Centre for Energy and Environmental Markets

UNSW THE UNIVERSITY OF NEW SOUTH WALES SYDNEY • AUSTRALIA

The role of Wind and PV in mitigating the impact of uncertainty in the Australian National Electricity Market

Peerapat Vithayasrichareon, Jenny Riesz, Iain MacGill

Centre for Energy and Environmental Markets, UNSW, Sydney, Australia

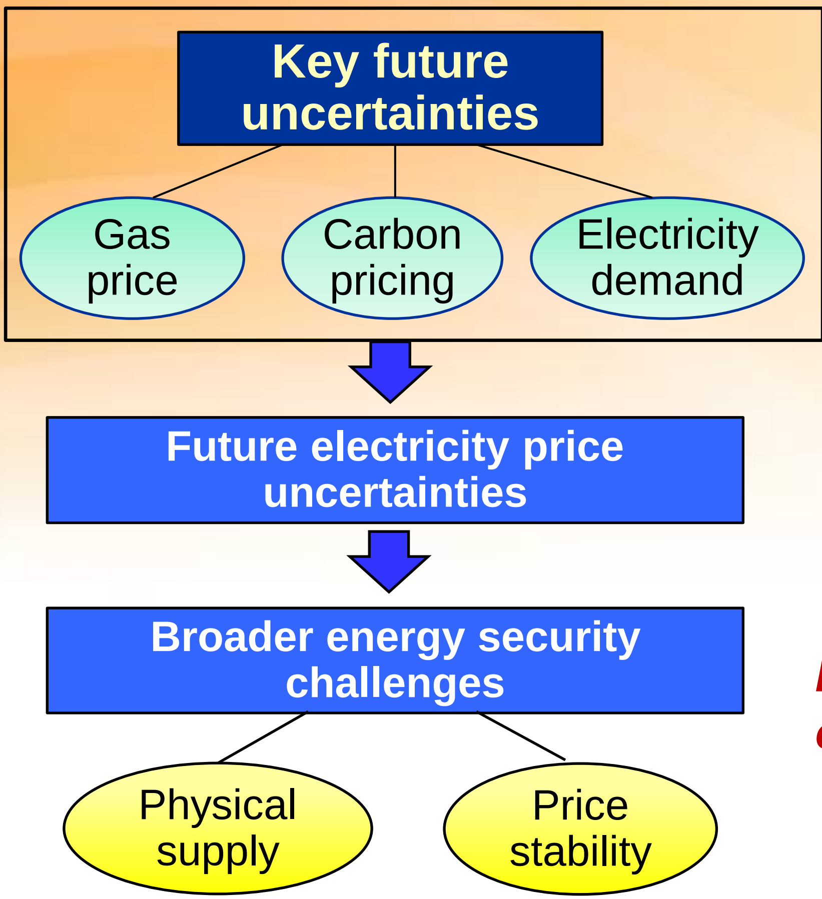
12th Wind Integration Workshop

London, UK, 22nd - 24th October 2013

Outline

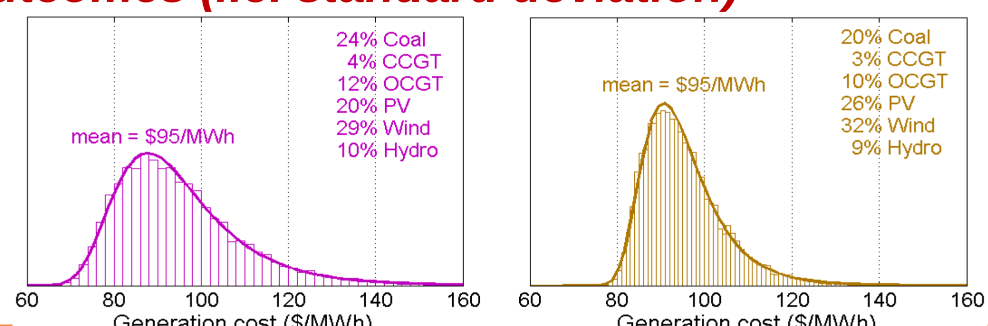
- Uncertainties in generation investment and planning
- The Australian National Electricity Market (NEM)
- Future generation investment in the NEM
- Generation Portfolio Modeling
- Modeling NEM investment scenarios for 2030
- Modeling results and implications

Uncertainties in investment decision making



- Uncertainty poses a significant challenge for generation investment and planning.
- Uncertainty leads to *Risk*
  - *the likelihood of unexpected high costs*
- Investment in a certain generation fleet can expose to external price risk
  - *Renewables potentially offer some low risk alternative!*

