Centre for Energy and Environmental Markets

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The Role of Renewables in Hedging against Future Electricity Industry Uncertainties and Addressing Energy Security Concerns

Dr Peerapat Vithayasrichareon
Centre for Energy and Environmental Markets and
School of EE&T, University of New South Wales, Sydney, Australia

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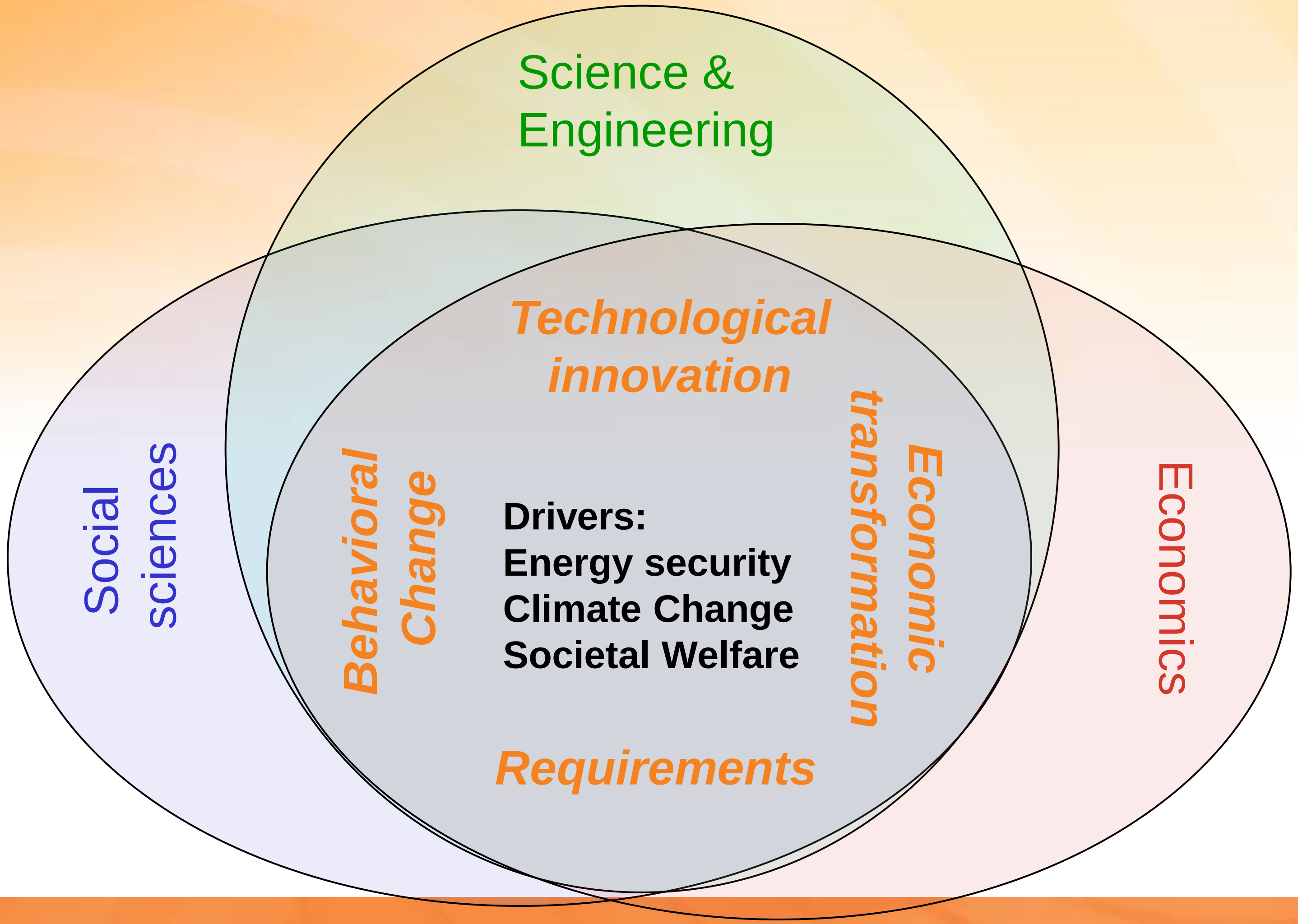
Outline

