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Assessing Long-term Security of Electricity Supply and the Role of Renewable Energy: A Probabilistic Generation Portfolio Analysis Approach

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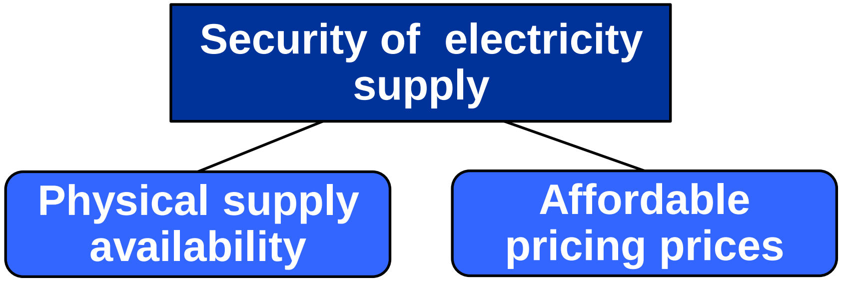
Outline

- Energy security – context
- Renewables and security of electricity supply
- Objectives and methodology
- Modelling used in this study
- The Australian National Electricity Market (NEM) case study
- Conclusions

Energy security – context

What is Energy Security?	• ***Uninterrupted availability*** of energy supply at an ***affordable price*** • Concerning with risks to availability and affordability of energy supply and management of such risks
What influences ?	• High dependence on imported fossil-fuels (exposed to fuel price uncertainty and longer-term availability).
Why is Energy Security important?	• Plays a key role in social and economic development • Energy security is one of main energy policy goals in many countries

- Traditionally the focus is on oil and gas (due to reliance on imports) but electricity has emerged as a vital component of Energy Security.



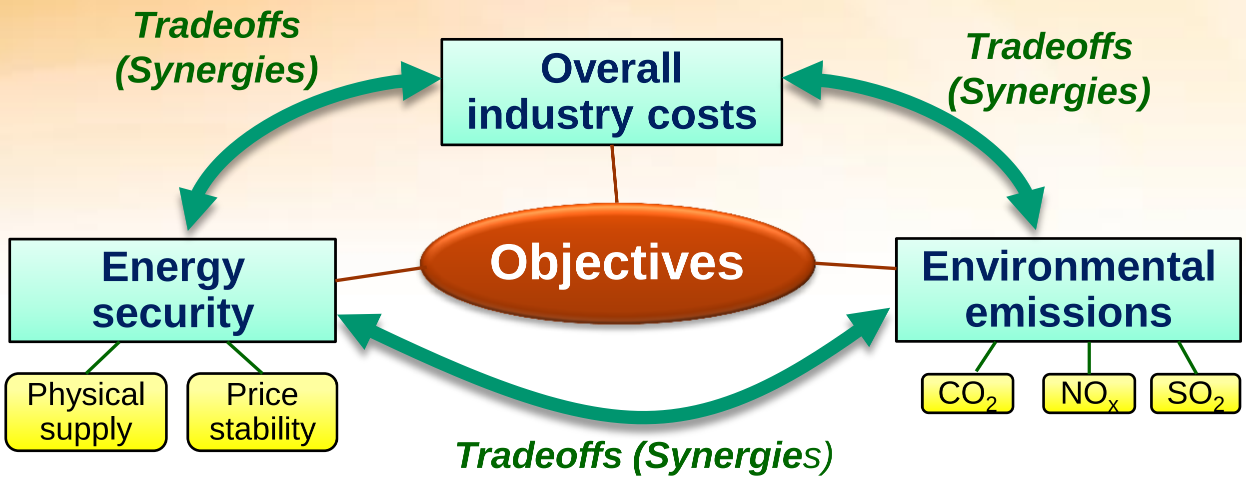
Renewables and security of electricity supply

- Renewable Energy (RE) technologies have potential to address energy security concerns??
  - **Risks of price fluctuation** - Not relying on fossil fuel where availability and prices are increasingly uncertain
  - **Risks of supply interruption** – Providing fuel diversity
- A well-diversified (or flexible) electricity generation portfolio can reduce exposure to cost risk and supply interruption risk?

Energy security and the overall policy objectives

How energy security fits within the overall policy objectives?

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



What about other options?