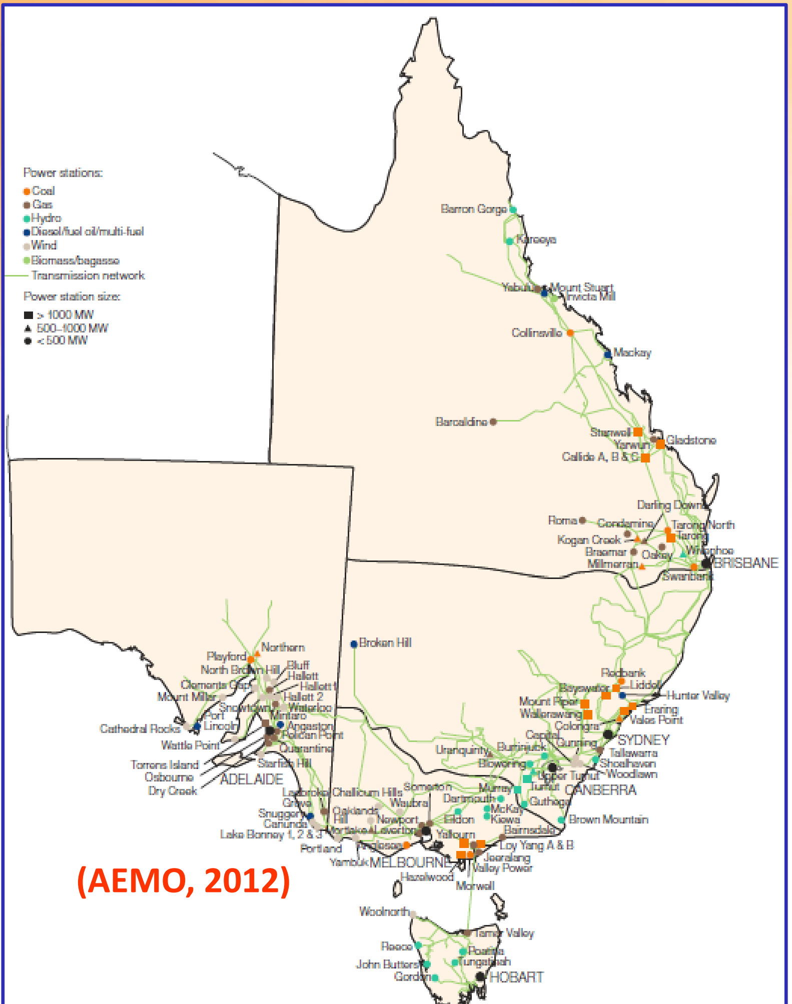
Risks can be quantified by spread of possible outcomes (i.e. standard deviation)



Existing generation planning frameworks

- Often focus on finding the ‘least-cost’ technology portfolio mix based on deterministic assumptions on key cost factors
- Limited treatment of future uncertainty and analysis of risk associated with particular decisions.
  - *Future demand, fuel costs, construction costs of possible generation investment options are highly uncertain*
- Multiple objectives in generation investment and planning
  - *i.e. Costs, energy security, CO_2 emissions.*

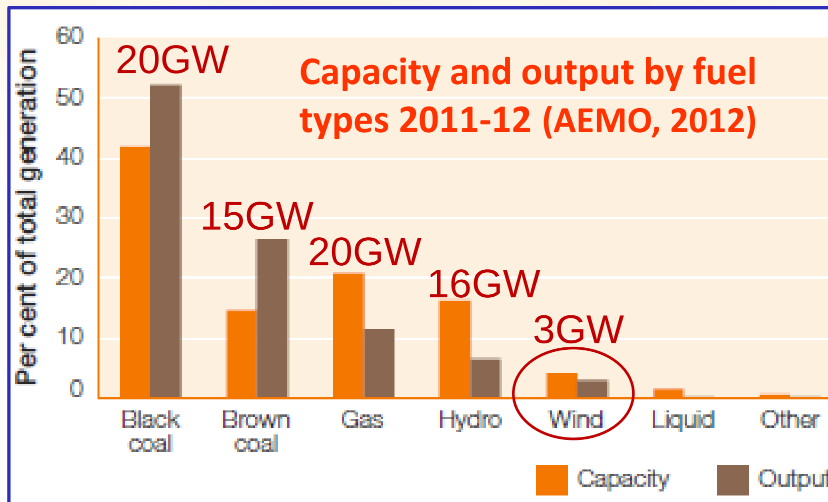
The Australian NEM



(AEMO, 2012)

- Australian National Electricity Market (NEM) covers all Eastern States – 90% of electricity demand.