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

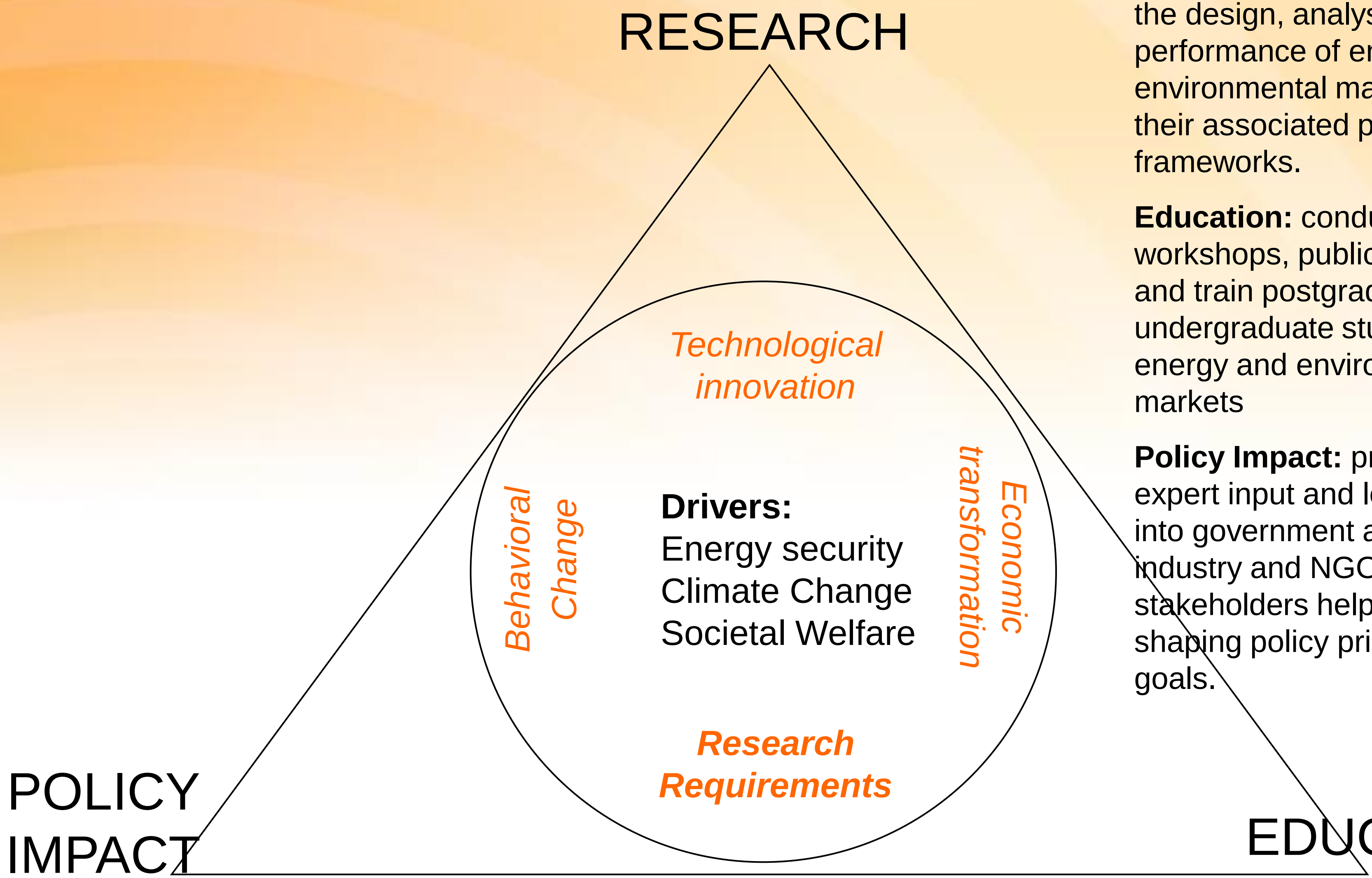
CEEM‘s Vision

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

Key interdisciplinary perspectives & tools required to address challenges – CEEM's key strength



CEEM‘s core tasks



Research: undertake interdisciplinary research in the design, analysis and performance of energy and environmental markets and their associated policy frameworks.