- Renewables, demand-side participation

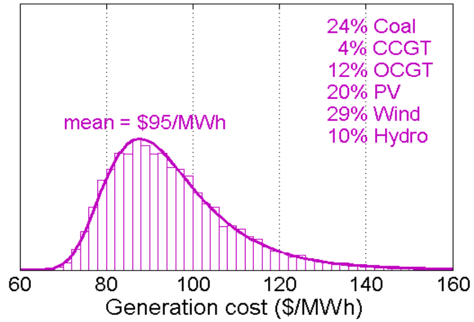
Electricity generation investment

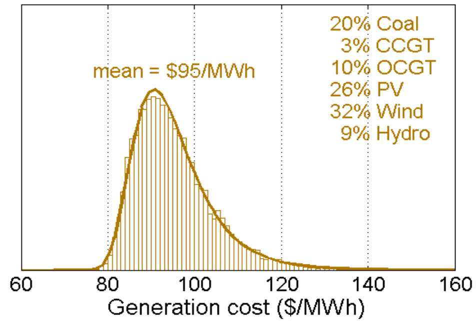
- **Coal** – cheap to run but high emissions.
- **Gas-fired** - energy security concerns (due to fuel import) but low emissions.
- **Nuclear** - expensive to build but zero operating emissions.

Objectives and methodology

- Explore the role of solar and wind in addressing long-term energy security concerns
- Assessing long-term security of electricity supply and other criteria (i.e. costs, emissions) of future electricity generation portfolios
  - **Price (cost) risk** – measured by a spread of possible future electricity prices (or overall industry costs) i.e. standard deviation
  - **Physical supply availability risk** – measured by diversity of fuel used for electricity generation

Cost risks can be quantified by spread of possible cost outcomes (i.e. standard deviation)





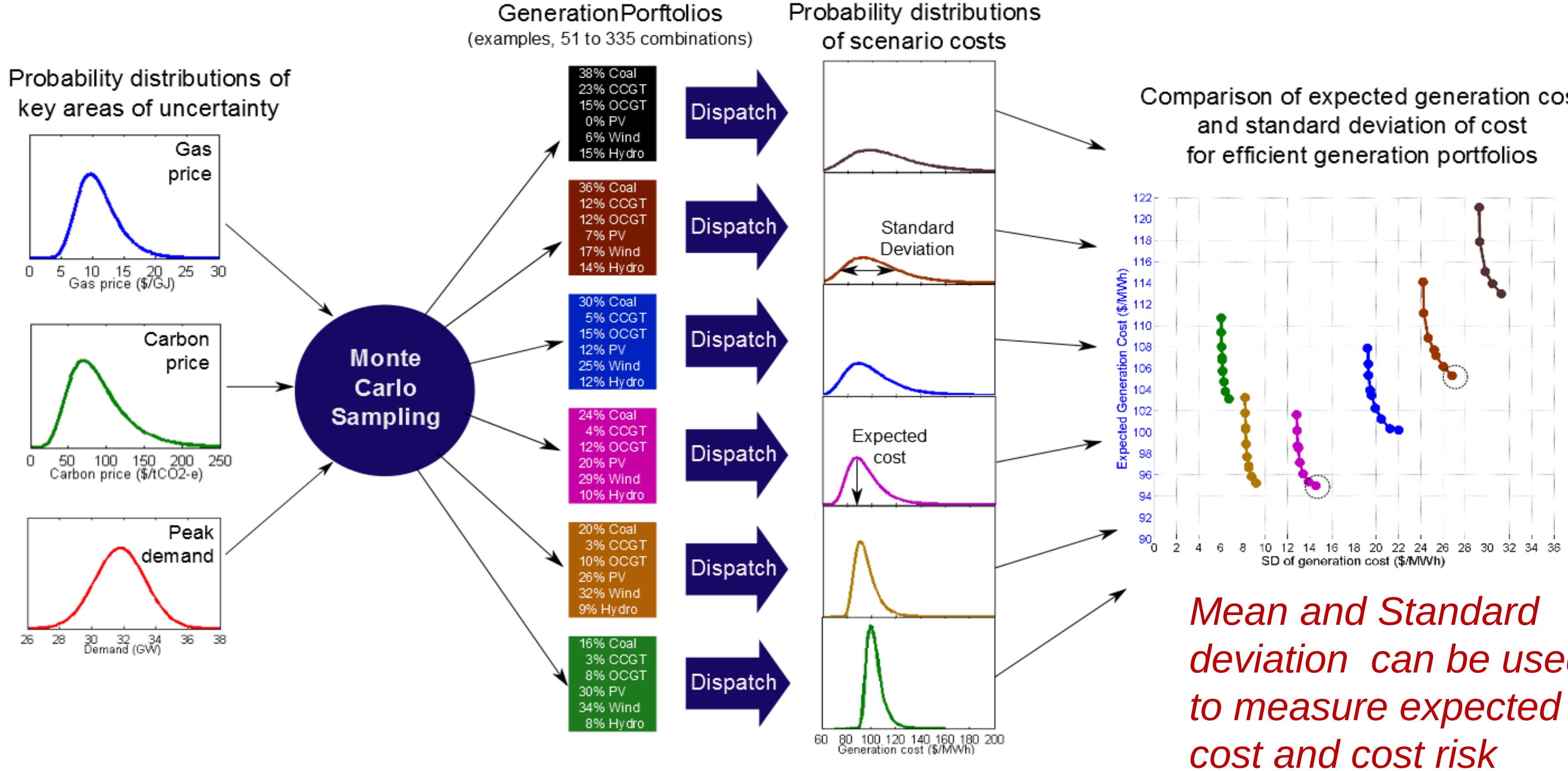
Fuel diversity can be measured by **Shannon Wiener Index (SWI)**

