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Environmental Markets

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The Role of Renewables in Hedging against Future Uncertainties and Enhancing Energy Security

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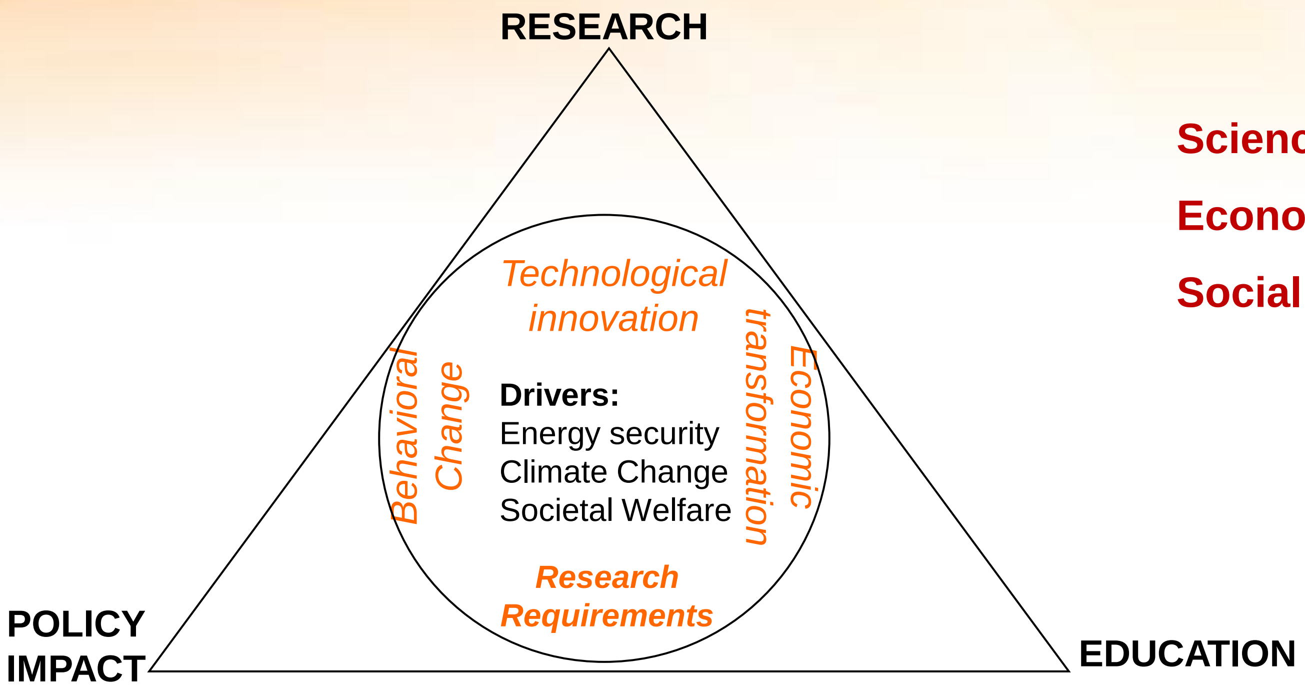
Our Centre at UNSW Australia

The Centre for Energy and Environmental Markets (CEEM) inspires and informs the transition to a more sustainable energy future nationally and internationally through objective interdisciplinary research.



Science & Engineering

Economics

Social Science

Research areas

Generation portfolio planning in the context of high uncertainty and high renewable penetration

- Using a probabilistic generation portfolio modelling framework to incorporate uncertainty in future carbon prices, electricity demand, fossil fuel prices and generation technology costs.
- Roles of renewables in reducing overall generation costs and risks (and emissions) and enhancing energy security.

Power system operational considerations with high renewables

- Using PLEXOS to explore the implications of operational constraints on long-term generation portfolio planning with high renewables.
- Frequency responses, Ramping requirements, no. of starts/shutdowns and start-up costs.

Revenue and wholesale electricity market price modelling

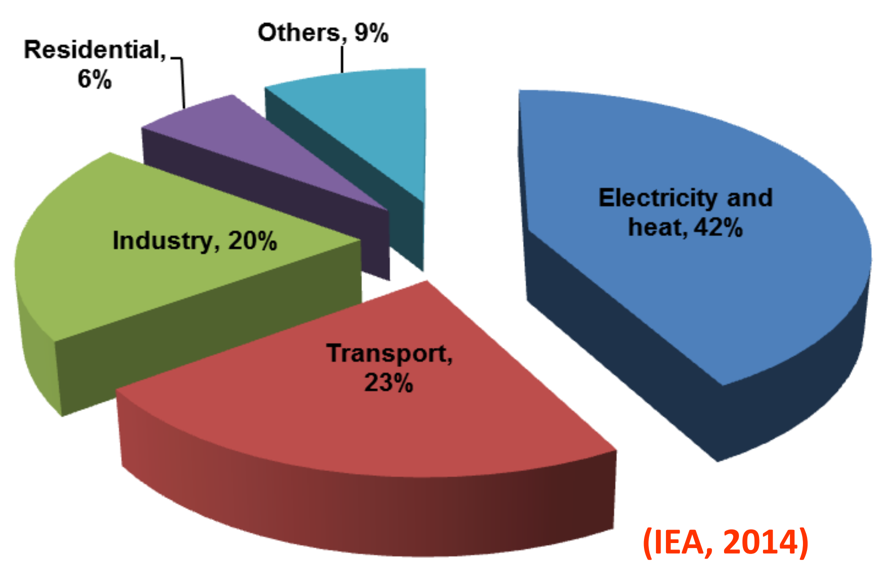
Outline

- Challenges for the electricity industry
- Generation investment and planning decision making
- Assessing energy security
- Australian National Electricity Market (NEM)
- A modelling study of generation investment in the NEM in 2030
  - Results and implications for policy decision making

Challenges for the electricity industry

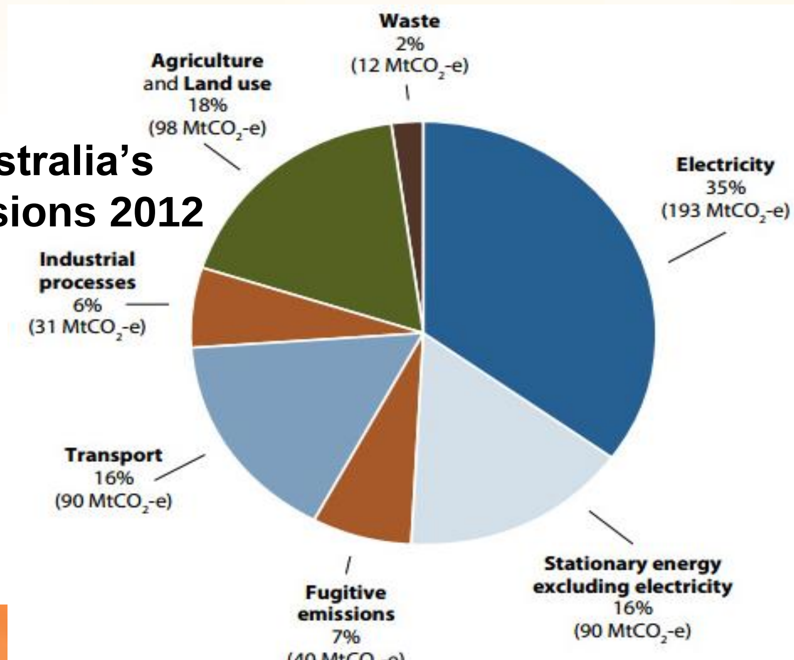
- Increasing challenges for electricity industries around the world
  - Rapid and highly uncertain demand growth
  - Energy security concerns – Aging infrastructure, high dependence on fossil-fuels.
  - Environmental sustainability – the electricity sector is the largest single contributor to global GHG emissions (IEA, 2014).

World CO_2 emissions by sector in 2012



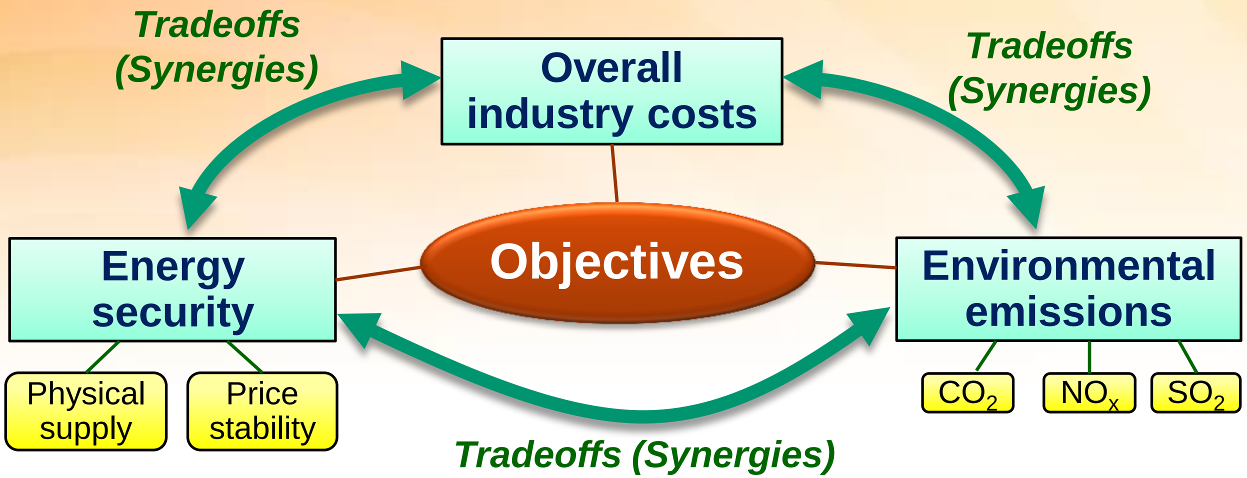
(IEA, 2014)

Australia's emissions 2012



Electricity industry objectives

- Multi-objective nature in policy decision making - industry costs, environment, energy security)