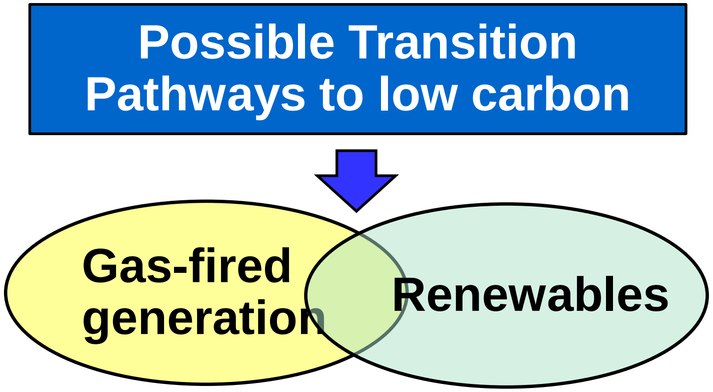
Installed capacity: 48 GW
Peak demand: 35 GW
Annual energy: 200 TWh



- Generation mix consist largely of coal with some Gas, Wind and hydro.

Future generation investment in the NEM

- Australia is among the highest emissions per capita countries.
  - *35% of national emissions from the electricity sector*
- A number of *RE and climate policies* to promote cleaner energy
  - *E.g. Renewable Energy Target (RET), Feed in Tariff (FiT), carbon pricing*
- Generation investment pattern is evolving in respond to such policies
  - *Increase in **Gas-fired** and **Wind generation** and substantially less coal.*
  - *Leads to significant increase in **PV** – around 2.5 GW as of 2013.*



This study examines different generation investment scenarios for 2030 in the context of high future uncertainty.

Probabilistic Generation Portfolio Modeling

- A modeling tool based on *Probabilistic Analysis* to assess a large number of future generation portfolio mixes given a range of uncertainties.
  - In terms of '*expected cost*', '*cost risk*' and '*CO_2 emissions*'
- Combines *Load Duration Curve* concepts with *Monte Carlo Simulation (MCS)* and *Financial Portfolio Analysis* technique

Identify key uncertain variables → Assign probability distributions to the uncertain variables → Generate random samples (i = n samples) → Calculate total ***Annual costs*** and ***Emissions*** → Range of possible results represented by a probability distribution

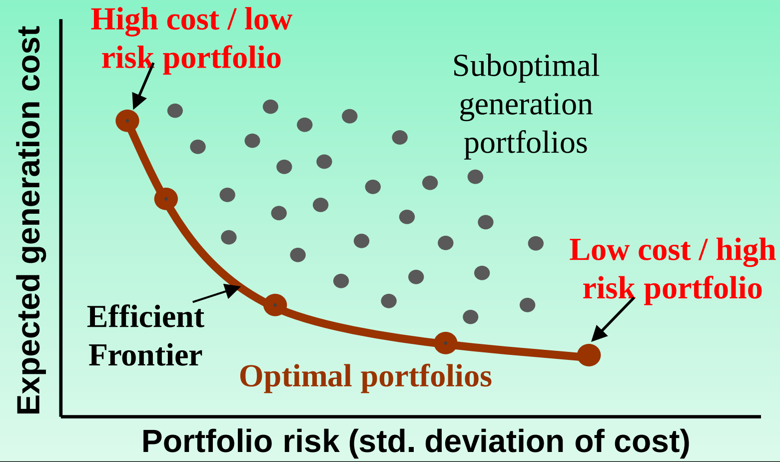
MCS process

Mean and SD can be used to measure expected cost and risk profile

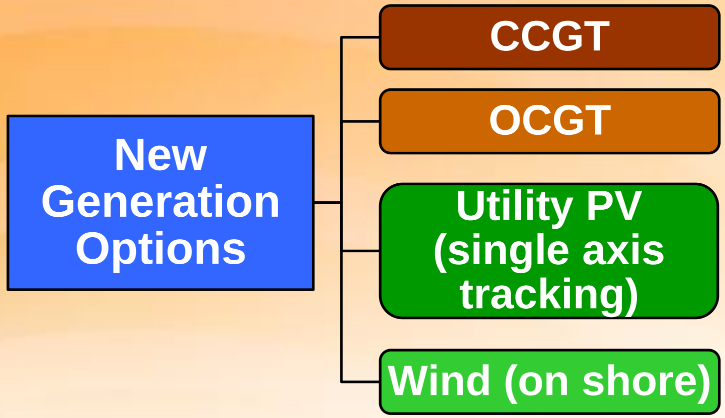
Generation Portfolio Analysis

Expected cost (mean) and cost risk (SD) of each portfolio is plotted to compare tradeoff.

