Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA



Renewable Technologies in the Future NEM

100% Renewables for Australia?

Dr Jenny Riesz

Australian Power Institute (API) Summer School – Wednesday 24th February 2016

Who am I?

Powerlink Queensland

ASI Australian Solar Institute

AGL

Ausgrid

ElectraNet electricity transmission

westernpower

Clean Energy Council

origin

Australian Coal Association

imo Independent Market Operator

RioTinto

Delta electricity

AEMC Australian Energy Market Commission

AEMO Australian Energy Market Operator

The University Of Queensland Australia

ROAM CONSULTING ENERGY MODELLING EXPERTISE

Centre for Energy and Environmental Markets

UNSW Australia

AECOM

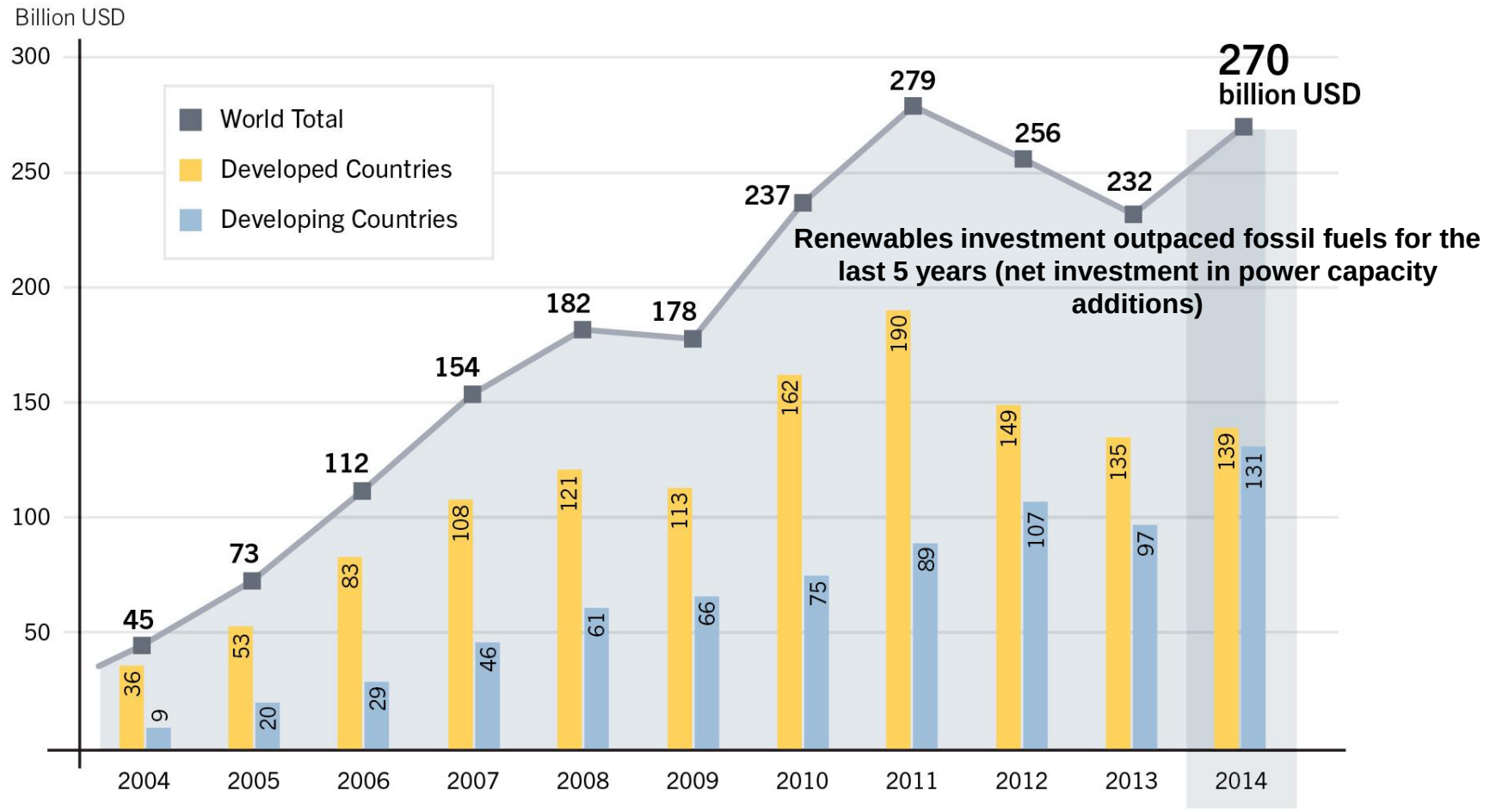
Overview

100% Renewables:

- Worth thinking about?
- Technically feasible?
- Costs?
- Will the market work?

Global New Investment in Renewable Power and Fuels

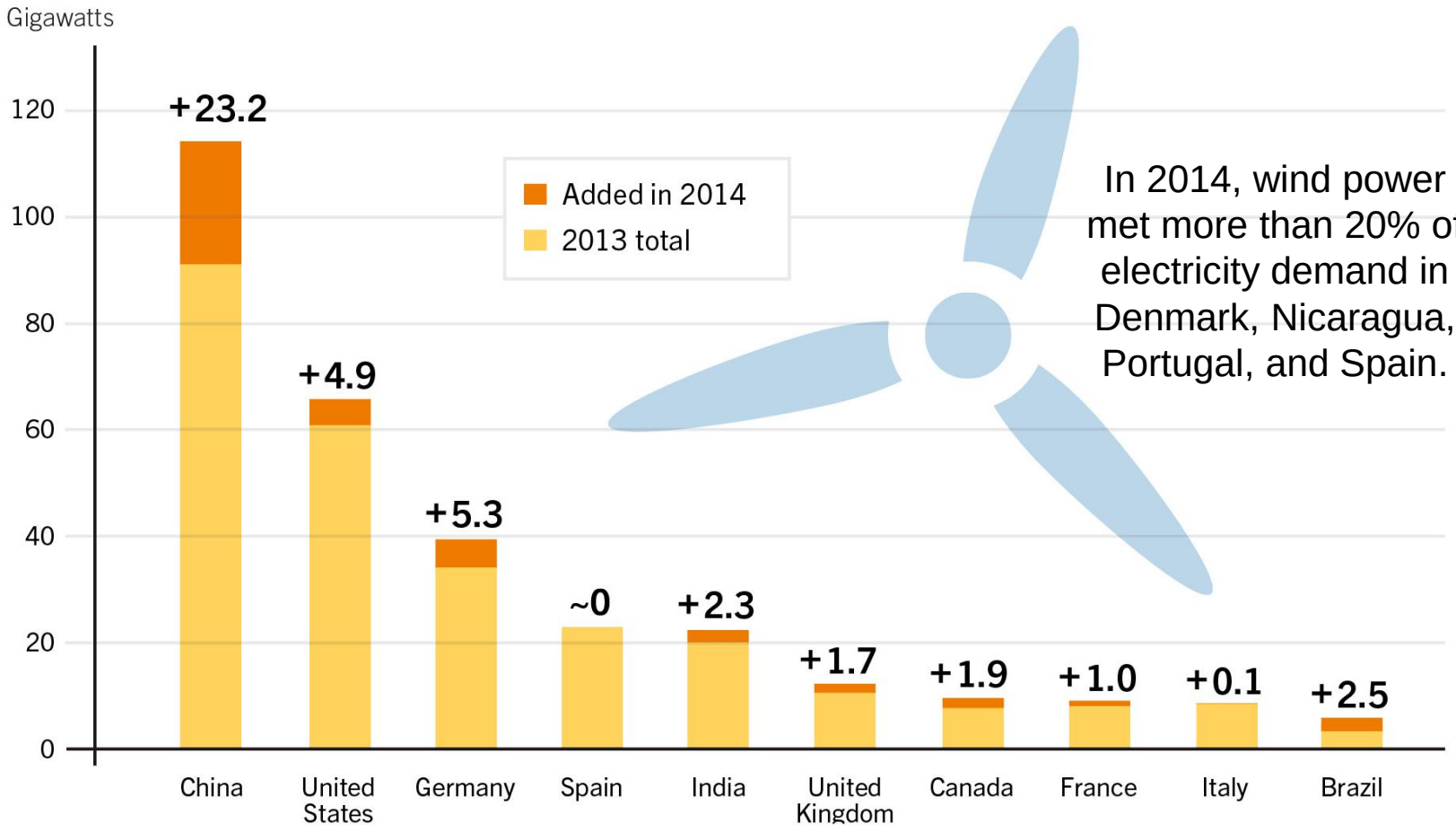
In 2014, renewables accounted for 59% of net additions to global power capacity.



REN21 *Renewables 2015 Global Status Report*

Source: Frankfurt School–UNEP and BNEF

Wind Power Capacity and Additions, Top 10 Countries, 2014



In 2014, wind power met more than 20% of electricity demand in Denmark, Nicaragua, Portugal, and Spain.

Additions are net of repowering.

REN21 *Renewables 2015 Global Status Report*

REN21 Renewable Energy Policy Network for the 21st Century

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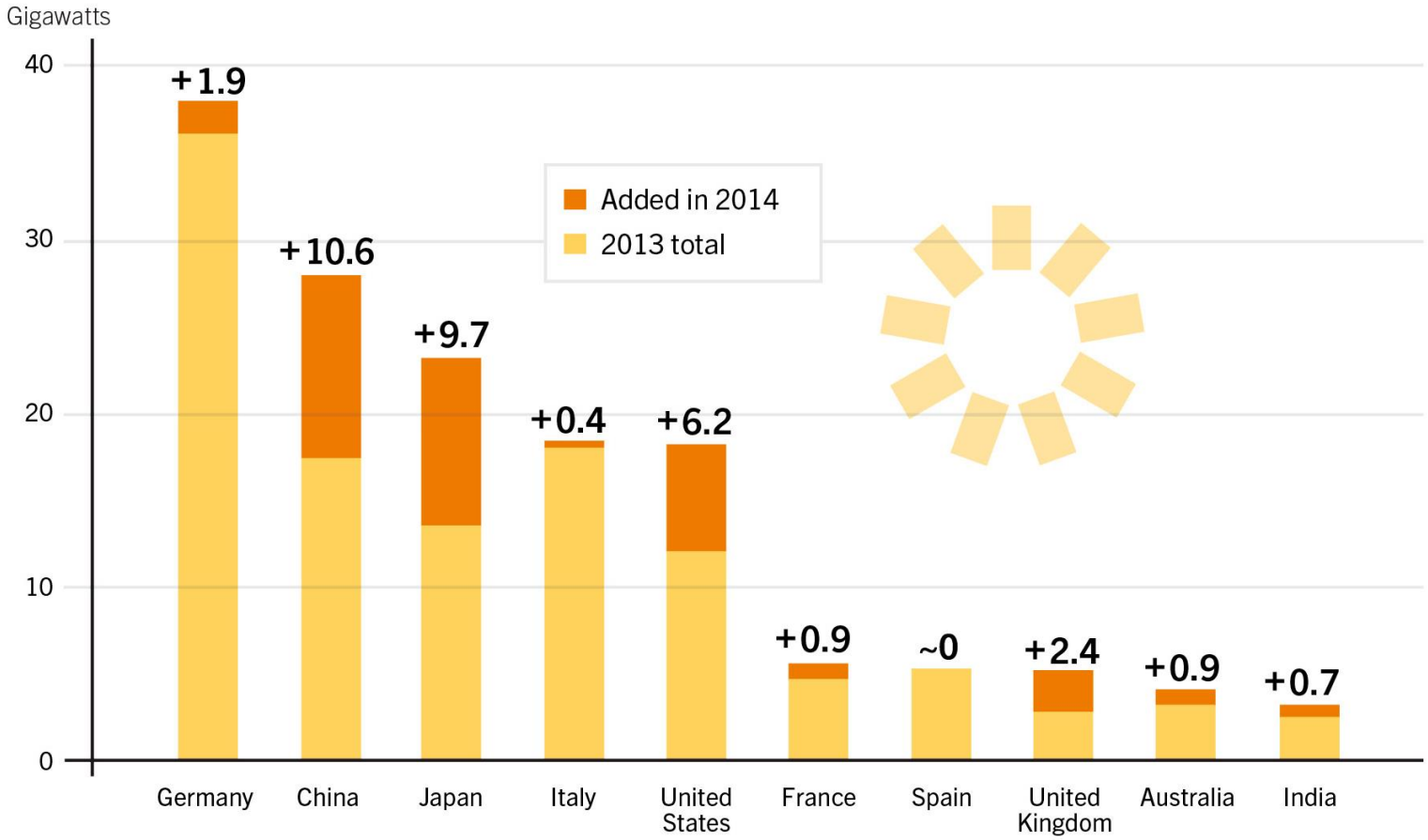
Solar PV Capacity and Additions, Top 10 Countries, 2014



REN21 *Renewables 2015 Global Status Report*

REN21 Renewable Energy Policy Network for the 21st Century

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What about Australia?

New coal?

- **New coal now costs more than renewables**
- Regulatory risks means very high cost of capital, if they can get financing at all

Gas?

- **Baseload CCGT can't get competitive gas supply contracts**
- Competition with LNG export market

Nuclear?

- **More expensive than renewables (large cost risk)**
- No existing industry or experience

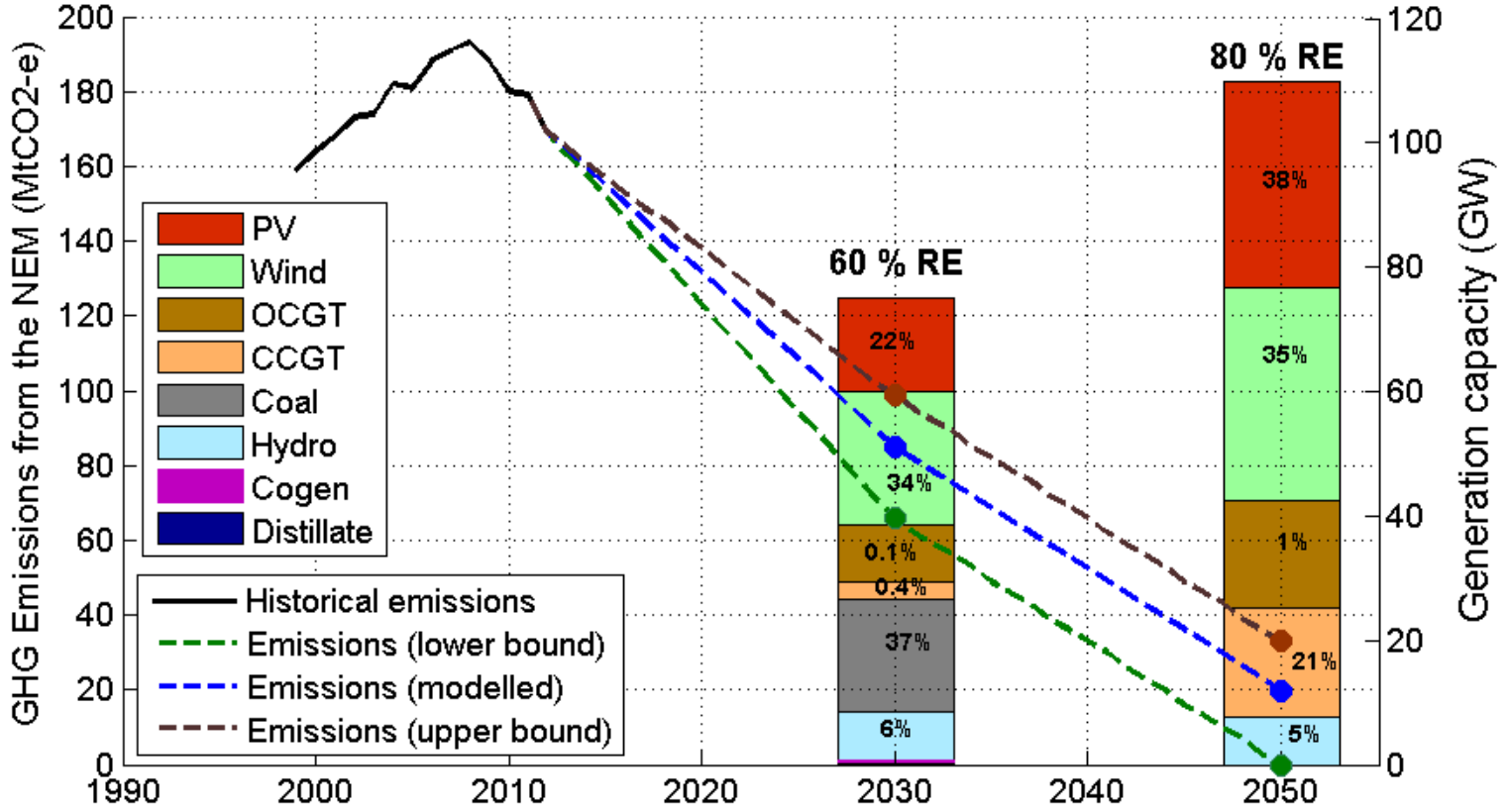
UK:
Hinkley Point C
$154/MWh
35yr PPA

Keep using what we've got?

