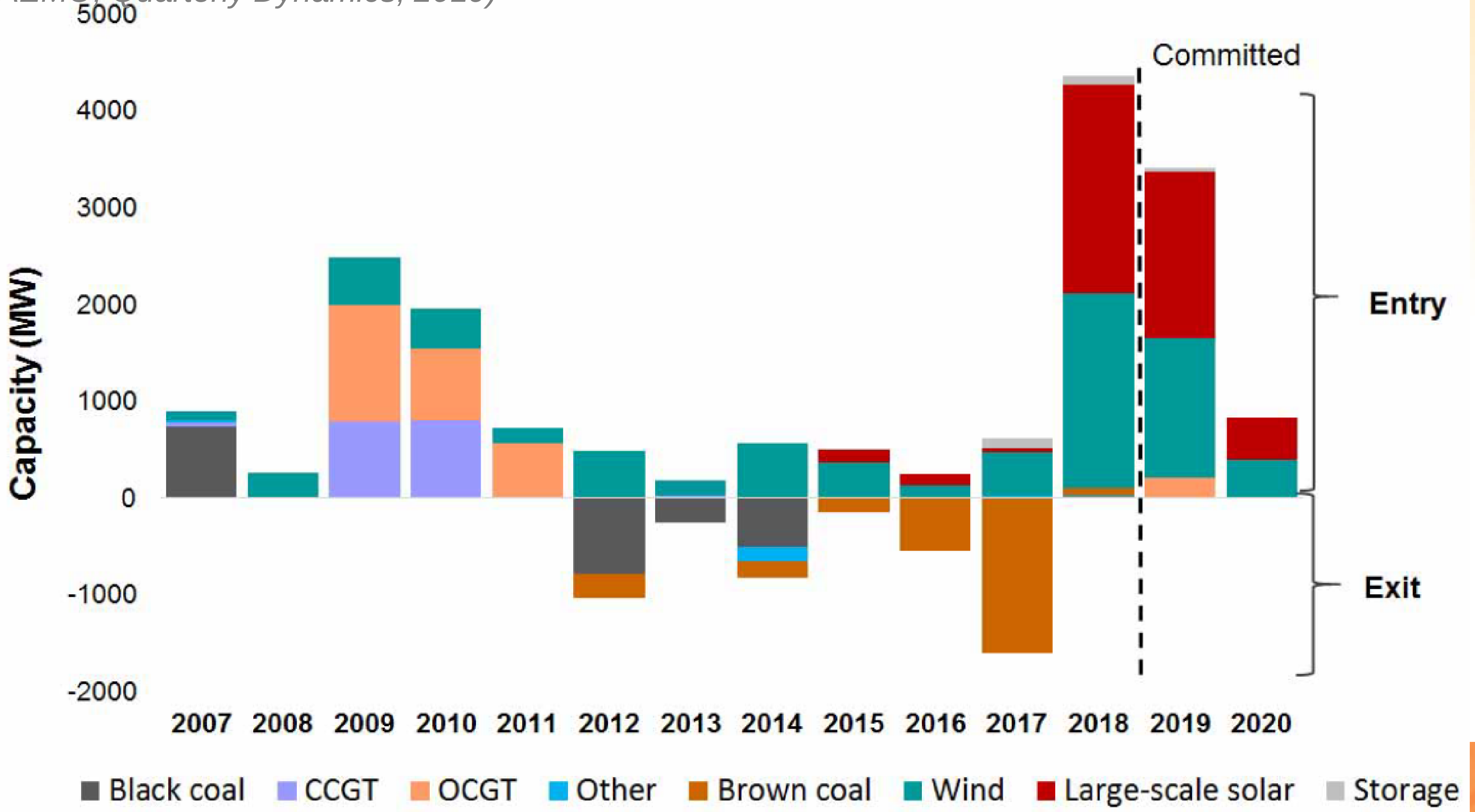
NEM temporal and regional pricing and use of RET means project developers see some technology, temporal and locational signalling – does State moves to auctioning reduce this? Merit Order Effect hits renewables harder than conventional plant – appropriateness of energy-only market for both RE as well as fossil-plant investment (and exit) requirements to be considered, growing o/s experience to draw upon

In the broader policy context, simply Shambolic here in Australia at present, and gravely damaging opportunities for effective and efficient RE integration

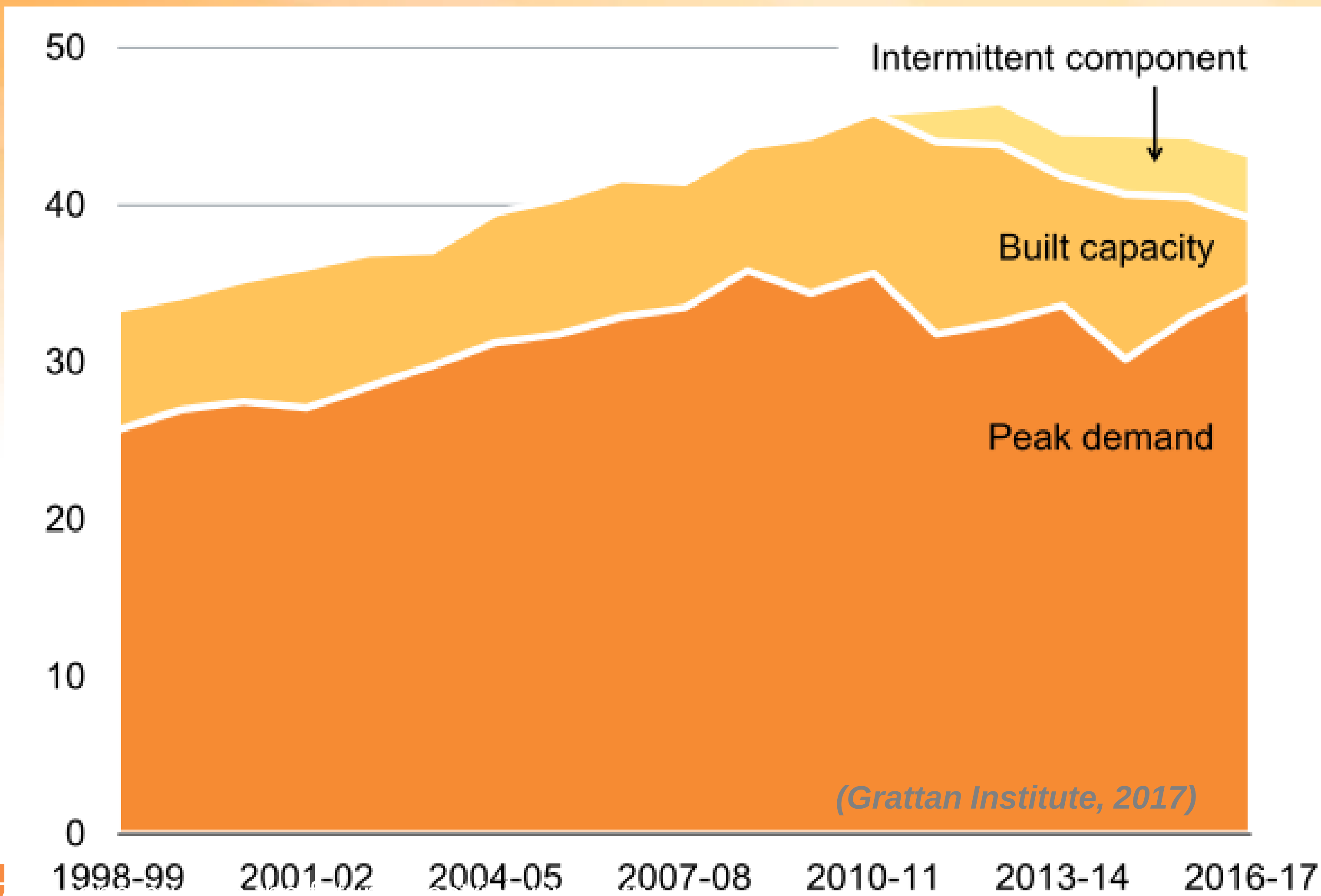
Not just adding RE but losing thermal plant