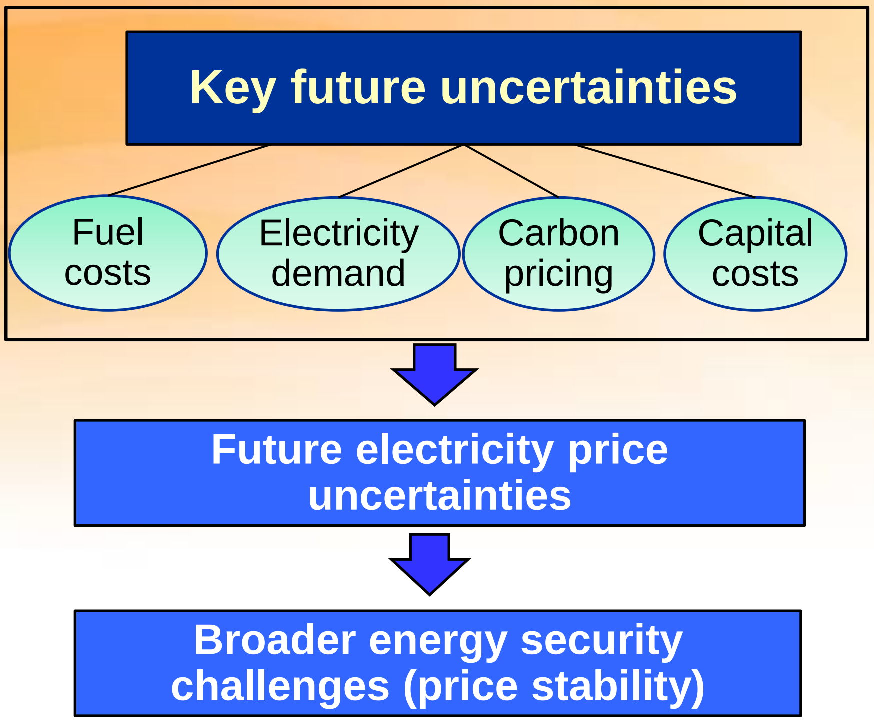


What about other options?
- Renewables, demand-side, etc.

Potential conflicts between these objectives in many countries

- **Coal** – cheap to run but high emissions.
- **Gas-fired** - energy security concerns (due to fuel import) but low emissions**.**
- **Nuclear** - expensive to build but zero operating emissions.

Uncertainty in decision making

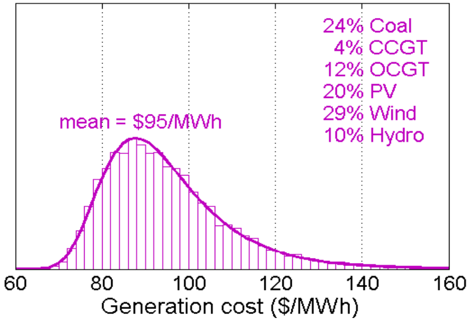


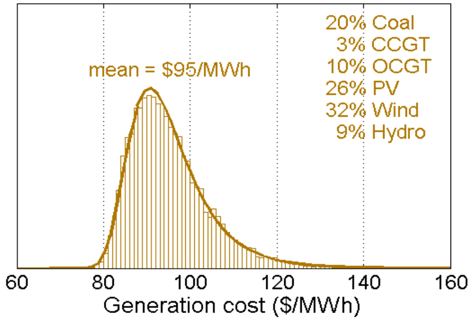
- Key cost factors are highly uncertain
  - Challenges for decision making
- Uncertainty leads to *Risk*
  - Likelihood of extreme price events
  - Price stability has economic value
- Uncertainty drives the need for flexibility
  - A well-diversified (or flexible) electricity generation portfolio can reduce exposure to price fluctuation (cost risk) and supply interruption risk?

Assessing security of electricity supply

- Availability of energy supply at an affordable (and stable) price
- Two aspects of energy security

Risks of price (cost) fluctuation	Risks of supply availability (interruption)
Due to reliance on fossil fuel (often imported) - exposed to fuel price uncertainty	Dependence on particular fuels for electricity generation
Cost risks can be measured by a spread of possible cost outcomes (i.e. standard deviation)	**Supply risks can be measured by diversity of fuel used for electricity generation**





Fuel diversity can be measured by **Shannon Wiener Index (SWI)**

$$SWI = -\sum_i p_i \,.\ln p_i$$

Higher SWI implies greater diversity

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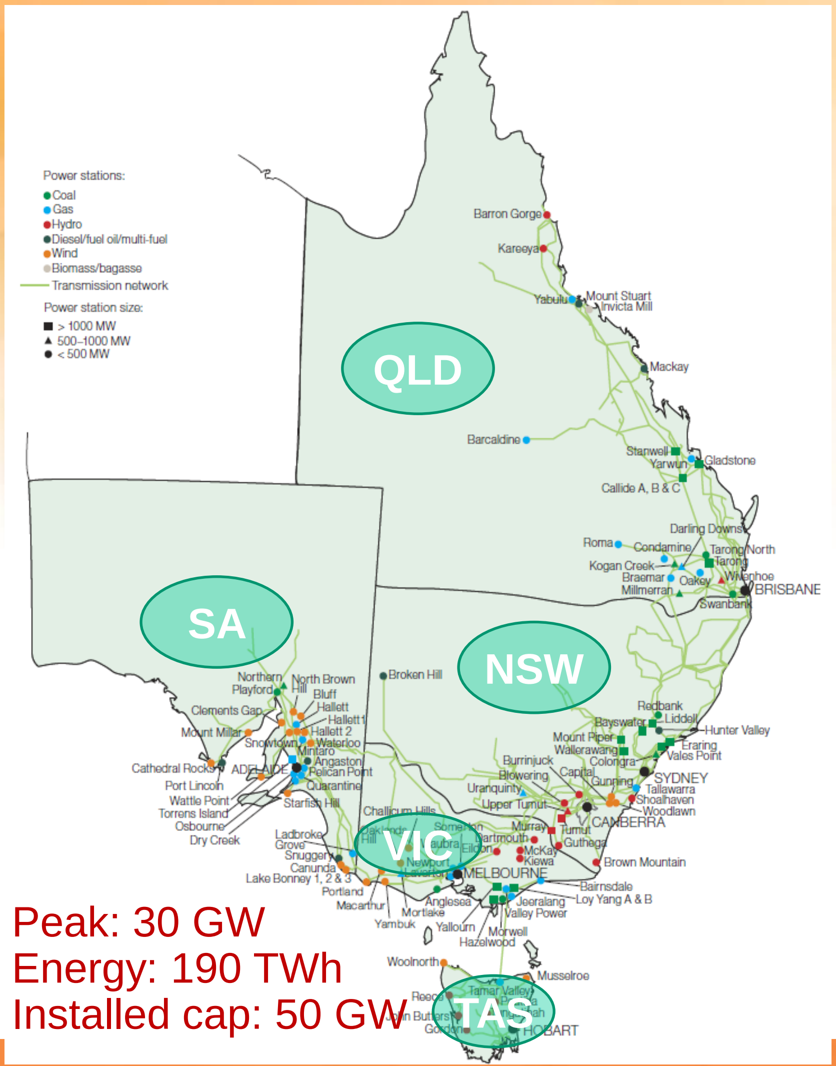
The Australian National Electricity Market

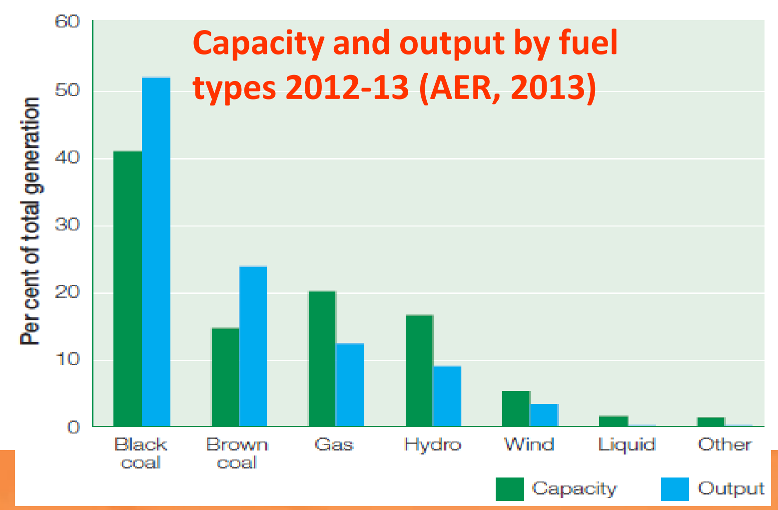


Peak: 30 GW

Energy: 190 TWh

Installed cap: 50 GW

- Covers all Eastern States – 90% of electricity demand
- Largely coal, around 15% renewables
  - Aging generation fleet
- Recent growth in wind and solar gen.
- Energy only market
  - Gross pool – real-time market



