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Generation Portfolio Analysis for Low-Carbon Electricity Industries with High Wind Penetrations

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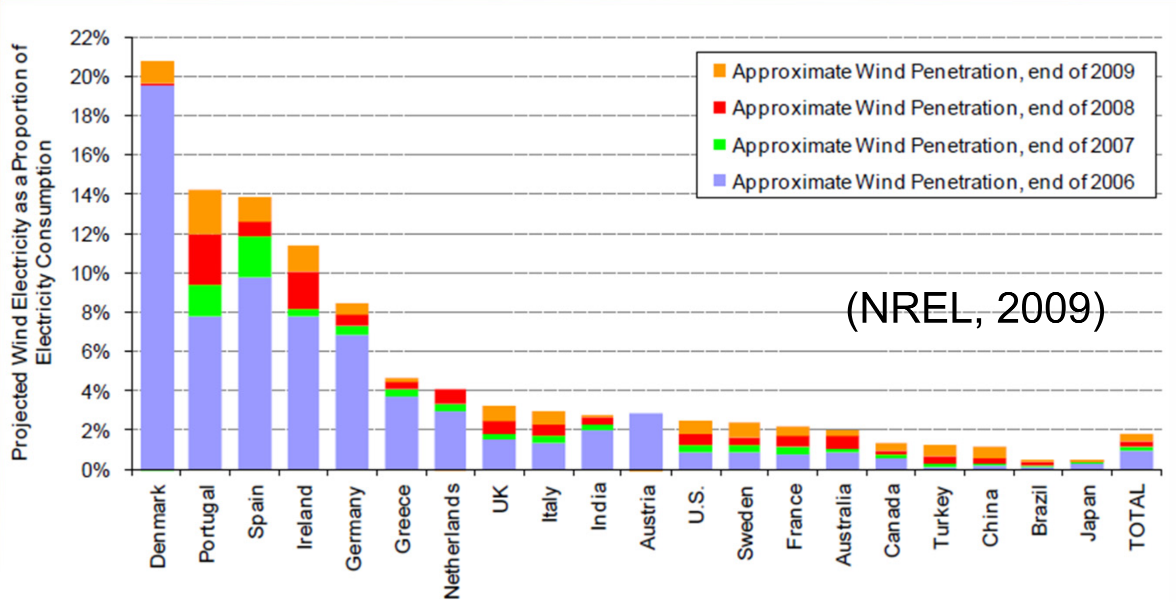
Presentation Outline

- Context for wind power and the electricity industry
- Generation portfolio evaluation under uncertainty to incorporate wind generation
- Case study of conventional generation portfolios with different wind penetrations
  - Descriptions and results
  - Some implications
- Conclusions

Wind power and the electricity industry



Rapid growth of wind power and becoming significant source

- *Due to uncertainty in fossil fuel prices, concerns over climate change.*

- High capital costs but no fuel costs and 'direct' emissions.
- First highly variable and non-storable energy source to reach significant penetration
  - *Implications for investment and planning in the electricity industry.*
- A key question: Potential impacts of high wind penetration on the optimal conventional plant mixes under uncertainties