- **Ageing generation fleet**
- By 2030, 65% of Australia's coal-fired power stations will be over 40yrs old

Lowest cost trajectory for the National Electricity Market

Given projected gas and carbon prices, and cost risk profiles



GHG emissions ranges as recommended by the Australian Government Climate Change Authority

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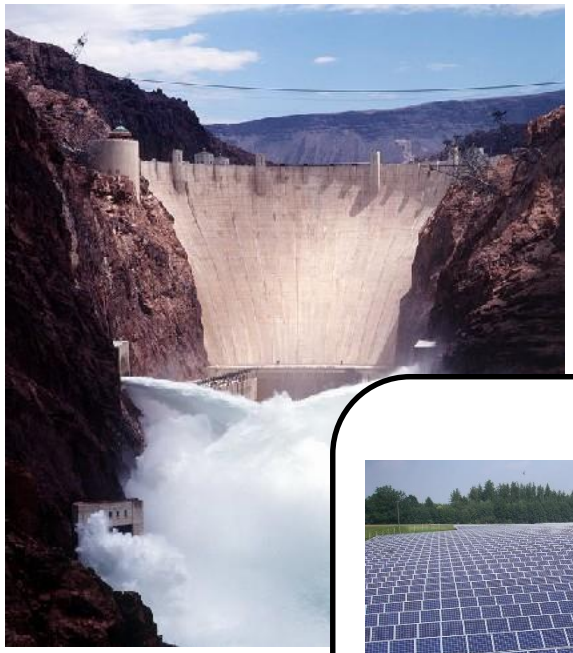
J. Riesz, P. Vithayasrichareon, I. MacGill, (2015) "Assessing "Gas Transition" pathways to low carbon electricity – An Australian case study", Applied Energy, 154, p. 794-804.

- Power systems with very high renewable proportions of renewables appear inevitable
  - It's not a question of "if", it's a question of when.

100% renewables – worth thinking about?

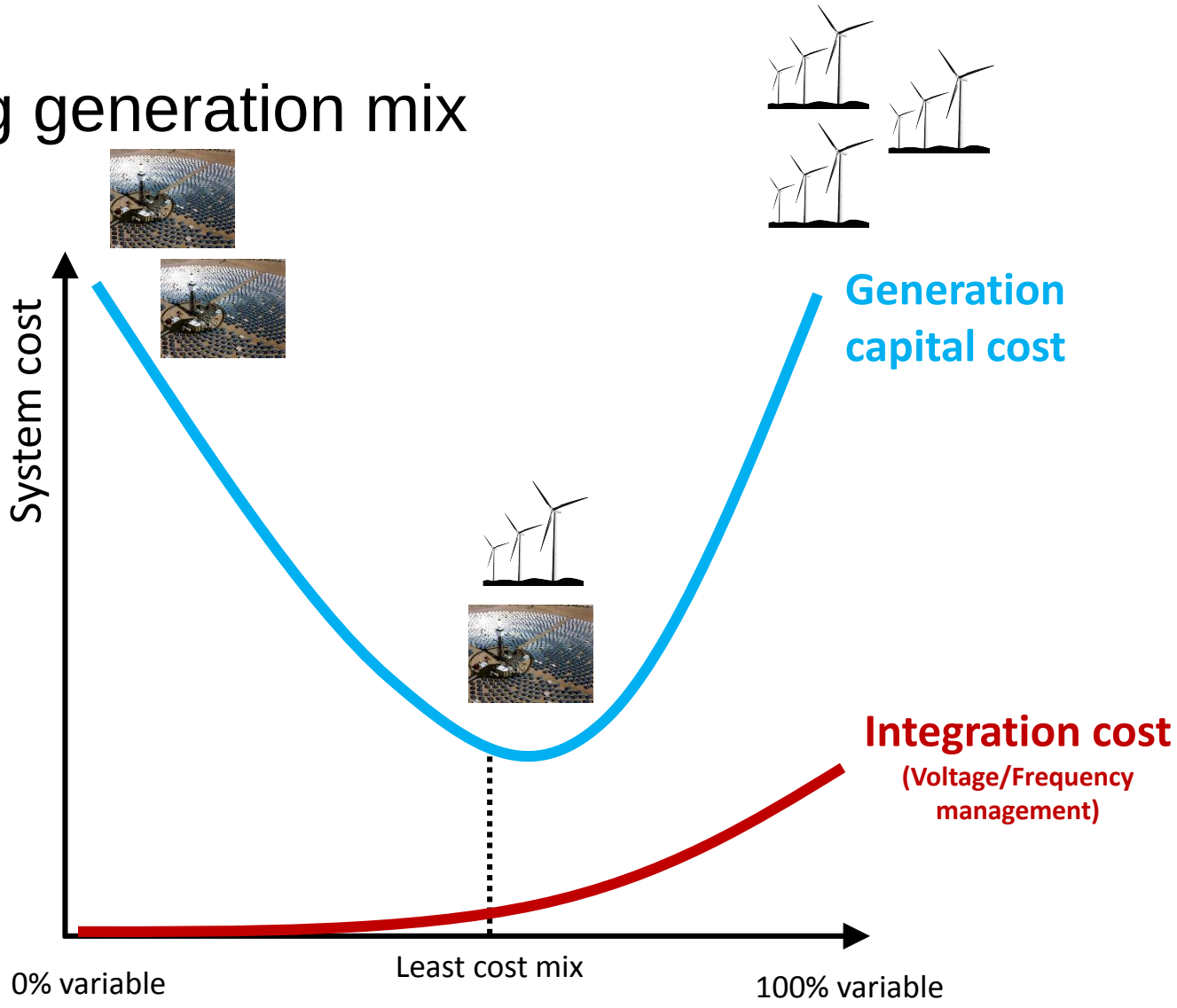
- But is it even technically feasible?!?

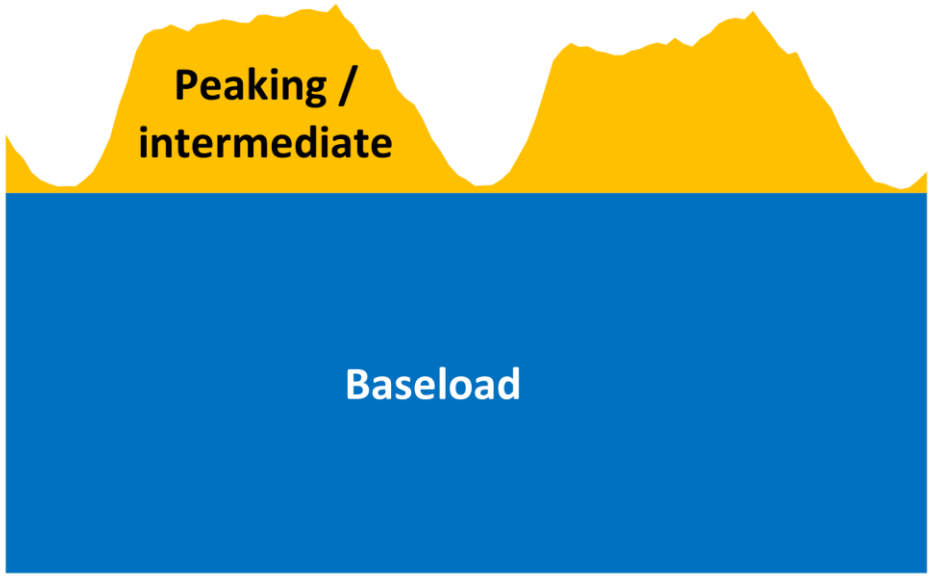
Renewable technologies



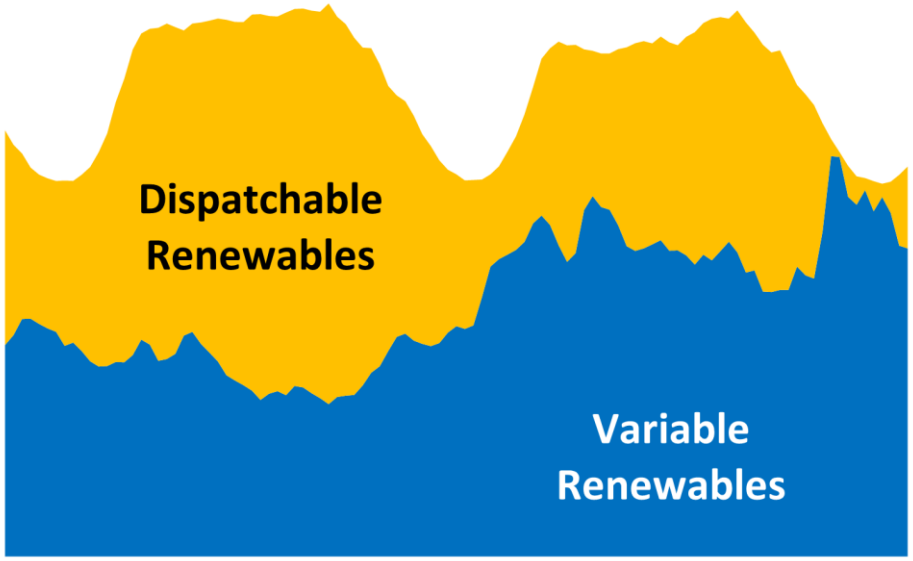
Variable & non-synchronous

Optimising generation mix





A new power system paradigm



Wind displaces baseload generation

J. Riesz, J. Gilmore, (2014) "Does wind need "back-up" capacity – Modelling the system integration costs of "back-up" capacity for variable generation". International Energy Workshop (Beijing)

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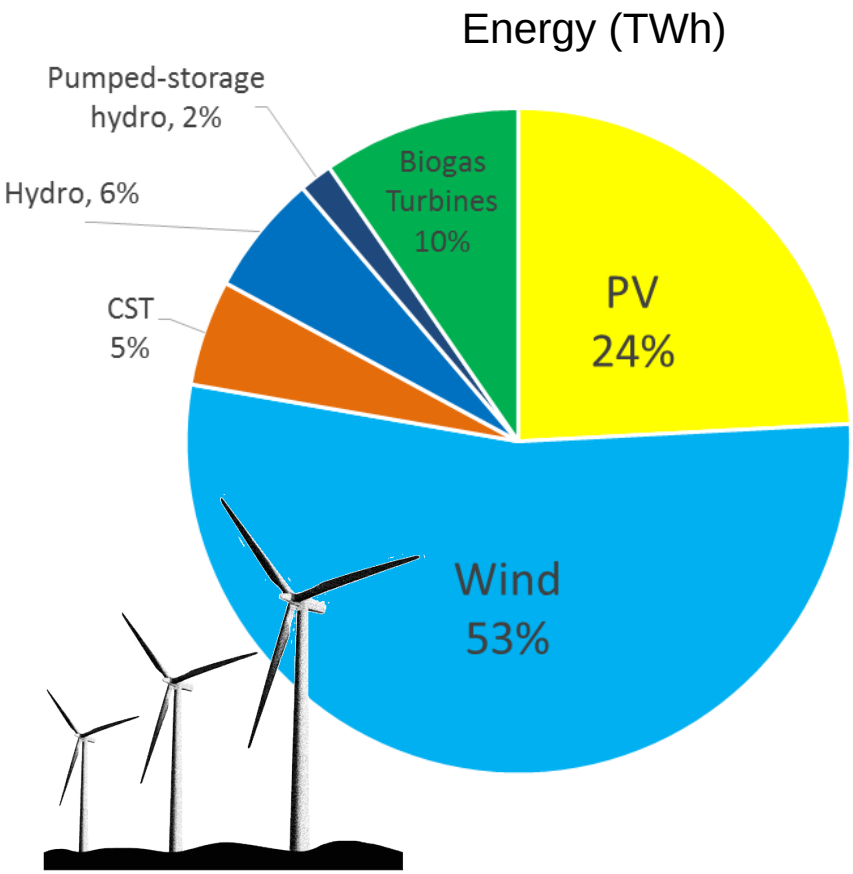
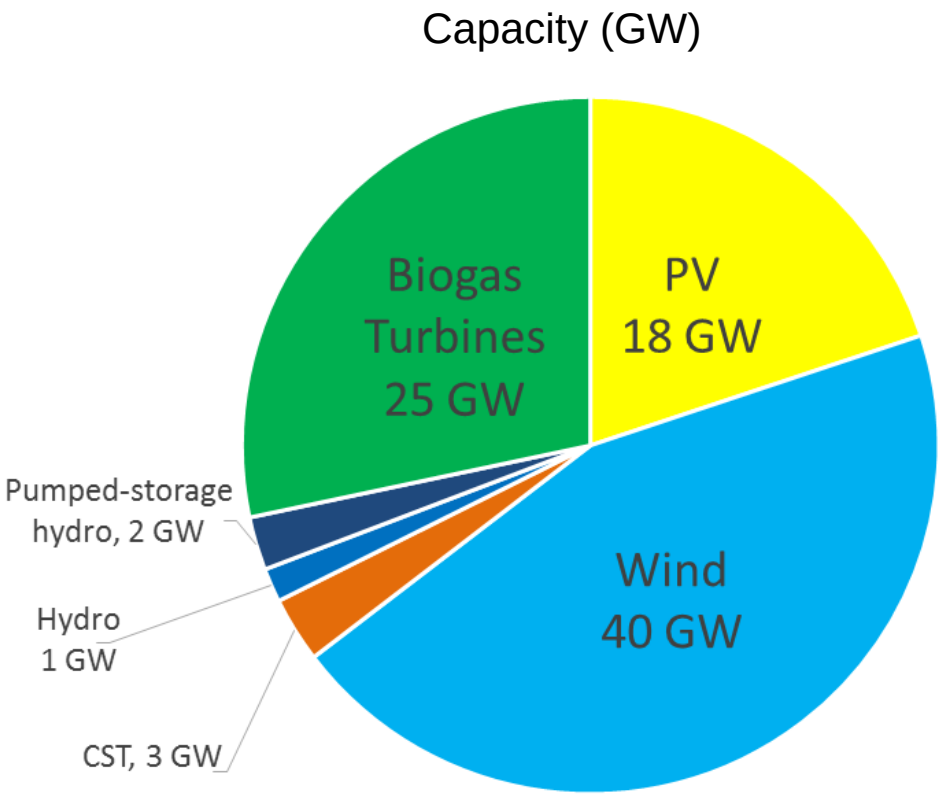
Least Cost Mix (UNSW modelling)