Optimal generation portfolios fall along ***"Efficient Frontier"*** *(Costs can only be reduced by accepting higher cost risks).*



Modeling Investment Scenarios for 2030



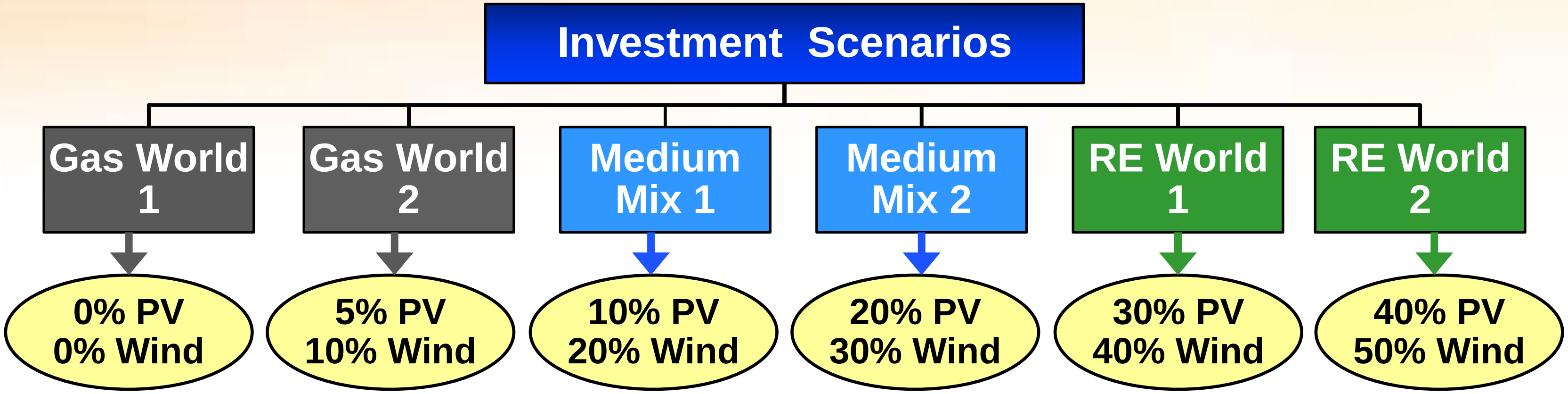
- Four new generation options.
- Existing generation capacity (in 2013)
  - ➢ C*oal, CCGT, OCGT, Hydro, Cogen, Distillate, Wind*

- No new investment in coal-fired generation
  - ➢ *High emissions and capital investment risk*
- Existing brown coal (lignite) plants are retired by 2030
  - ➢ *Relatively old and inefficient*
- Consider different retirement plans for black coal (from zero to full retirement.