Figure 1: Entry and exit of generation capacity in the NEM, 2007 to 2020

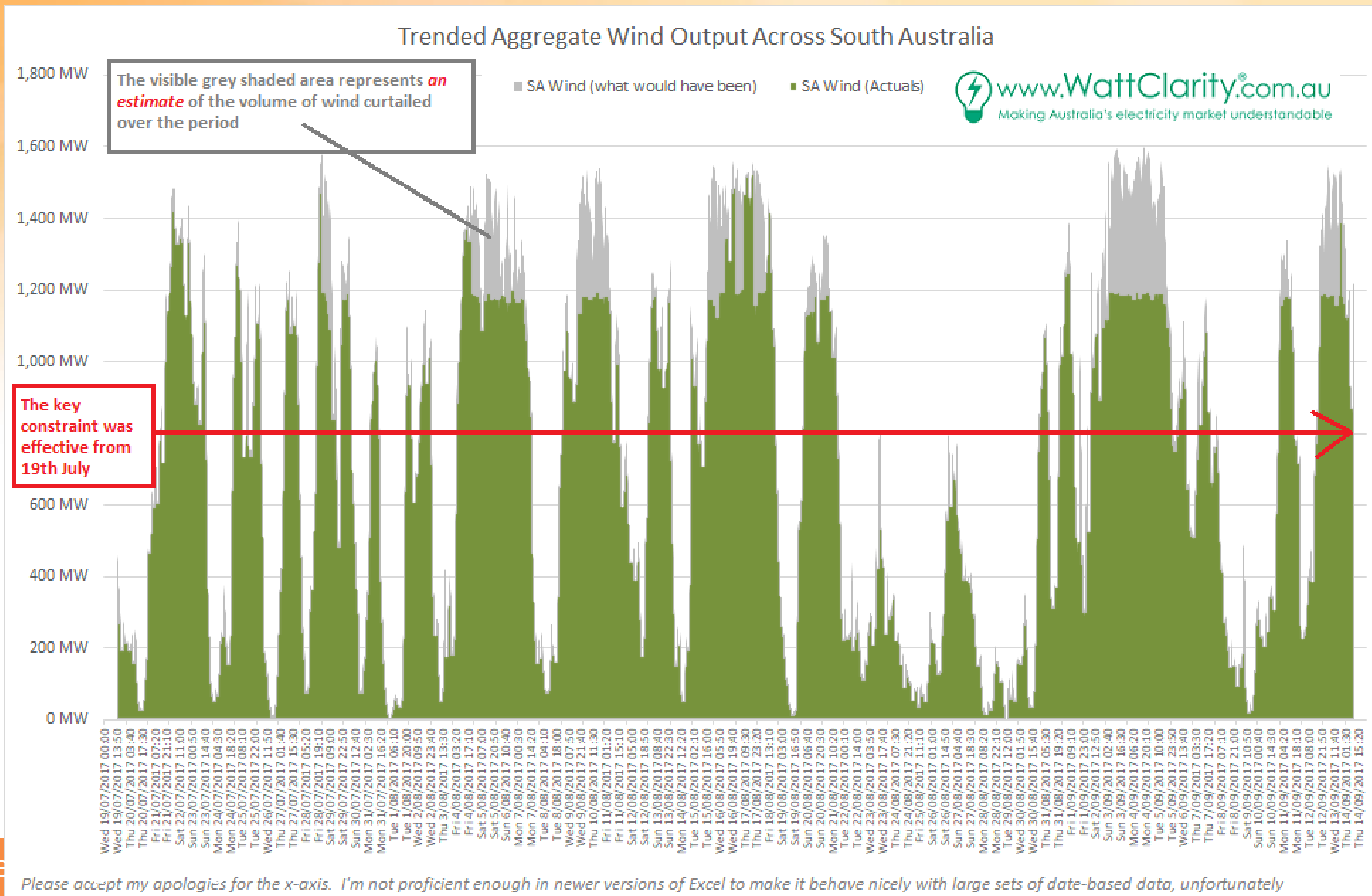
(AEMO, Quarterly Dynamics, 2019)



Resource adequacy tightening



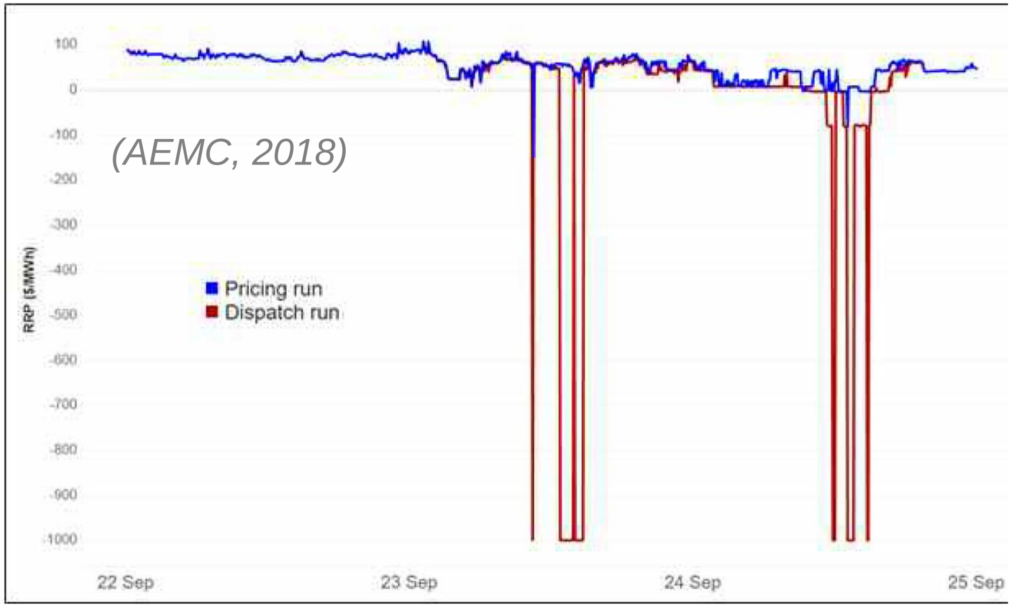
Wind, PV curtailment not necessarily bad



In South Australia

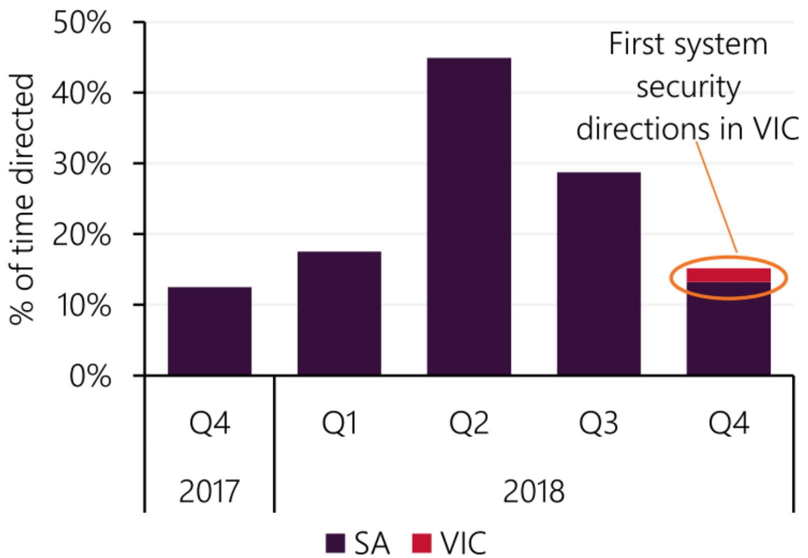
- Present arrangements appear to be struggling with existing wind and PV penetrations
- And the evident solution of increased Tx investment doesn't necessarily solve the wider NEM integration challenge as penetrations continue to climb

Figure 6.4: Impact of direction on SA prices - 22-25 September 2017



Source: AEMC analysis of NEM data
Note:

Figure 27 Directions for system security in South Australia and Victoria



The future NEM

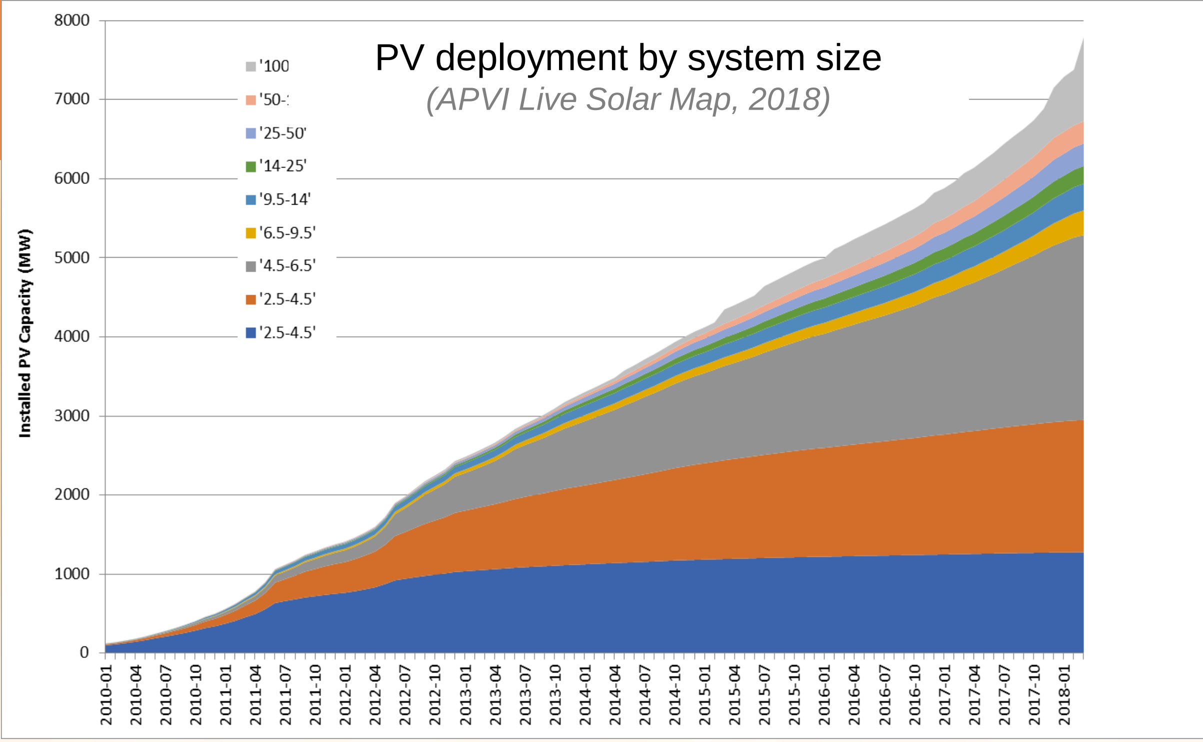
- How renewable?
- **How distributed?**
- How competitive?