Monte-Carlo Based Decision Support tool

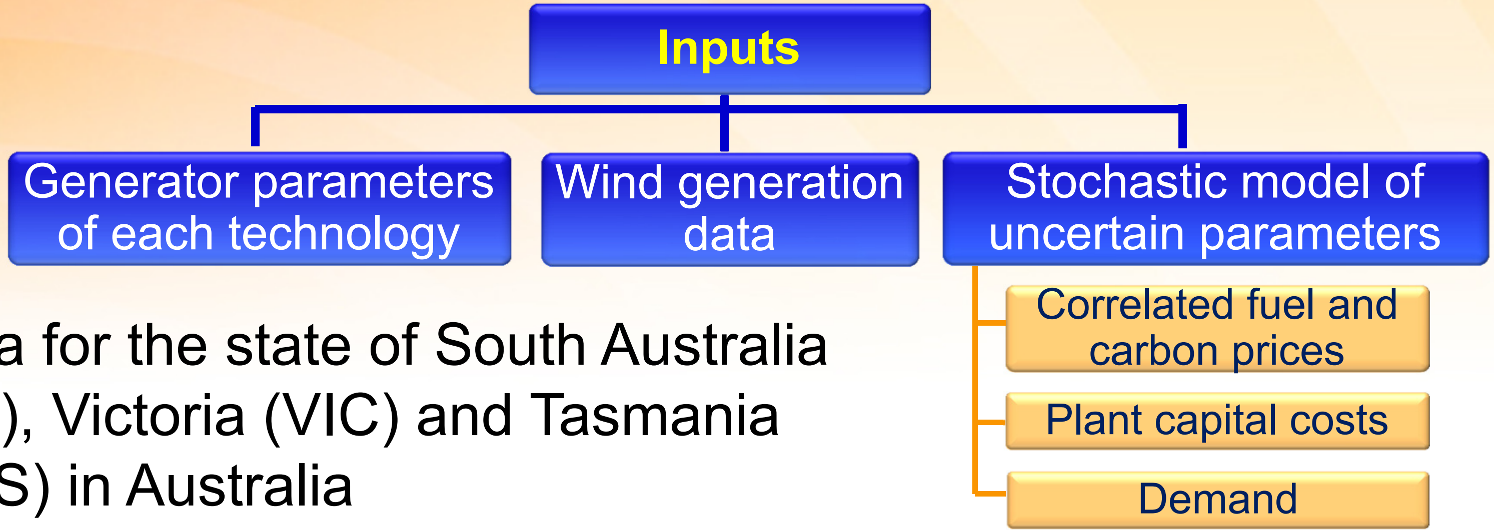
- Combines ***optimal generation mix*** concepts with ***Monte Carlo Simulation*** (MCS) and ***financial portfolio analysis*** technique
  - *Incorporating uncertainty into key cost assumptions using MCS*
- Determine the expected generation cost ($/year), 'cost uncertainty' (risk) and CO_2 emissions of various generation portfolios
  - *Generation cost outputs from MCS represent a range of possible results - Mean and SD are used to measure cost-risk profile.*

Incorporating Wind generation

- Analyzing generation portfolios of conventional generation options with different wind penetrations under future uncertainties
- Wind is modeled negative load (non-chronological)
  - *Altering demand profile of an electricity system.*
  - *Net demand (after accounting for wind generation) is to be served by conventional generation technologies*

Case study

- An electricity industry with ***Coal, CCGT, OCGT and Wind generation*** options that faces uncertain ***future fuel and carbon prices, demand, and capital costs.***



- Data for the state of South Australia (SA), Victoria (VIC) and Tasmania (TAS) in Australia
  - *30-minute demand and wind generation data in 2009*
  - *Fuel costs, new entrant generator data*

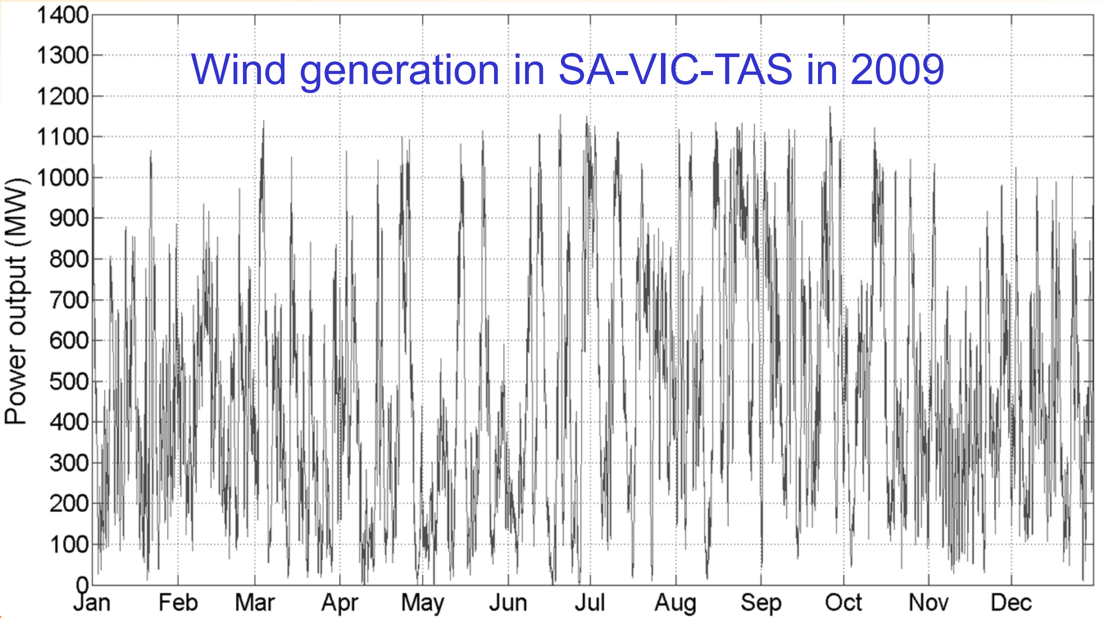
- Lognormal distribution to represent fuel prices, carbon price and capital cost uncertainties.
- Normal distribution to represent demand uncertainty