Modeling Investment Scenarios for 2030

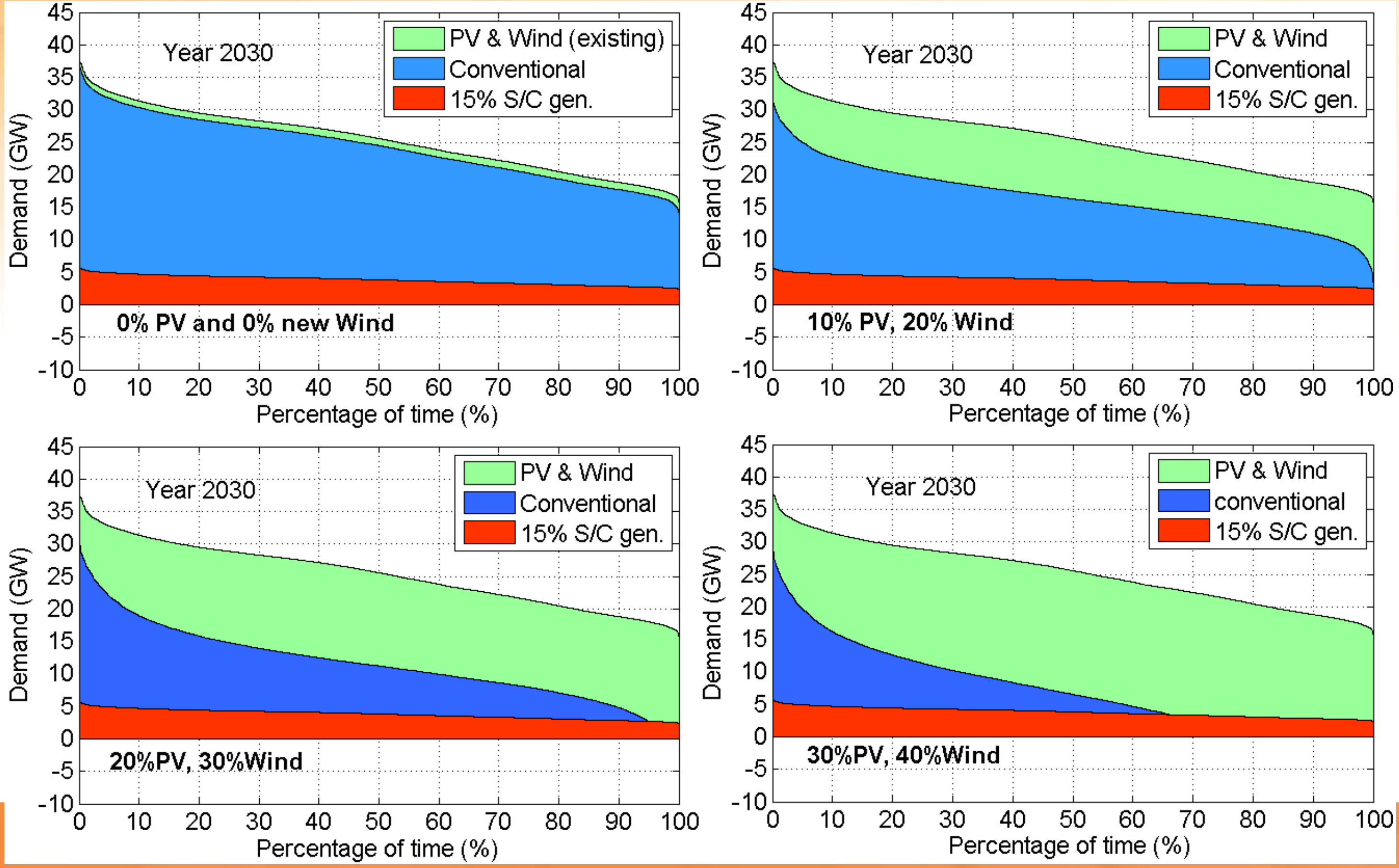
Different generation investment scenarios are modelled

- *Range from gas only (no new RE) to some mix of gas and RE through to investing primarily in RE (minimal gas)*



Generation dispatch

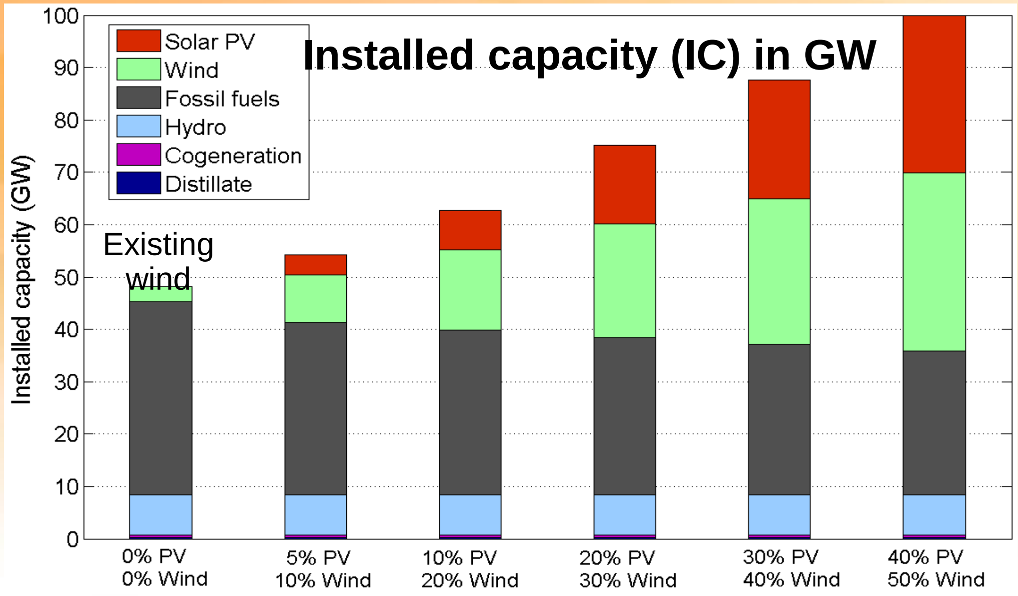
- Merit order dispatch in each period of the ***Load Duration Curve***.
- Priority dispatch for PV and wind – *treat as negative demand.*
- Minimum *synchronous generation* of 15% in any one hour period.