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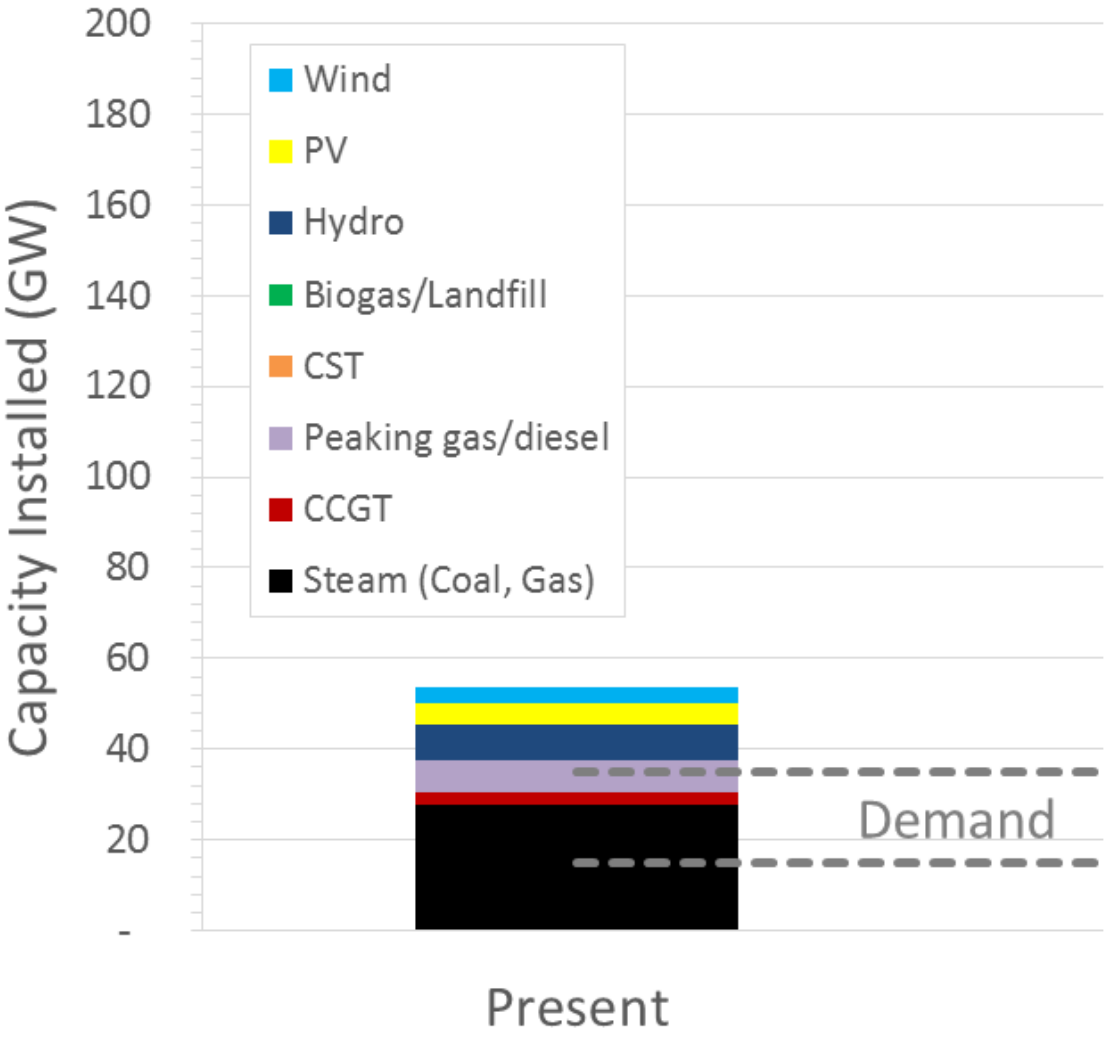
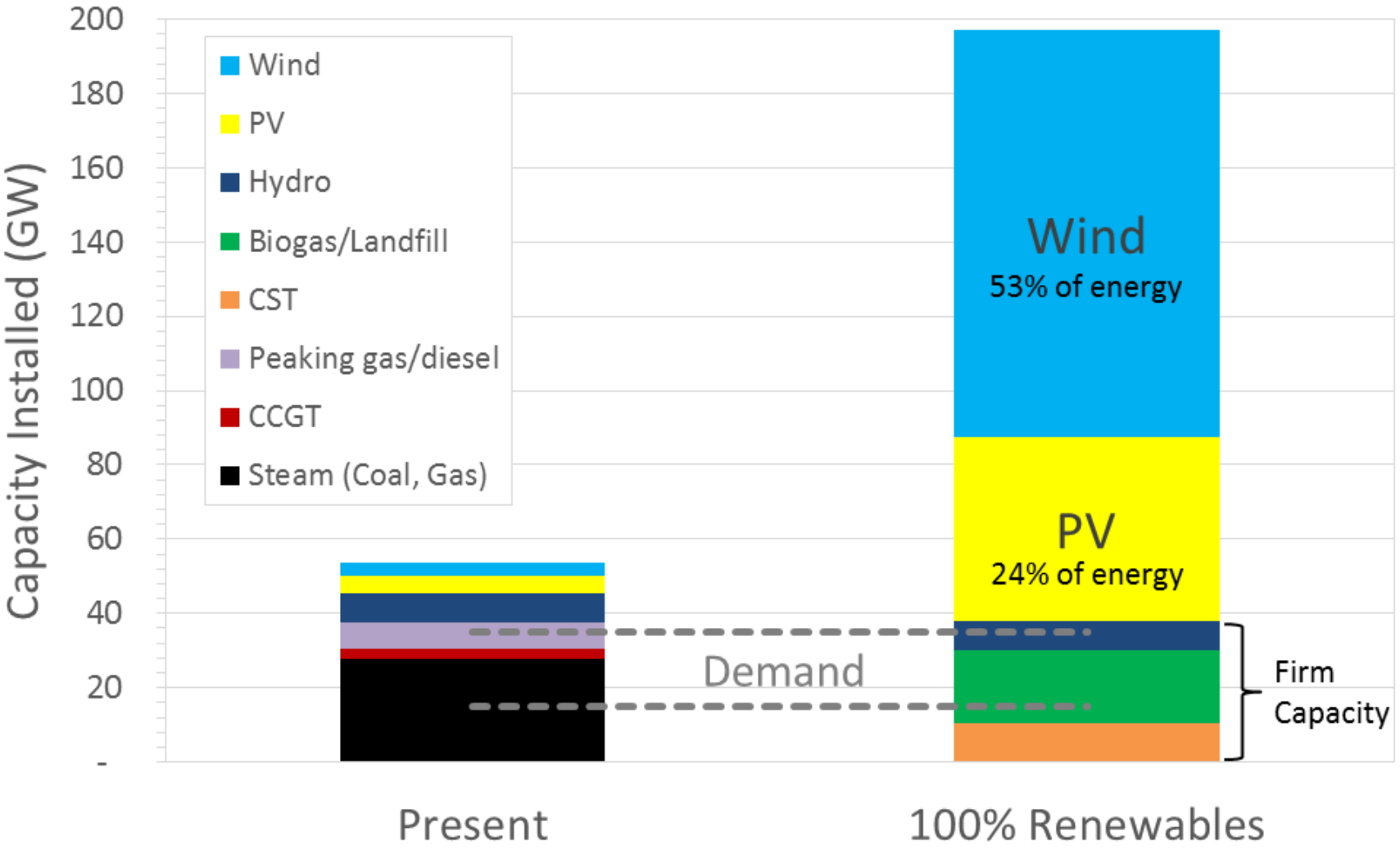
J. Riesz, B. Elliston, "The impact of technology availability on the costs of 100% renewable electricity generation scenarios for Australia", 38th IAEE International Conference, Antalya, Turkey, May 2015.


200
180
160
140
120
100
80
60
40
20
-
Capacity Installed (GW)
Wind
PV
Hydro
Biogas/Landfill
CST
Peaking gas/diesel
CCGT
Steam (Coal, Gas)
Demand
Present



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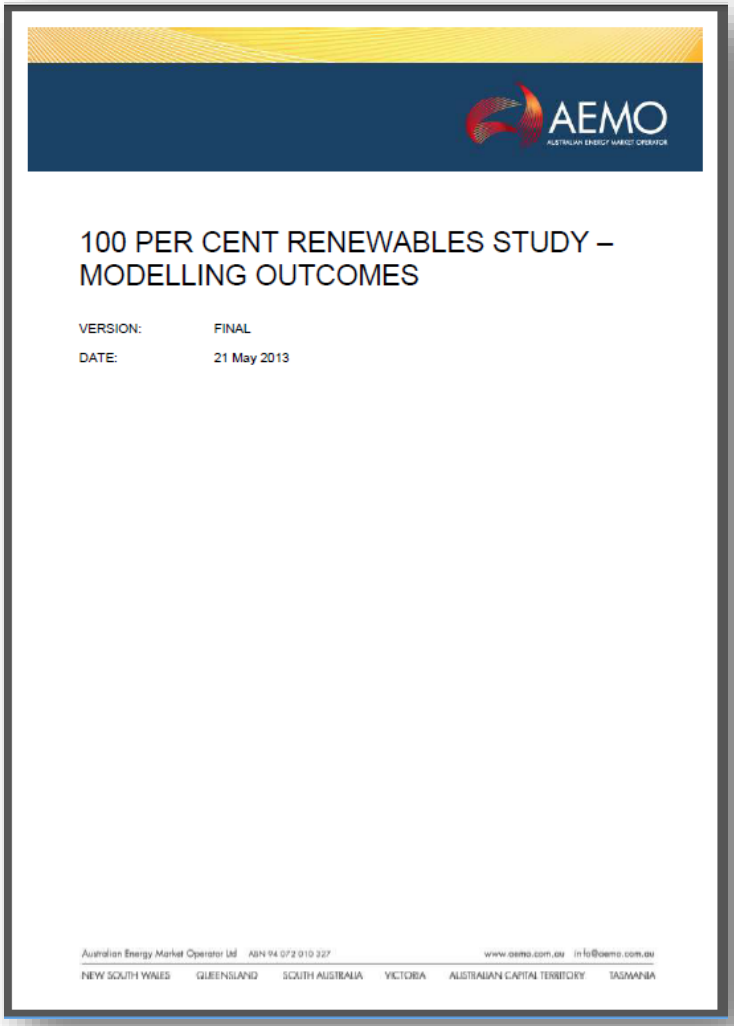
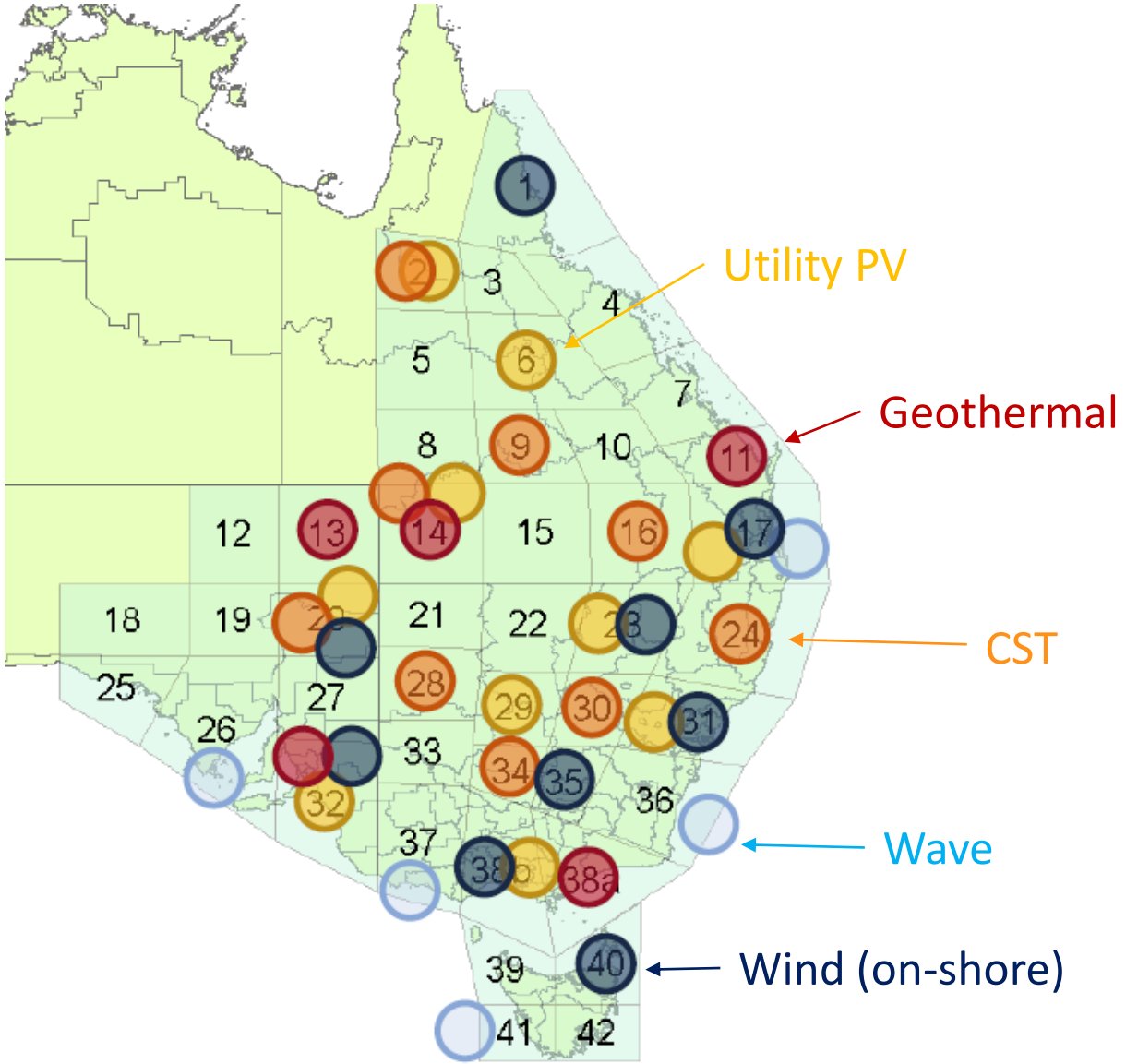
AEMO Modelling of 100% Renewables

- Australian Energy Market Operator (AEMO)
  - Landmark modelling study in 2013
  - Most detailed analysis of 100% renewables to date
  - First time 100% renewables considered by an official planning body in Australia



A massive data collection process

Hourly traces for wind/solar technologies developed based upon historical observations (2003-04 to 2011-12)



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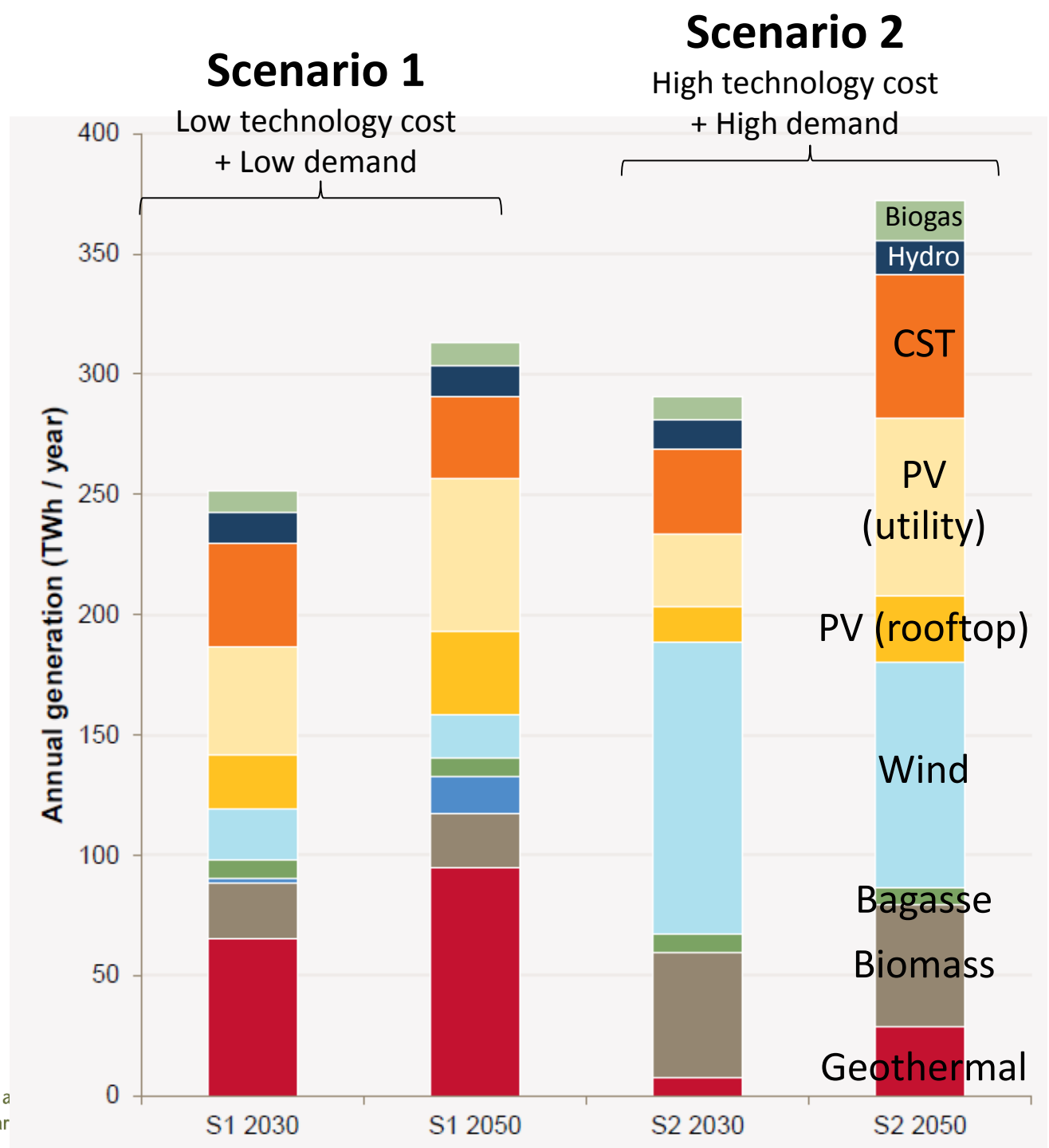
- Generation mix to meet the Reliability Standard:
- Diverse portfolio is key