Education: conduct workshops, public seminars and train postgraduate and undergraduate students in energy and environmental markets

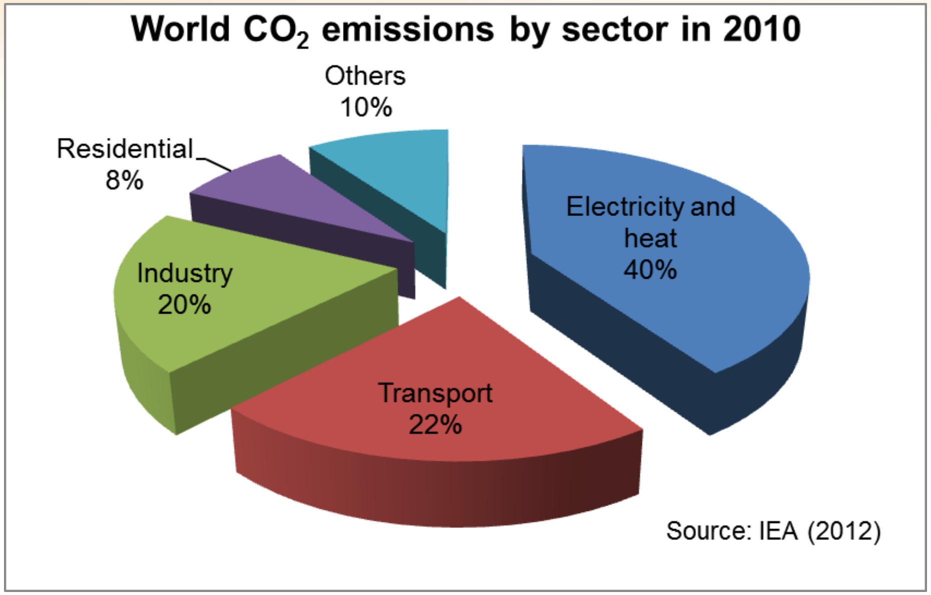
Policy Impact: provide expert input and leadership into government and other industry and NGO stakeholders helping shaping policy priorities and goals.

