Centre for Energy and Environmental Markets

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Impacts of Generation-Cycling Costs on Future Electricity Generation Portfolio Investment

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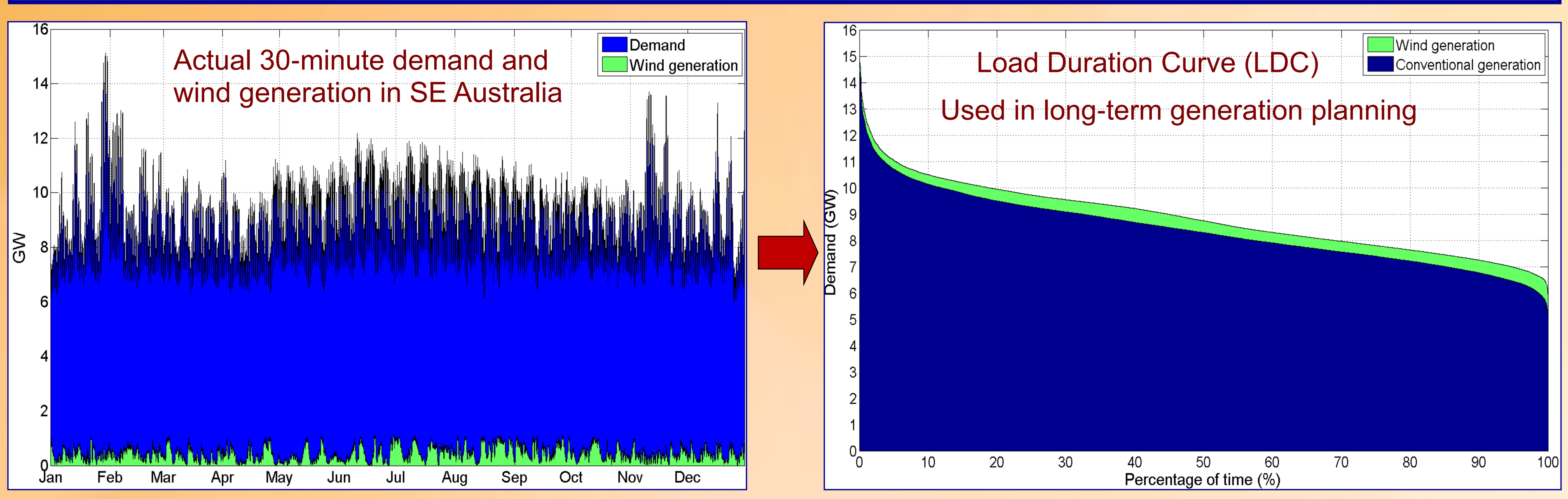
1. Background

- Generation investment and planning decisions require a long-term perspective due typically to long lead times, large unit sizes, irreversible.
- Over longer-term planning horizon, generation investment decisions often ignore short-term electricity industry operational aspects.
- *Load Duration Curve* techniques are often used in generation planning where chronological demand is rearranged in order of magnitude.
- However, in reality, thermal generating plants have inter-temporal operational constraints (i.e. *minimum operating level, ramp rates, startup time*), and costs associated with these e.g. plant startup costs.
- Recent growth of highly variable renewable generation can pose operational challenges for such plants (cycling operation) and may increase overall industry costs and emissions.
- These operational criteria might have significant implications for future generation portfolios obtained from long-term planning frameworks.