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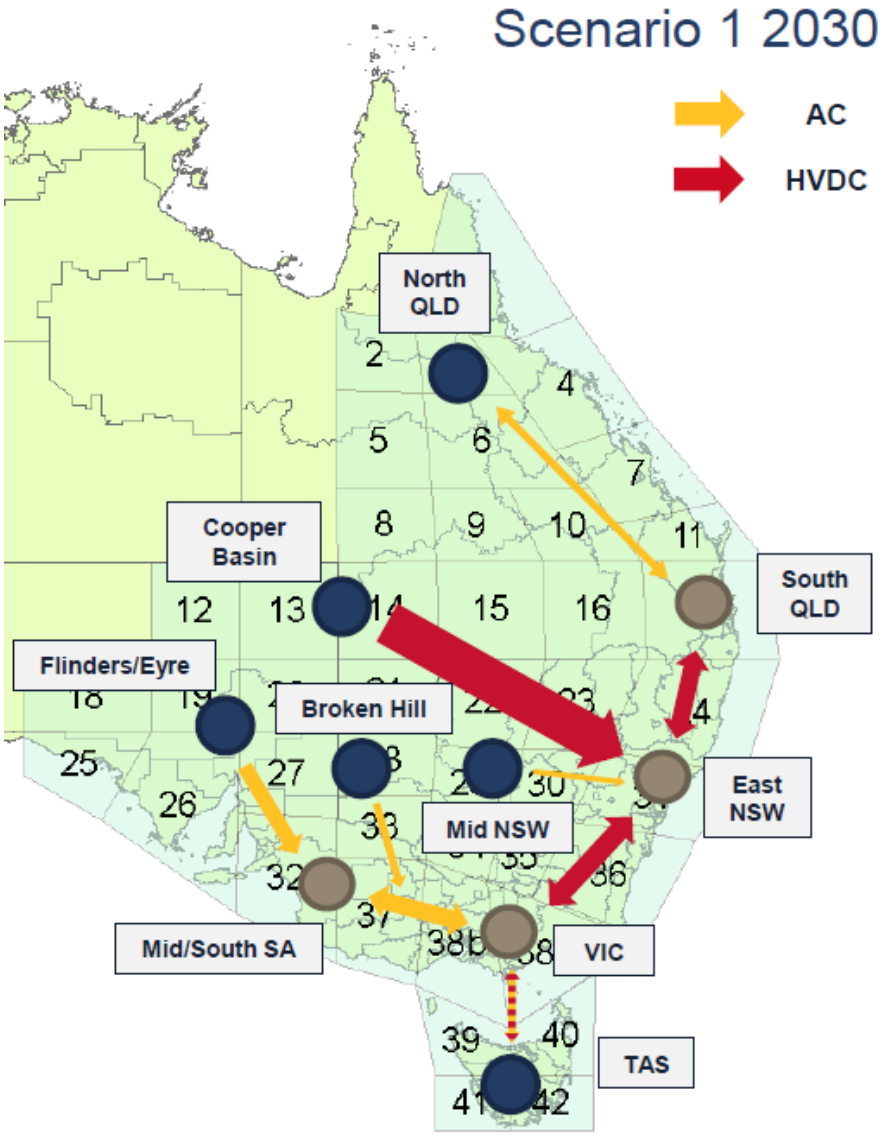
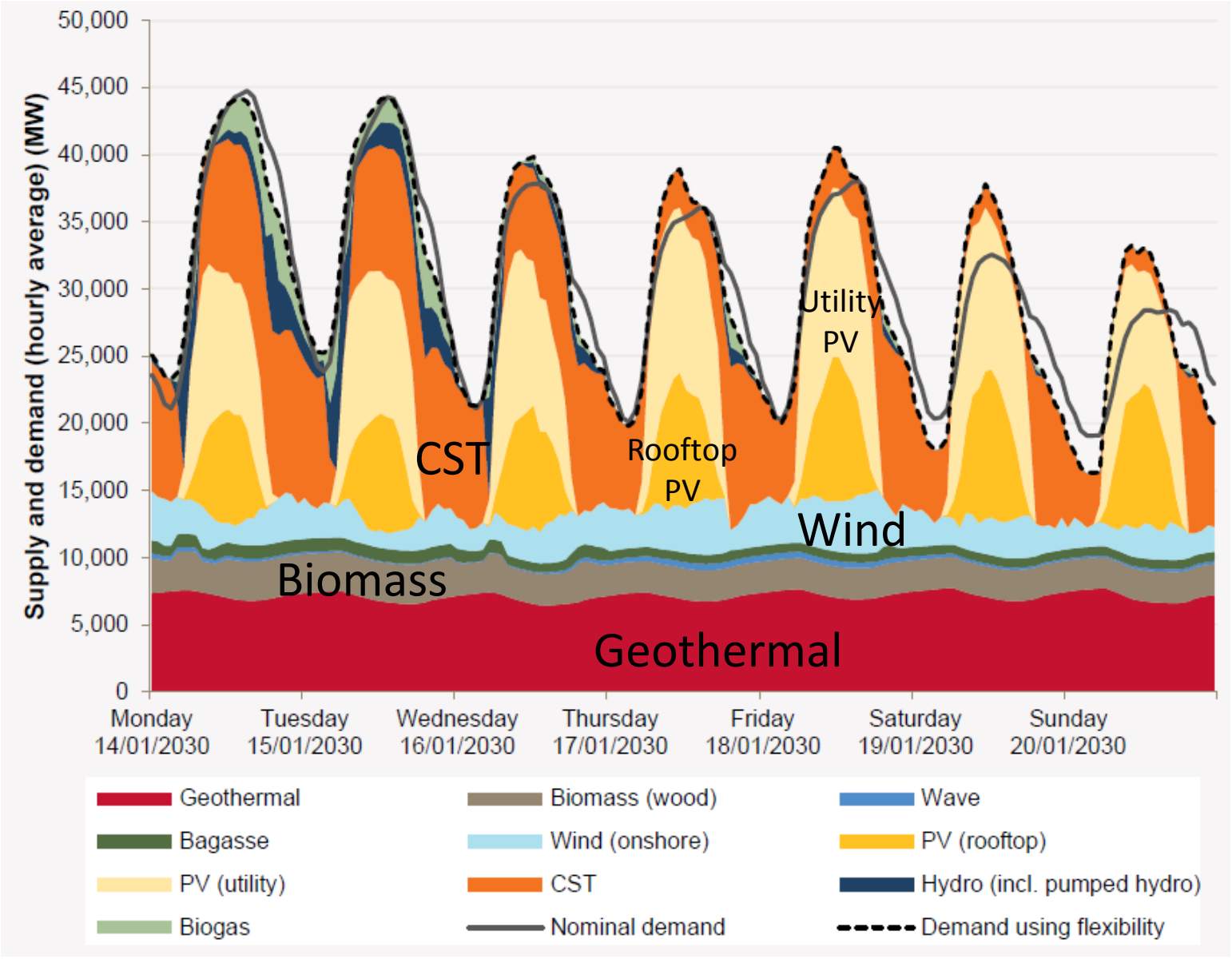
Environmental Mar

New transmission

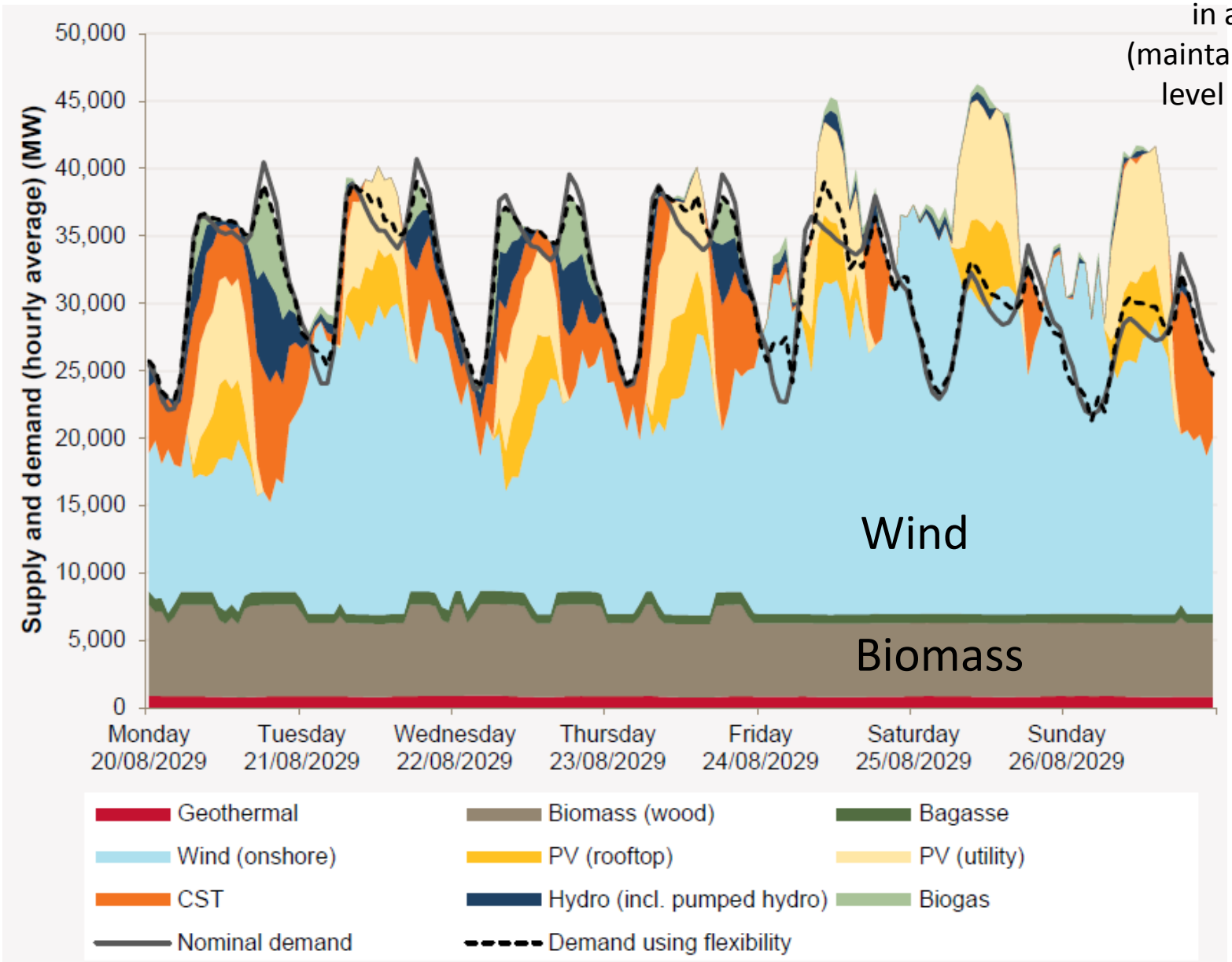


Example: Summer, Scenario 1, 2030



Example: Winter, Scenario 2, 2030

Model constrained to minimum 15% synchronous generation in all periods (maintain inertia, fault level feed-in, etc)



AEMO's assessment

- Reliability standard maintained
- Operational issues "appear manageable" (high level review, based upon international research)

"High penetrations of semi-scheduled and non-synchronous generation would constitute a system that may be **at or beyond the limits of known capability and experience anywhere in the world to date…**"

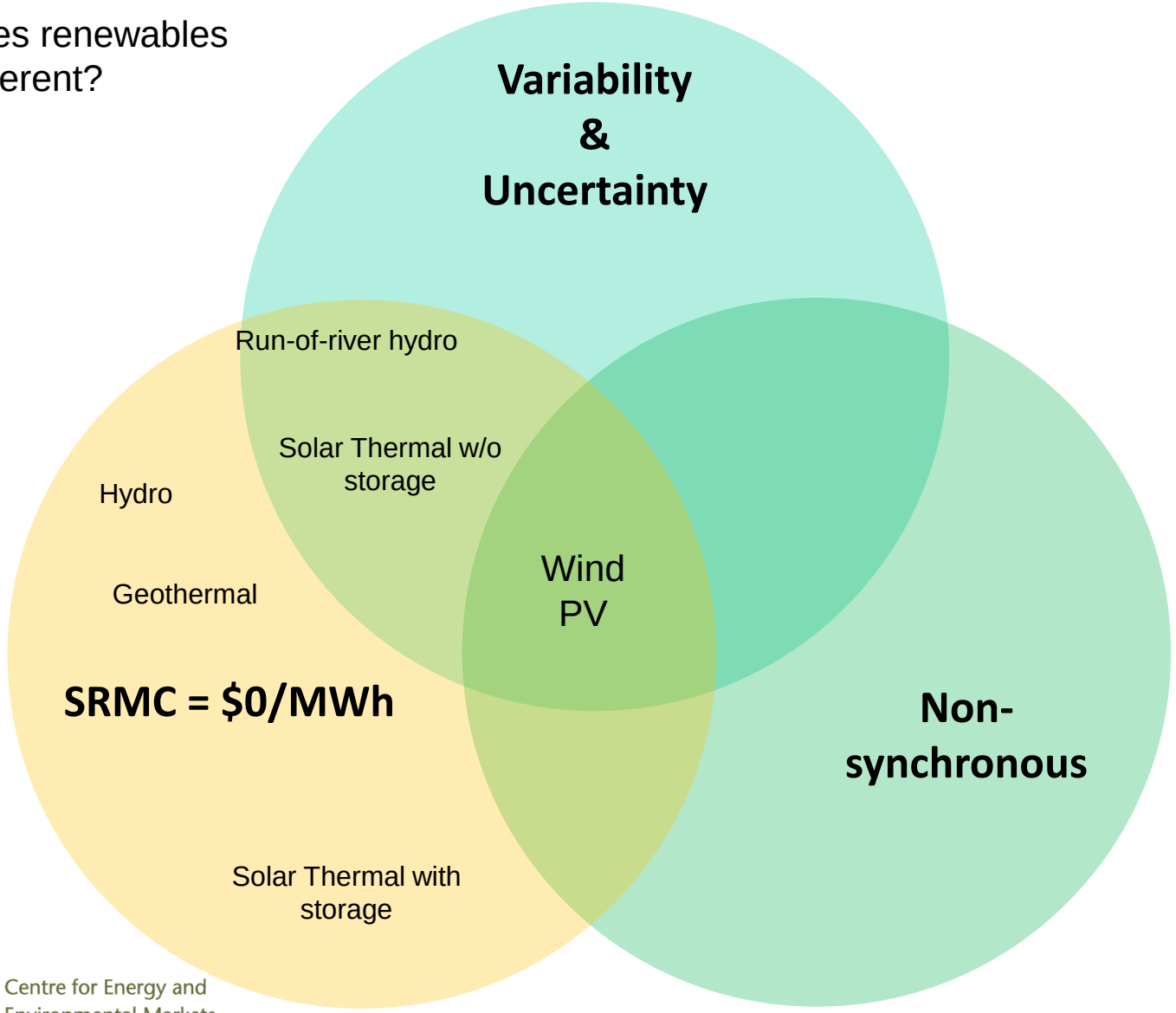
but…

"There are **no fundamental technical limitations** to operating the given 100 per cent renewable NEM power system generation portfolios that have been identified."

AEMO (2013), "100 per cent renewables study – Modelling outcomes".

Renewable integration challenges

What makes renewables different?



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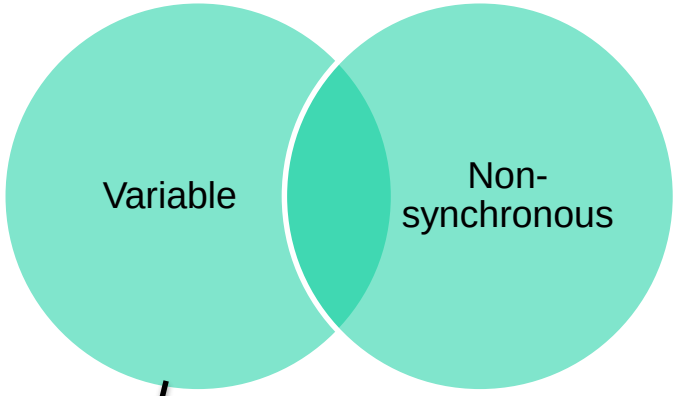
Wind and PV bring new integration challenges



Increased system variability

FREQUENCY CONTROL

Matching supply and demand at all times

Regulation Service: Manages variability within 5min dispatch intervals

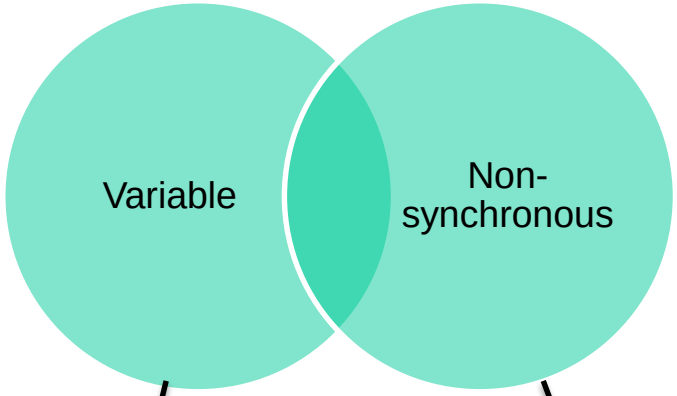
Regulation costs likely to increase significantly

	Wind installed	Regulation requirement	Regulation settlements	Regulation cost for wind generators
2015	4 GW	± 120 MW	$5 million pa	$0.40 /MWh
2020	8 - 10 GW	± 800 MW	$200 million pa	$8 /MWh
2030	??	??	??	??

- Significant opportunities for optimisation
  - Address inefficiencies and “unfair” procedures
  - Some apparent in SA already, many more will be coming

J. Riesz, F. Shiao, J. Gilmore, D. Yeowart, A. Turley, I. Rose, “Frequency Control Ancillary Services for High Penetration Wind in Australia,10th International Workshop on Large-Scale Integration of Wind Power into Power Systems, 2011, Aarhus, Denmark.

Wind and PV bring new integration challenges



Increased system variability

Displacement of synchronous generation

FREQUENCY CONTROL

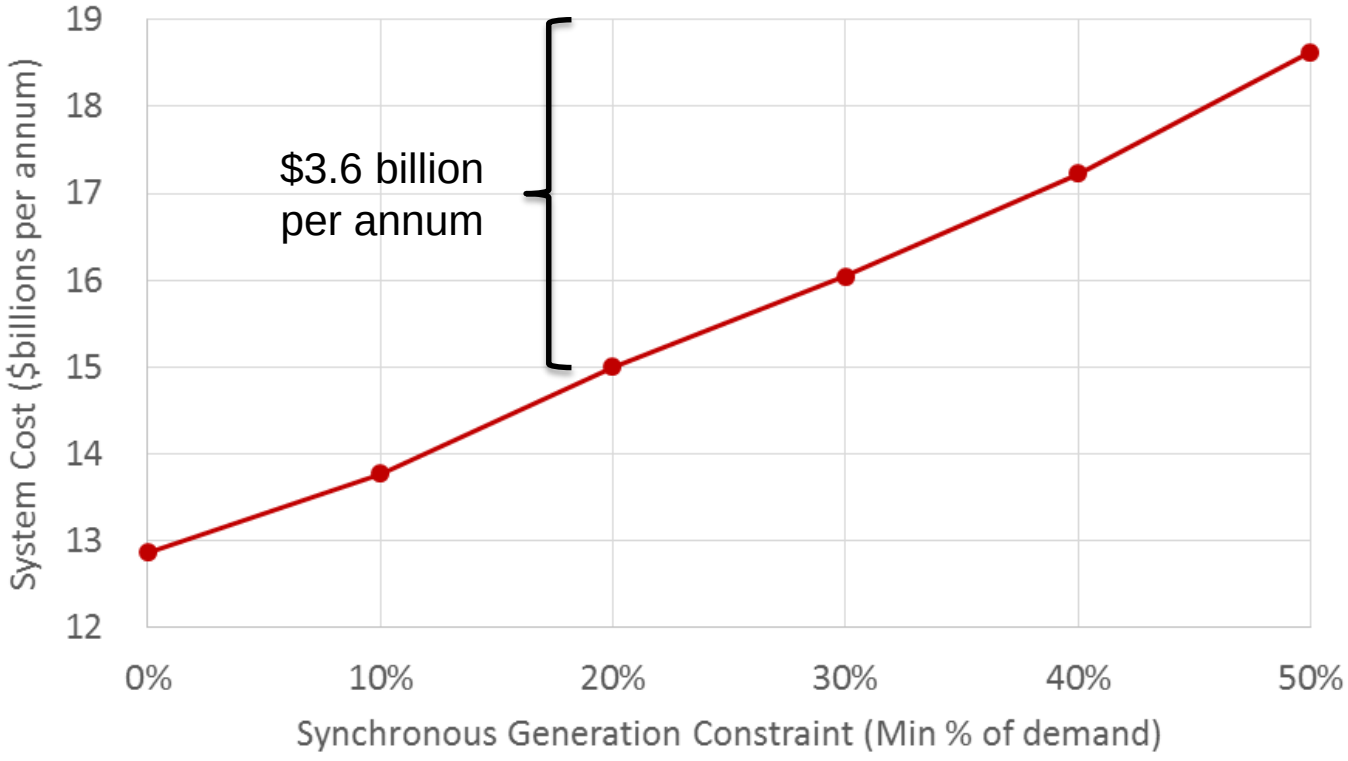
Matching supply and demand at all times

Regulation Service: Manages variability within 5min dispatch intervals

Inertia: Stabilises frequency on very short timeframes (seconds)

Managing low inertia systems

- Can be managed by minimum synchronous generation limits
  - Ireland (50% minimum), NEM (interconnector constraints)
- May be appropriate initially, but costs escalate as renewables grow
- Significant value in exploring alternatives
  - Lots of options, but which are most technically and economically feasible?
- Implementation mechanism required



P. Vithayasrichareon, T. Lozanov, J. Riesz, I. MacGill, "Impact of Operational Constraints on Generation Portfolio Planning with Renewables", 2015 IEEE PES GM, Denver

J. Riesz, B. Elliston, "Research priorities for renewable technologies - Quantifying the importance of various renewable technologies for low cost renewable electricity systems," To be submitted to Applied Energy, 2015.