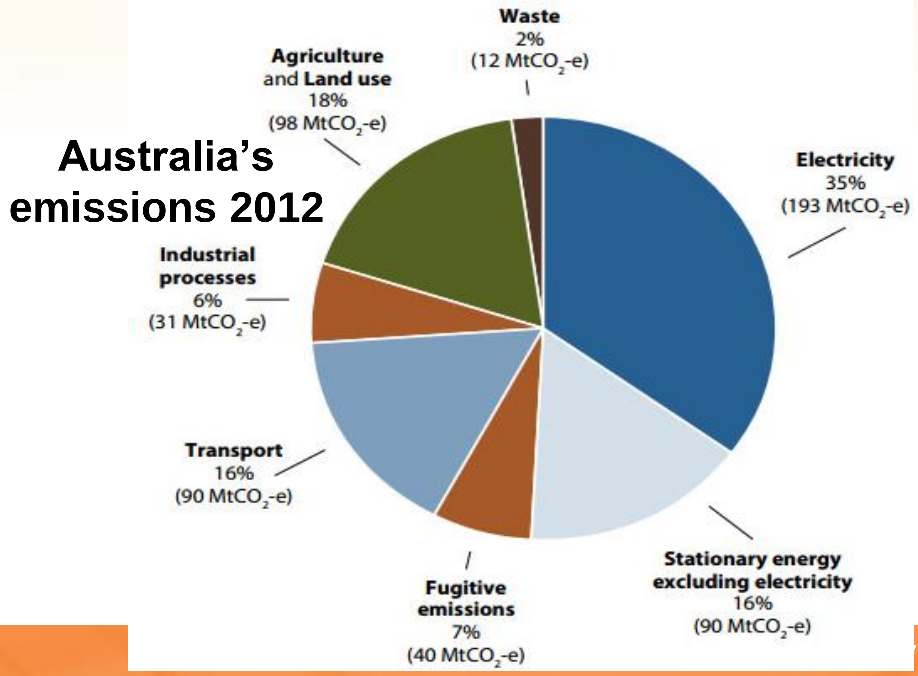
CEEM's emerging research priorities

- Sustainable Energy Transformation
  - *Development of better electricity industry operational and investment models including high renewables penetrations, modelling studies of possible new market designs.*
  - *Analysis of integrated resource planning opportunities and challenges for low-carbon transition particularly looking at future grids.*
- Energy & Environmental Market Design, related policies
  - *Energy and environmental market designs for emerging operational and investment challenges, Empirical analysis of existing designs.*
  - *Extension into market integrity and distributional impacts.*
  - *Analysis of China's pilot emissions trading schemes and potential impacts on electricity sector. Investment modelling for Chinese electricity with a particular focus on State owned enterprises*. *Accounting implications of a carbon price in China*
  - *Analysis of reporting and disclosure of significant carbon inventory of fossil fuel companies, particularly how climate change risks are integrated in asset valuation, implications for markets*
- Energy-related decision making for distributed energy
  - *Better economic and commercial assessment tools for different options such as PV, electric vehicles and distributed storage integrated into distribution network*
  - *Retail market design to facilitate distributed energy opportunities. Empirical analysis of current market performance, models for testing possible new market designs.*
  - *Frameworks for greater community engagement in energy decision making.*

Challenges in the electricity industry

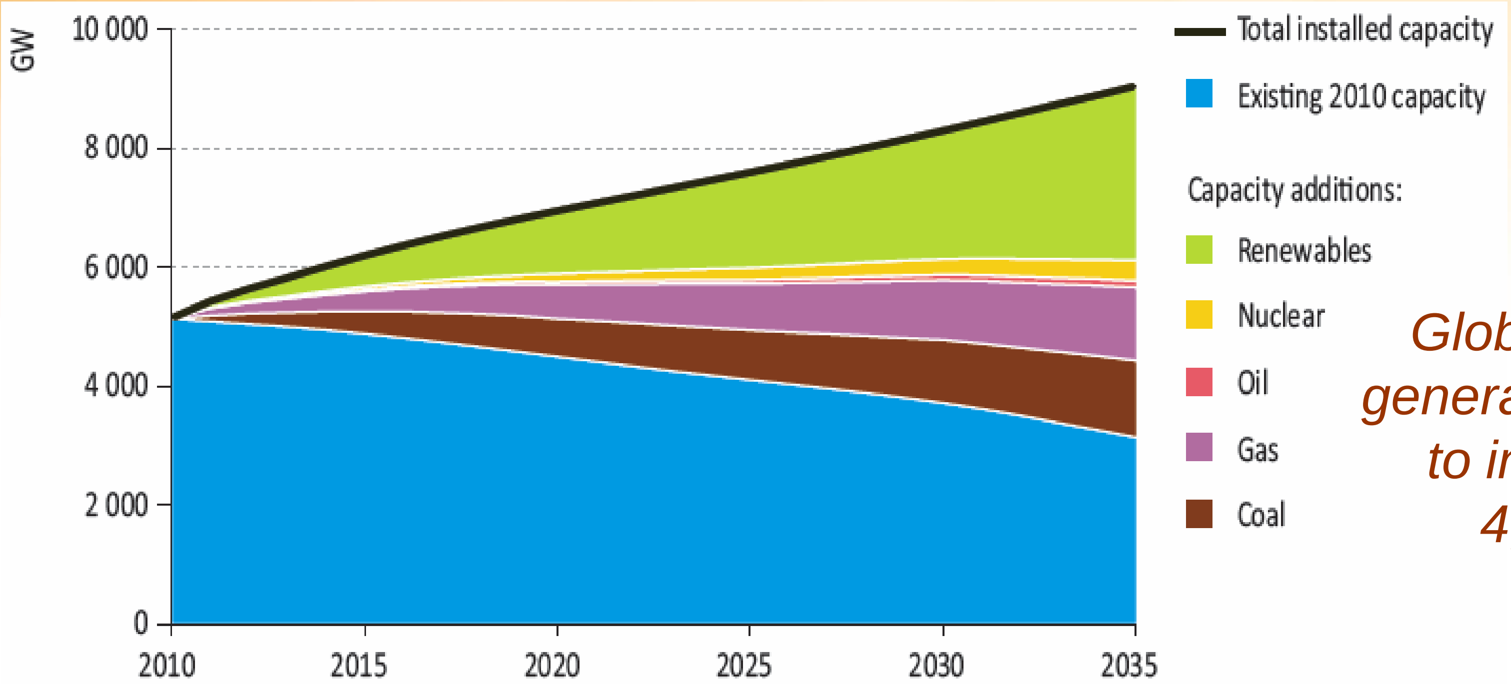
- Increasing challenges for electricity industries around the world
  - Rapid and highly uncertain demand growth
  - Energy security concerns – Aging infrastructure, high dependence on fossil-fuels.
  - Environmental sustainability – the electricity sector is the largest single contributor to global GHG emissions (IEA, 2012).