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

Higher SWI implies greater diversity

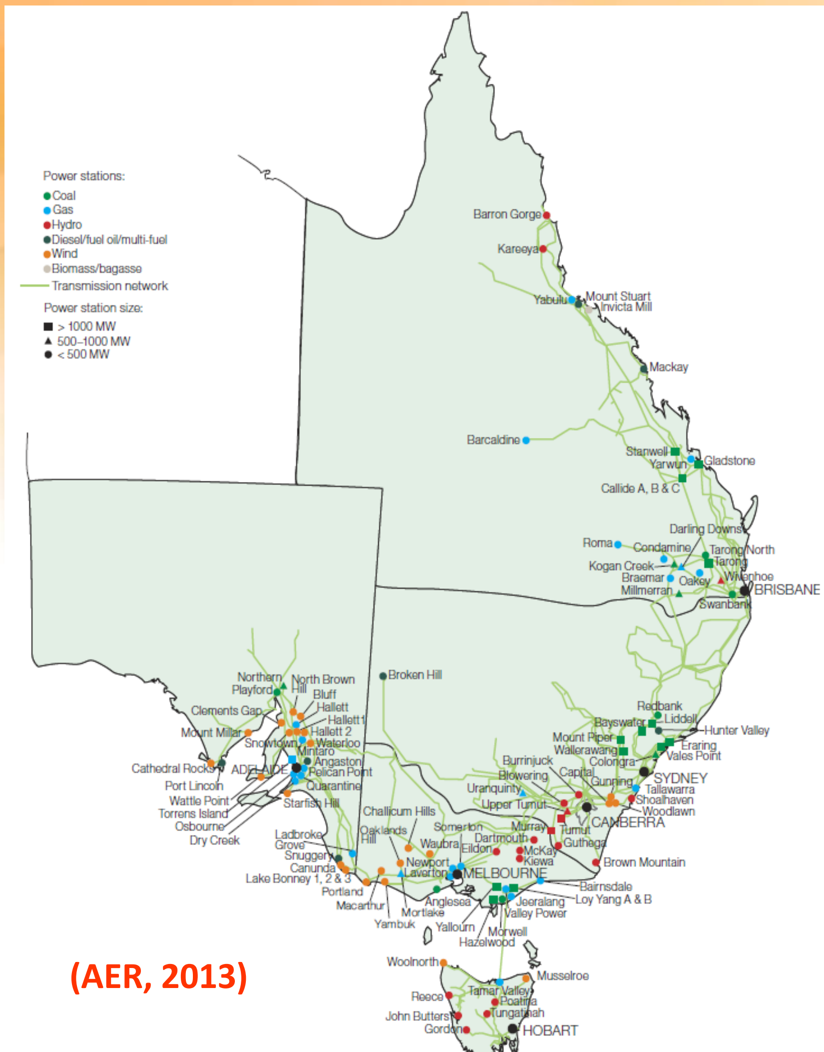
Probabilistic generation portfolio modelling