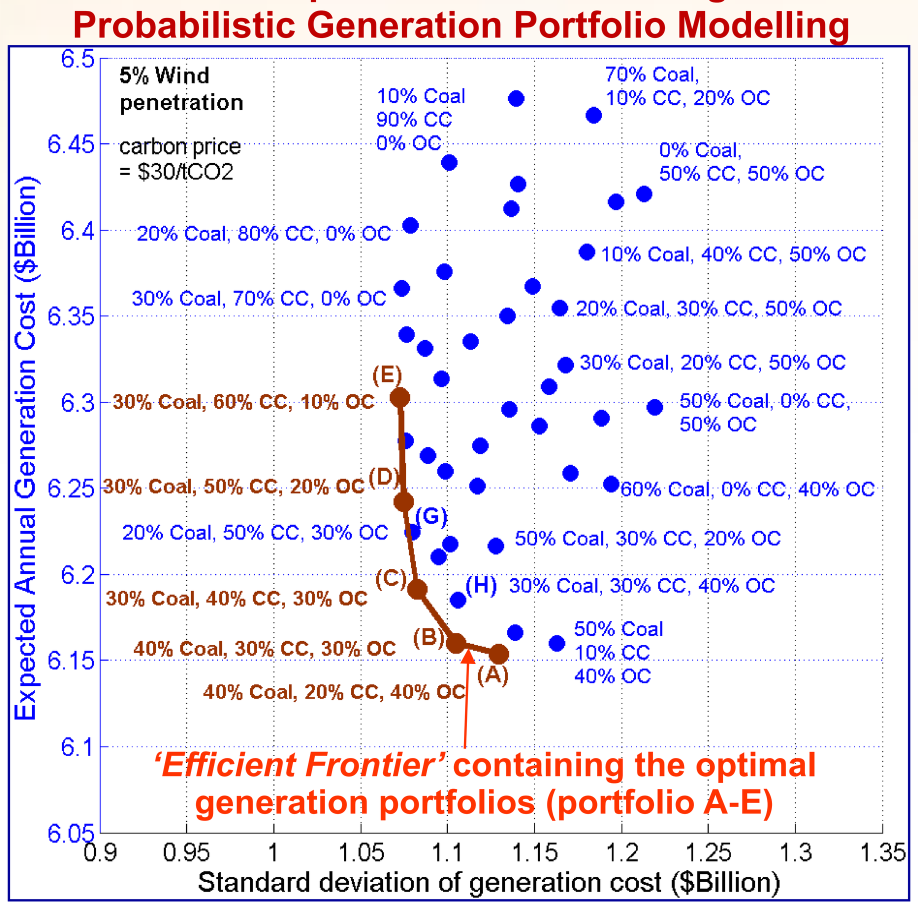
2. Objectives

- To assess the impacts of operating constraints and associated costs on optimal portfolios obtained from long-term planning frameworks.
  - *Operational viability*, *economics* and *emission* implications.
  - Indices of possible violations of plant operating constraints including number of startups and ramp rates.

3. Extensions to Generation Portfolio Modelling

- In previous work, a probabilistic generation portfolio modelling tool was developed to assess future generation portfolios under uncertainty.
  - Optimal generation portfolios in terms of '*expected cost*' and '*cost risk*' were obtained (where standard deviation of costs represents cost risk).
  - But the modelling did not consider the short-term operational aspect.
- Extensions are implemented in this study to incorporate generating unit constraints and time-varying generation dispatch.
  - Candidate portfolios from the long-term generation portfolio modelling are rerun through a year of sequential 30-minute constrained dispatch.
  - Two generation dispatch strategies are considered.

Generation portfolios from the long-term Probabilistic Generation Portfolio Modelling



Generation Dispatch

Min Start/Stop	*Max Low-Cost Gen*
Minimize unit startup/shutdown	Maximize outputs from low running-cost units
• Dispatch low cost units at part-load to allow other units to remain online although they are more costly to run.	• Dispatch the lowest cost technology as close to its maximum capacity as possible.
• Startups/shutdowns only occur when online units cannot increase or reduce their outputs any further	• Shutdowns only occur if outputs of the lowest cost units would have to be reduced

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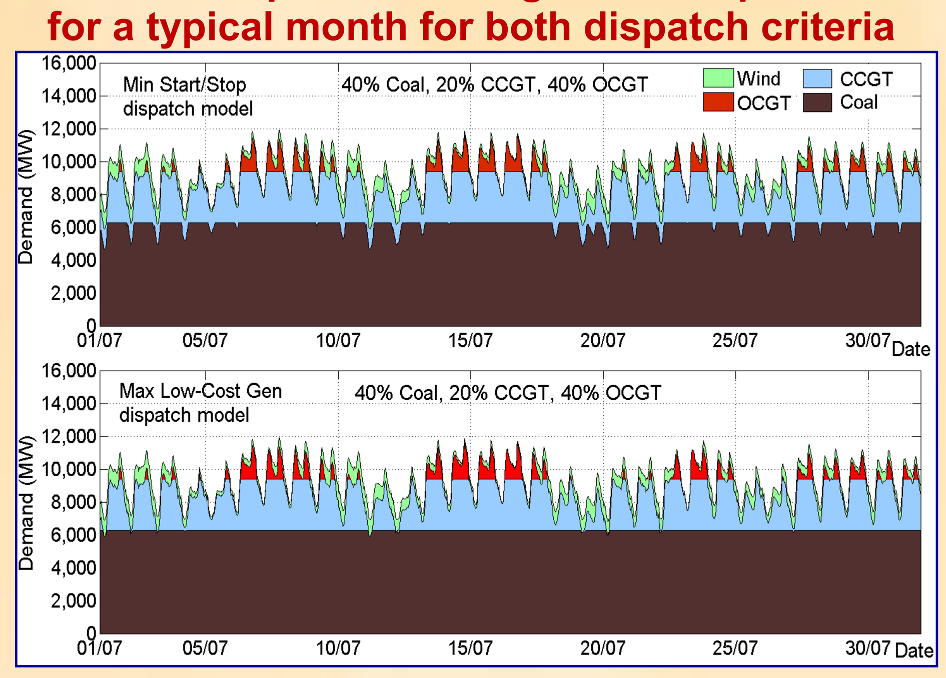
4. Impacts of Short-term Operational Criteria

- A case study of generation portfolios with *coal, CCGT, OCGT* and *wind generation* in Australia, with 5% wind penetration and a carbon price.
- Assess *the Operational*, *Economic* and *Emissions* implications for candidate generation portfolios (those on or near the *Efficient Frontier*).
  - ***Operational*** - number of startups and ramp-rate violations.
  - ***Economic*** - changes in overall costs due to additional operating costs.
  - ***Emissions*** - changes in the annual CO_2 emissions.