Challenges in the electricity industry

- $17 trillion of global investment is required over the next 20 years to expand infrastructure and meet demand growth (IEA 2012)
  - 60% in generation capacity, 40% in network.



Global installed generation capacity and additions by technology type (IEA, 2011)

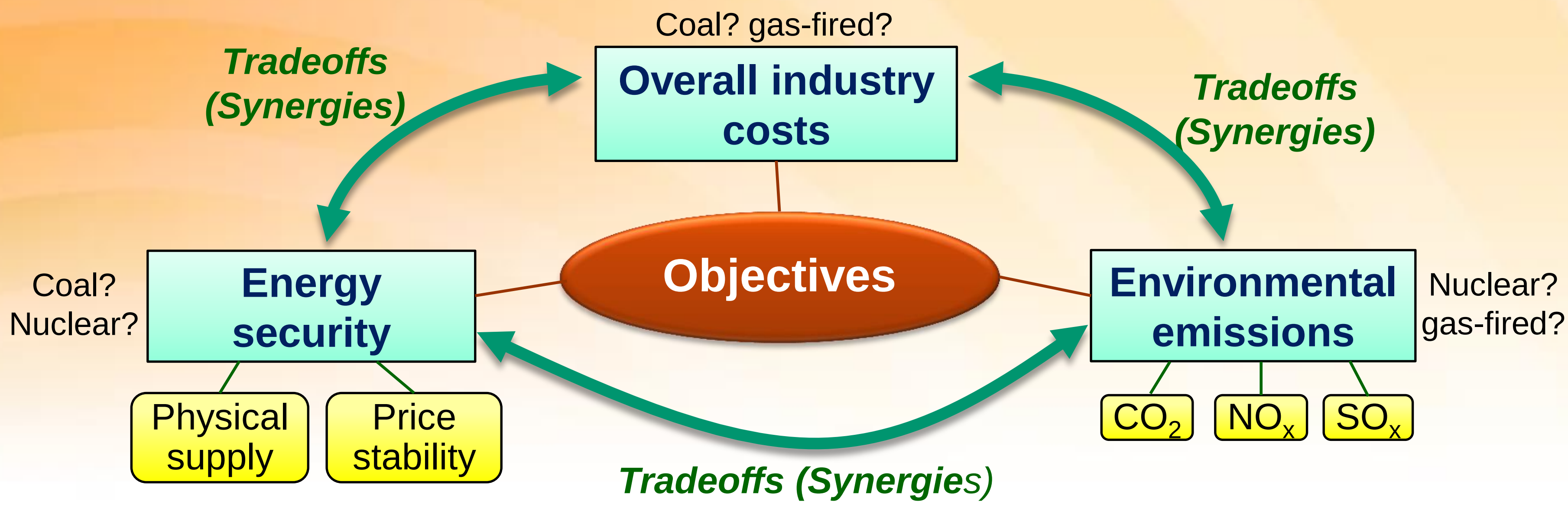
Global installed generation capacity to increase by 4,000GW

Generation investment and planning decisions

- One of the most critical and challenging decisions
  - Complex nature of generation investment: capital intensive, long-lived assets, significant lead times, irreversible.
  - What, when, where and how much to build
  - Must commit large investments ahead of time.
- Different generation investment options with different characteristics (economic, operating, emissions)

Technology	Capital cost	Operating cost	Emissions
Coal-fired	High	Low	High
CCGT	Moderate	Moderate	Moderate
OCGT	Low	High	Moderate
Nuclear	Very high	Low	Low
Renewables	High	Very low	None