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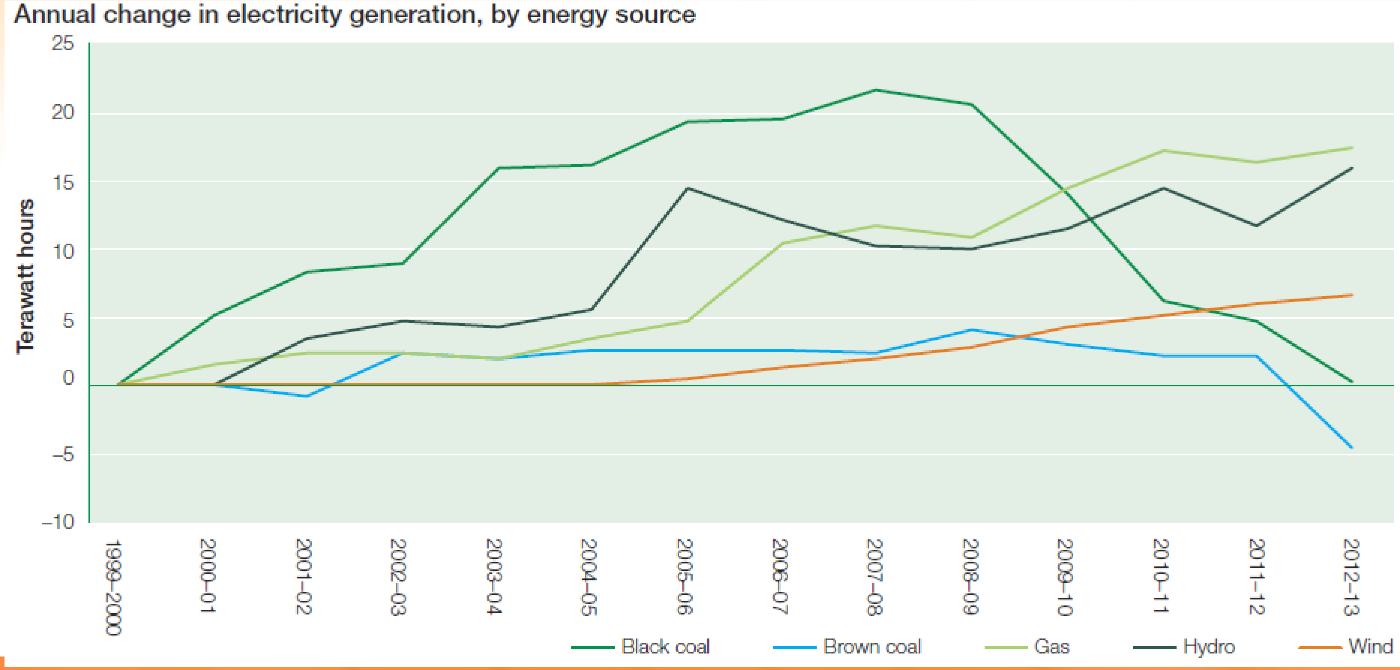
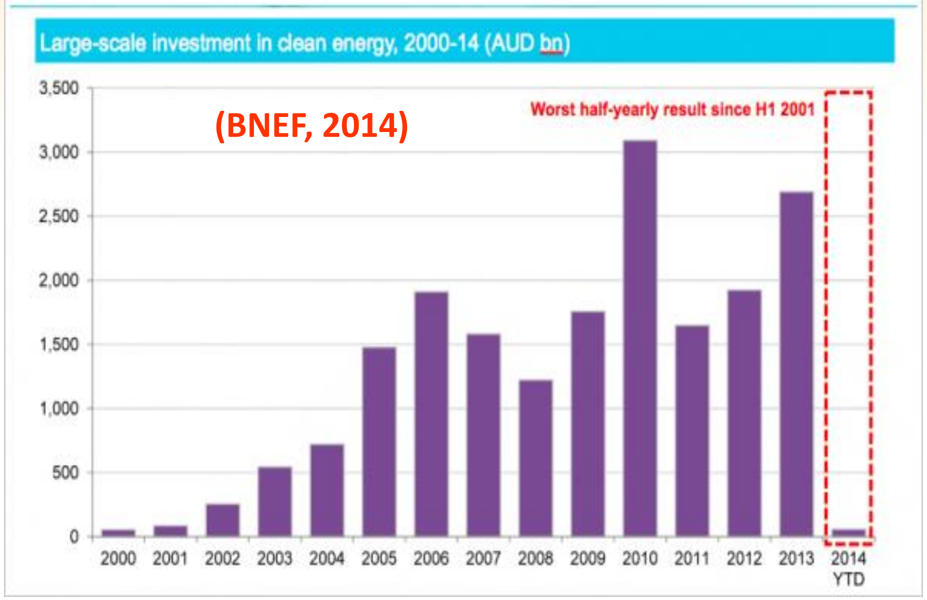
Future generation investment in the NEM

- Australia is among the highest emissions per capita countries.
  - 35% of national emissions from the electricity sector
- Generation investment pattern is evolving in respond to energy policies
  - Increase in **Gas-fired** and **Wind generation** and substantially less coal.
  - Significant increase in solar PV and wind.

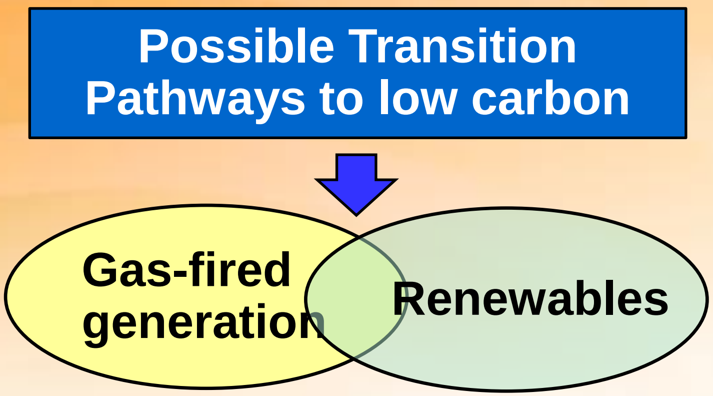


High uncertainties in Australian Energy Policy

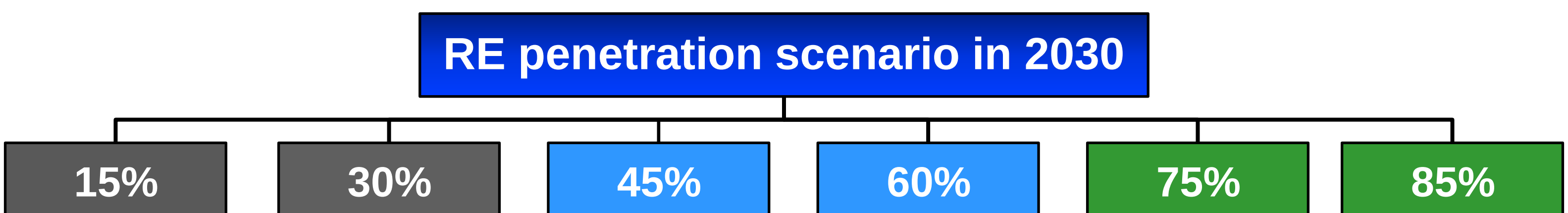
- Carbon pricing legislation
  - Recently repealed on 17 July 2014 (first country to successfully removed a price on carbon).
  - Introduced in July 2012 – price set at \$23 - \$25/tCO_2
- Renewable Energy Target
  - Similar to RPS based approach
  - Initially set at 41 TWh (20% based on 2010 demand) by 2020
  - The target has recently been reduced to 33 TWh by the current Government.



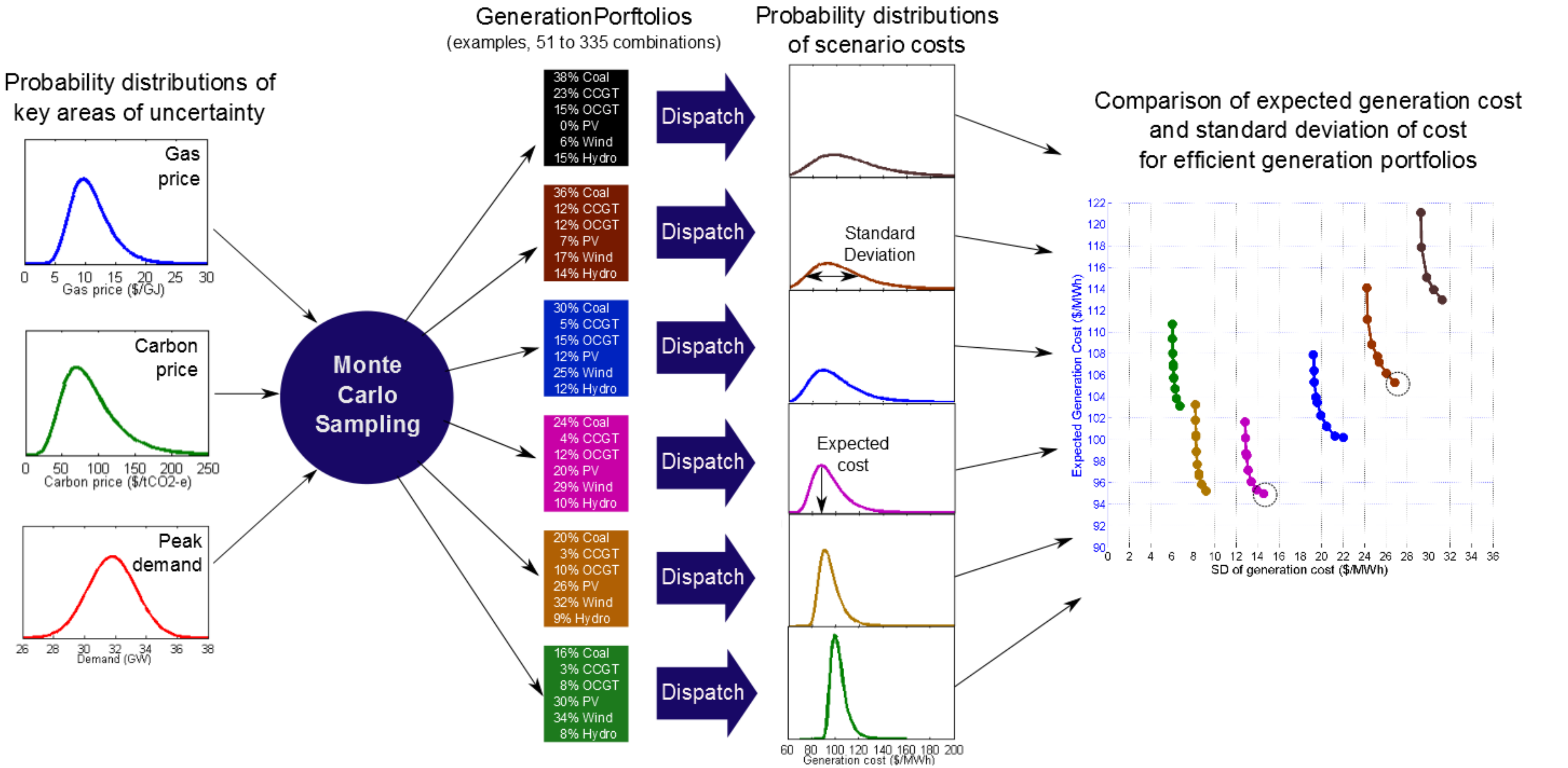
Modelling investment scenarios in 2030



- Examining different generation portfolio mixes in 2030 in the context uncertain *fuel prices*, *carbon pricing* and *electricity demand*.
  - Range from gas only (no renewables) to investing primarily in renewables
- Assessing the role of solar and wind in future generation portfolios
  - Industry costs, energy security, environment