Case study

Attributes	Technology			
	Coal	CCGT	OCGT	Wind
Plant life (Years)	40	30	30	30
Capital cost ($/MW)	2,500,000	1,400,000	1,000,000	2,600,000
Fixed O&M ($/MW/yr)	43,000	13,000	7,500	20,000
Efficiency (%)	34	52	31	N/A
Variable O&M ($/MWh)	1.2	4.85	7.5	1.6
EF(tCO_2/MWh)	1.0	0.45	0.7	0

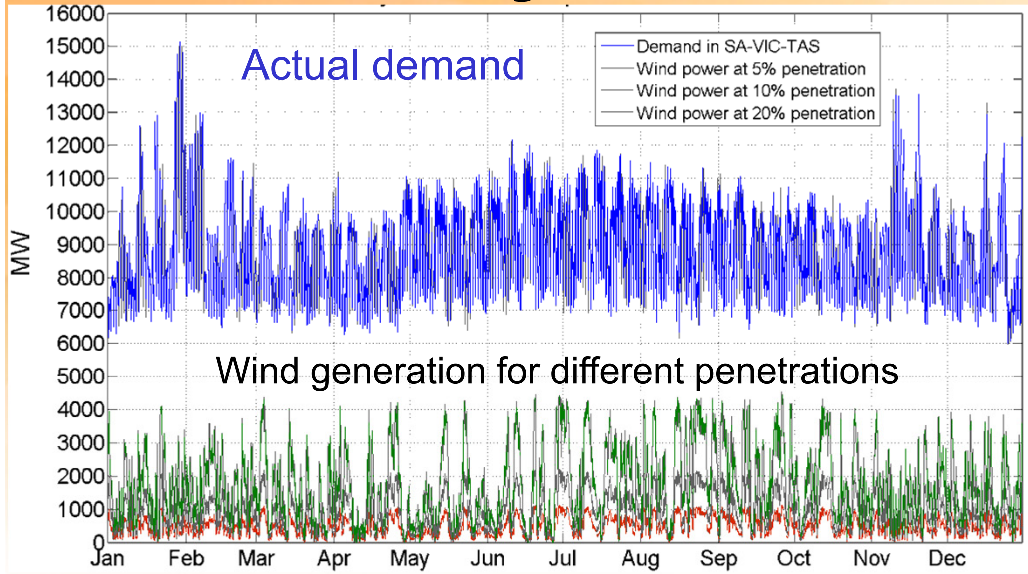
Sources: Acil Tasman (2008, 2009)

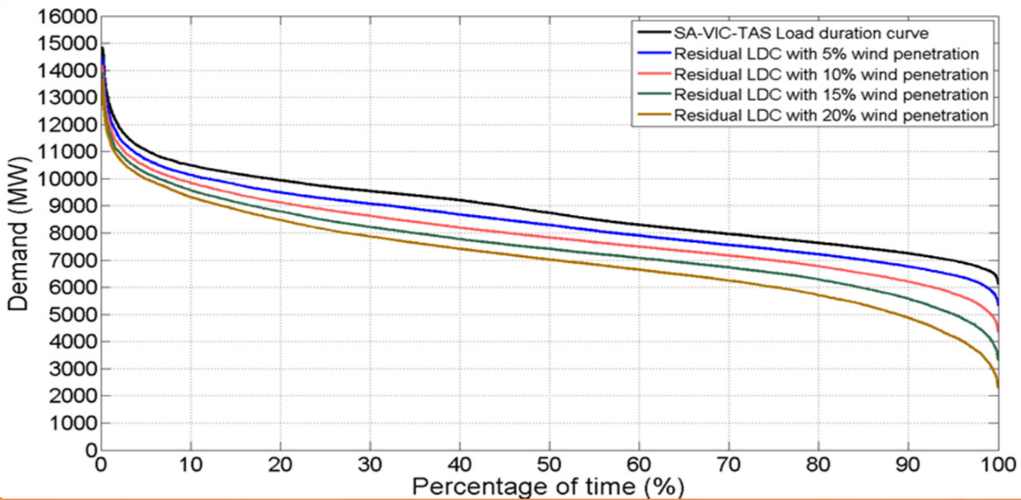
Coal price ($/GJ)	Gas price ($/GJ)
0.6	5.2