Unit commitment and operating constraints are not considered

Some excess energy at high RE penetrations

Generation portfolios

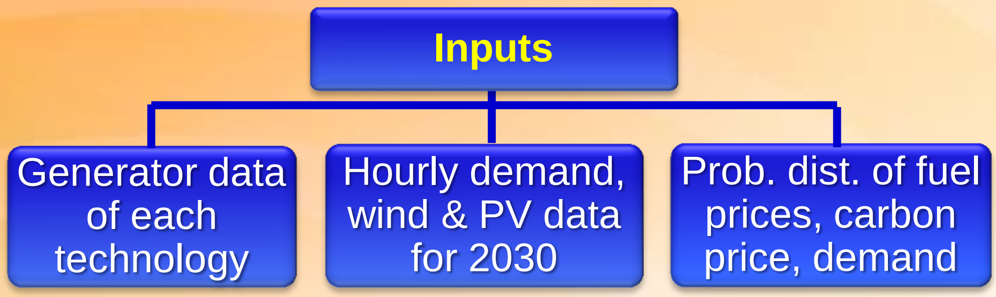


- PV and wind can displace fossil fuel generation (although lower capacity value).
- IC of hydro, cogen and distillate remain fixed.
- IC of fossil fuel (coal & gas) is determined based on NEM reliability standard (0.002% of unserved energy).

For each different investment scenario (each RE penetration)

- Analyse different possible permutation of ‘fossil-fuel’ generation portfolios
  - *Vary the share of black coal, CCGT and OCGT in 10% intervals (0% to 100%)*
  - *Essentially considers different cases of black coal retirements.*
  - *Max capacity of black coal in 2030 is capped at existing capacity (~20GW)*

Modeling Inputs

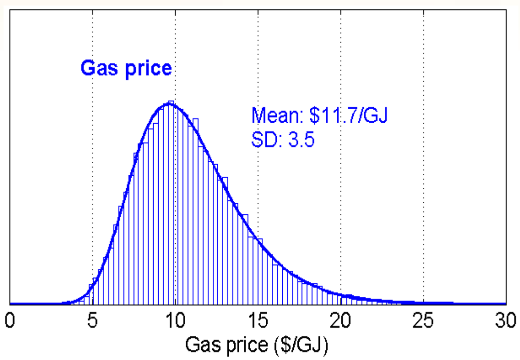


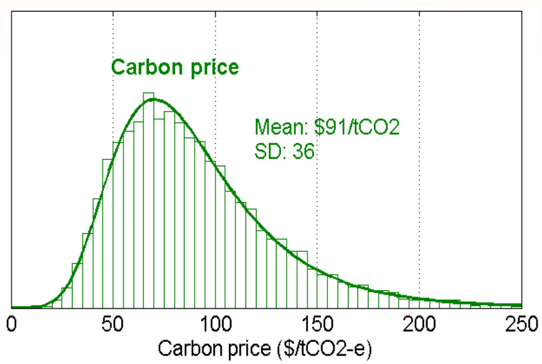
NTNDP (AEMO)
AETA (BREE)

AEMO 100% RE study

Estimated from
- AETA (BREE)
- Australian Treasury modelling

- Lognormal dist. are applied to future gas and carbon prices.
- A normal distribution for electricity demand.
- SDs are estimated based on the spread between low and high projections for 2030.