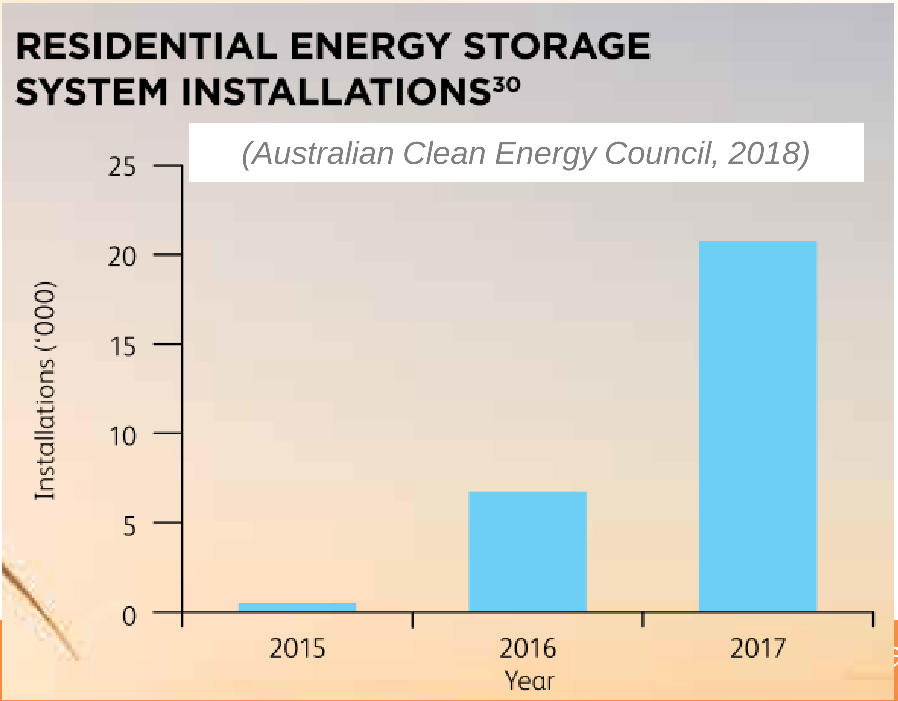
PV's ultimate scalability

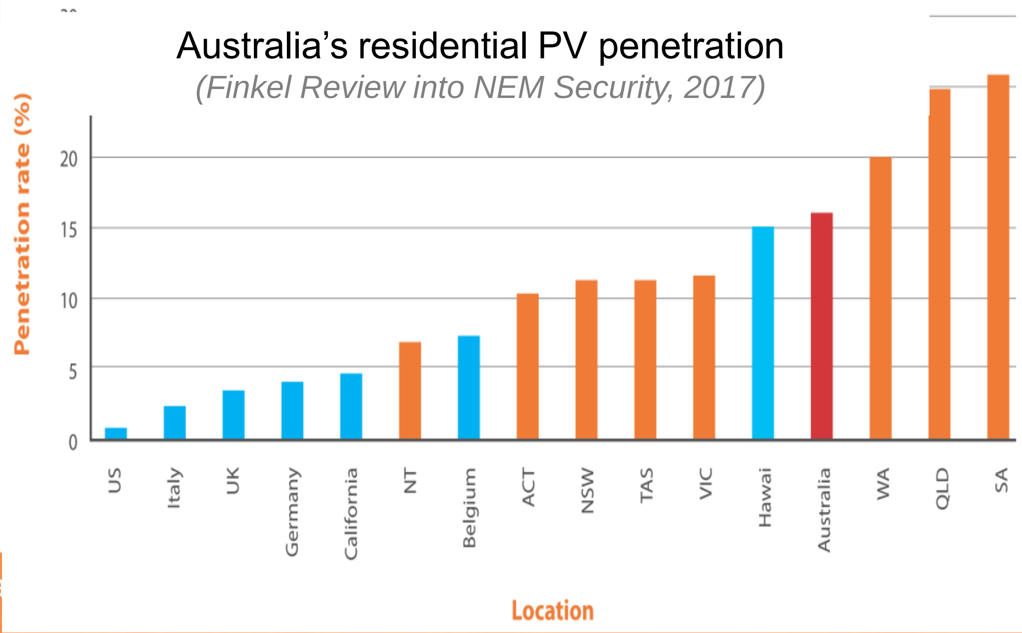
Centre for Energy and Environmental Markets

Australian PV

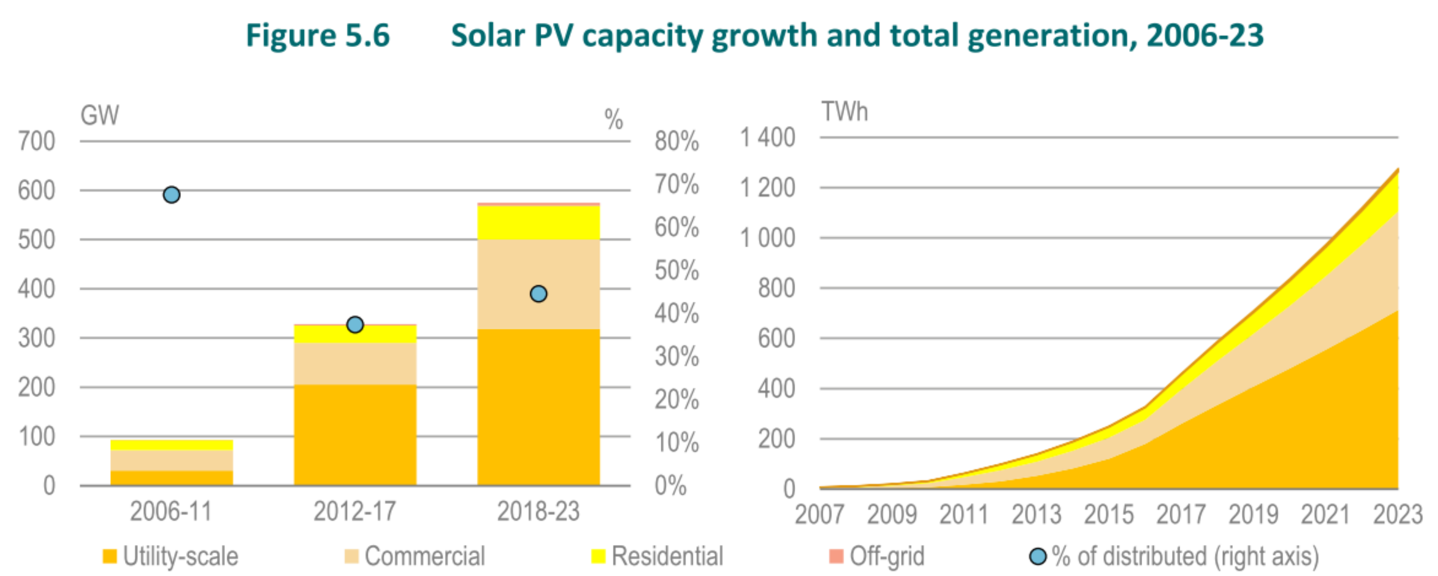
- Over 80% is ‘rooftop’ PV
- World leading residential PV penetration
- ~15% new Residential PV includes energy storage



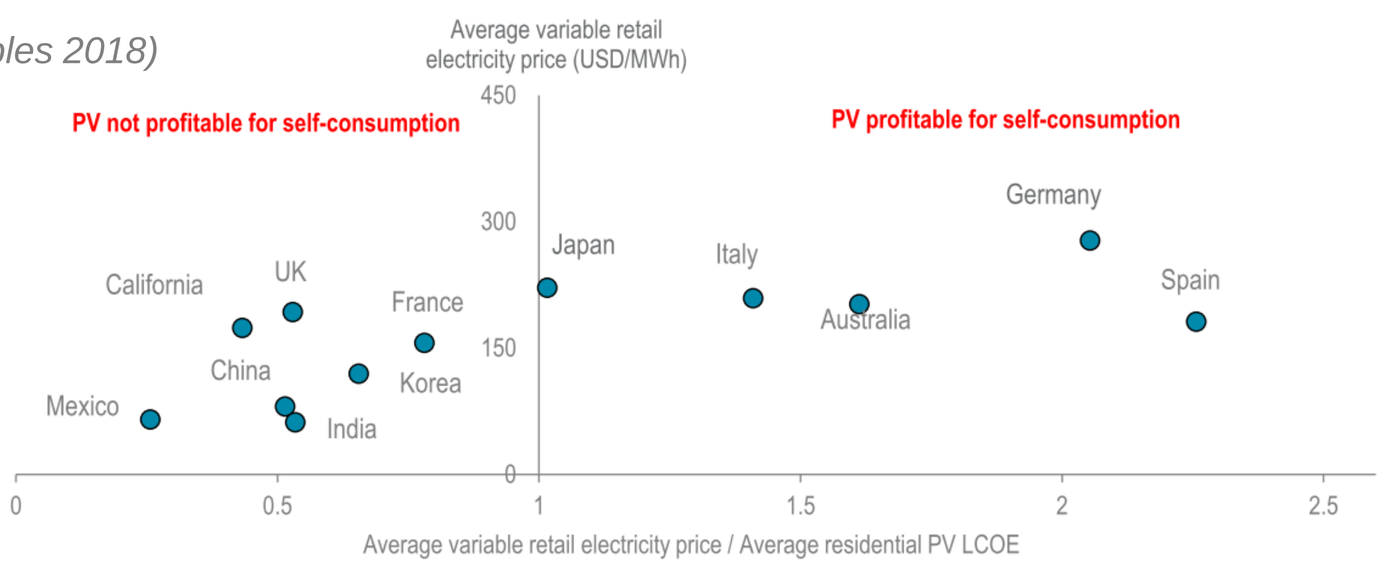




Global perspectives



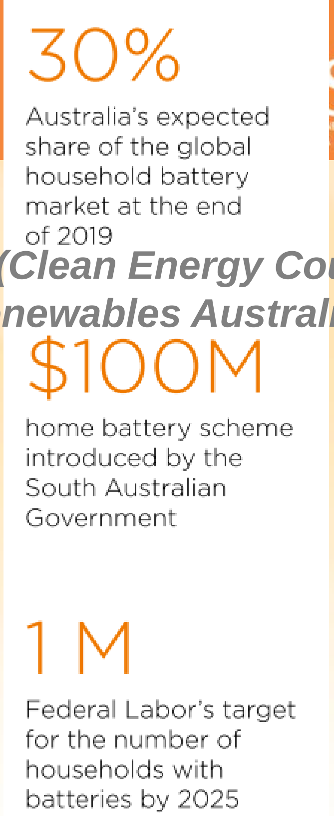
(IEA, Renewables 2018)



Li Ion energy storage even more scalable

PV + BESS – large, small or all?