- *Significant wind generation in this region already in place – about 5.2%*
- *Installed wind capacity increased from 962.65 MW to 1,446.65 MW during 2009.*

Case study





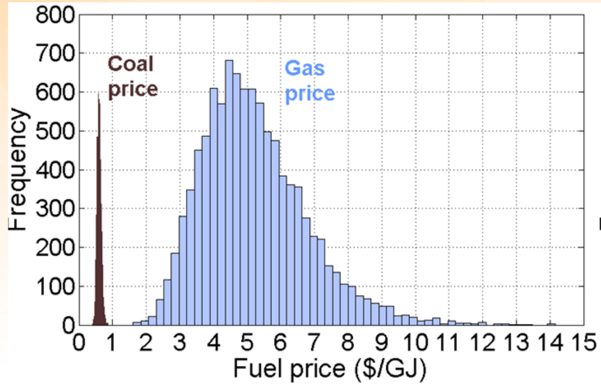
- Simulate for different wind energy penetrations
  - *Directly scaled up or down*
  - *0 – 20% wind penetration at 5% increments*
- Wind generation is modeled as negative load
  - *Result in Residual Load Duration Curve (RLDC)*
  - *RLDC to be served by conventional generation technologies.*
- Installed wind generation capacity for different penetration is determined based on 35% wind capacity factor

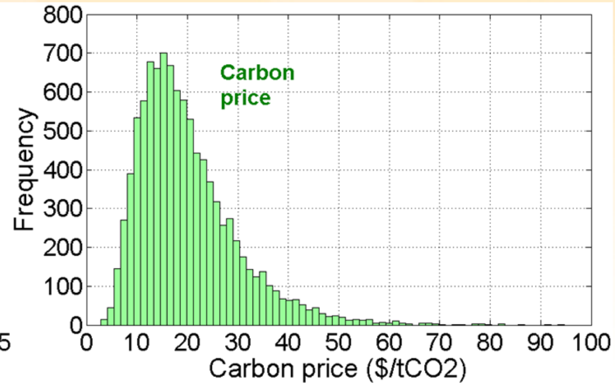
Case study – Modeling uncertainties

- For each scenario of wind penetration
  - *Overall costs and CO_2 emissions of each generation portfolio is calculated for 10,000 simulated years of uncertain future fuel prices, carbon price, demand and capital costs*

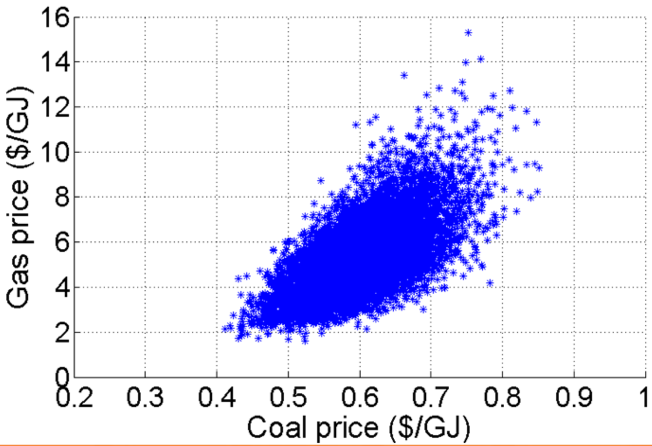
	Coal price ($/GJ)	Gas price ($/GJ)	Carbon price ($/tCO$_2$)
Mean	0.6	5.2	20
SD	10%	30%	50%

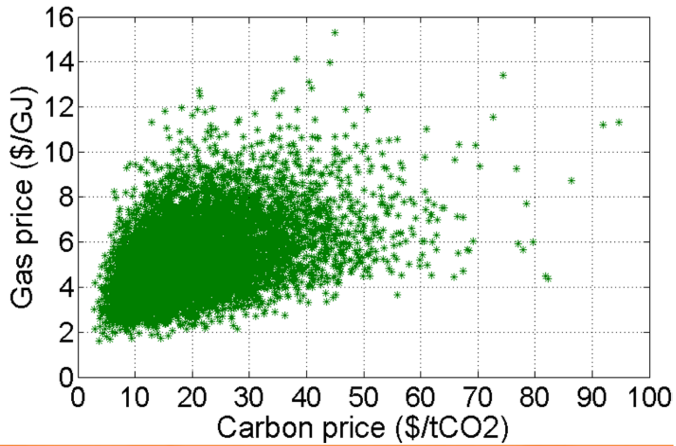
Correlation	Coal	Gas	Carbon
Coal	1	0.65	-0.32
Gas	0.65	1	0.45
Carbon	-0.32	0.45	1