Generation patterns of a generation portfolio for a typical month for both dispatch criteria

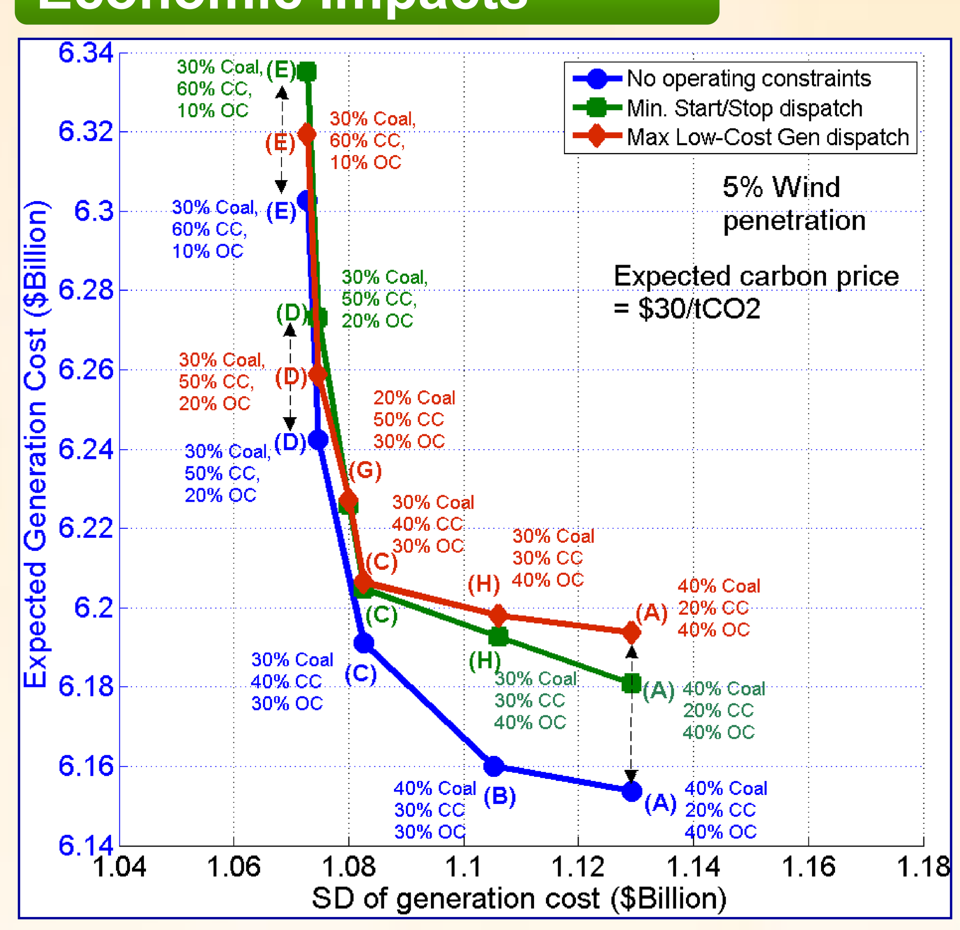


- Generation merit order
  - ***Coal*** *- baseload capacity*
  - ***CCGTs*** *- intermediate load-following*
  - ***OCGTs*** *- peaking capacity*
- Outputs of baseload units in ***Min Start/ Stop*** vary more frequently than ***Max Low-Cost Gen*** dispatch (to avoid startup/shutdown of other units).
- Dispatch strategy influences the cycling, costs and emissions.

Operational Impacts

- **No ramp rate violations and number of startups are within design limits.**
  - *CCGTs incur frequent startups in **Max Low-Cost Gen** dispatch (highest of 270 starts/unit/year) but still within design limits.*
  - *Baseload coal units are rarely shut down but still required to vary their outputs.*
- **Number of unit startups also depends on the mix of technologies.**

Economic Impacts



- **Short-term operational constraints increases the overall generation costs obtained under the long-term portfolio planning**
  - *Due to additional startup costs and running costs of generating units.*
- **May lead to changes in the merit of optimal generation portfolios on the *Efficient Frontier***
  - *Affecting selection of the most appropriate generation portfolios.*

Emission Impacts

- Reductions in emissions for ***Min Start/Stop*** dispatch since baseload coal units operate at lower load factors (to allow higher cost CCGTs to remain online).
- For ***Max Low-Cost Gen*** dispatch, the amount of CO_2 emissions are about the same as the unconstrained dispatch from the long-term planning.

If carbon price is high and more renewables

- **Changes in merit order between coal and CCGTs at a high carbon price.**
- **Coal units will incur frequent starts/stops and ramping to meet demand.**
  - *Ramp rates and number of startups of coal units can exceed design limits.*
  - *Significantly higher industry costs due to high startup cost of coal units.*
- **High renewable penetrations increase variability and operational challenges.**

5. Conclusions

- With modest carbon price and wind penetration, short-term operation constraints have moderate impacts on the appropriate portfolios, and the overall costs obtained from the long-term generation portfolio framework.
- These impacts are certain to be more significant in future electricity industries with high renewables and carbon prices.
- Different generation dispatch criteria can influence the cycling operation.

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