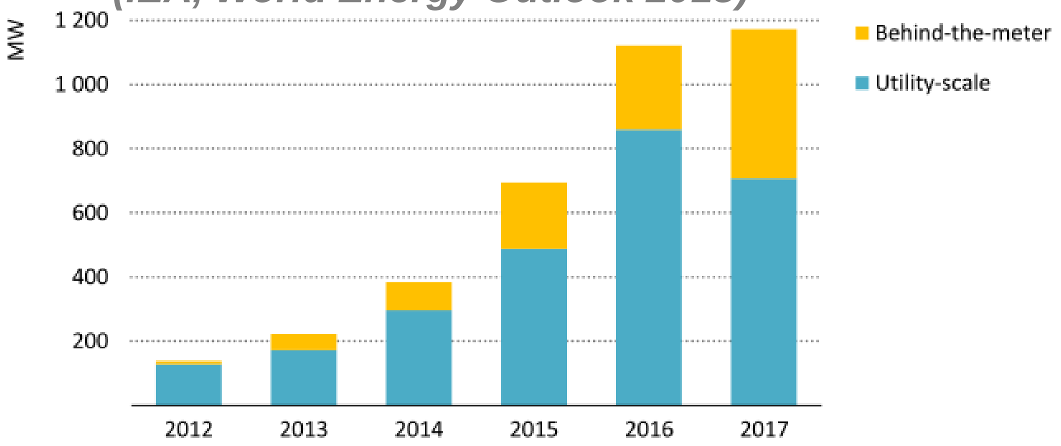
- Can distributed PV + storage do everything that large utility scale plant can?
  - Speed of response?
  - Ride-through major power system disturbances
  - Operational envelope subject to local network conditions
- Can it do things that large utility PV + storage can't?
  - Local network services
  - Consumer self-reliability
  - Improved consumer bills
- *Where is it most valuable?*



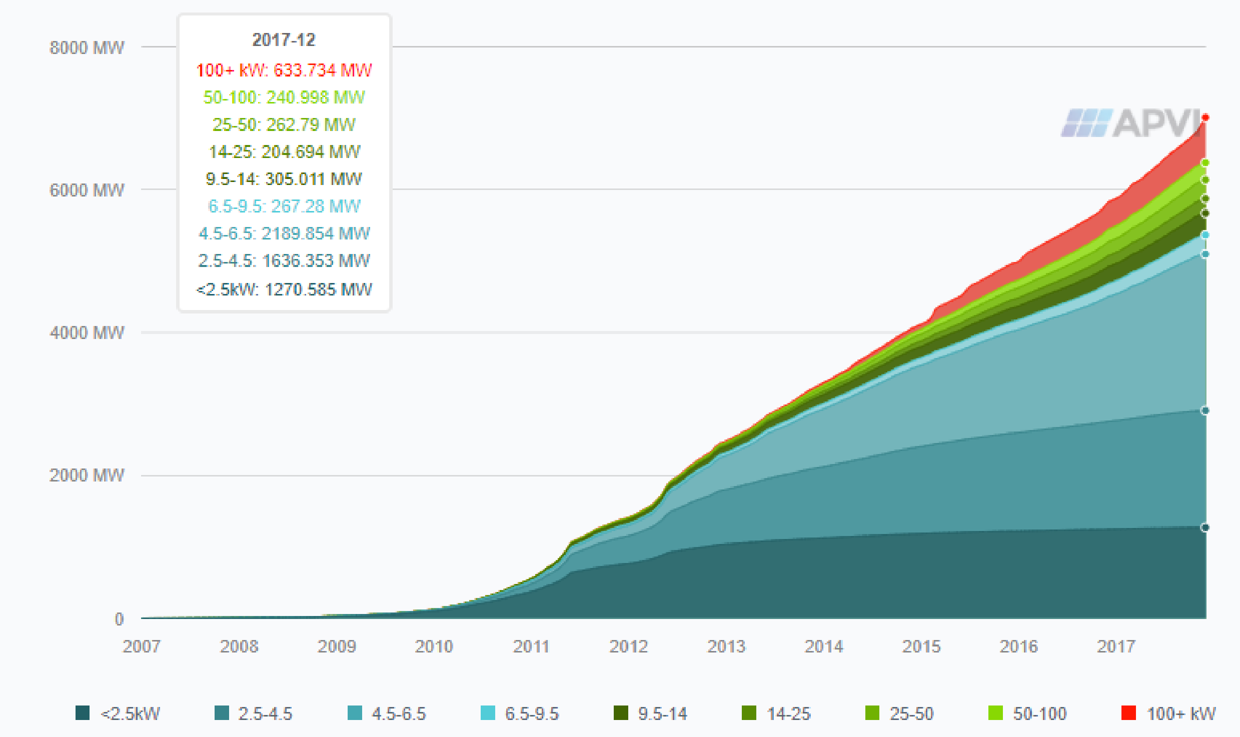
(Clean Energy Council, Renewables Australia 2018)

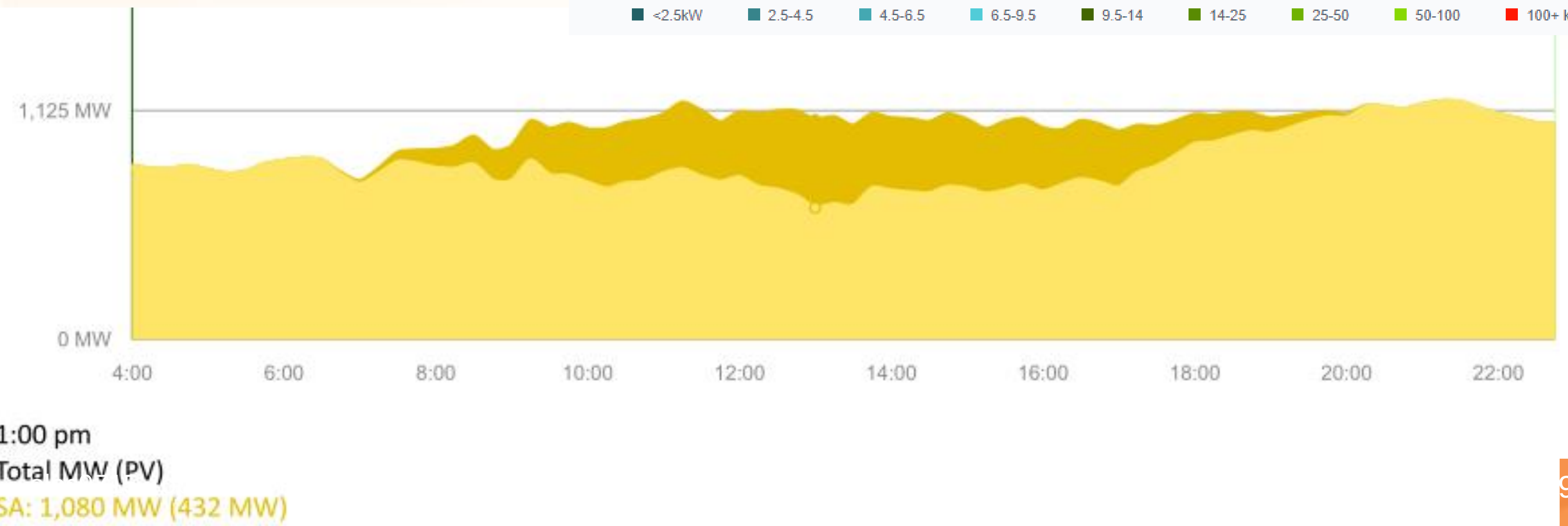
Figure 7.23 ▹ Annual additions of behind-the-meter and utility-scale battery storage, 2012-2017

(IEA, World Energy Outlook 2018)



Distributed 'rooftop' PV an increasingly significant whole-sale market, as well as security, issue