- A modeling tool to assess possible future generation portfolios given a range of *future uncertainties* (e.g. fossil fuel prices, carbon price, demand)
  - Assess tradeoffs between multiple criteria - *costs, energy security, emissions*



Mean and Standard deviation can be used to measure expected cost and cost risk

The Australian National Electricity Market

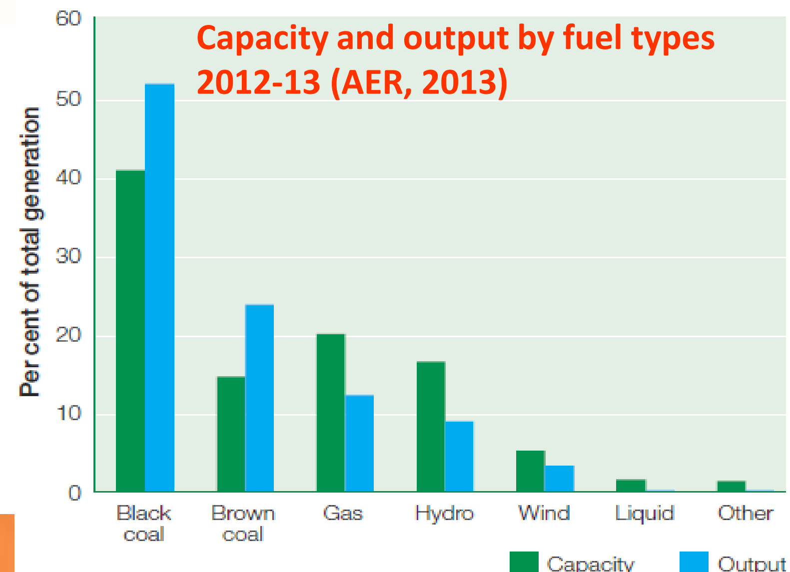


(AER, 2013)

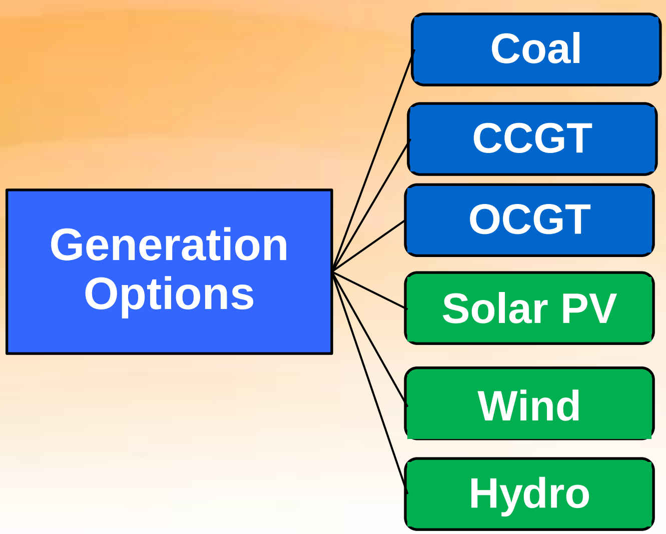
- Australian National Electricity Market (NEM) covers all Eastern States – 90% of electricity demand.

    Installed capacity: 50 GW
    Peak demand: 35 GW
    Annual energy: 190 TWh

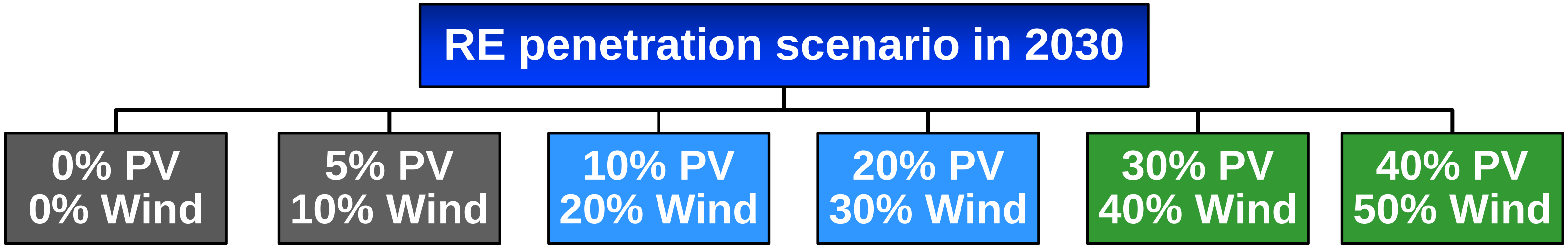
- Largely coal, around 15% renewables
- Recent growth in wind and solar PV