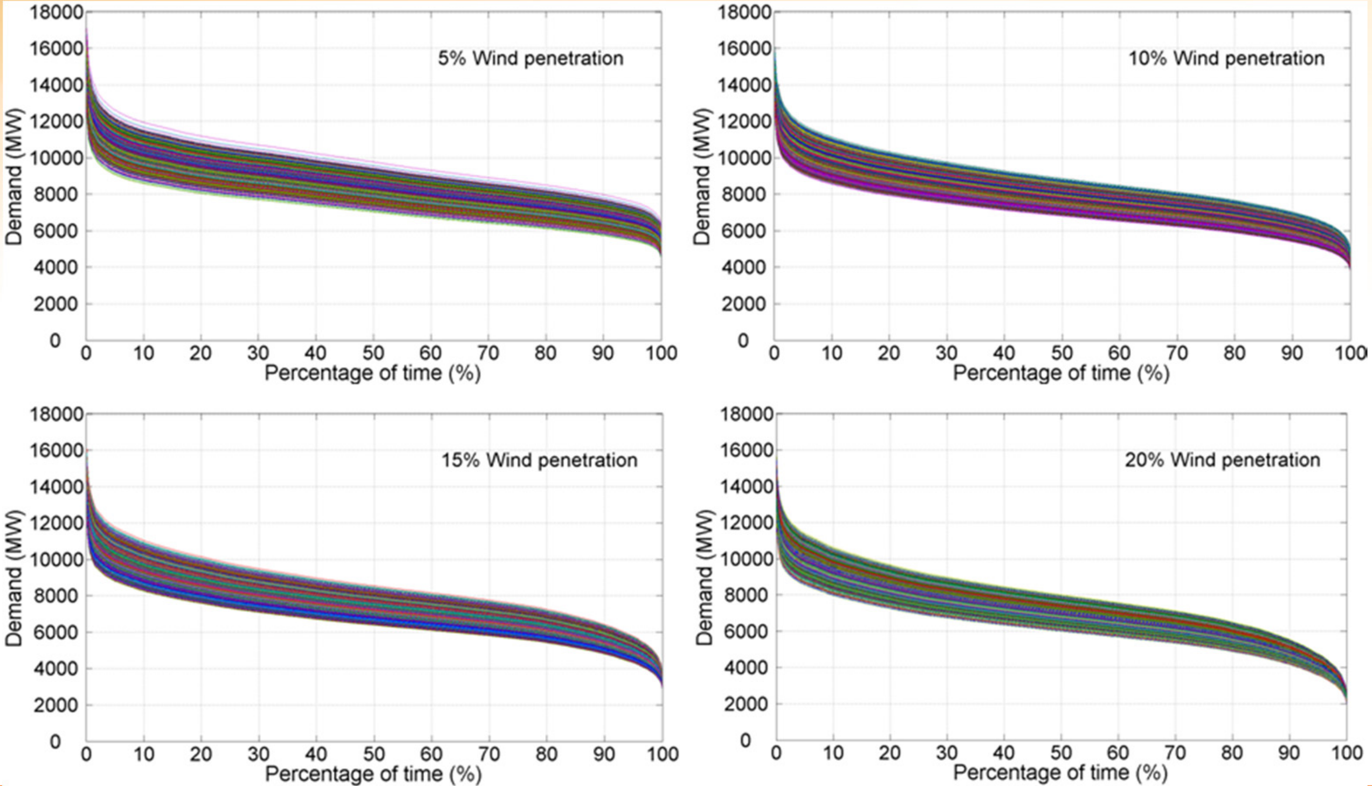
Multivariate lognormal simulation to generate 10,000 sets of correlated fuel & carbon prices





Case study – Modeling uncertainties

- Demand uncertainty is modeled as variations in RLDC for each wind penetration level - *SD of peak demand is 4% of the expected peak*
- Each RLDC is derived from each sample of residual peak demand
  - *Normal distribution to represent peak demand uncertainty*