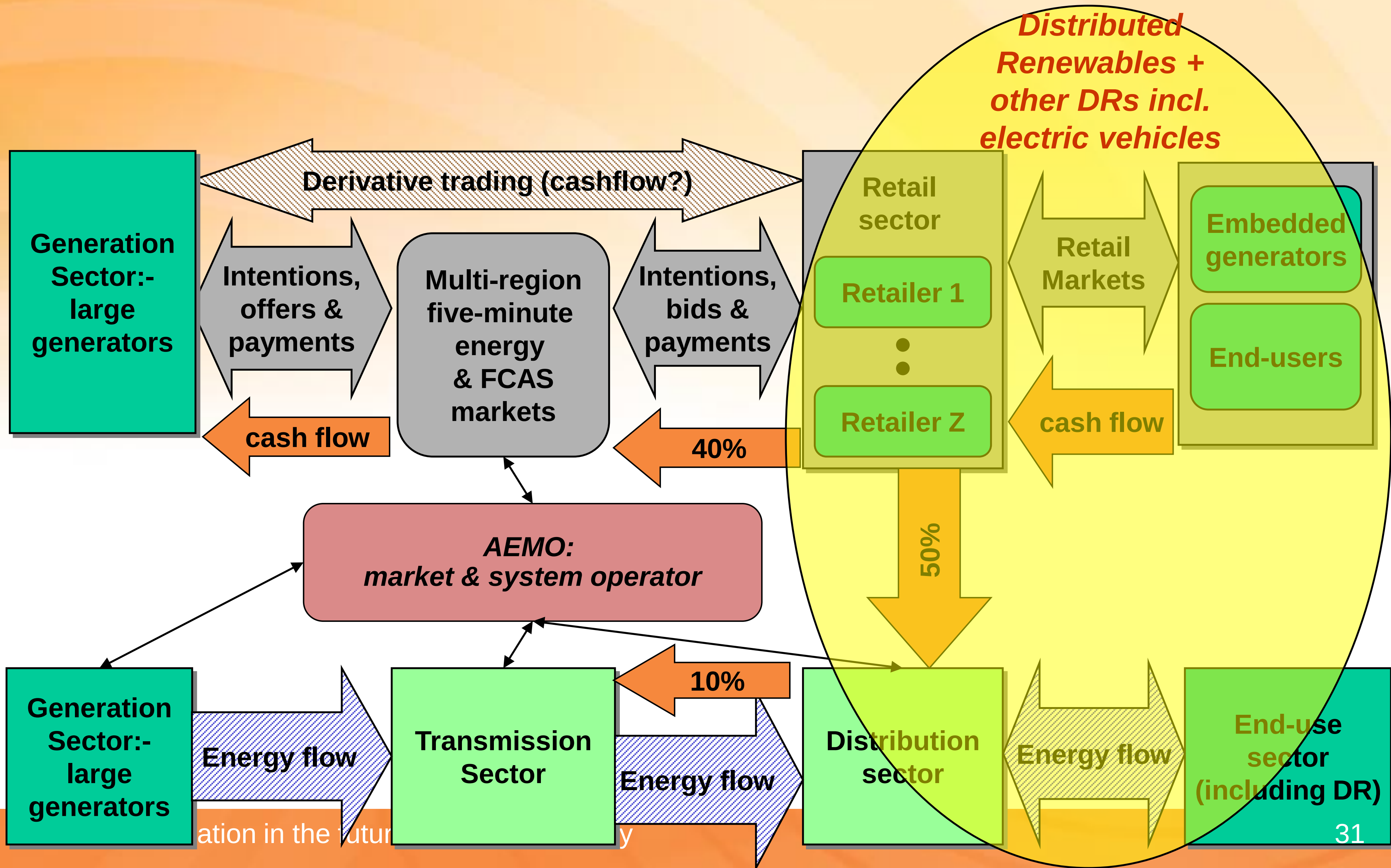


Distributed energy has a range of possible value propositions…

- Improved customer reliability
- Reduced network peak demand, hence expenditure
- Reduced generation capacity requirements
- Facilitating integration of generation technologies with energy storage challenges – PV, but also ‘baseload’ plant
- Ancillary service provision
- ‘leaving the grid’ options
- Clean energy provision

However, only some of these possible value propositions are appropriately incentivised under current ‘commercial’ settings

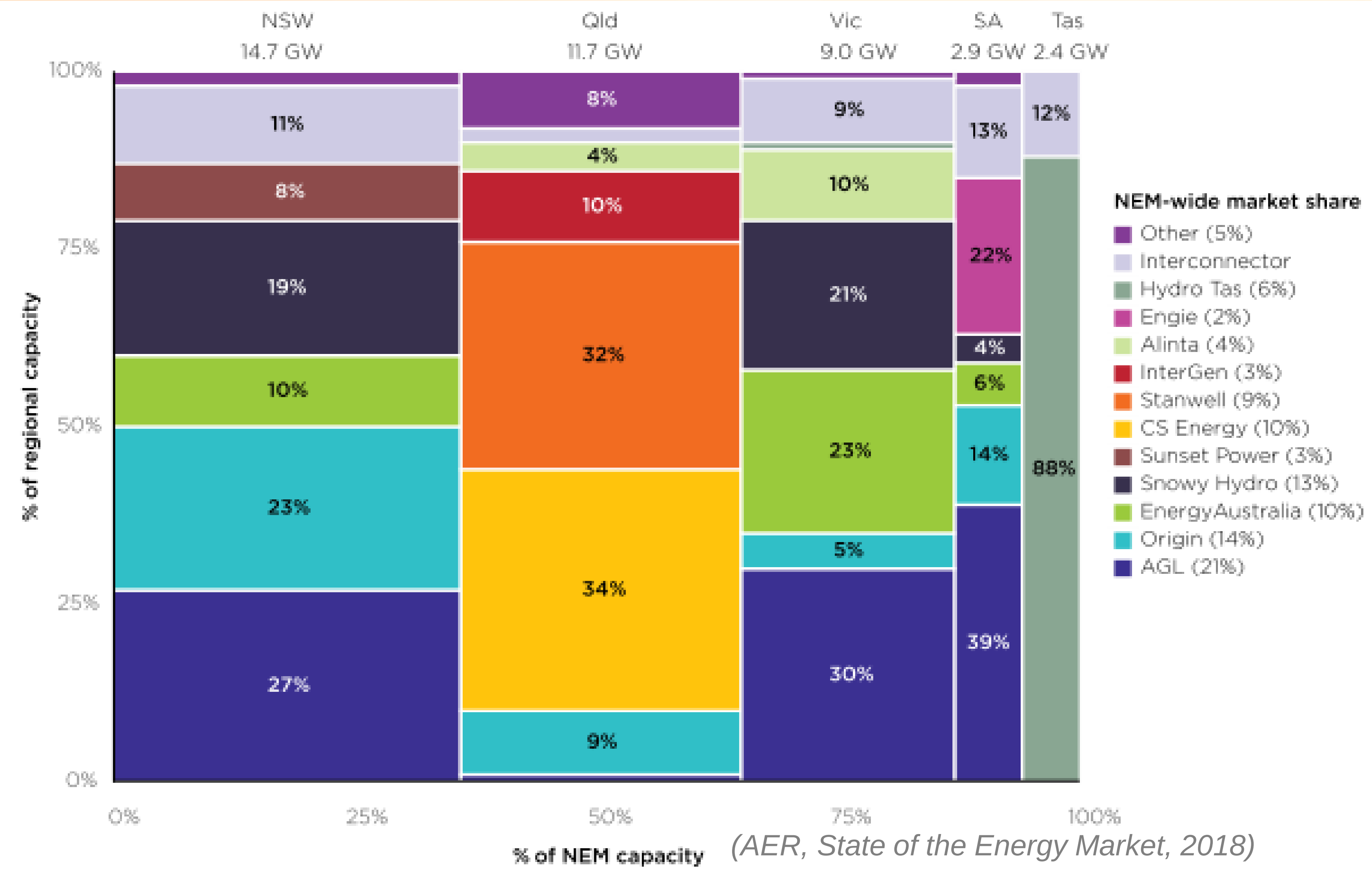
But a disfunctional world for DER integration



The future NEM

- How renewable?
- How distributed?
- **How competitive?**

Structure of NEM – ownership of GW

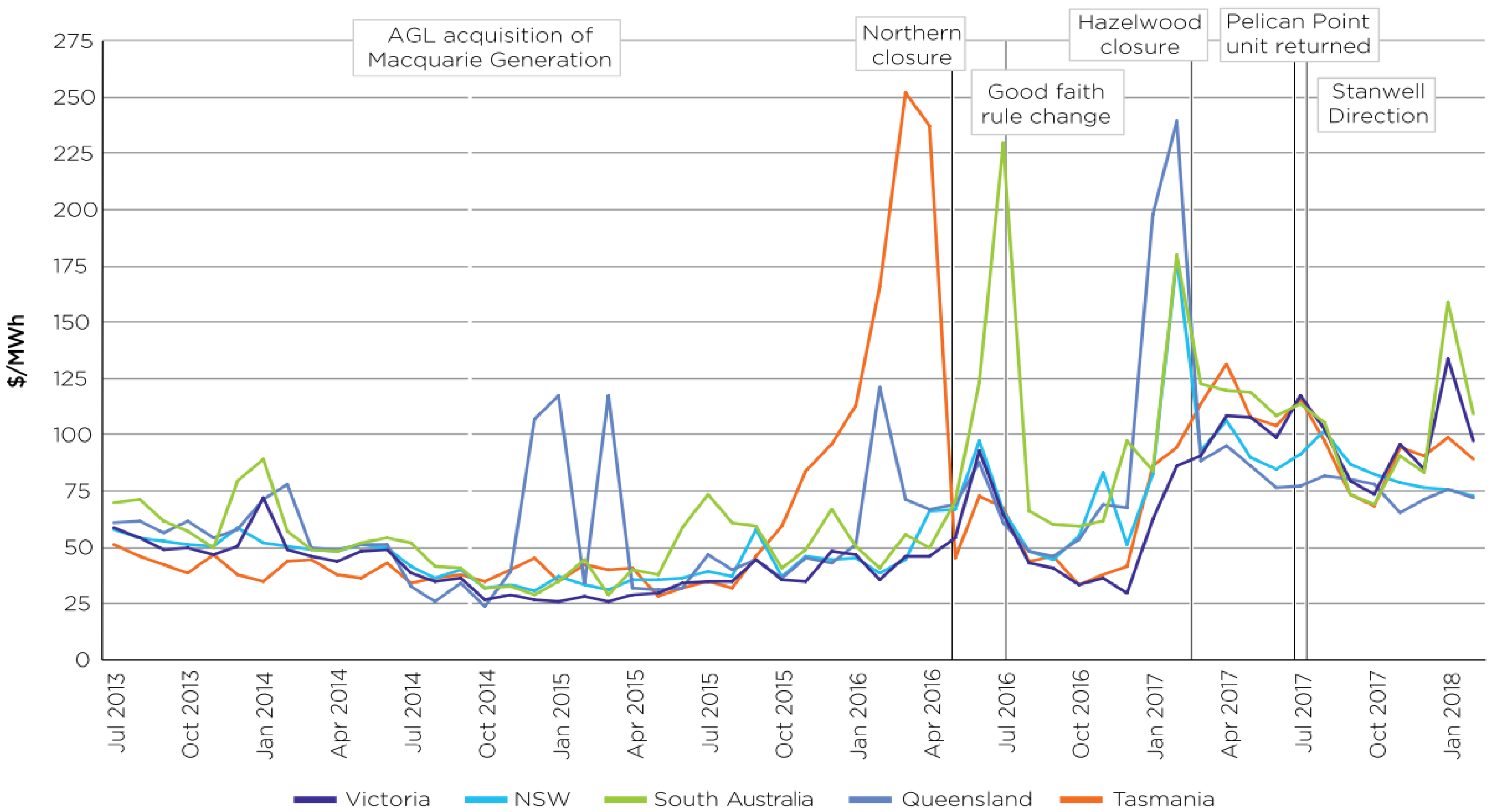


(AER, State of the Energy Market, 2018)

Evident exercise of market power

(AER, State of the Energy Market, 2018)

Figure 3.12: Monthly average spot prices by NEM region, July 2013 to February 2018, ($/MWh nominal)



Energy users – a changing industry context

- From clients
  - Early tailored industrial or commercial (lighting) applications
- ..to citizens
  - Electricity as an essential public good – rural electrification
- ..to consumers
  - The vertically integrated utility of growing size and scope
- ..to customers
  - Electricity industry ‘reform’, liberalisation, deregulation, restructuring
- ..to perhaps partners, competitors, or even ‘deserters’?
  - Demand Response, Self-generation, Energy Storage…

Now all of the above – how do we design appropriate interface?