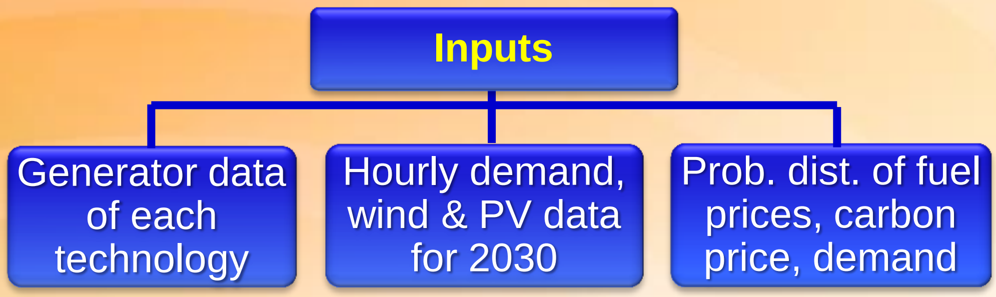
Modelling future generation portfolios in 2030



- Examining different generation portfolios for 2030 in the NEM in the context uncertain *fuel prices*, *carbon pricing* and *electricity demand*.
  - Consider different wind and PV penetrations
  - Different mixes of fossil-fuel technologies (coal, CCGT and OCGT)



Modeling Inputs



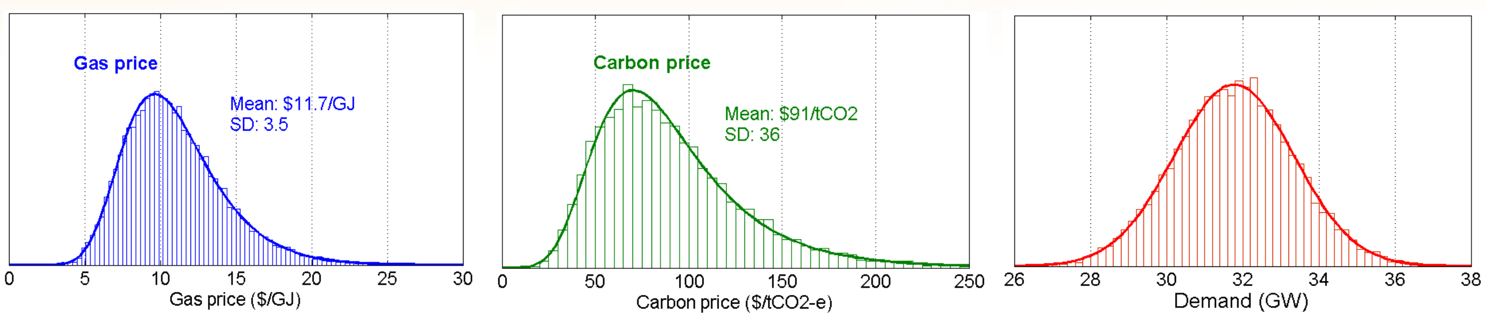
NTNDP (AEMO)
AETA (BREE)

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.