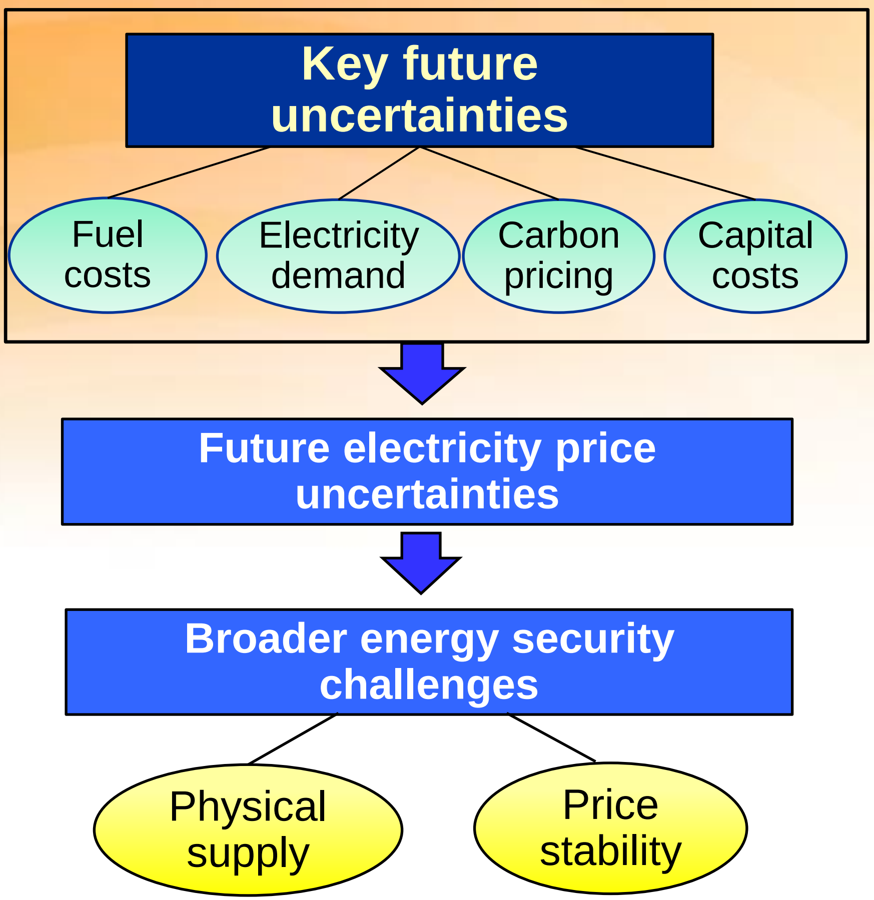
Multiple objectives in decision making



Potential conflicts between these objectives in many countries

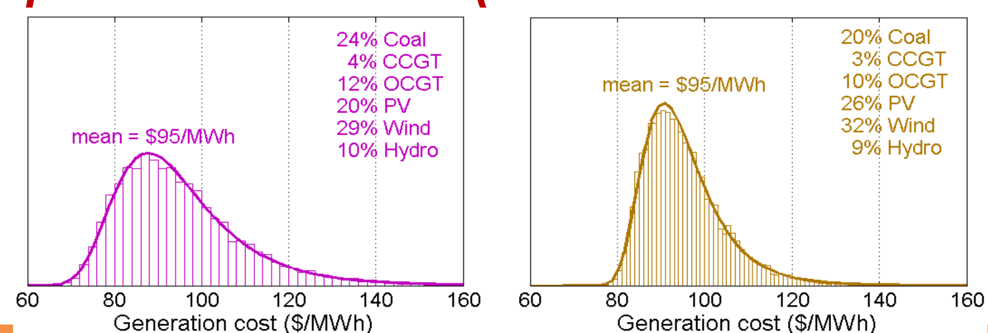
- **Coal plants** - *cheap* to run but *high emissions*.
- **Gas-fired plants** - *energy security concerns* but *low emissions*.
- **Nuclear** - *expensive* to build but *zero operating emissions*.

High uncertainty



- 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
  - Flexible generation fleet that can cope with uncertainty and risk

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



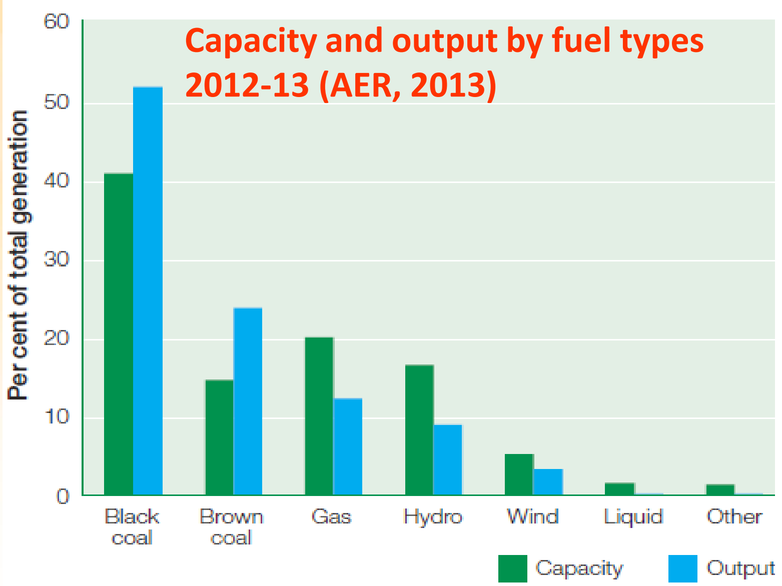
The Australian National Electricity Market