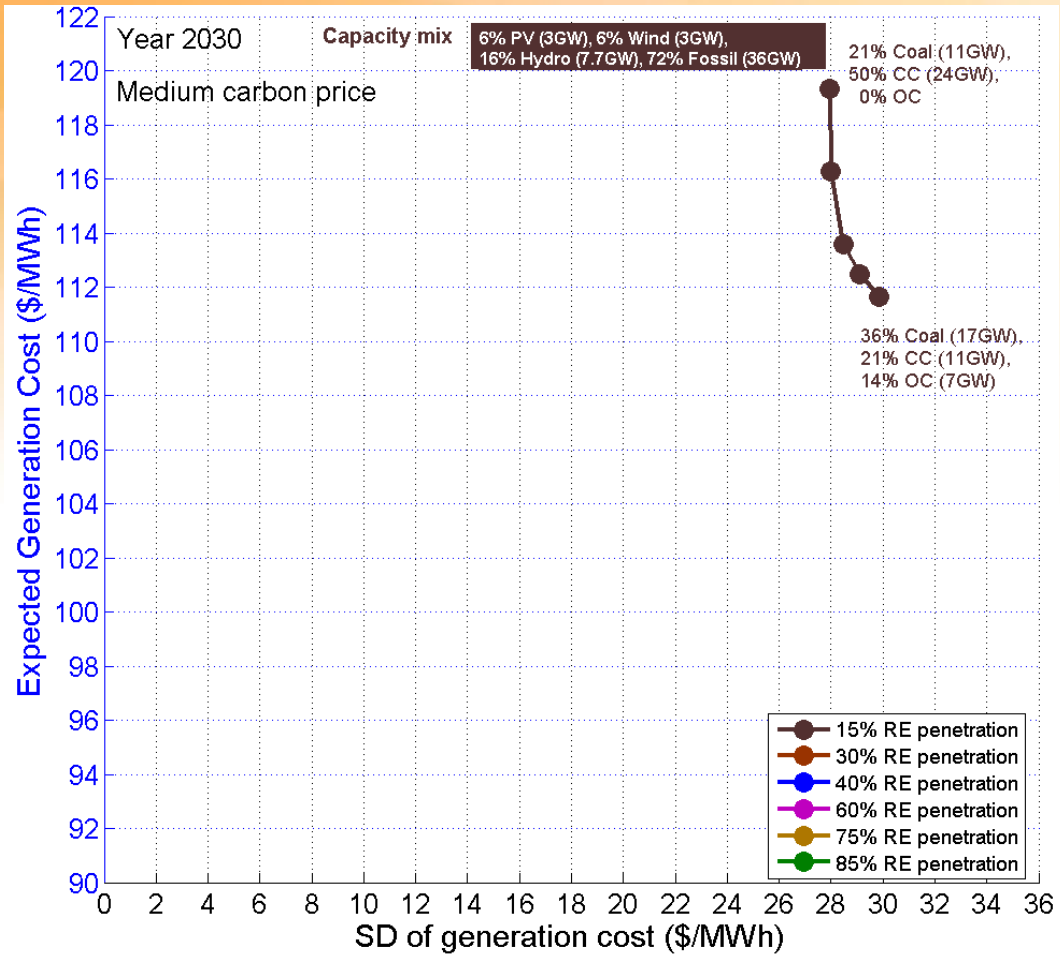


Probabilistic generation portfolio modelling



Optimal portfolios for each RE scenario

'Efficient Frontier' (EF) for each RE penetration

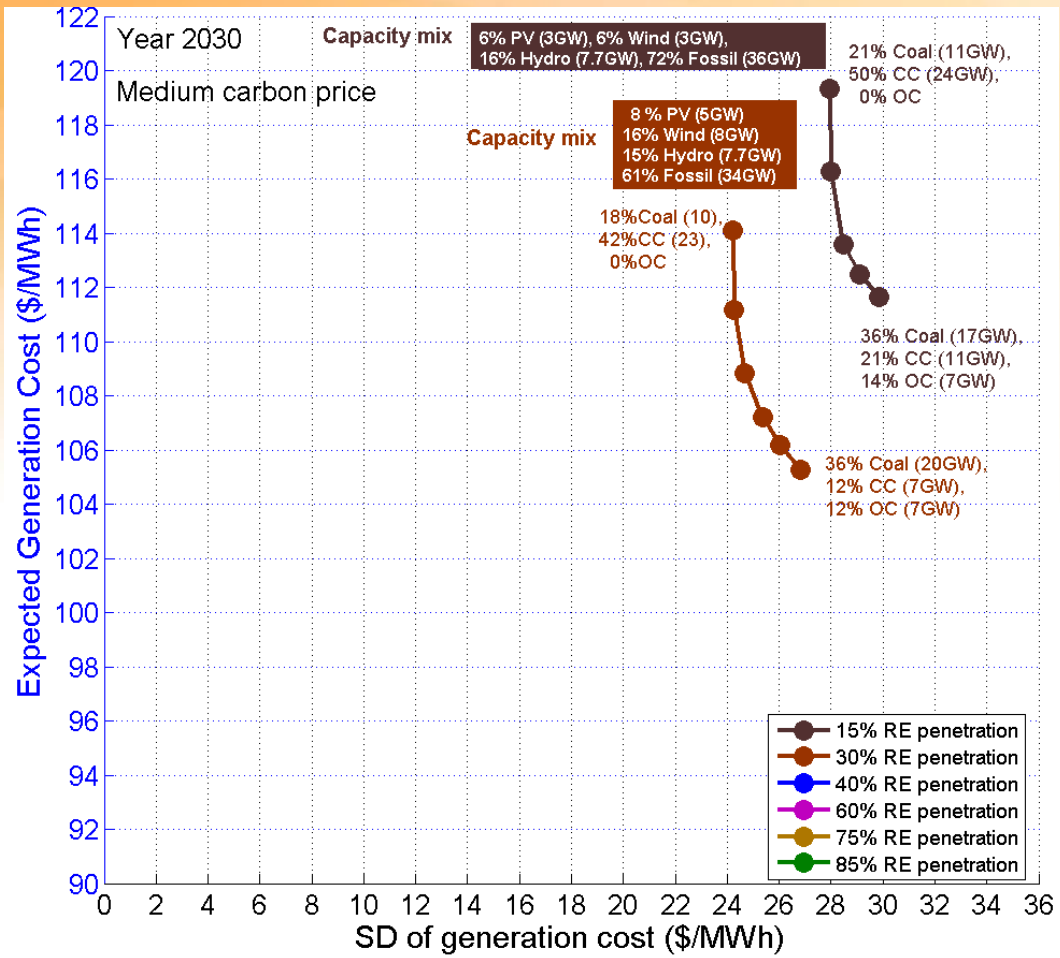


- *Expected cost (mean)* and *cost risk (SD of cost)* of generation portfolios (on Efficient Frontier) are plotted on different axis.
- EF contains optimal generation portfolios

% RE	Cost range ($/MWh)
15%	A$112 - $120

Optimal portfolios for each RE scenario

'Efficient Frontier' (EF) for each RE penetration



30% RE penetration
(5% new PV, 10% new Wind)

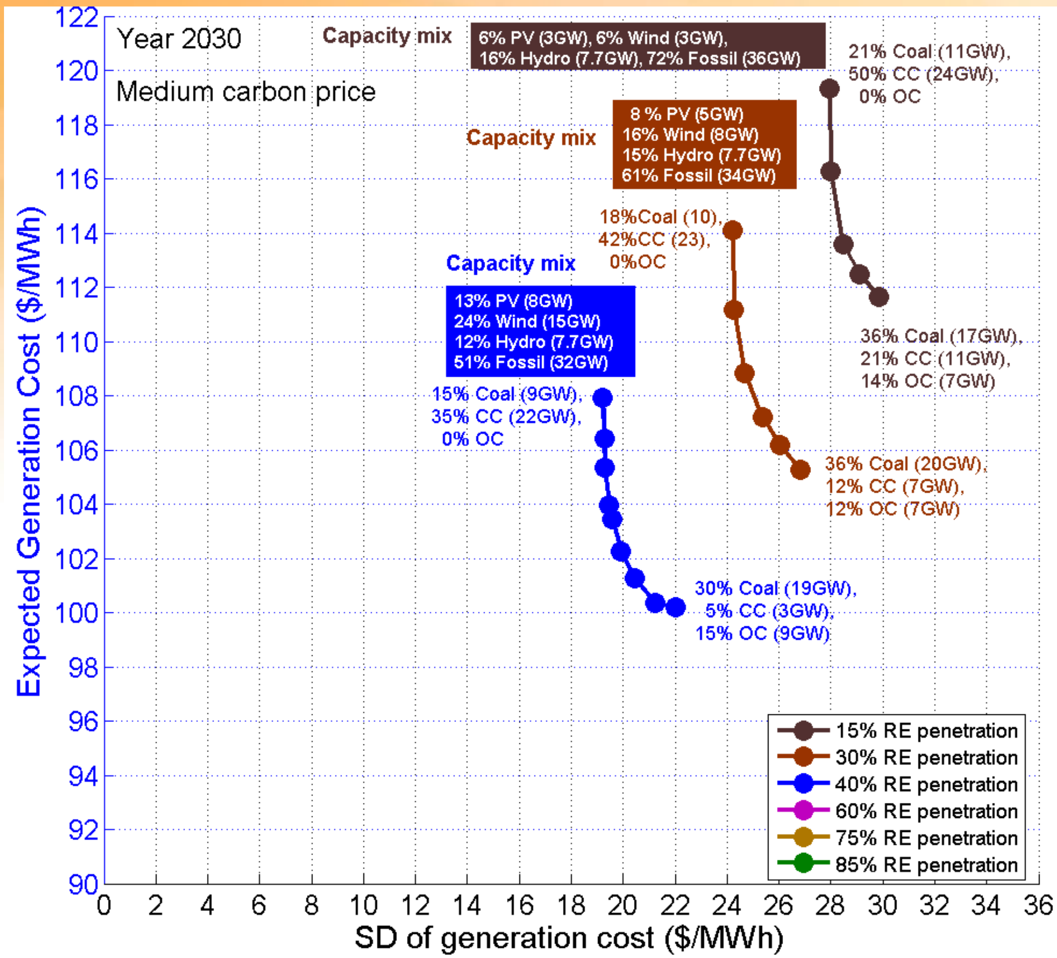
Reductions in both cost and cost risk (SD) as PV and Wind increase