Engineering challenges identified by AEMO

Variability and Uncertainty

Frequency control - seconds (inertia)

- Displacement of synchronous generation

Frequency control - minutes (regulation)

- Increasing variability and uncertainty → increase in regulation reserves

Frequency control - hours (ramping)

- Managing long wind & PV ramps

Fault level in-feed

- Non-synchronous technologies don't provide sufficient fault feed-in
- Protection systems may no longer be able to determine when and where a fault has occurred

Grid code performance standards

- New reactive power and voltage support capabilities required during disturbances

Reliability and Resource Adequacy

- Need to assess differently to present

AEMO Conclusions:

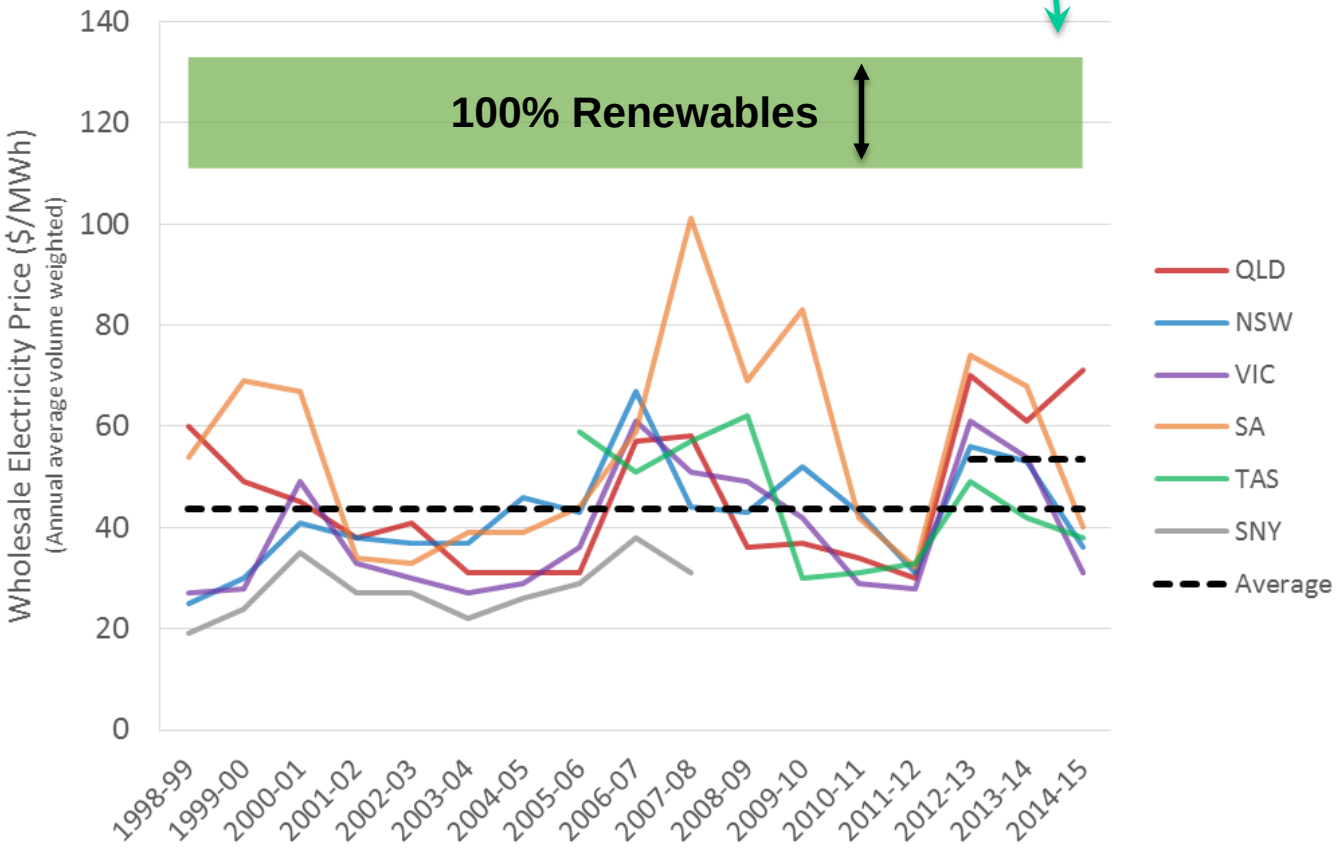
"Many issues remain to be determined without doubt, but it is valuable to note that this operational review has uncovered no fundamental limits to 100% renewables that can definitely be foreseen at this time."

- Transition will occur dynamically over time, allowing proper scope for learning and evolution with additional experience gained.

100% renewables – Technically feasible?

A question of cost…

	Cost for 100% renewables (AEMO)
Total capital cost including transmission	$219 - 332 billion
Wholesale cost including opex	$111 - 133 /MWh



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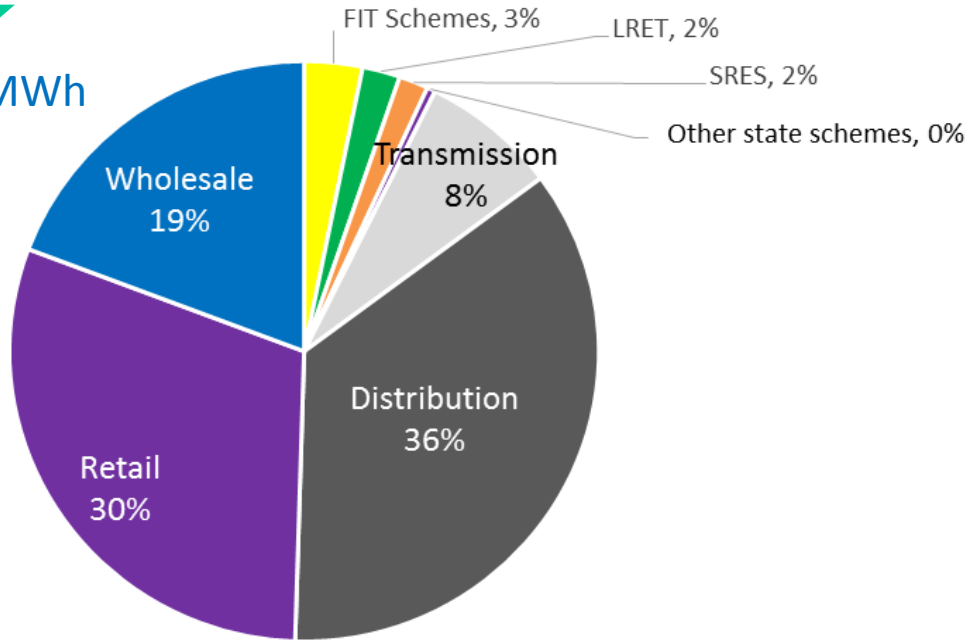
Components of retail prices

- Increase of 6-8c/kWh on retail tariffs (20-30c/kWh)
- 20-30% increase

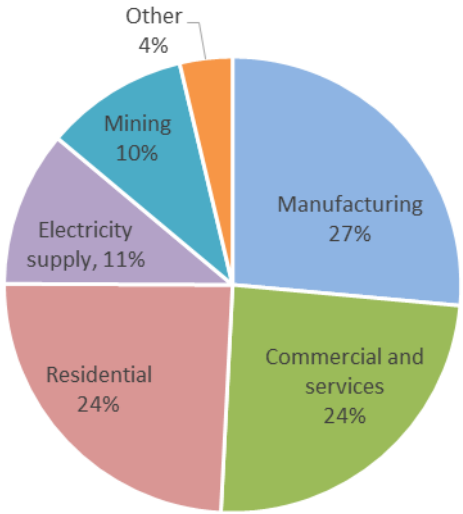
$55 /MWh

$110 /MWh



Although it's a different story for industry…

Australia's electricity consumption by sector (2012-13)



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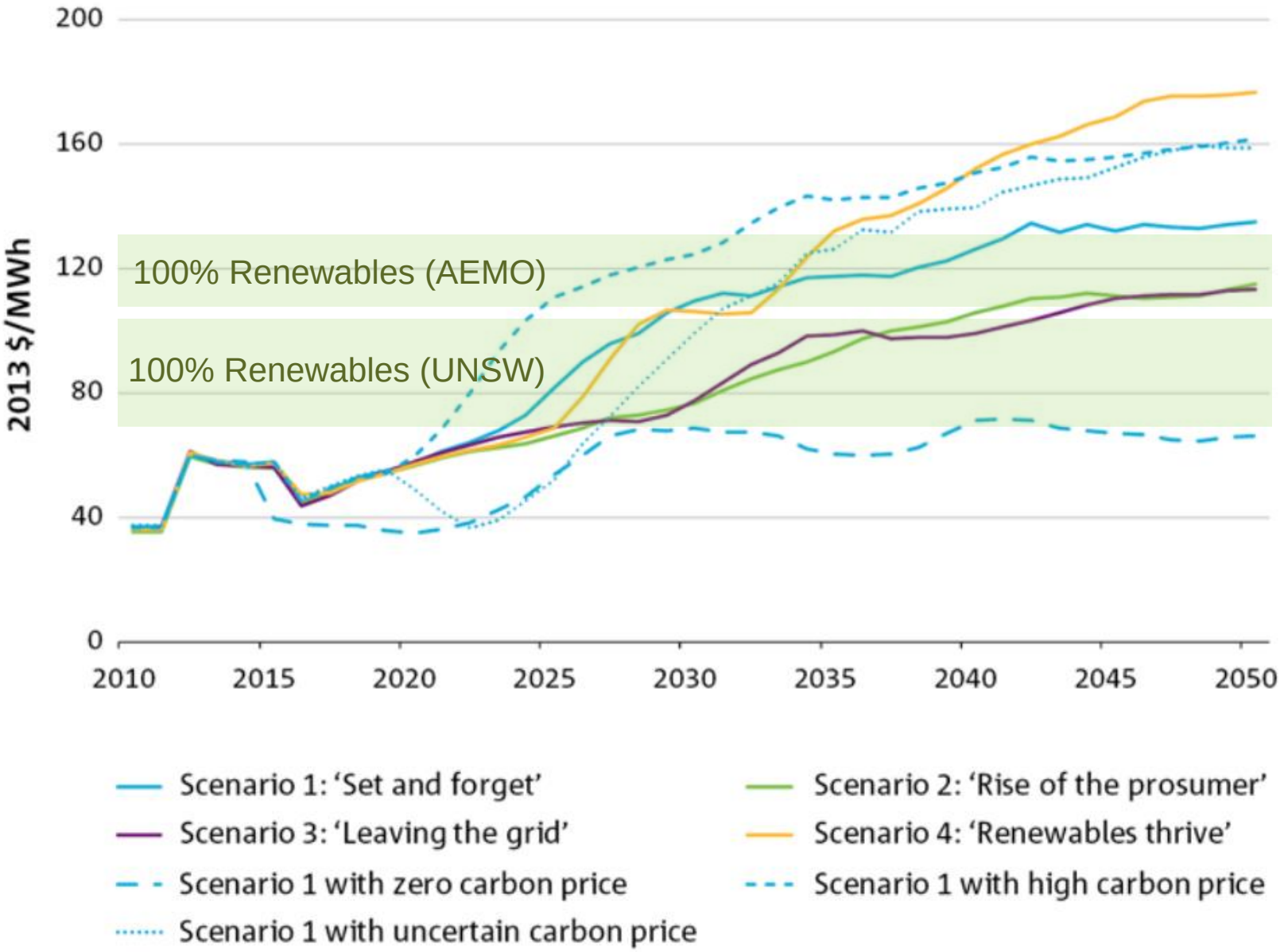
AEMC, Electricity Price Trends Final Report, March 2013, Results for QLD in 2012-13.

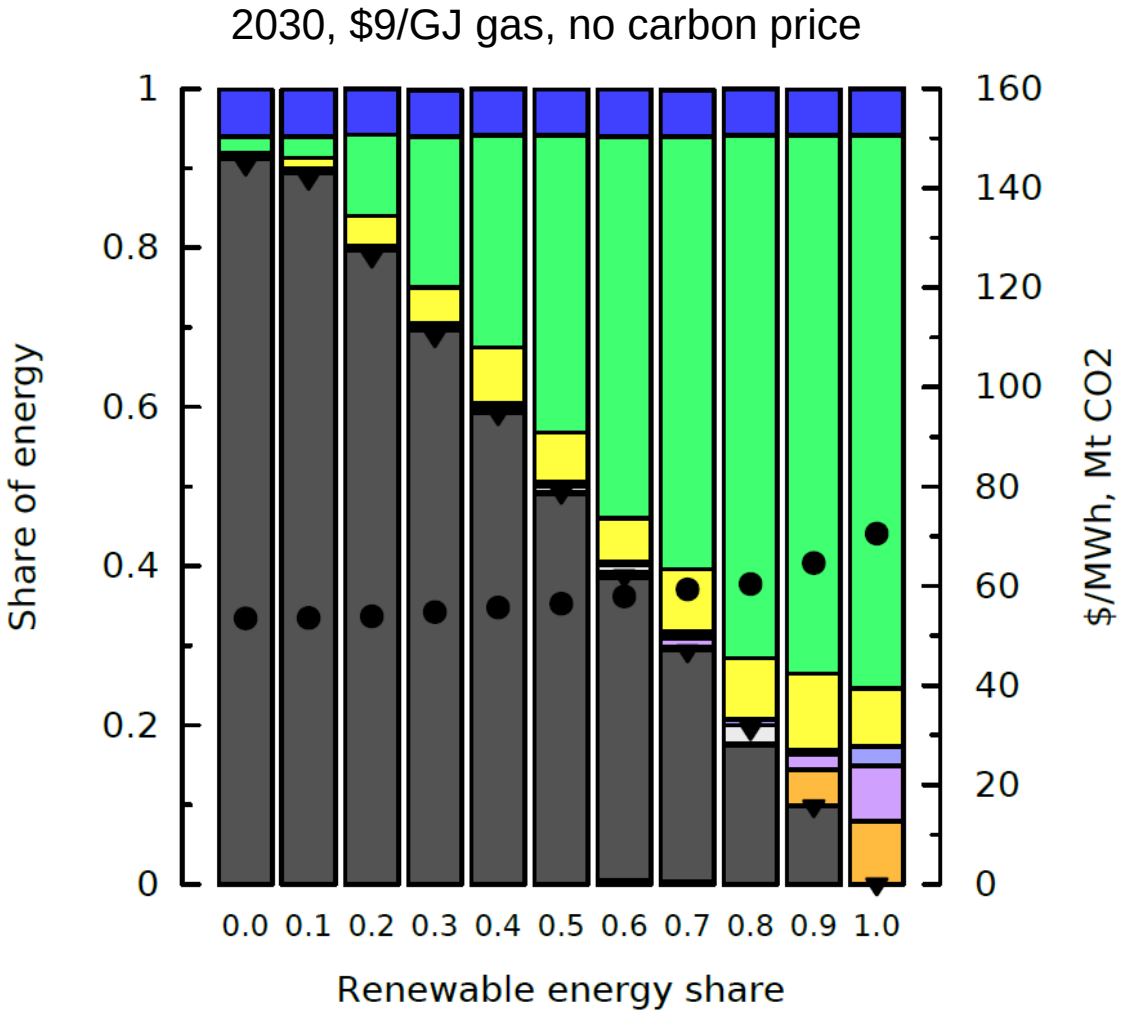
Costs are going up anyway...