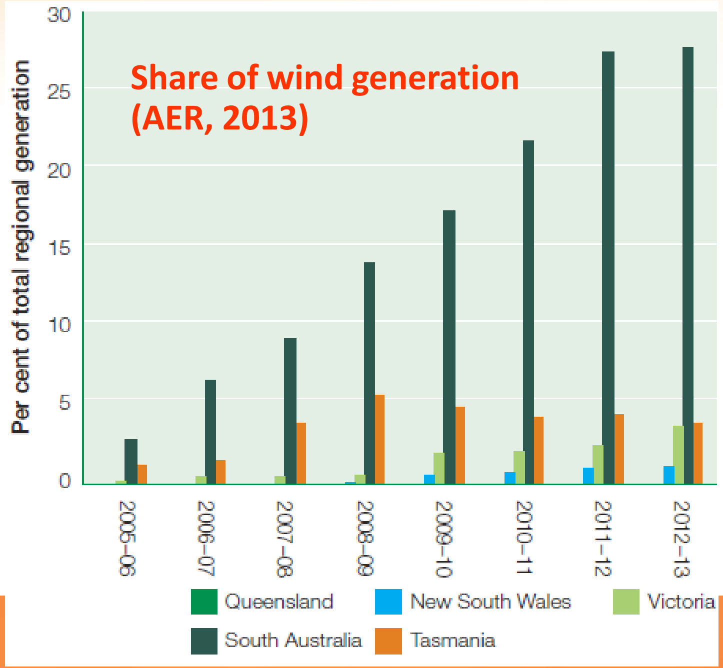
(AER, 2013)

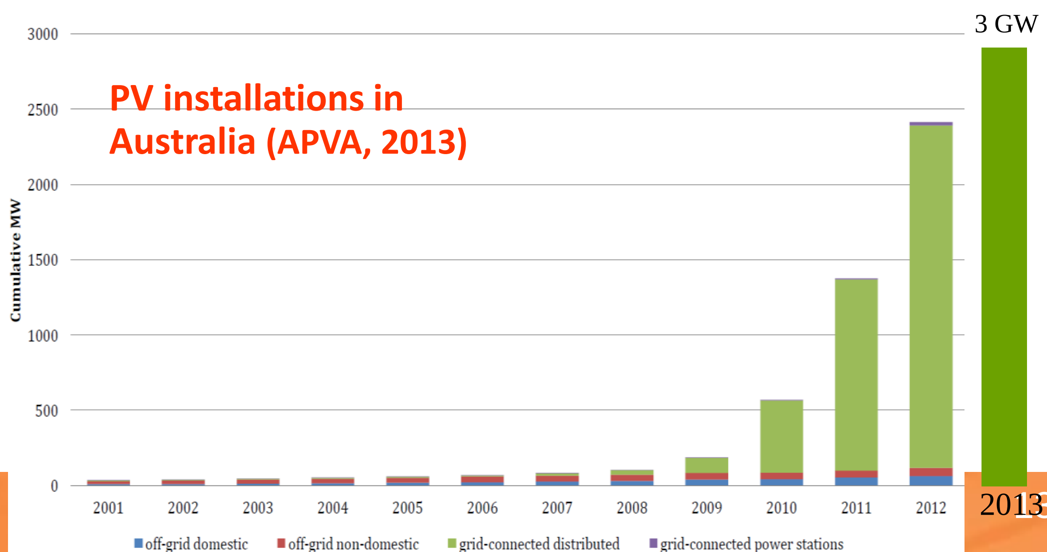
- Australian National Electricity Market (NEM) covers all Eastern States – 90% of electricity demand.
- Installed capacity: 50 GW
- Peak demand: 35GW
- Annual energy: 190 TWh
- Energy only market
  - Reliability standards: 0.002% of unserved energy
  - Price cap: $13,500/MWh (2013-2014)
  - Price floor: -$1,000/MWh