(Downward movement of Efficient Frontier)

% RE	Cost range ($/MWh)
15%	A$112 - $120
30%	A$105 - $114

Optimal portfolios for each RE scenario

'Efficient Frontier' (EF) for each RE penetration



40% RE penetration
(10% new PV, 20% new Wind)

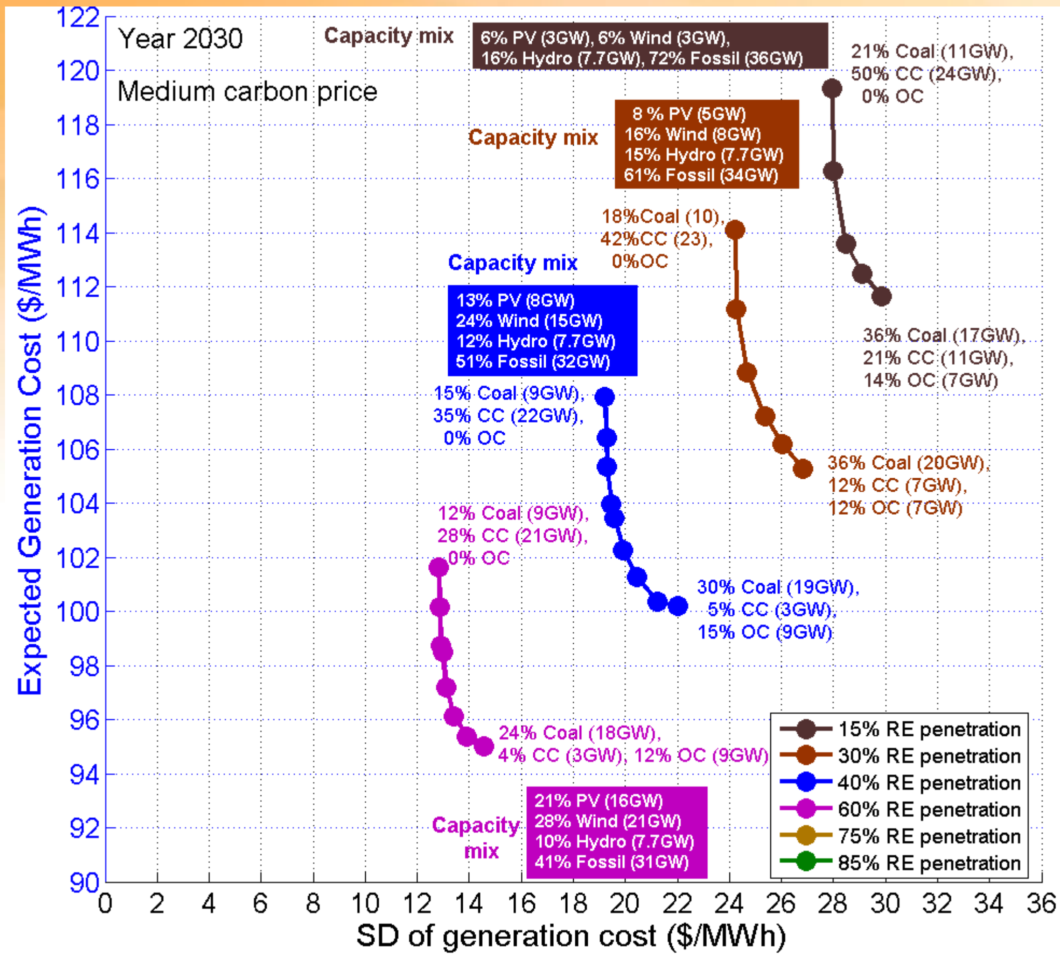
Reductions in both cost and cost risk (SD) as PV and Wind increase

(Downward movement of Efficient Frontier)

% RE	Cost range ($/MWh)
15%	A$112 - $120
30%	A$105 - $114
40%	A$100 - $108

Optimal portfolios for each RE scenario

‘Efficient Frontier’ (EF) for each RE penetration



60% RE penetration
(20% new PV, 30% new Wind)

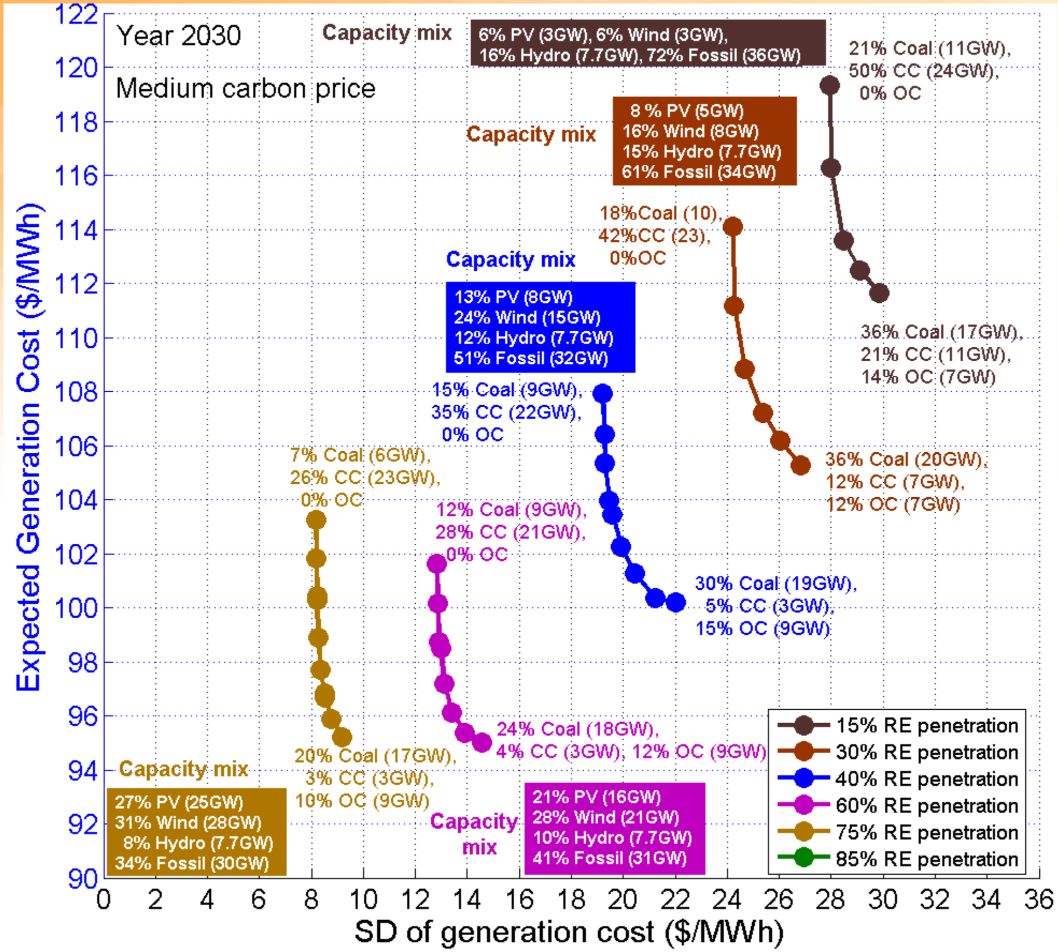
Reductions in both cost and cost risk (SD) as PV and Wind increase

(Downward movement of Efficient Frontier)

% RE	Cost range ($/MWh)
15%	A$112 - $120
30%	A$105 - $114
40%	A$100 - $108
60%	A$95 - $102

Optimal portfolios for each RE scenario

'Efficient Frontier' (EF) for each RE penetration



75% RE penetration
(30% new PV, 40% new Wind)