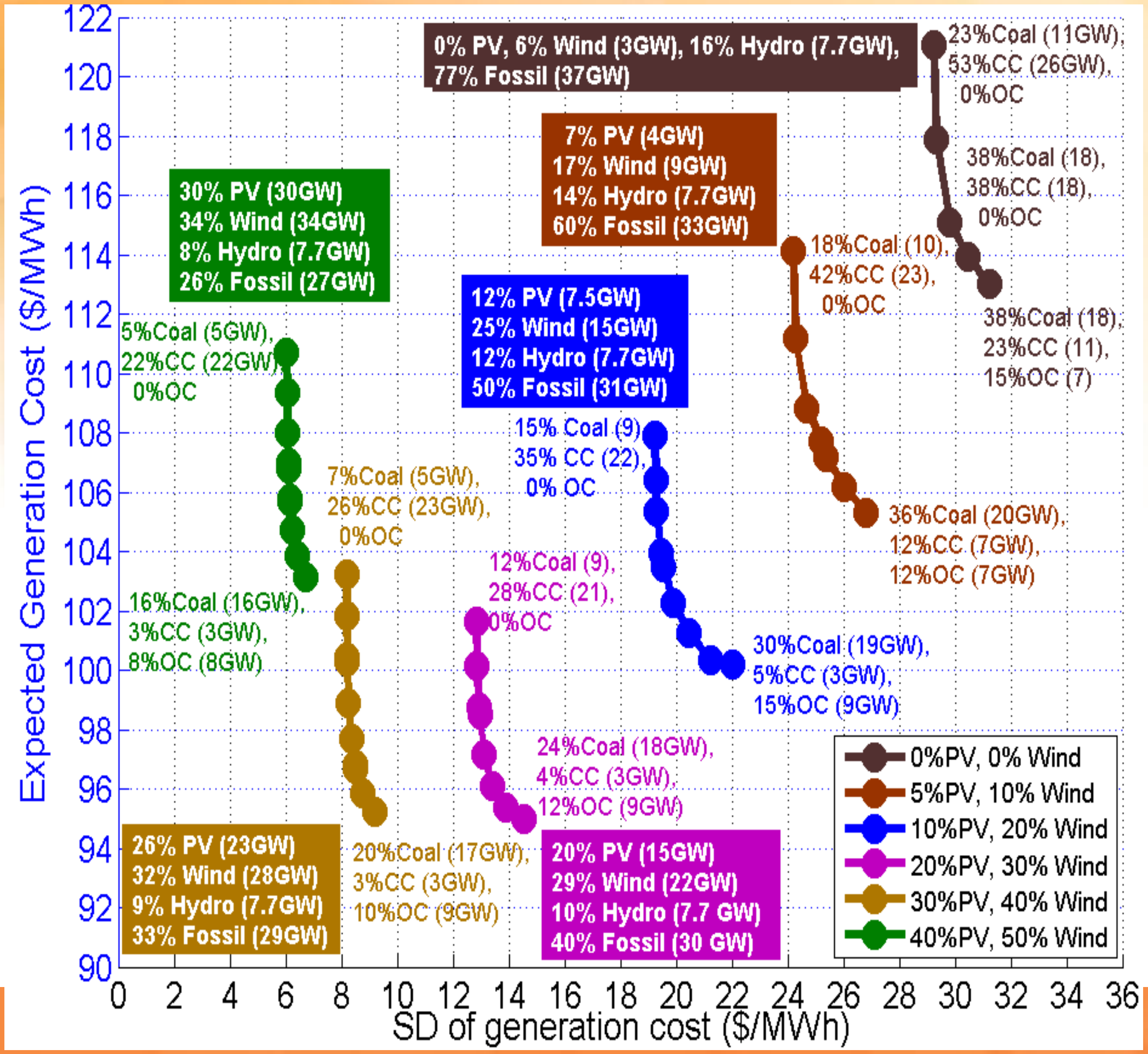


Histogram of gas price, carbon price and peak demand over 10,000 simulations

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

Cost VS cost risks optimal generation portfolios

‘Cost VS Cost risk Efficient Frontier’ (EF) for each RE penetration



Expected costs start to increase as RE penetration is greater than 70%