CSIRO Future Grid (2013) "Change and Choice – The Future Grid Forum's analysis of Australia's potential electricity pathways to 2050"



UNSW modelling

- High wind, low PV
- Costs increase ~ linearly to 80% RE
- Wind displaces coal



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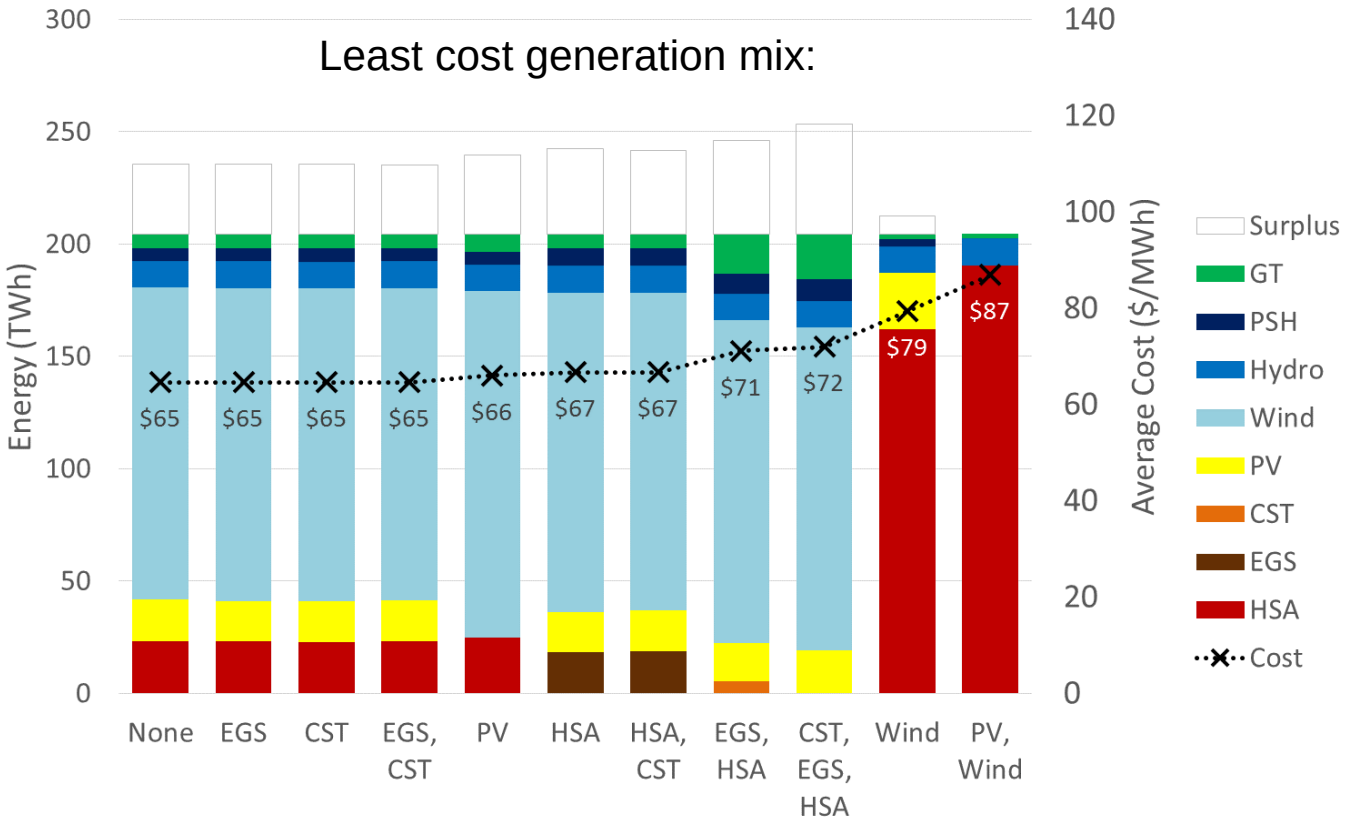
B. Elliston, J. Riesz, I. MacGill, (2015) "What cost for more renewables? The incremental cost of renewable generation - an Australian National Electricity Market case study"

Technology availability

- Can meet reliability standard with various technologies unavailable
  - Robust ability to achieve 100% RE
- Costs $65 - $87 /MWh
  - Wind typically provides ~70% of energy, most expensive scenarios don't have wind



J. Riesz, B. Elliston, "The impact of technology availability on the costs of 100% renewable electricity generation scenarios for Australia", 38th IAEE International Conference, Antalya, Turkey, May 2015.

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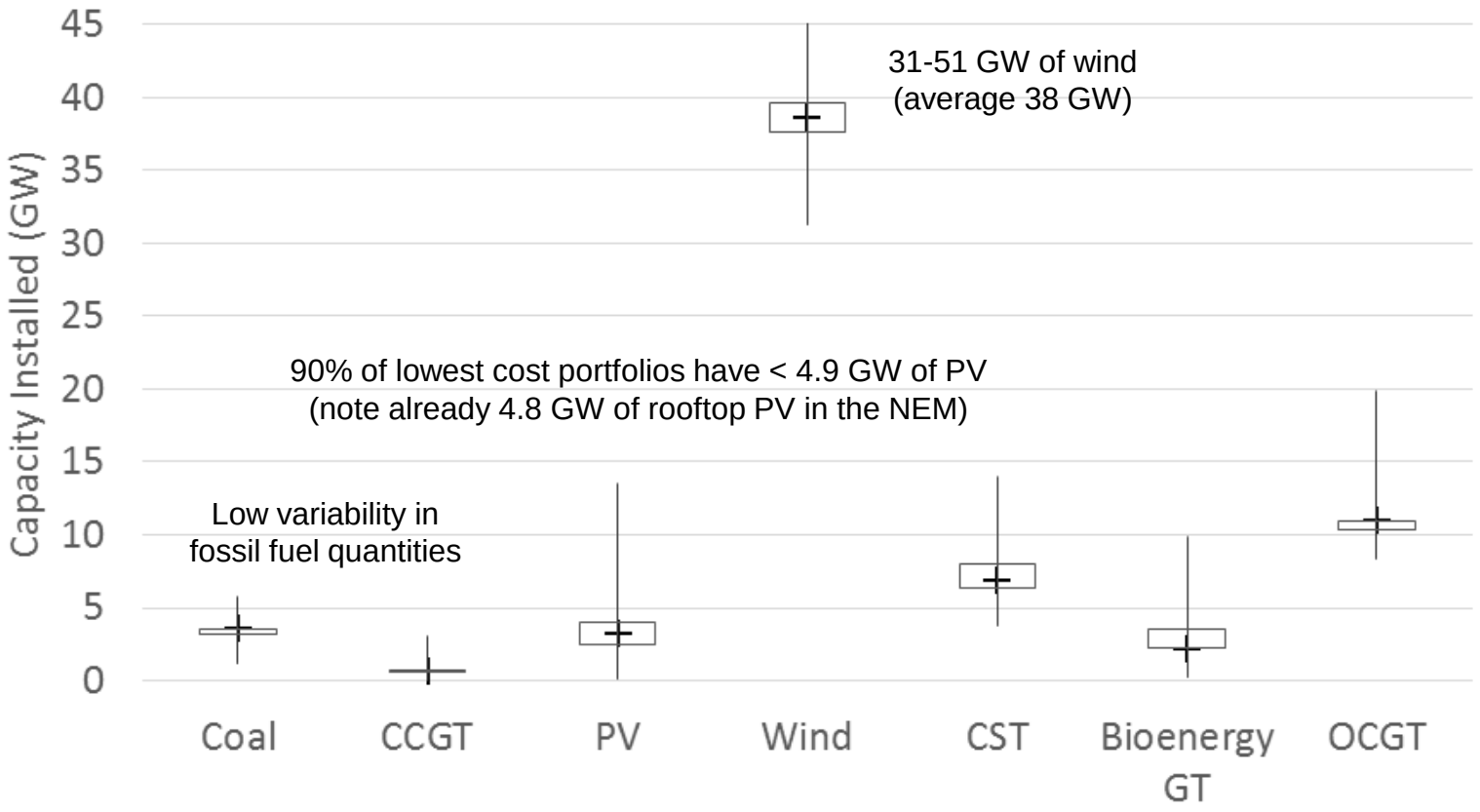
Portfolios within $10/MWh (15%) of lowest cost



Boxes: 1st & 3rd Quartiles, Lines: Max & Min, Crosses: Median

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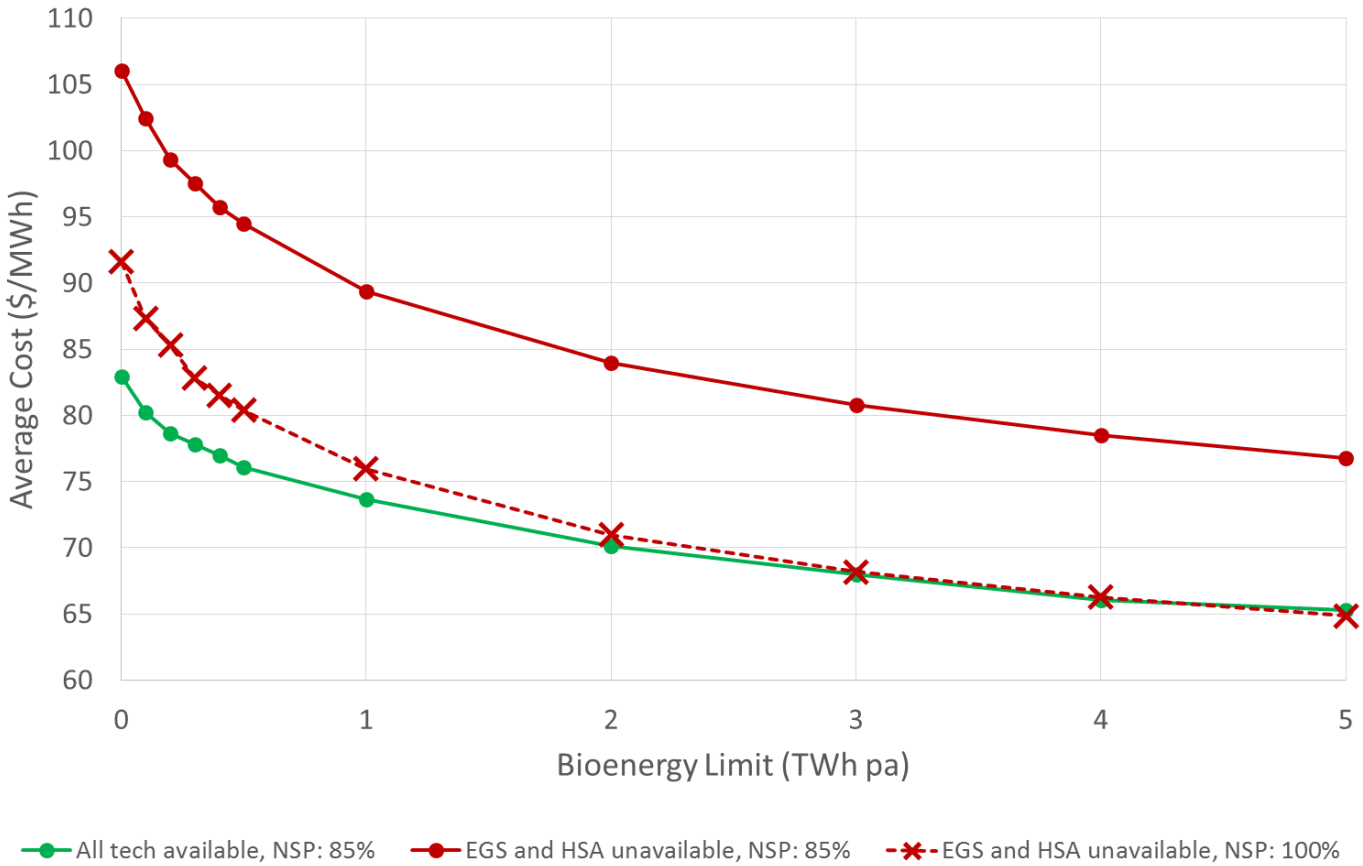
- Bioenergy (even a very small amount) also brings costs down significantly
  - Importance of enabling “peaking” renewables to achieve 100% RE
  - But same result from:
    - Small amount of natural gas turbines (peaking)
    - Rarely activated demand side participation
    - Batteries NOT equivalent for most applications (high capital cost)



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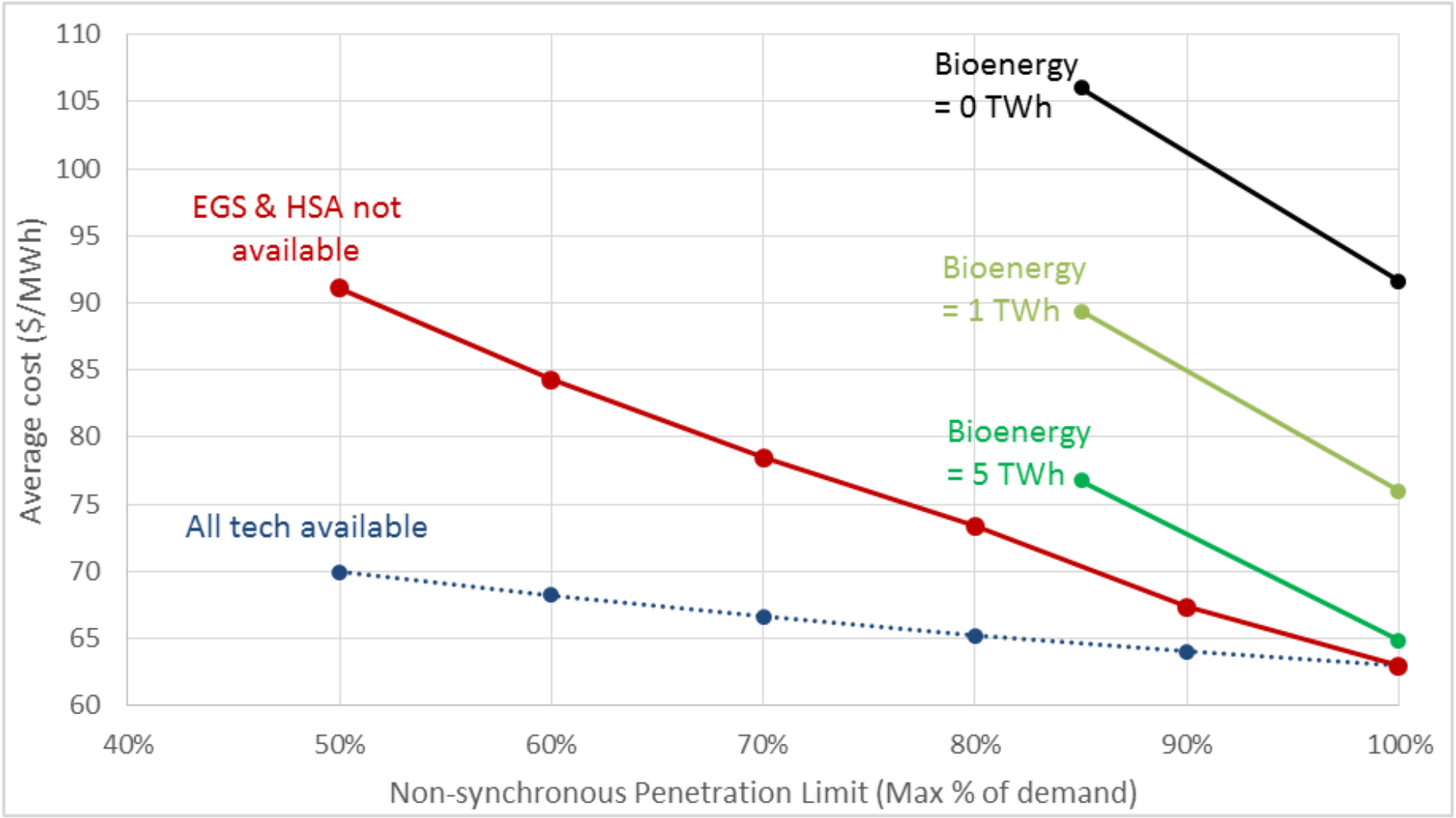
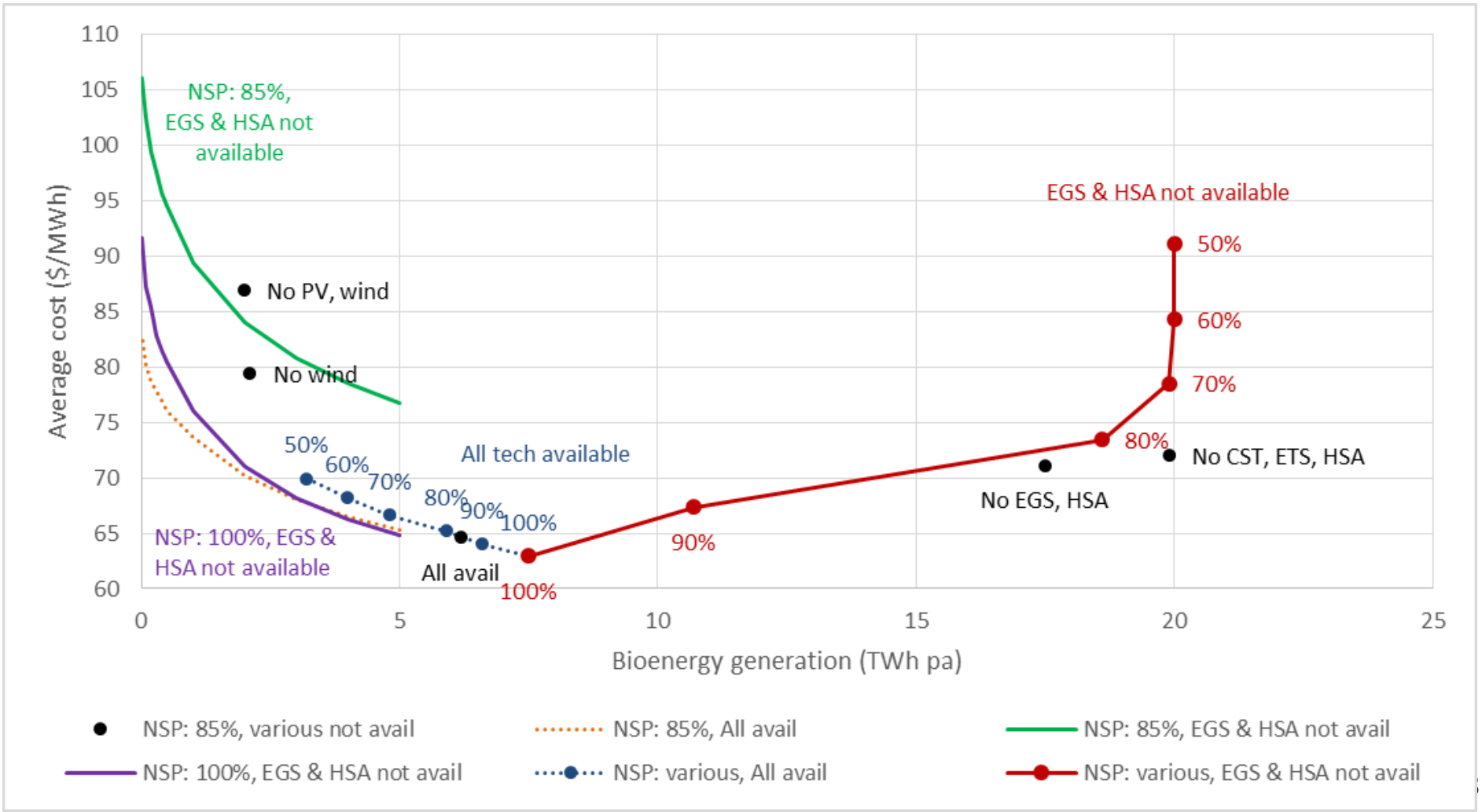
- Non-synchronous penetration (NSP) limit also has significant effect on costs
  - Especially when other technology combinations aren't available
- Value in research to minimise the NSP limit (eg. wind & PV integration)



- Costs significantly affected by:
  - Non-synchronous penetration (NSP) limit
  - Lack of wind
  - Lack of biogas GTs (peaking technology)
- "Baseload" renewables relatively less important (CST, geothermal)



- 100% renewables (or very high renewables) appears similar in cost to other possible power systems in the future

100% renewables – Cost competitive?