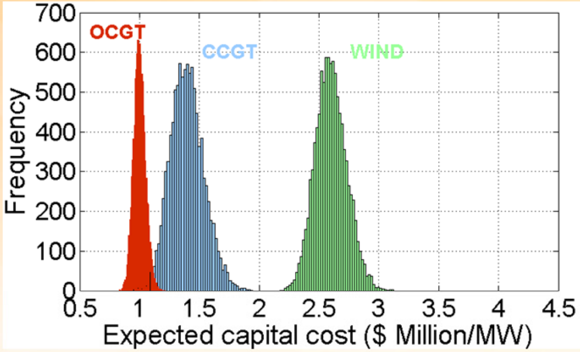


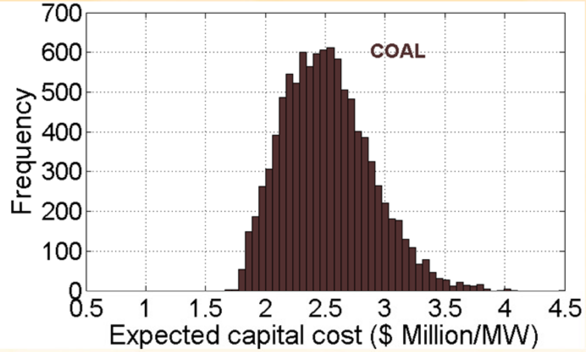
Wind penetration	Peak demand (MW)	
	Mean	SD
0%	14,861	594
5%	14,506	580
10%	14,202	568
15%	13,933	557
20%	13,673	547

Case study – Modeling uncertainties

- Lognormal distribution to represent capital cost uncertainty of each generation technology

Capital cost ($Million/MW)	Coal	CCGT	OCGT	Wind
Mean	2.5	1.4	1.0	2.6
SD	15%	10%	5%	5%