(MacGill & Smith, Consumers or prosumers, customers or competitors?—Some Australian perspectives on possible energy users of the future., EEEP, 2017)

Do we have a ‘real’ retail electricity market?

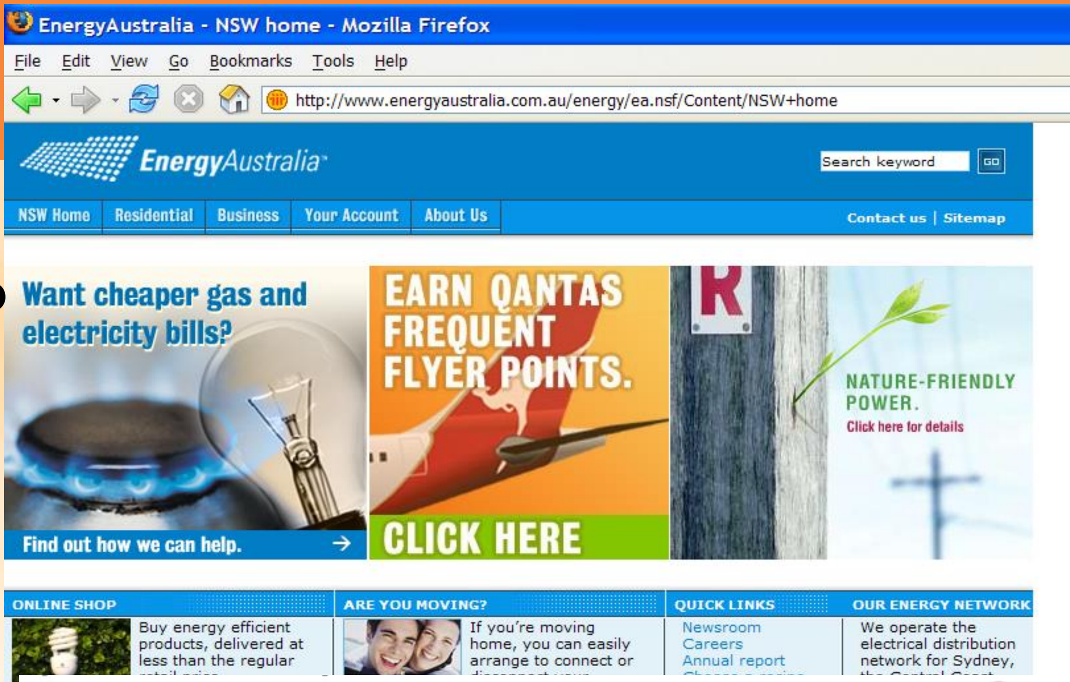
Depends who you ask

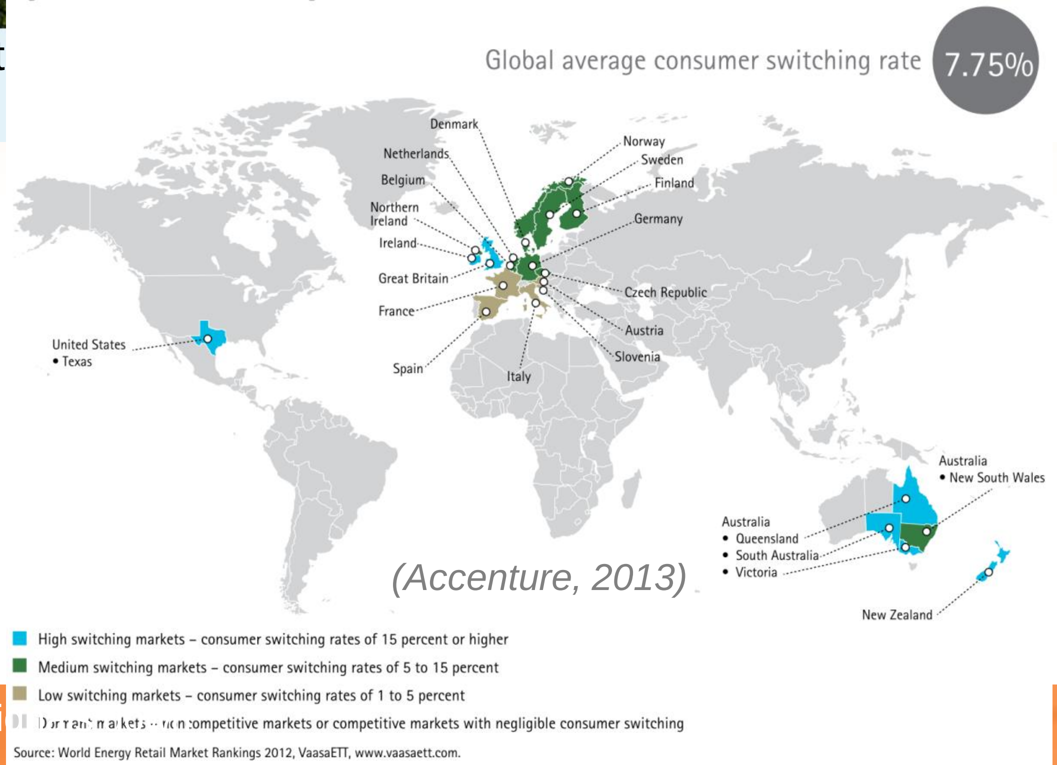
- Internationally, NEM often argued to be a leading example
- …but Current measures of competition miss key issues
  - Yes, NEM high switching rates – but real customer choice or just churn?
  - Yes, NEM price spreads – but reflect competition or stickiness

Certainly little focus on energy services and engagement

> **“… an important reason there is effective competition in Victoria is .. because the provision of energy is viewed as a homogenous, low engagement service“** ***(AEMC, 2008)***

- An oligopoly of large ‘gentailers’



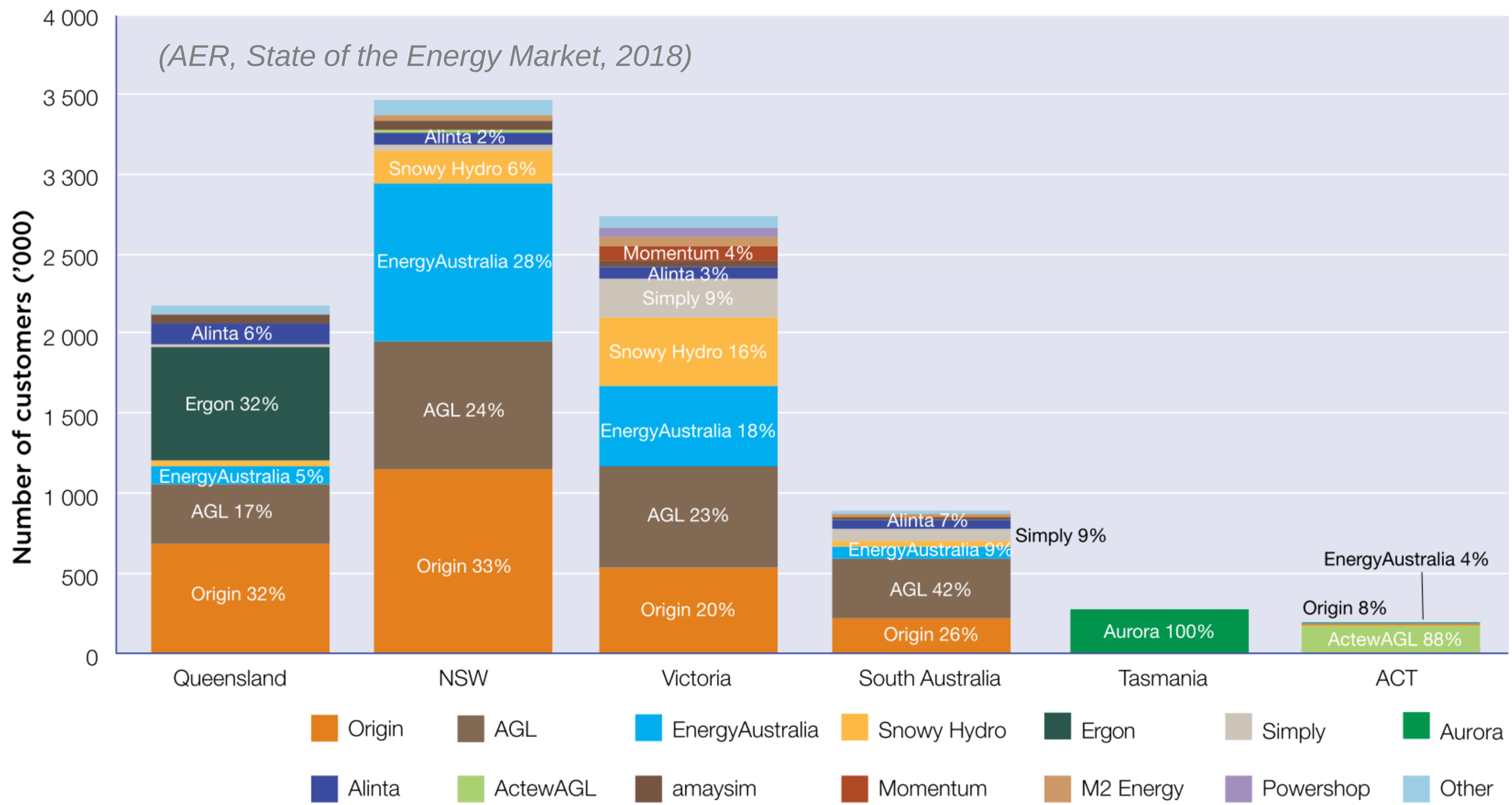


(Accenture, 2013)

Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

NEM retail market share



Note (figures 1.10 and 1.11): Includes residential and small business customers. All data at June 2018, except Victoria (June 2017).