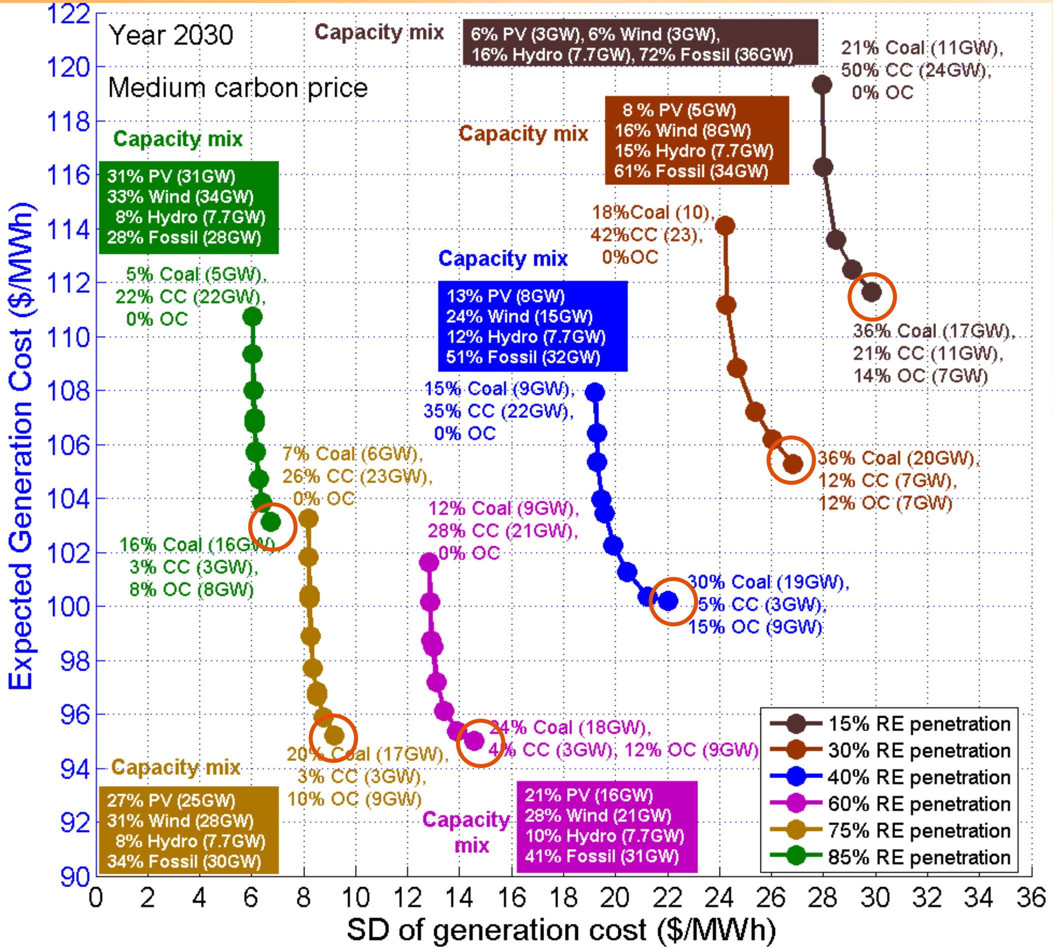
Expected costs start to increase as RE penetration is greater than 75%

(but still lower cost risk)

% RE	Cost range ($/MWh)
15%	A$112 - $120
30%	A$105 - $114
40%	A$100 - $108
60%	A$95 - $102
75%	A$95 - $104

Optimal portfolios for each RE scenario

'Efficient Frontier' (EF) for each RE penetration

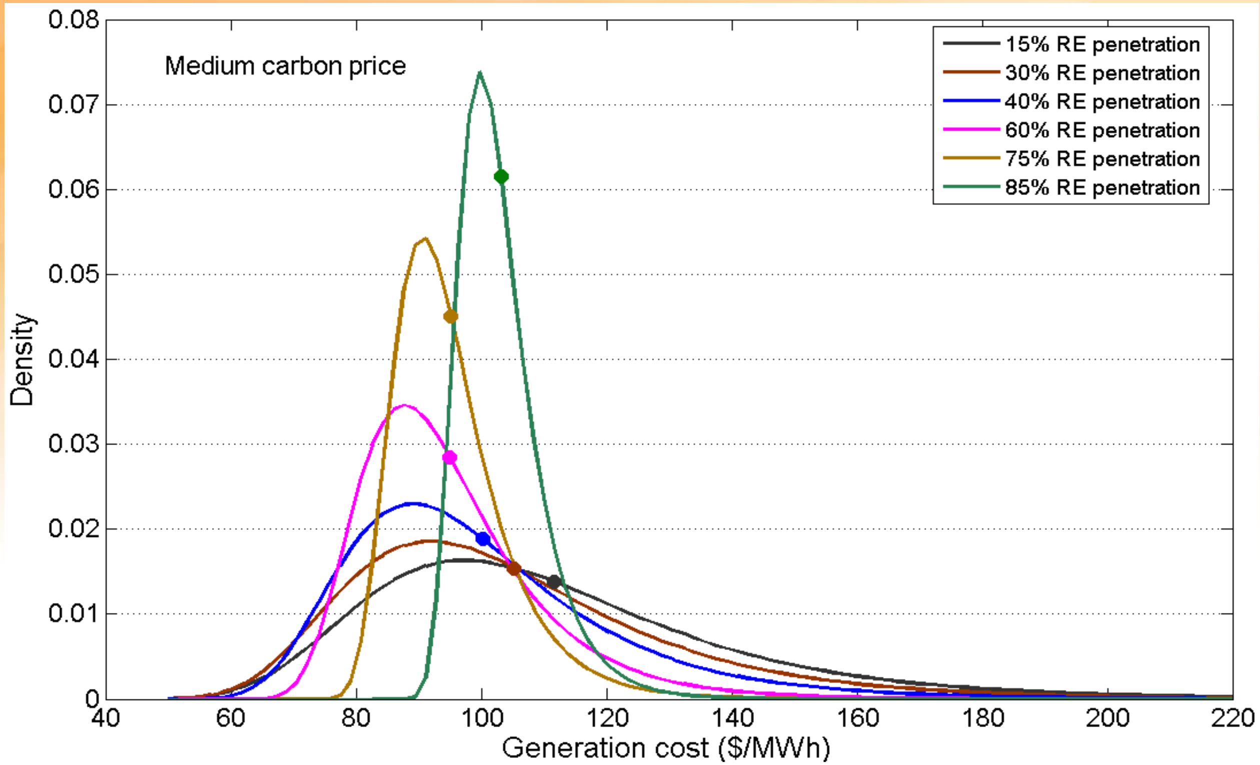


Expected costs start to increase as RE penetration is greater than 75%

(but still lower cost risk)

% RE	Cost range (A$/MWh)
15%	\$112 - \$120
30%	\$105 - \$114
40%	\$100 - \$108
60%	\$95 - \$102
75%	\$95 - \$104
85%	\$103 - \$112

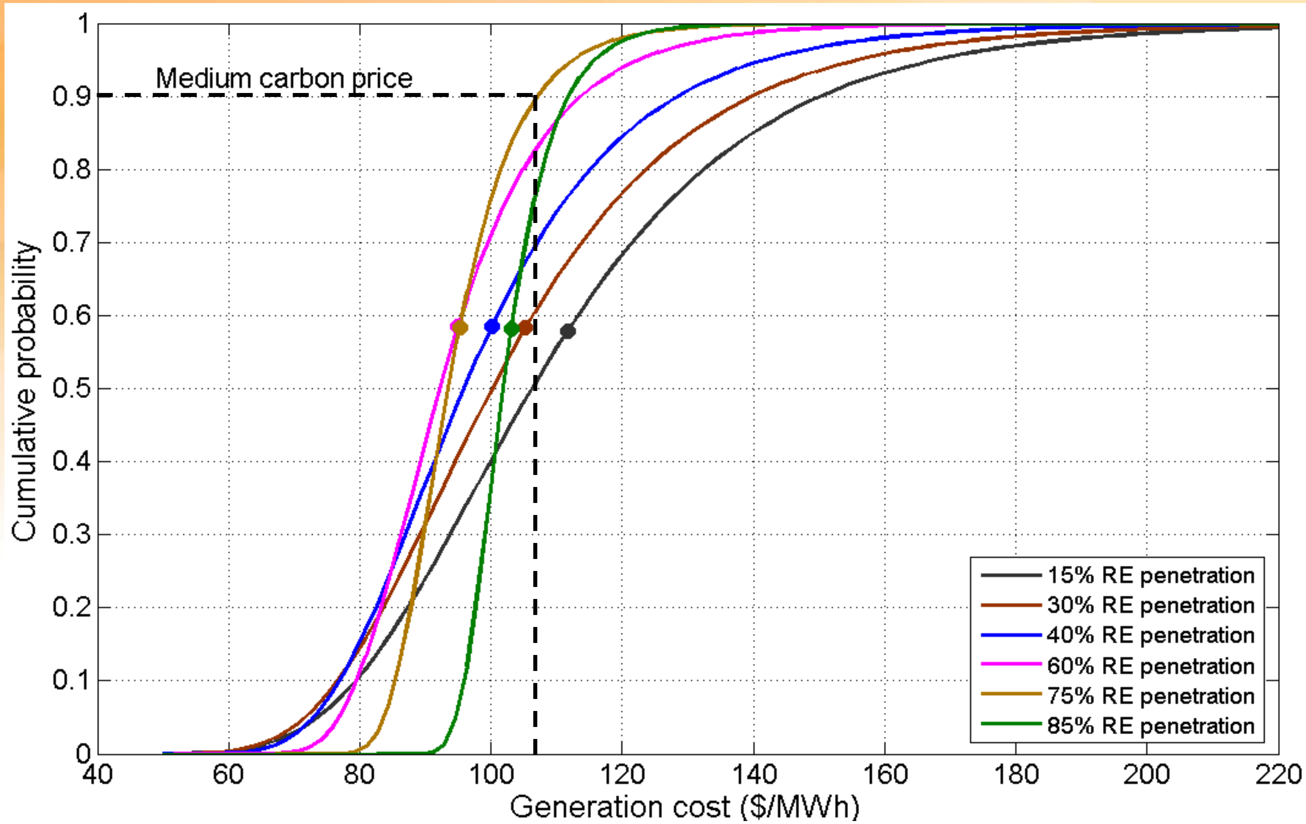
Comparing least-cost portfolios



Generation cost distribution of the ‘Least cost’ portfolio for each RE penetration

- A full spectrum of possible cost outcomes
- Additional RE would reduce overall cost risk
  - Less cost spread (i.e. ‘cost risk) with greater RE penetration