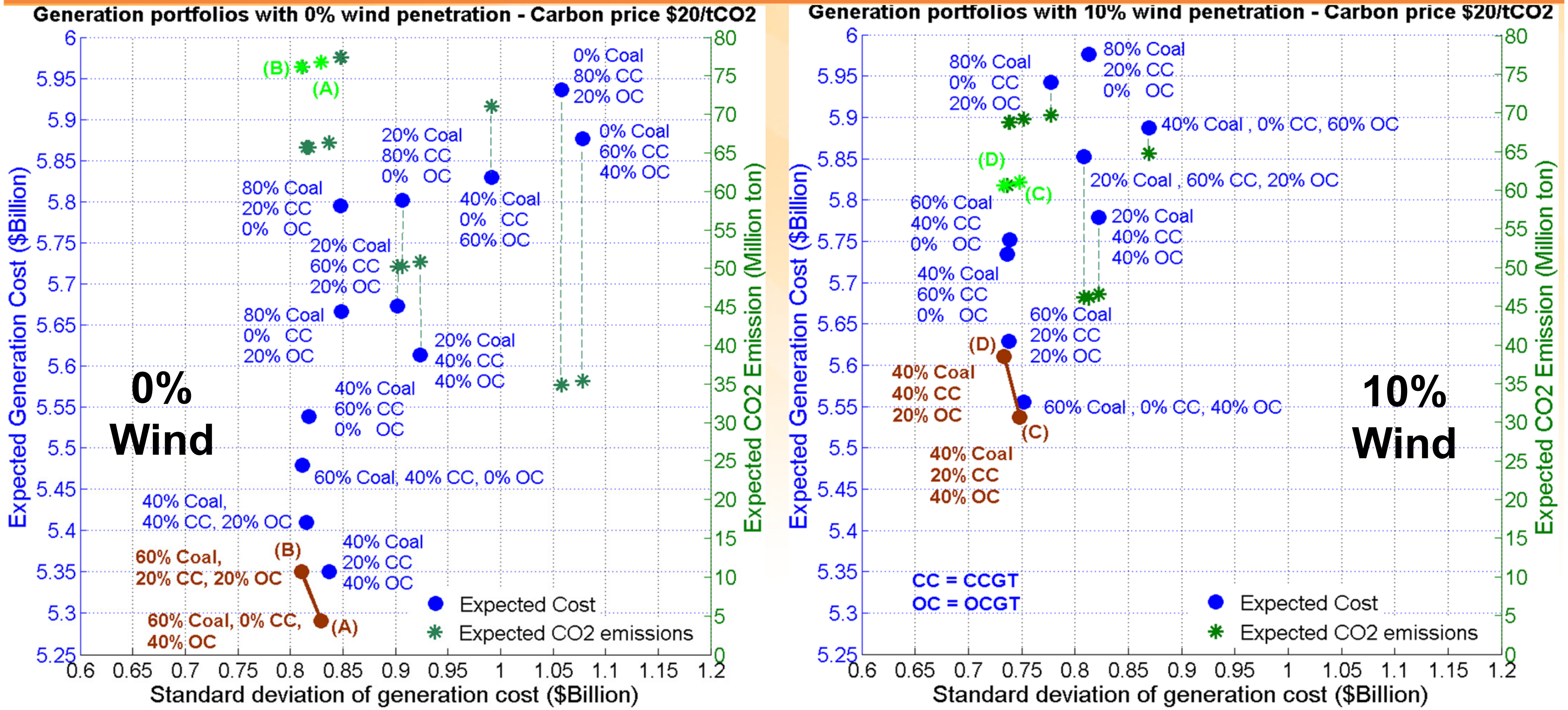




No.	%Share of technology		
	coal	CCGT	OCGT
1	0	0	100
2	0	20	80
3	0	40	60
4	0	60	40
5	0	80	20
6	0	100	0
7	20	0	80
8	20	20	60
9	20	40	40
10	20	60	20
11	20	80	0

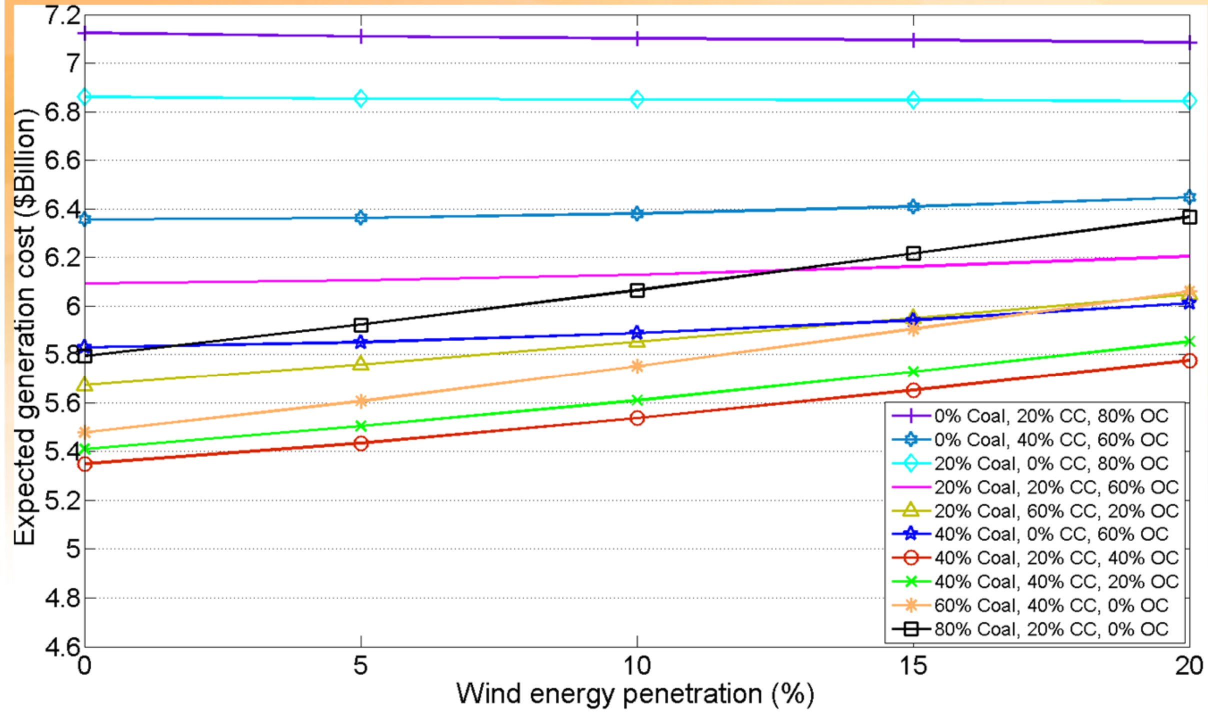
No.	%Share of technology		
	coal	CCGT	OCGT
12	0	0	100
13	0	20	80
14	0	40	60
15	0	60	40
16	0	80	20
17	0	100	0
18	20	0	80
19	20	20	60
20	20	40	40
21	20	60	20

- **For each wind penetration -** Simulated fuel & carbon prices, demand and capital cost are used for calculating expected generation cost, cost uncertainty and CO_2 emissions of each portfolio.
  - *Share of each conventional generation technology ranges from 0-100% of total capacity in 20% increments*