What might a real mkt look like? *A focus on*

- Consumer energy services rather than ‘commodity’ kWh/MWh prices
- Consumers’ long-term interests, including need for energy transition
- Facilitation for energy users to participate in a wide range of services
  - Aggregating up vital for distributed storage to contribute value that takes coordinated behaviour, not necessarily all the way to wholesale *where NEM currently has limited locational pricing, opaque derivatives, market power and inefficient by design because don’t include env. externalities*
  - Sending prices down also vital in appropriate circumstances, not necessarily all the way down to all consumers *as very consumer and context dependent; and major reform of interface b/n supply + demand sides of electricity sector and Network Service Providers required before genuine ‘price discovery’ can occur.*
  - ***We need ESCOs, not retailers*** - have to properly support new players with innovative business, community and other models for efficiently delivering end-user energy services, coordinated end-user participation

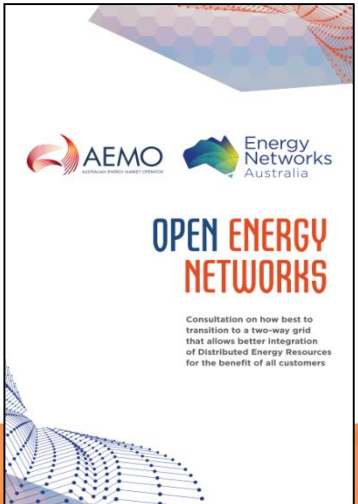
Possible ‘coordination’ paths forward

Single Integrated Platform (SIP) - The single platform model envisages a unitary point of entry to the entirety of the NEM and WEM. Under this option, the platform would be an extension of the wholesale market. AEMO would provide the platform as part of its market and system responsibilities and along with the individual distribution utilities will develop a single integrated platform that will use a set of agreed standard interfaces to support the participation in the integrated multi-directional market by retailers, aggregators, and VPP platform companies. The SIP will then simultaneously solve local security constraints and support wholesale market entry. Under this configuration, access to the platform will be a one-stop shop that provides market participants the opportunity to participate anywhere in the NEM or WEM without having to develop separate systems or tools to integrate with the various individual distribution platforms. Network businesses will be linked into the platform, with distribution business providing information on local constraints to AEMO. AEMO would consider this information and economically dispatch these resources alongside other resources (transmission connected load, large scale generation etc.).

Two Step Tiered Regulated Platforms - A second alternative is a model where there is a layered distribution level platform interface operated by the local distribution network and an interface between the distribution network's platform and AEMO. Under this design, individual distribution networks can design interfaces that best meet their system requirements. Participants would then need to communicate directly with the distribution level platform for the local constraint issues and the distribution network would optimise these resources against local network constraints based on bids from the aggregators servicing the area.

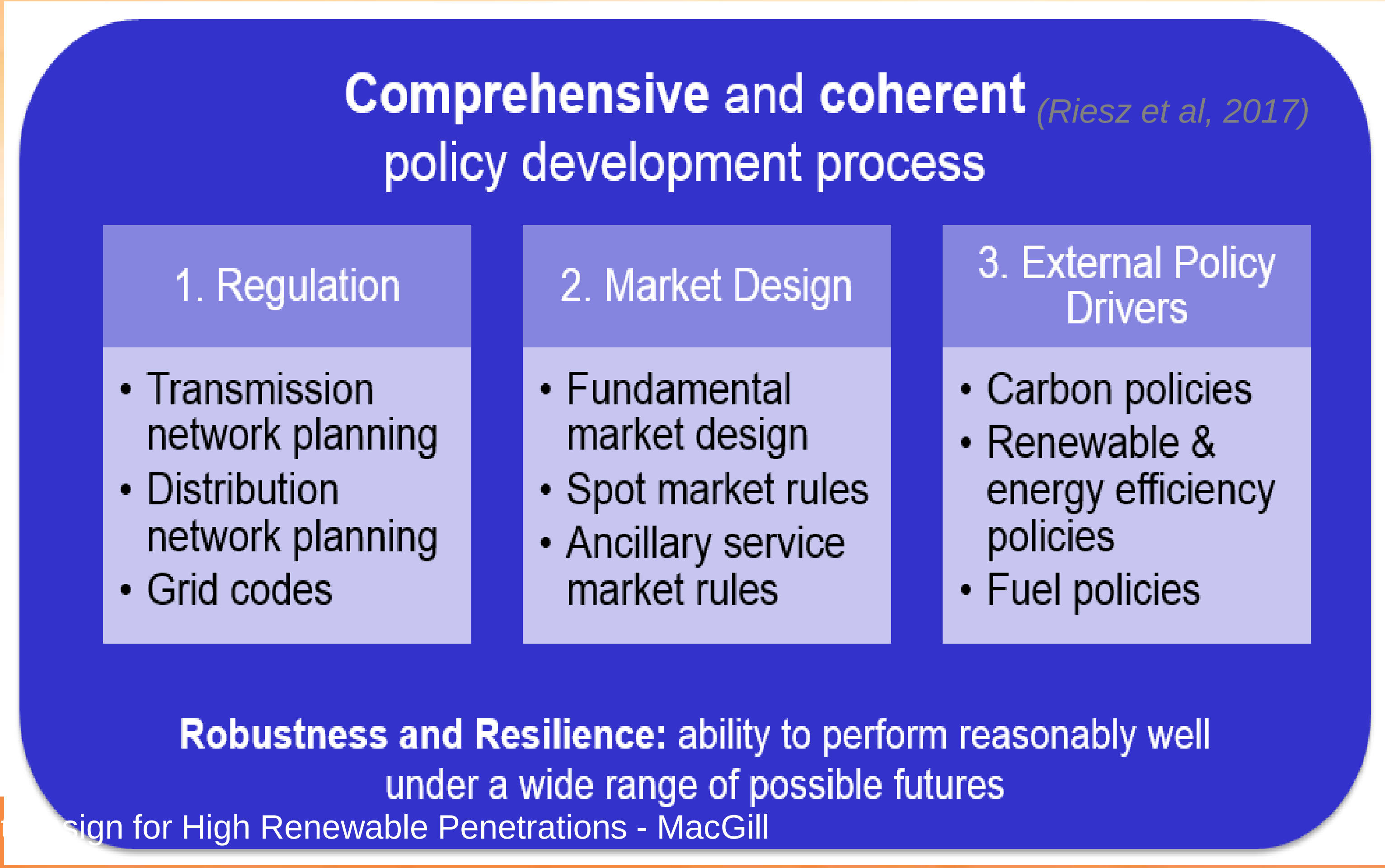
Distribution networks would provide an aggregated view per the transmission connection point. AEMO would take this information and consider the overall system security and economic dispatch.

Independent DSO - A third option, that is a variant of the second, is for an independent party – a DSO that is separate from AEMO and the distribution utility. Under this model the independent DSO would work with the distribution utility to optimise the dispatch of the DER based upon local system constraints that are provided by the network business, provide the aggregated bids to AEMO for incorporation into the larger dispatch. This option will be more complex than the others and may be significantly more costly.



Regardless, a broader design challenge

across regulation, markets and external policies
and with a focus on robustness, rather than efficiency



Centre for Energy and Environmental Markets

Open data, tools … and processes

Energy scientists must show their workings

Public trust demands greater openness from those whose research is used to set policy, argues **Stefan Pfenninger**.

The global transition towards a clean and sustainable energy future is well under way. New figures from Europe this month show that the continent is on track to reach its goal of a 20% renewable-energy share by 2020, and renewable capacity in China and the United States is also rising. But many technical, political and economic uncertainties remain, not least in the data and models used to underpin such policies. These uncertainties need open discussion, and yet energy strategies all over the world are based on research not open to scrutiny.

Researchers who seek, for example, to study the economic and energy model used by the US government (called NEMS) are met with a forbidding warning. On its website, the Energy Information Administration, which is developing the model, pronounces: "Most people who have requested NEMS in the past have found out that it was too difficult or rigid to use."

At least NEMS (National Energy Modelling System) is publicly available. Most assumptions, systems, models and data used to set energy policy are not. These black-box simulations cannot be verified, discussed or challenged. This is bad for science, bad for the public and spreads distrust. Energy research needs to catch up with the open-software and open-data movements. We energy researchers should make our computer programs and data freely accessible, and academic publishing should shun us until we do.

Our community's models are relevant to policy because they explore alternative scenarios that remain hidden, like the costs of technologies, can largely determine what comes out of such models. In the United Kingdom, opaque and overly optimistic cost assumptions for onshore wind went into models used for policymaking, and that may well have delayed the country's decarbonization.