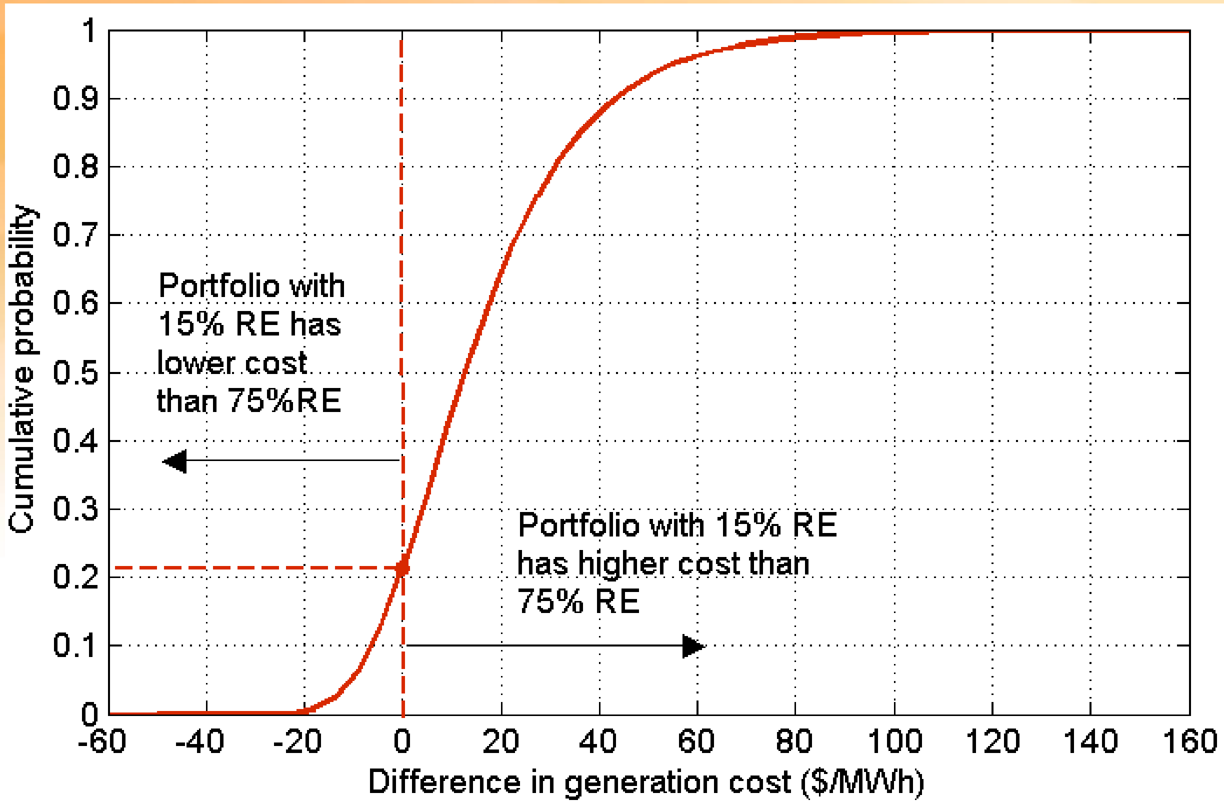
Comparing least-cost portfolios



Cumulative probability of generation cost

- For the 75% RE portfolio -> 90% chance that costs < $110/MWh
- For the 15% RE portfolio -> 10% chance that costs > $150/MWh

The risk between different portfolios



Risk associated with choosing between generation portfolios

15% RE **VS** 75% RE

- 80% probability that costs of the15% RE portfolio will have higher costs than the 75% RE portfolio.
- The cost difference could be as high as $100/MWh

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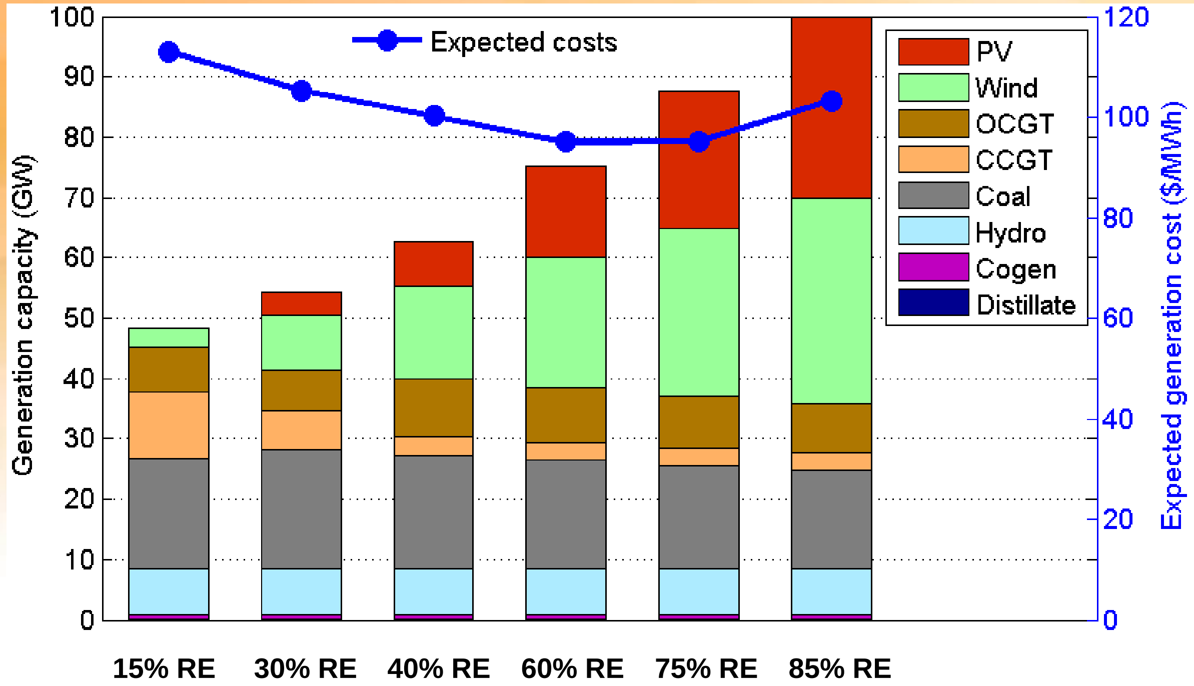
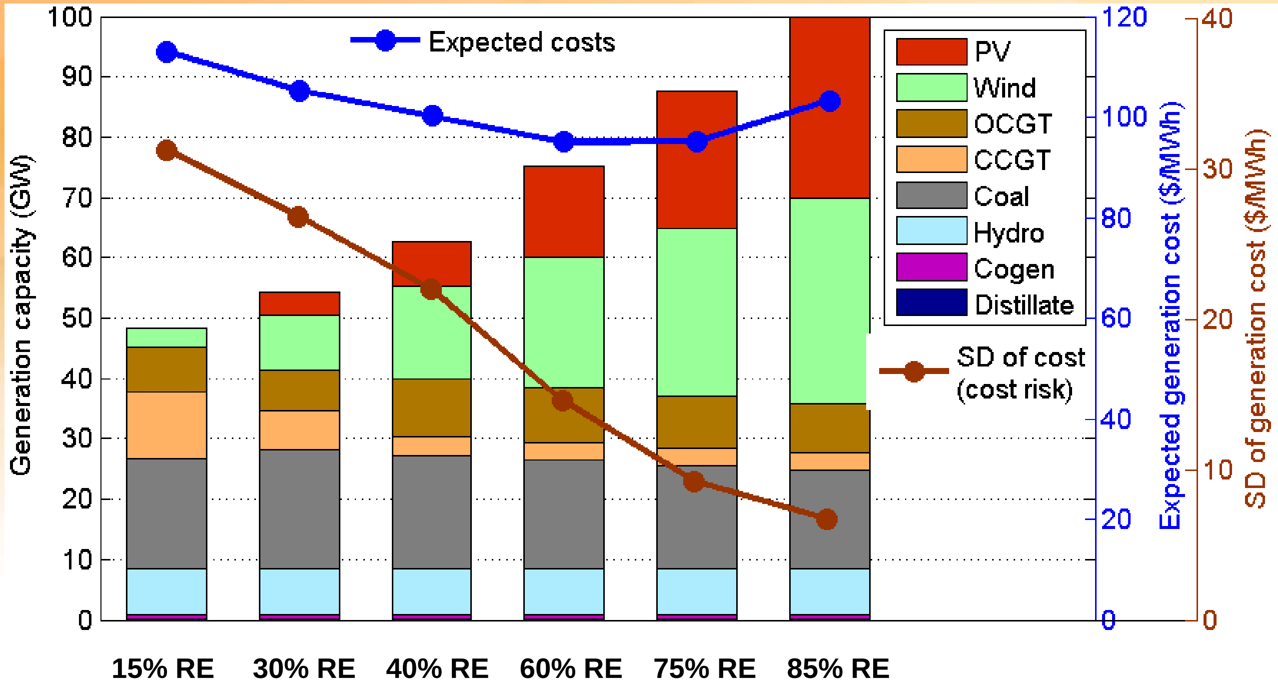
Comparing different RE penetrations