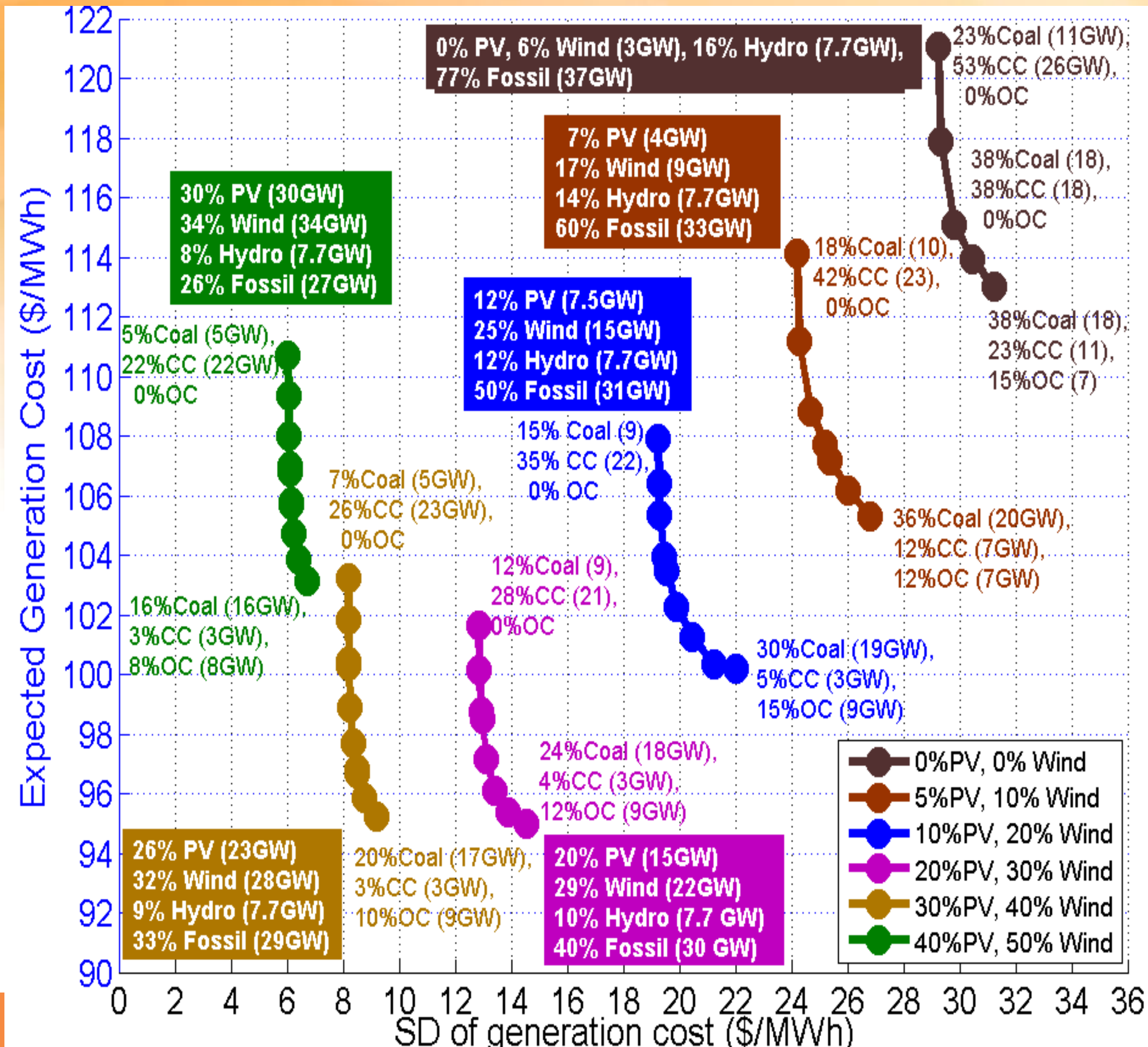


Histogram of gas price, carbon price over 10,000 simulations

- Overall cost and CO_2 emission of each generation portfolio is calculated for 10,000 simulated fuel prices, carbon price, and electricity demand.