What about the *market?*

Competitive market → Generators offer close to SRMC → Price close to zero in majority of periods

How do generators recover costs?

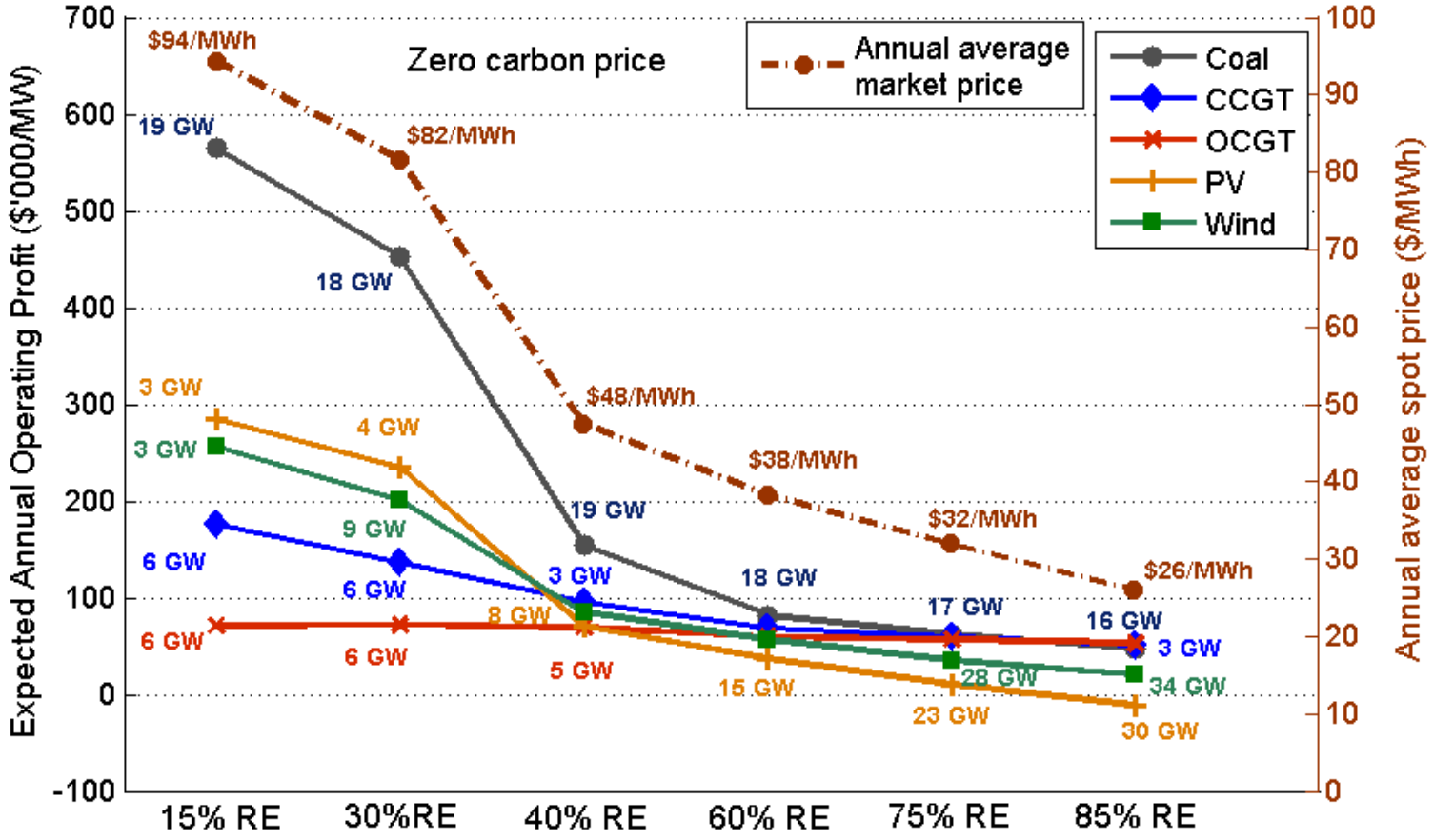
How do we maintain accurate investment incentives?

SYSTEM ADEQUACY

Market modelling with high renewables

Increase wind & PV → Prices fall

Wind & PV themselves are particularly affected (especially PV)



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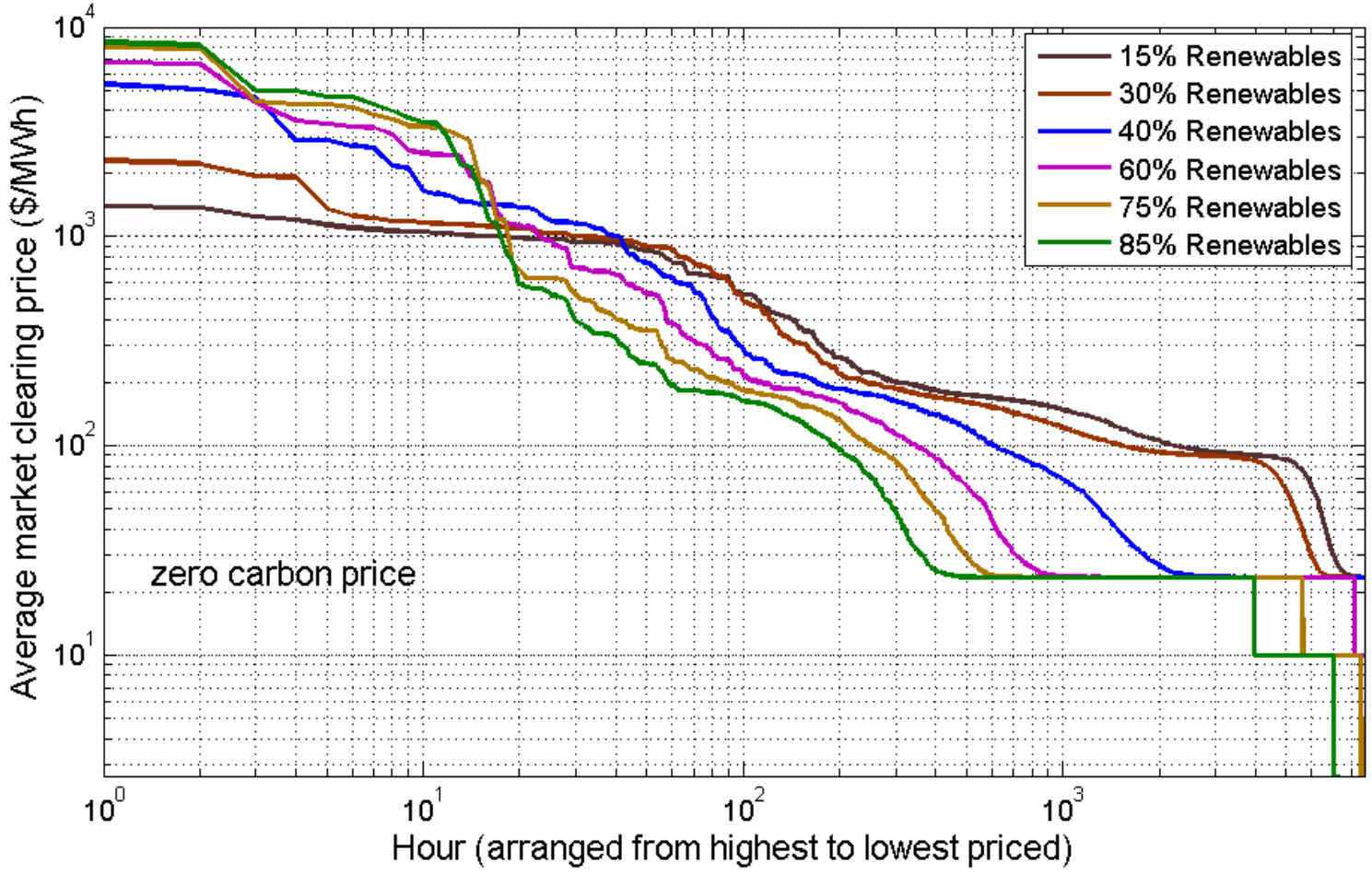
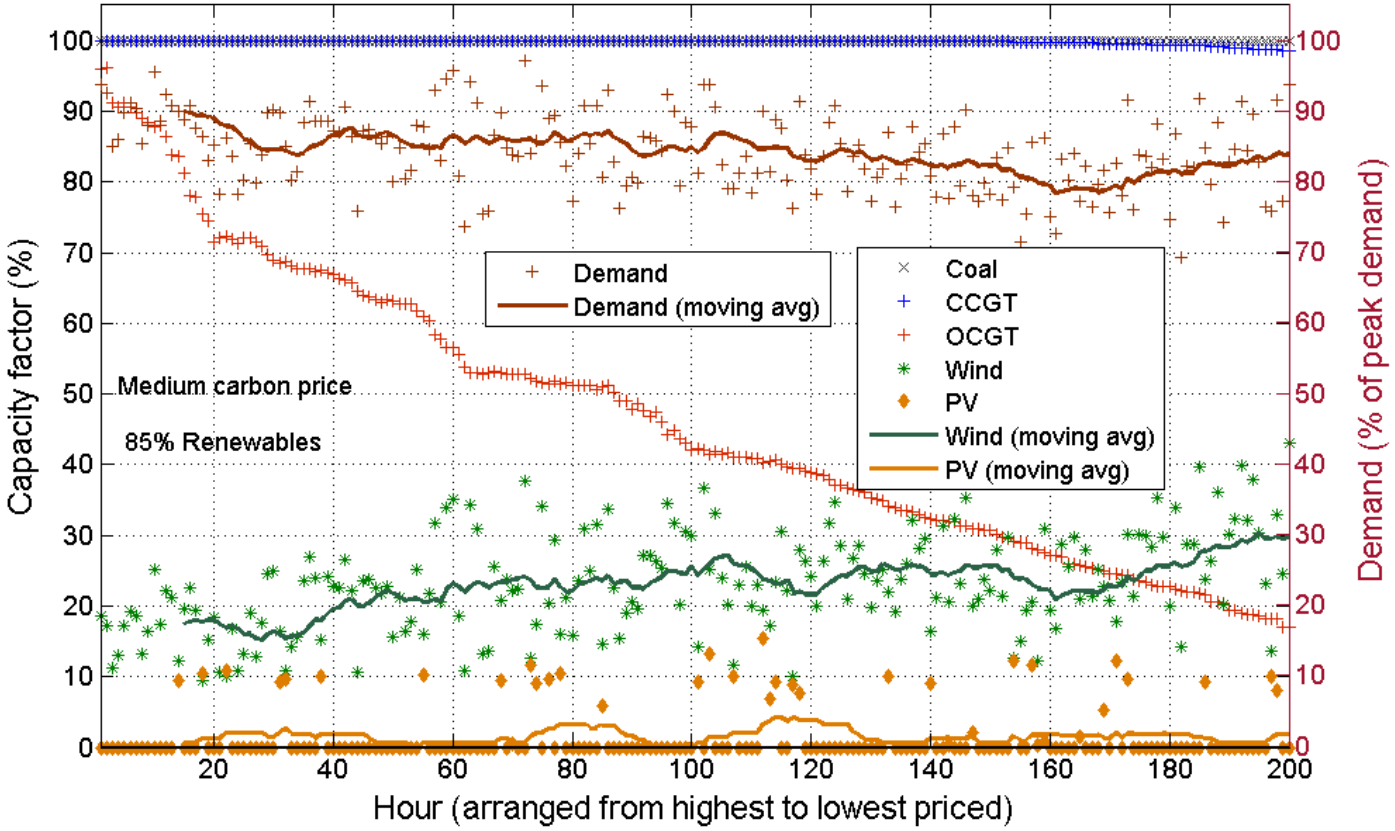
- Greater incidence of zero and low prices as renewable proportions grow
- BUT, also greater incidence of extreme high prices
- May not need to increase Market Price Cap very much to maintain same incentives to contract?



- Top priced 200hrs:
  - Very low PV, moderate wind
  - High demand, and coal, CCGT & OCGT almost fully operating (full benefit of high prices)
  - Greater demand for cap contracts? (more periods at extreme prices)
  - Invest in PV with caution

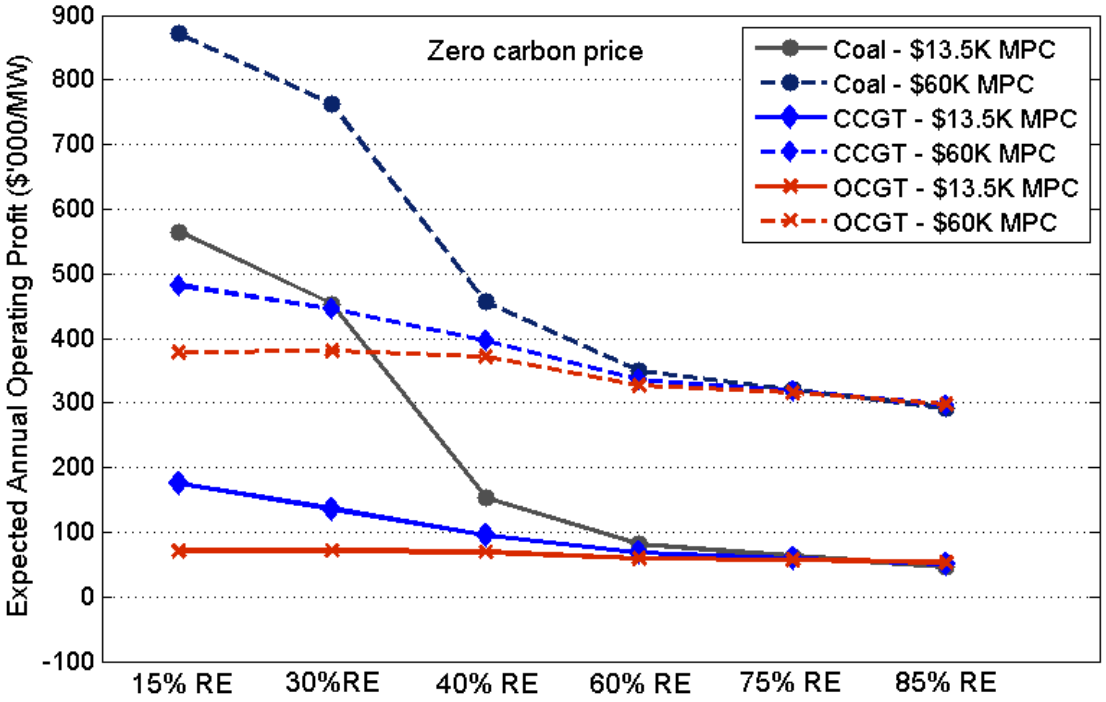


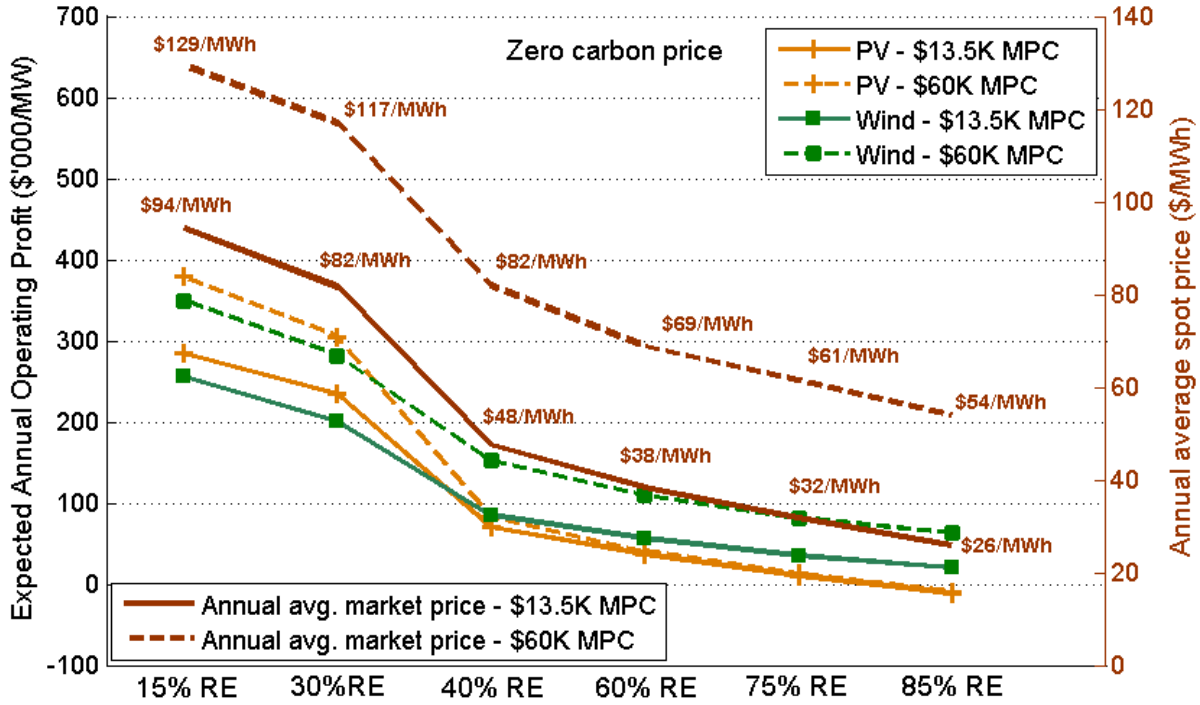
Increasing the MPC:

- Main mechanism to increase investment to meet the reliability standard
- Successfully increases average prices
- Significantly increases revenues of OCGTs, CCGTs and coal
- Increases wind profitability somewhat
- PV profitability unchanged at high renewable levels (too much PV)

Key conclusion:

- The present energy-only market *could* work, if we can increase the MPC, and the contracts market is sufficiently robust.