'Least cost' portfolios for each RE penetration

Industry cost

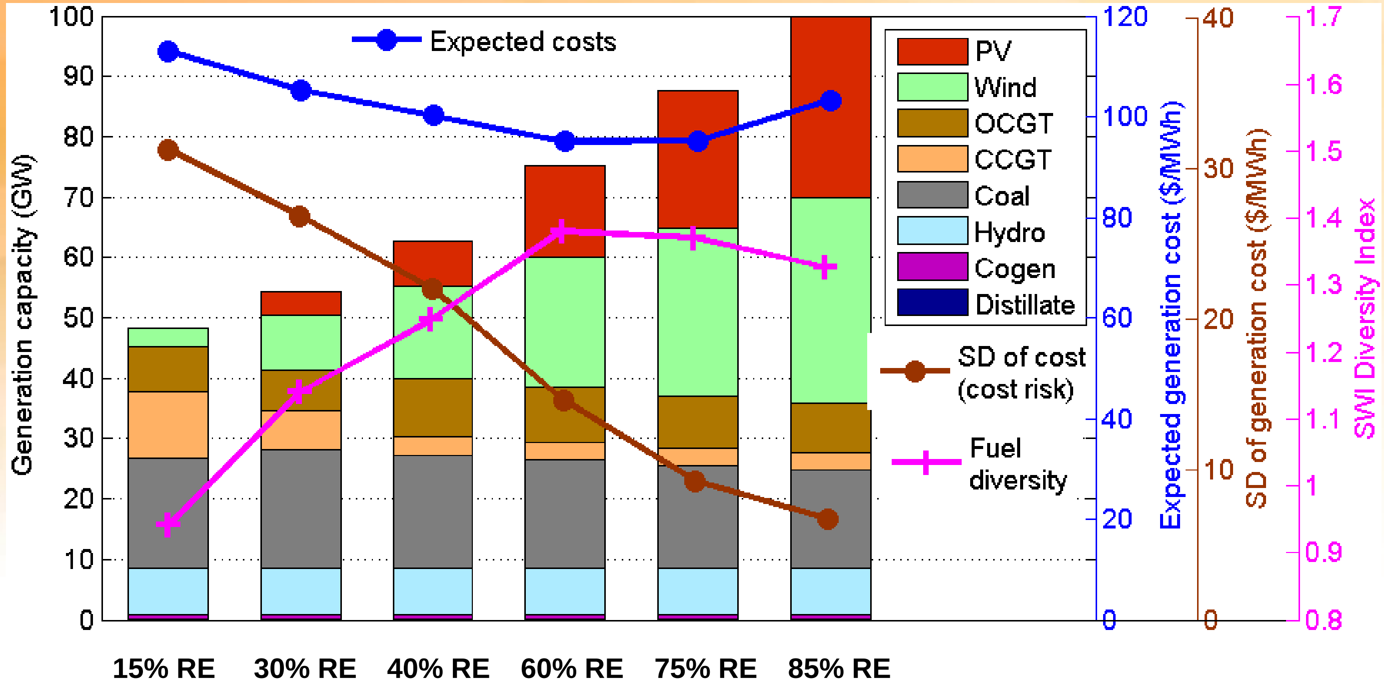
Comparing different RE penetrations



'Least cost' portfolios for each RE penetration

Cost risk (SD of cost)

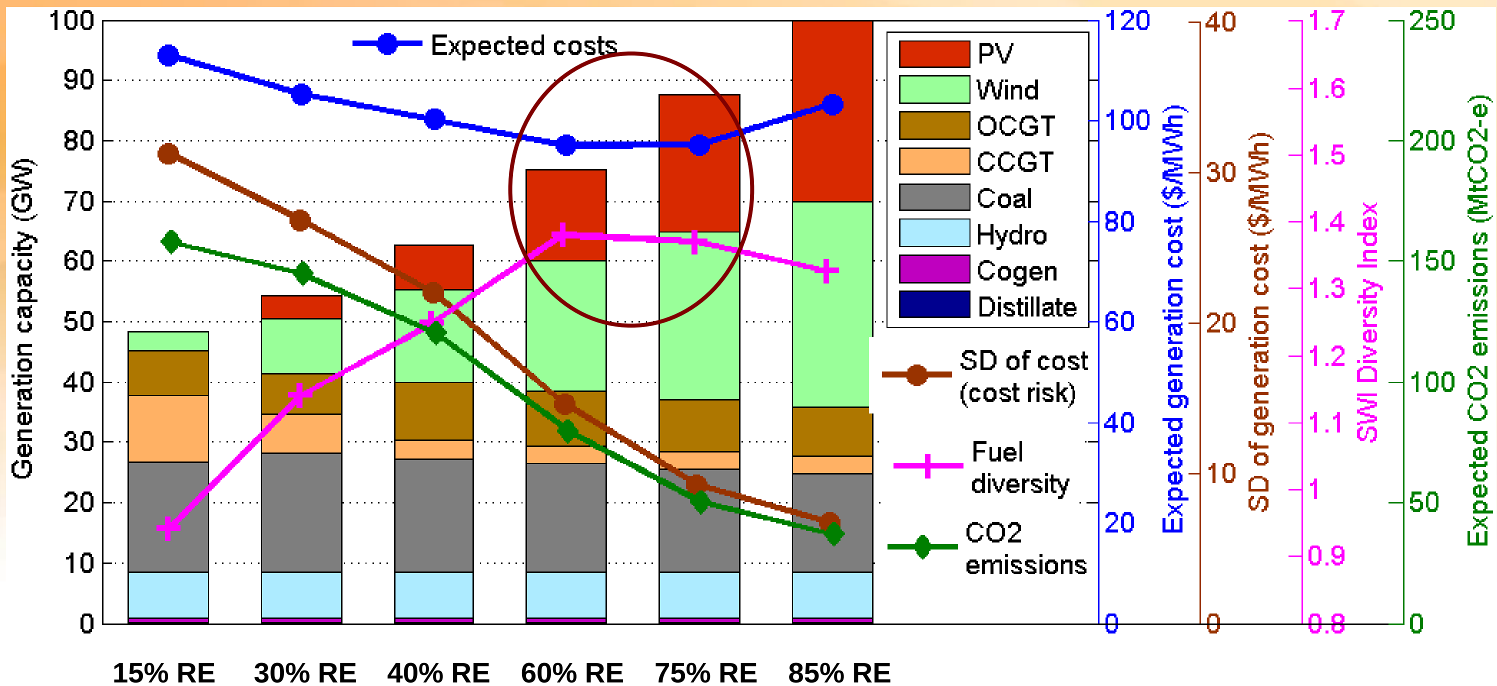
Comparing different RE penetrations



'Least cost' portfolios for each RE penetration

Fuel diversity

Comparing different RE penetrations

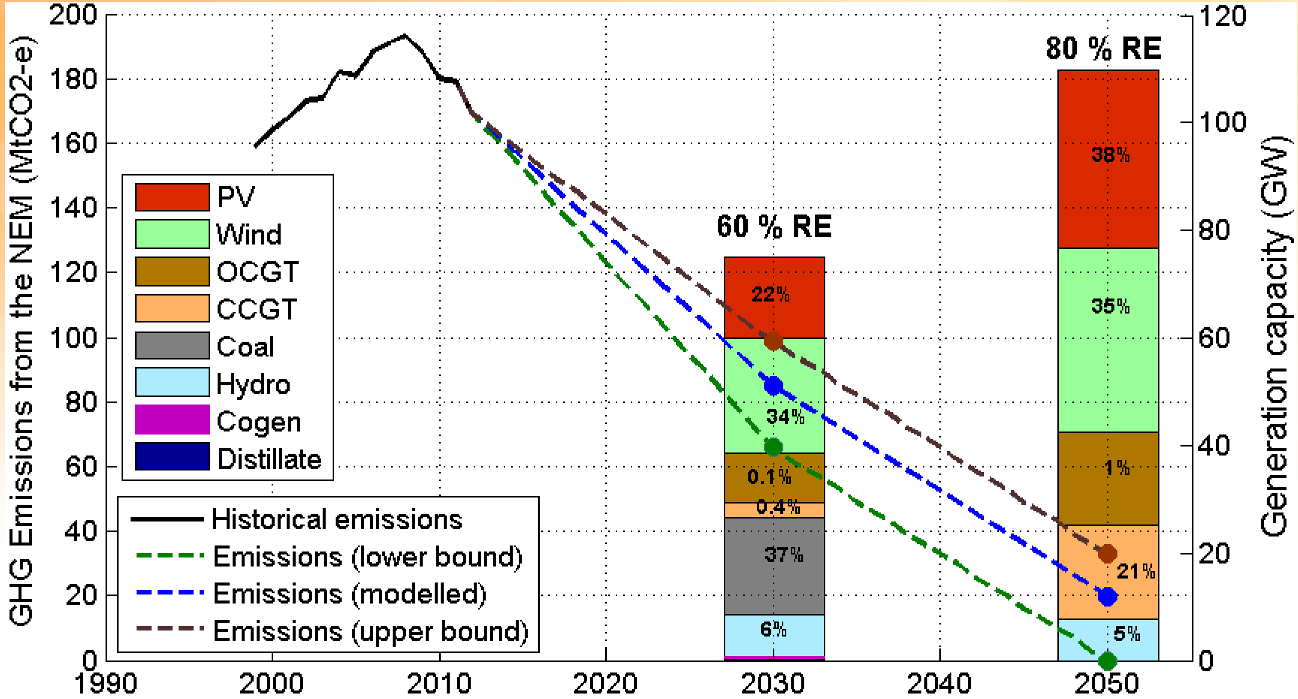


'Least cost' portfolios for each RE penetration

CO_2 emissions

- Significant decline in ***industry cost***, ***cost risk*** and ***emissions*** while ***fuel diversity*** increases with higher RE.
- The industry cost is minimised at 60% - 75% RE – also the level that generation portfolio is most diversified
- Portfolios with low RE are not well diversified in terms of fuel mix (SWI < 1.0)

Optimal transition pathways for the NEM



In the long term (year 2050)

- Considerable investment in renewables and continue using existing coal plants but as peaking capacity (i.e. in 2030).

What do these imply for policy decisions?

- RE can help address energy security concerns and emissions
- Portfolios are less diversified with extremely high renewables but not necessarily means the system is less secured – different risk nature compared to fossil fuels
- Investment in RE is preferable to gas-fired generation due to high gas and carbon price uncertainty
- Needs policy intervention since RE can't compete at present
  - Long-lead time nature of generation investment
  - Need to act immediately to achieve a high RE target in 2030
- Existing coal plants still play a role as peaking capacity
  - Policy to promote retirement of coal plants may not be a desirable policy

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Thank you,

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