This closed culture is alien to younger researchers, who grew up with collaborative online tools and share code and data on platforms such as GitHub. Yet academia's love affair with metrics and the pressure to publish set the wrong incentives: every hour spent on cleaning up a data set for public release or writing open-source code is time not spent working on a peer-reviewed paper.

Nevertheless, some academic-led projects are pushing towards more openness. The Enipedia project is building a worldwide open database on power plants, with data such as their locations and emissions. The Open Power System Data project gathers data such as electricity consumption from government agencies and transmission-network operators, and pushes for clarity on the licensing under which these data are made available. The Open Energy Modelling Initiative is emerging as a platform for coordinating and strengthening such efforts.

BLACK-BOX **SIMULATIONS** CANNOT BE **VERIFIED,** DISCUSSED OR **CHALLENGED.**

Regulation can also help. The European Union has mandated open access to electricity-market data, resulting in the creation of the ENTSO-E Transparency Platform to hold it, and there are good arguments for the creation of national

openmod open energy modelling initiative

Openmod in a nutshell

The Open Energy Modelling (openmod) Initiative promotes open energy modelling in Europe.

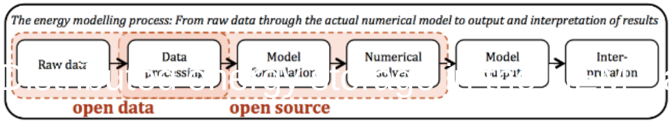
Energy models are widely used for policy advice and research. They serve to help answer questions on energy policy, decarbonization, and transitions towards renewable energy sources. Currently, most energy models are black boxes – even to fellow researchers.

"Open" refers to model source code that can be studied, changed and improved as well as freely available energy system data.

We believe that more openness in energy modelling increases transparency and credibility, reduces wasteful double-work and improves overall quality. This allows the community to advance the research frontier and gain the highest benefit from energy modelling for society.

We, energy modelers from various institutions, want to promote the idea and practice of open energy modeling among fellow modelers, research institutions, funding bodies, and recipients of our work.

The idea of openmod



Home | About Us | Research | Open Source Tools | Publications | Events | Contact us

CEEM's researchers believe in the value of open source modelling in the Energy and Environmental research space. In this regard, we have developed a series of open source tools which are listed below. For a list of some of our under development tools you can refer CEEM's Github page.

NEMOSIS - NEM Open Source Information Service:

Open-source access to Australian National Electricity Market data.

Links: Github

NEMO - National Electricity Market Optimiser Tool:

NEMO, the National Electricity Market Optimiser, is a chronological dispatch model for testing and optimising different portfolios of conventional and renewable electricity generation technologies. It has been developed since 2011 and is maintained by Ben Elliston through his PhD at CEEM. NEMO is available under a free software license (GPL version 3) and requires no proprietary software to run, making it particularly accessible to the governments of developing countries, academic researchers and students. The model is available for others to inspect and to validate results.

Links: Github, OzLabs

TDA - Tariff Design and Analysis Tool:

We have developed a modelling tool to assist stakeholders wishing to contribute to network tariff design in the Australian National Electricity Market. It is an open source modelling tool to assist stakeholders in assessing the implications of different possible network tariff designs, and hence facilitate broader engagement in the relevant rule making and regulatory processes in the NEM. Our tool takes public energy consumption data from over 5000 households in NSW, and allows users test a wide range of existing, proposed and possible tariffs structures to see their impacts on network revenue and household bills. Demographic survey data of the households allows you to explore the impacts of these tariffs on particular household types – for example, families with young children. The tool can also show how well different tariffs align these household bills with a households' contribution to network peak demand. The tool and data are open source – you can check, validate and add your own data sets; test existing or even design your own tariffs, and validate and even modify the underlying algorithms.

Links: Project page, Github, Researchgate

Local Solar Sharing Scheme Model:

Intended for modelling embedded networks, local solar and peer to peer electricity networks. This software was developed by Naomi Stringer, Luke Marshall and Rob Passey at CEEM. A working build with a simple user interface for OSX can be found here.

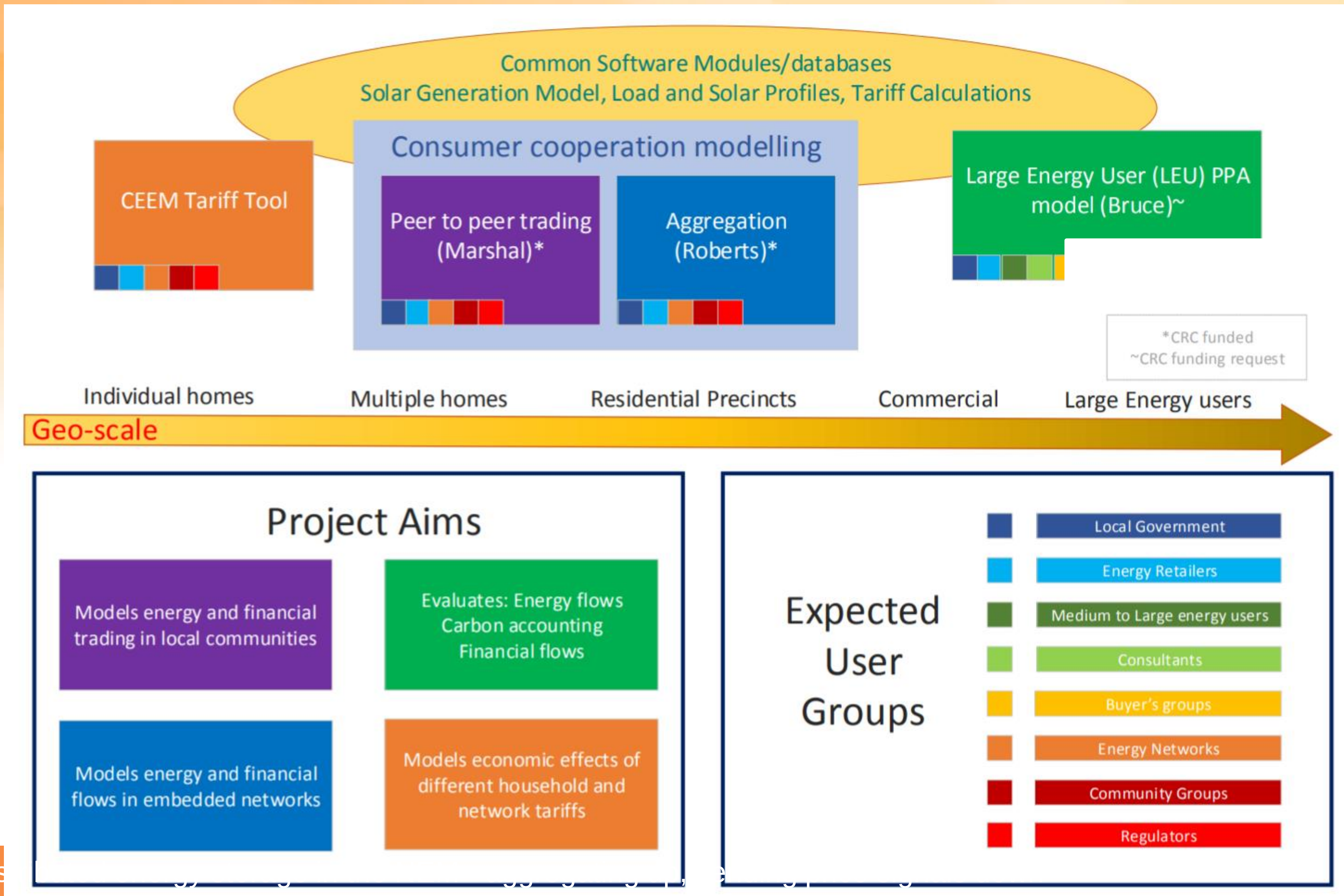
Links: Github

NemLite - Open Source model of NEM Dispatch Engine:

Intended to replicate the performance of the National Electricity Market Dispatch Engine (NEMDE).

Links: Github

SPREE/CEEM open-source DER modelling tools



The future NEM

How affordable, secure and sustainable?

- In part an outcome of past, often poor, choices, but excellent opportunities to improve outcomes

How renewable, distributed and competitive?

- Achieving goals seems likely to require effectively integrating much higher levels of renewable generation
- Which seems likely to require higher levels of energy user engagement and participation in terms of both establishing social consensus as well as providing flexibility
- Which will likely require greater levels of genuine, meaningful competition in energy services…. or abandonment of much of the current ‘competitive construct’

Thankyou from the SPREE/CEEM Energy Modelling and Analysis Team

Anna Bruce (a.bruce@unsw.edu.au)
Jose Bilbao (j.bilbao@unsw.edu.au)
Jessie Copper (j.copper@unsw.edu.au)
Nicholas Gorman (n.Gorman@unsw.edu.au)
Emi Gui (emi.gui@unsw.edu.au
Navid Haghdadi n.haghdadi@unsw.edu.au
Zoe Hungerford (z.hungerford@unsw.edu.au)
Iain MacGill (i.macgill@unsw.edu.au)
Luke Marshall (luke.marshall@unsw.edu.au)
Rob Passey (r.passey@unsw.edu.au)
Mike Roberts (m.roberts@unsw.edu.au)
Alistair Sproul (a.sproul@unsw.edu.au)
Naomi Stringer (n.stringer@unsw.edu.au)
Sharon Young (Sharon.young@unsw.edu.au)
Kanyawee (k.keeratimahat@unsw.edu.au)

www.ceem.unsw.edu.au

facebook.com/ceem.unsw/
twitter.com/ceem_unsw
linkedin.com/company/ceem.unsw/
github.com/unsw-ceem

Centre for Energy and Environmental Markets

UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

Thank you… and *questions*

Many of our publications are available at:
www.ceem.unsw.edu.au