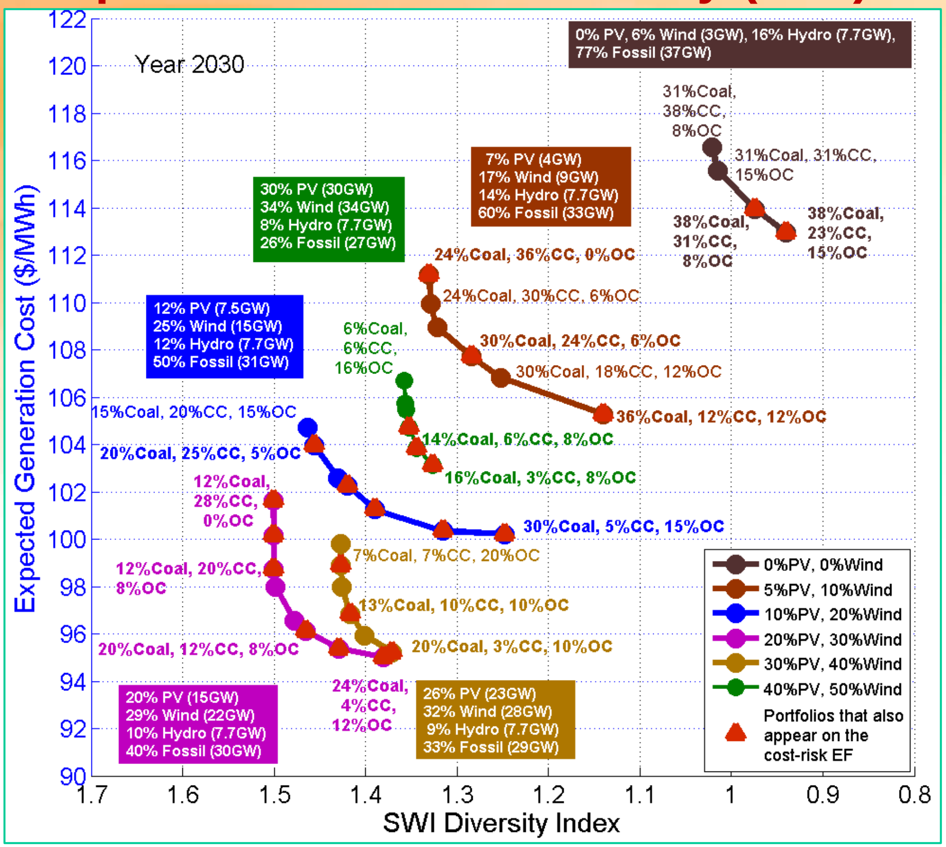
(but still lower cost risk)

Higher RE, lower cost risk

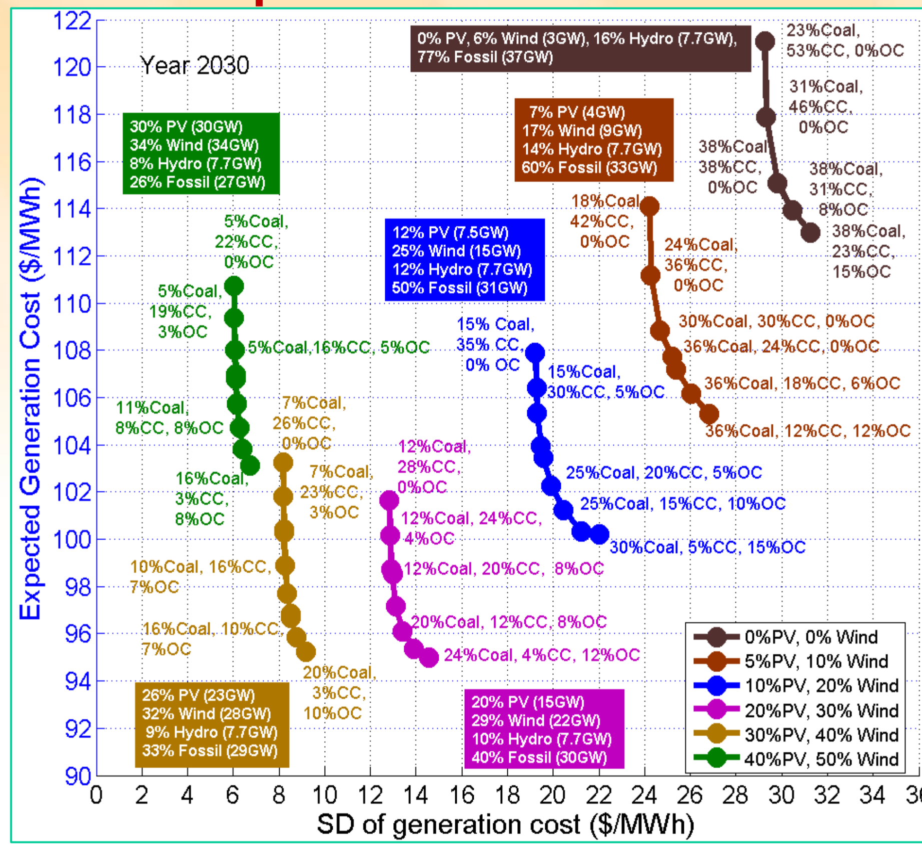
% RE	Cost range ($/MWh)
0%	$112 - $122 (¥620 - 670)
15%	$105 - $114 (¥580 – 630)
30%	$100 - $108 (¥550 – 600)
50%	$95 - $102 (¥525 - 565)
70%	$95 - $105 (¥525 - 580)
90%	$103 - $111 (¥570 – 610)