- Efficient frontier (EF) containing optimal generation portfolios - *along EF generation cost cannot be reduced without increasing 'cost uncertainty'*
- As wind penetration increases - overall generation cost increases but CO_2 emissions and cost uncertainty are significantly reduced.
  - *Portfolios with significant share of coal on the EF are replaced.*

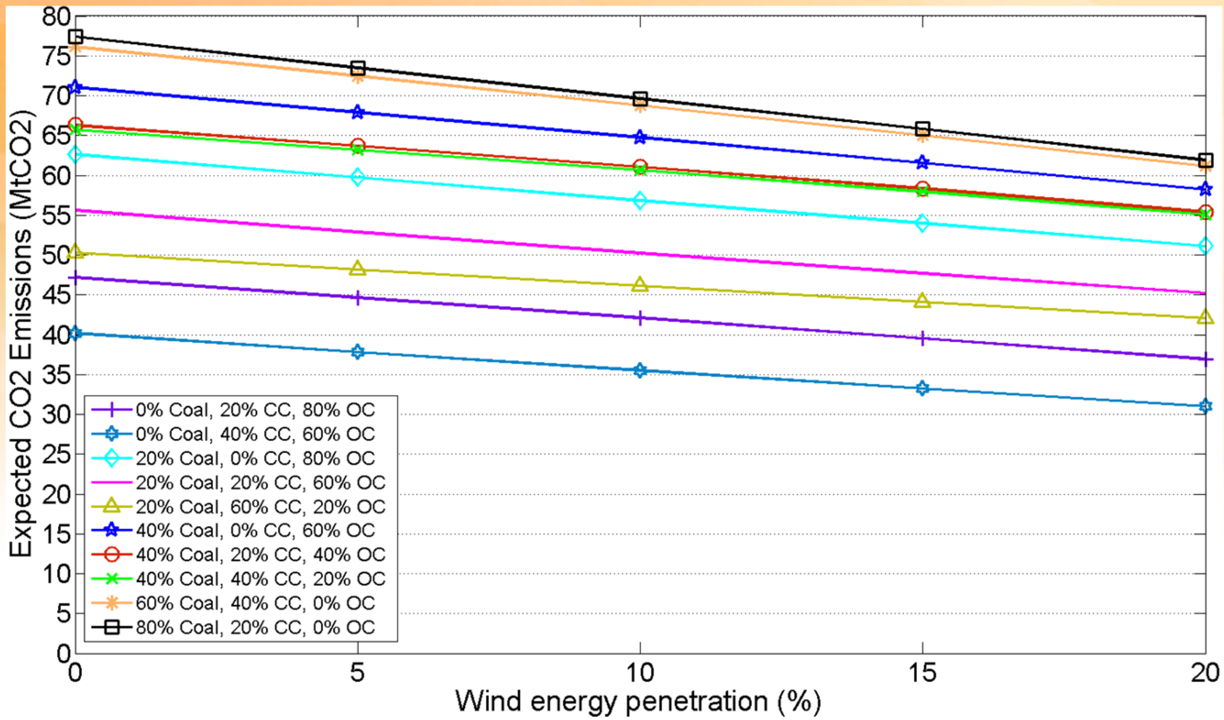
Impact of different wind penetration (1)



- Impact of wind generation on generation costs depends on particular generation portfolios.
- For most generation portfolios – *generation cost increases with increasing wind penetration*

- For generation portfolios with large share of OCGT – *costs reduce or increase only slightly with higher wind penetration*
  - *With increasing wind penetration, the reduction in variable cost is greater than the increase in fixed cost due to high variable cost of OCGT*

Impact of different wind penetrations (2)



Impact on CO_2 emissions of generation portfolios

- Increased wind penetrations reduce the overall CO_2 emissions of every generation portfolio at similar rate
  - *Wind generation provides useful emission reductions for all conventional plant mixes*

Conclusions

- Demonstrate the application of Monte Carlo based decision support tool to include wind generation
- Case study of thermal generation portfolios in the context of varying wind penetration
  - *Using real and simulated 30-min demand and wind generation data in the states of SA, VIC and TAS in Australia*
- Generally high wind penetrations increase overall costs but reduce associated cost uncertainty and CO_2 emissions
  - *Due to its high capital costs, free fuel and zero emissions*
- The impact of wind generation on the expected cost, cost uncertainty of generation portfolios depends on proportion of fixed and variable costs – *synergies between wind and OCGT*
- Wind generation has an important role in hedging against future fuel and carbon prices volatility.

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