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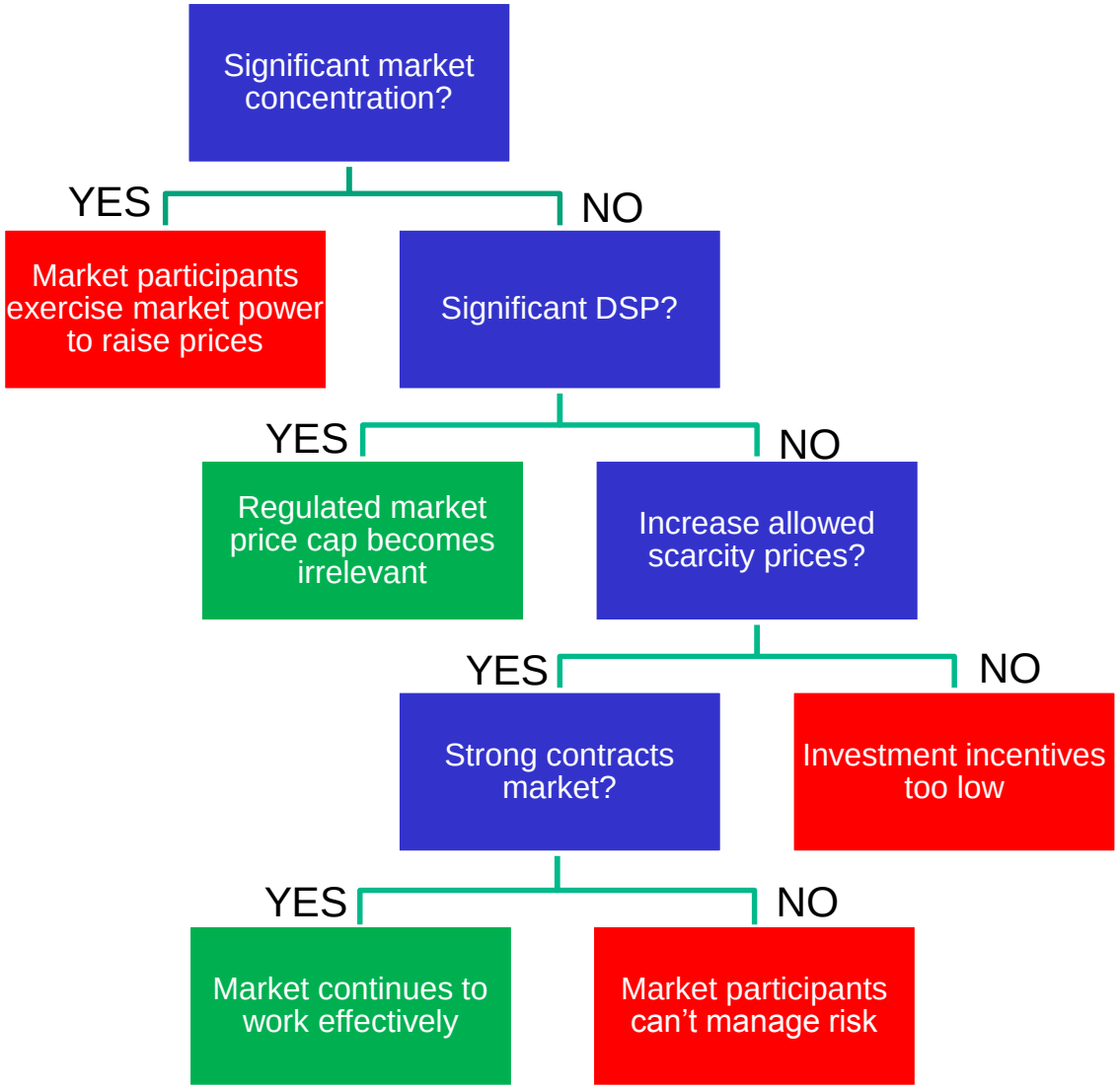
Will the market work with high renewables?



Constant monitoring is wise – new issues will arise over time

Summary

100% renewables – worth thinking about?

- Inevitable - a question of when

100% renewables – technically feasible?

- Yes, with high confidence, although many technical issues to address

100% renewables – costs?

- Appear manageable, and likely lower than other generation types (given anticipated gas and carbon costs)

100% renewables – will the market work?

- Will challenge existing market models, but dramatic market reform is unlikely to be warranted at this time.

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Thank you

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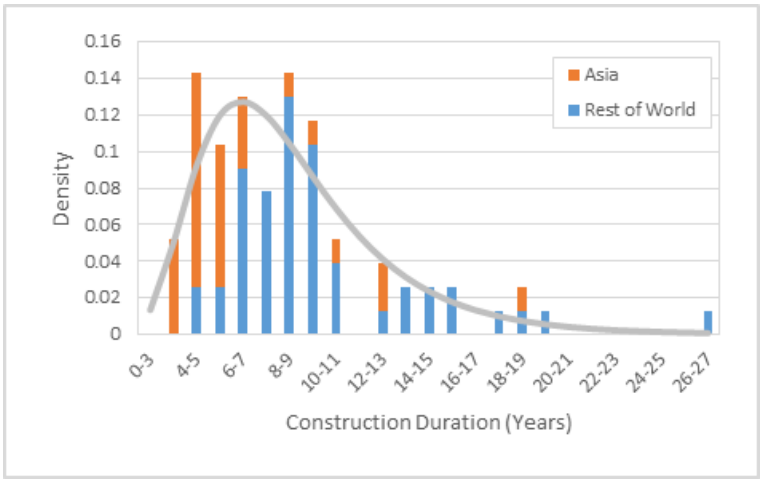
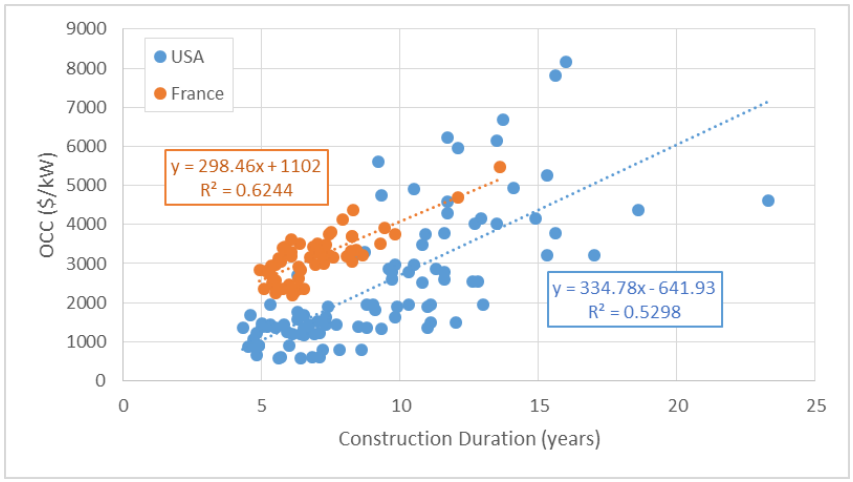
Nuclear cost risk

- What is the *cost risk* associated with nuclear?
  - Important factor for comparison with other technologies
  - Quantified uncertainty in nuclear cost components
  - Combined with Monte Carlo simulation
- Most important contributors to nuclear cost risk:
  - Pre-construction and construction cost escalation
  - Pre-construction and construction period duration

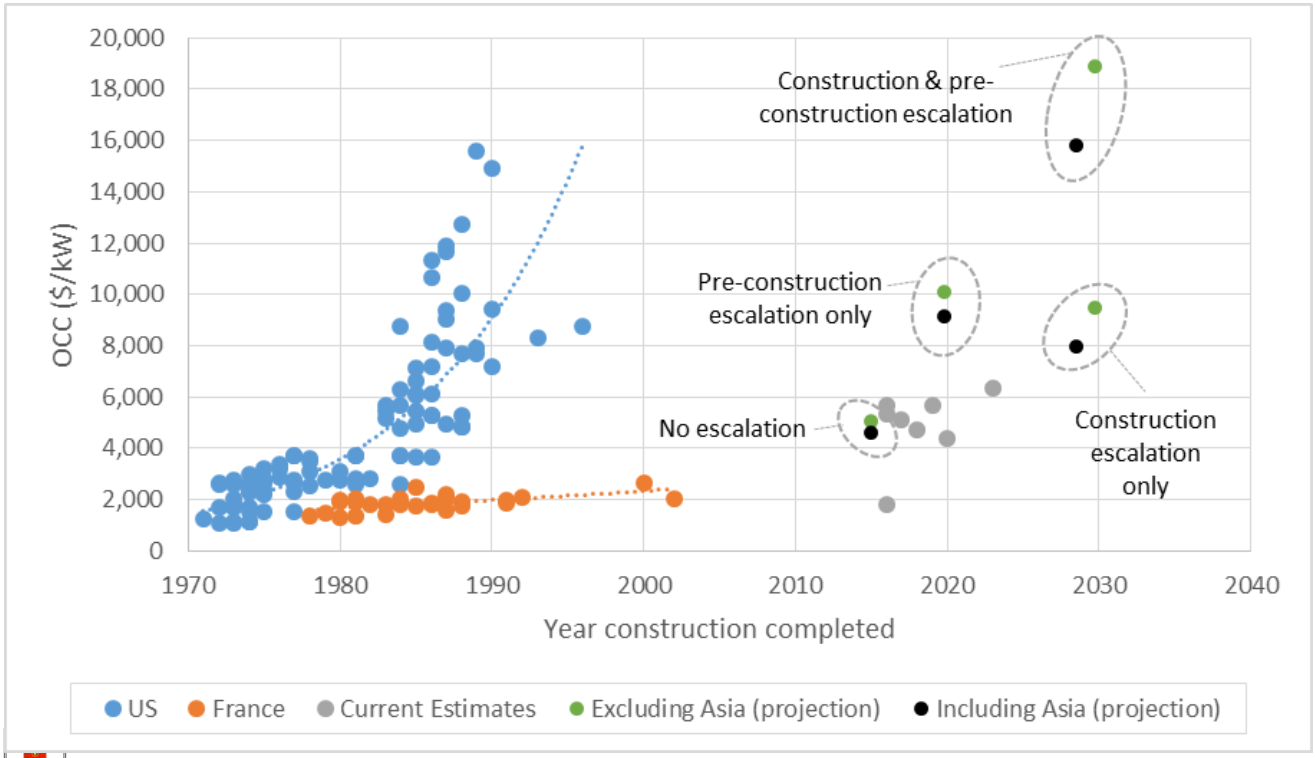




Correlation between OCC and construction duration (use correlated probability distributions for Monte Carlo simulation)

Construction period cost escalation

Jurisdiction	Cost escalation (real, compounded p.a.)
French PWR build program (58 reactors, 1970-2000)	3.6%
US nuclear build program (99 reactors, 1970-1990)	8.1%
Flamanville-3 (France) (1 reactor)	9.9%
Olkiluoto-3 (Finland) (1 reactor)	12.2%



Applied weighted average cost escalation rate

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Impact on Levelised Cost of Energy (LCOE)

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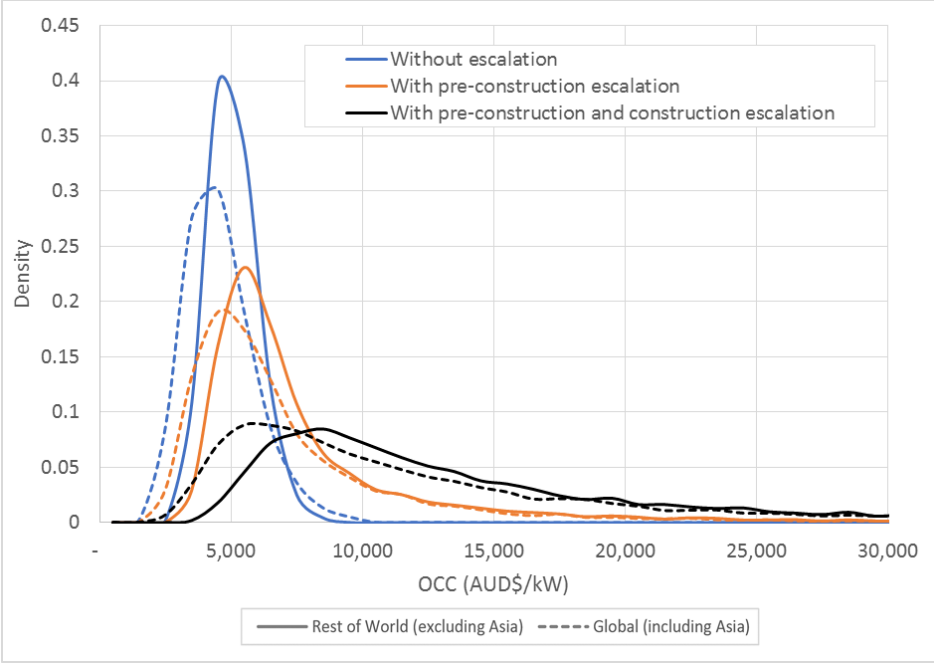
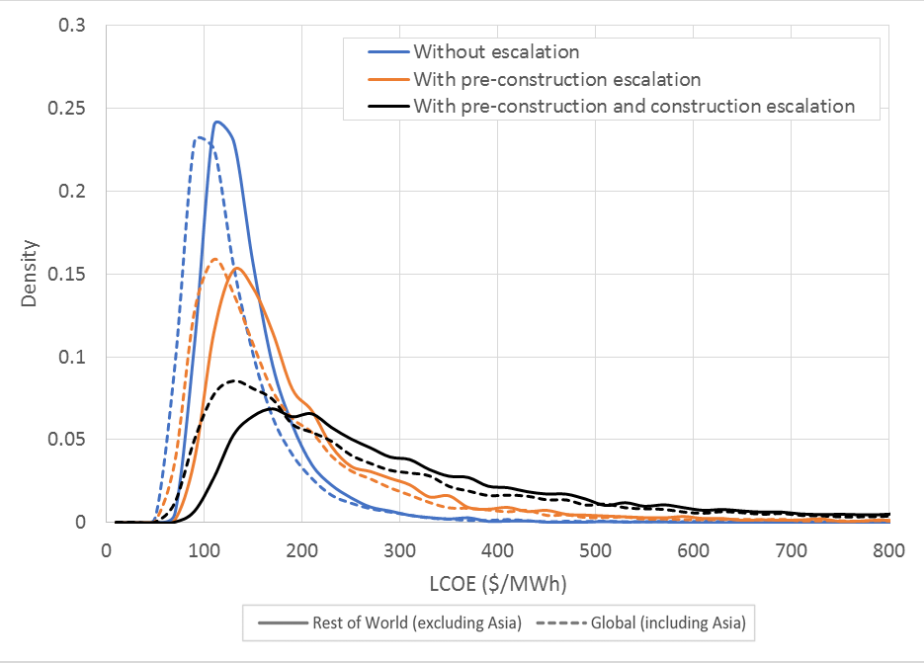
Probability Distributions

- Nuclear costs have an 80% probability of exceeding AU$170/MWh
- Nuclear costs have a 50% probability of exceeding AU$278/MWh
- The mean LCOE for nuclear is AU$515/MWh, with a standard deviation of AU$2,646/MWh





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