Optimal portfolios for each investment scenario

'Efficient Frontier' (EF) for each RE penetration



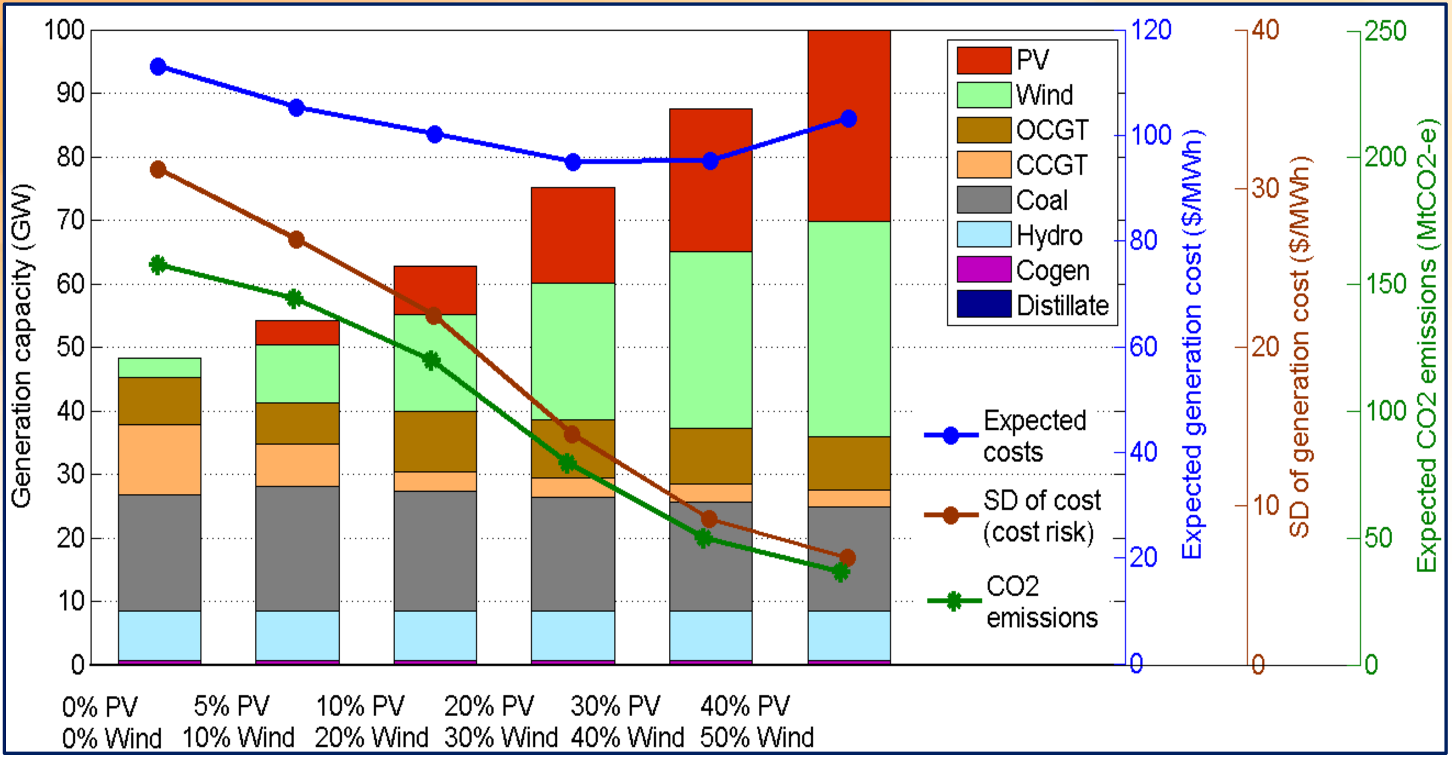
- *Expected cost (mean)* and *cost risk (SD of cost)* of generation portfolios (on Efficient Frontier) are plotted on different axis.
- EF contains optimal generation portfolios

Reductions in both cost and cost risk (SD) as PV and Wind increase

(Downward movement of Efficient Frontier)

% RE	Cost range ($/MWh)
0%	$112 - $122 (€73-80)
15%	$105 - $114 (€70-75)
30%	$100 - $108 (€66-72)
50%	$95 - $102 (€63-67)
70%	$95 - $105 (€63-69)
90%	$103 - $111 (€68–73)

Comparing Least-Cost Portfolios



'Least cost' portfolios for each RE penetration

- ***Technology mix***
- ***expected cost***
- ***cost risk***
- ***CO_2 emissions***

- System installed capacity increases considerably with higher RE penetration.
- Capacity of coal and OCGT changes only very slightly.
- Significant decline in ***cost risk*** and ***emissions*** as RE penetration increases.
- The overall cost is minimised at around 50% - 70% RE penetration.

Conclusions

- Future generation portfolios with high RE penetration can reduce overall costs, associated cost risk and CO_2 emissions.
- A Shift to renewables can decouple electricity price from fossil-fuel and carbon price uncertainty.
- Gas peaking plants play an important role in complementing renewables.
- Renewable energy and climate policies, (i.e. carbon pricing,) play a key role to facilitate the integration of renewable technologies.
    - *Incorporate environmental externalities*

Issues and limitations

- Implications associating with Wind and PV curtailments at high penetration levels.
- Only considers a specific future year without looking at multi-stage (year by year) investment
- Inter-temporal (time-varying) operational implications were ignored
- Transmission costs are not included.

Centre for Energy and Environmental Markets

UNSW
THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY • AUSTRALIA

Thank you,
and
Questions?

peerapat@unsw.edu.au

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