Availability of supply risks – fuel diversity

Expect cost VS fuel diversity (SWI)



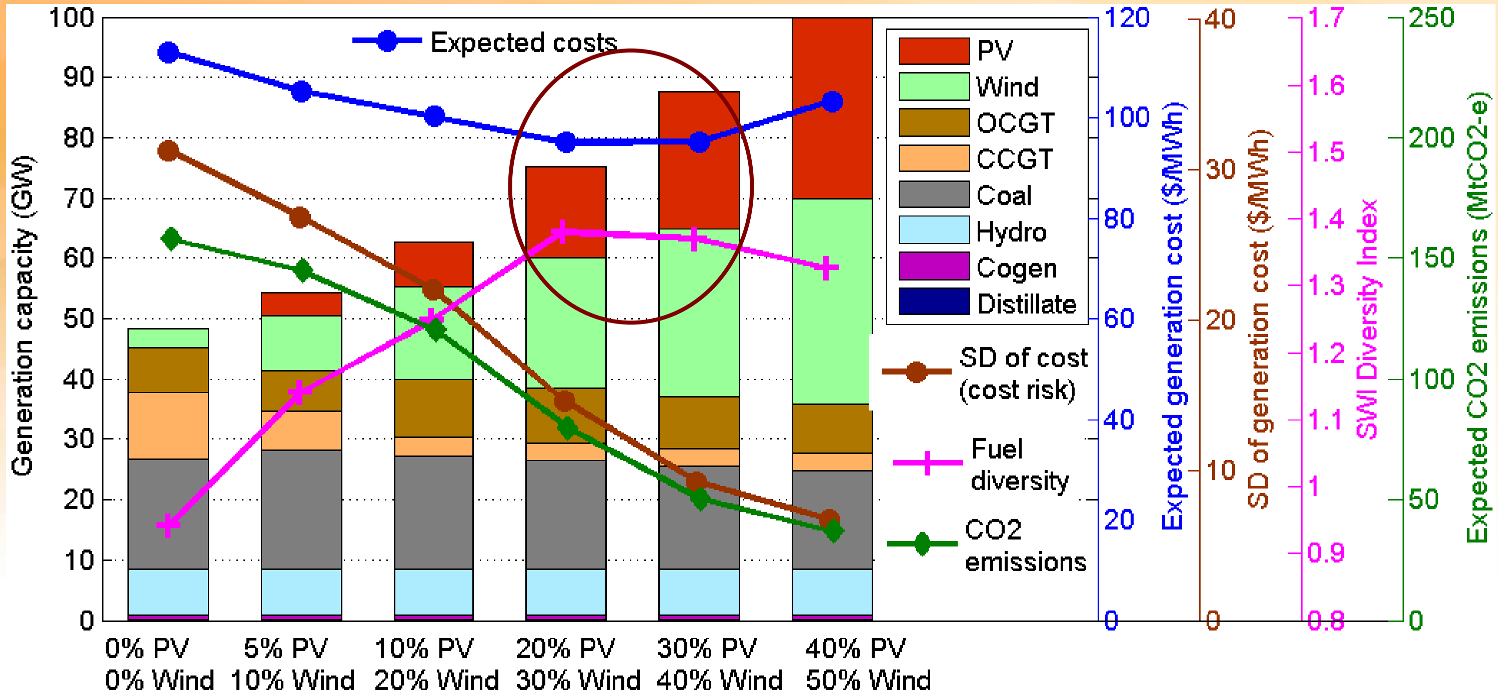
Expect cost VS cost risk



Reductions in both **expected cost and fuel diversity (SWI)** as RE increases from 0% to 70%

Cost risk (price stability) and **fuel diversity (physical supply)** are highly correlated indicators

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 50% - 70% 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)

Conclusions

- RE can help address energy security concerns and emissions
  - Price (cost) risk - mitigate against uncertainties and cost risk
  - Physical supply availability risk – fuel diversification
- Portfolios are less diversified with extremely high renewables but not necessarily means the system is less secured – different risk nature compared to fossil fuels
- Some limitations of SWI diversity index
  - Different risk of disruptions associated with various fuel and resource types are not reflected
- Flexibility from the perspective of short term operation will need to be considered

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