Electricity generation in the NEM

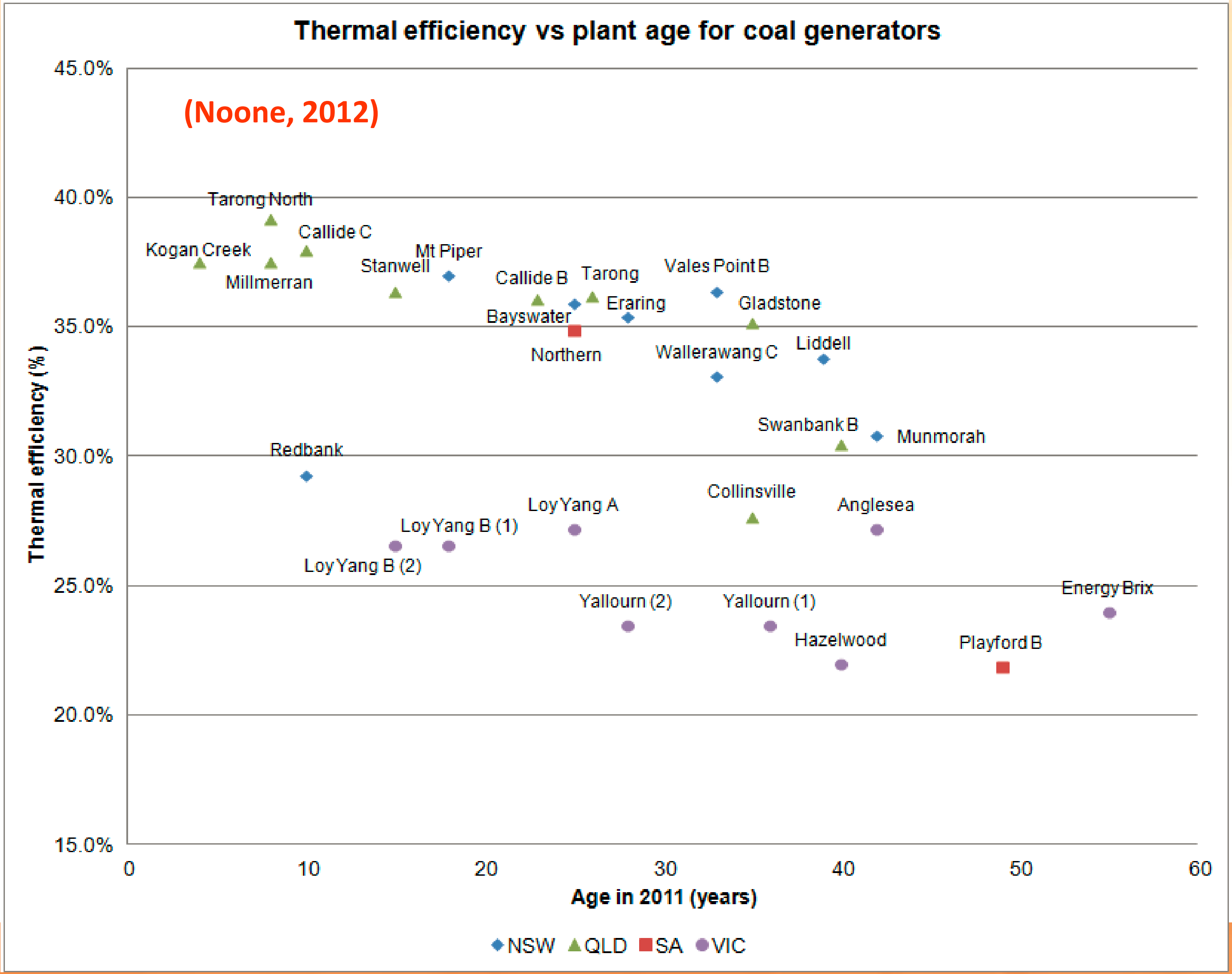
- Capacity consists largely of coal with some gas, hydro and wind
  - Around 15% renewables
  - Aging generation fleet
  - Recent growth in wind and solar PV







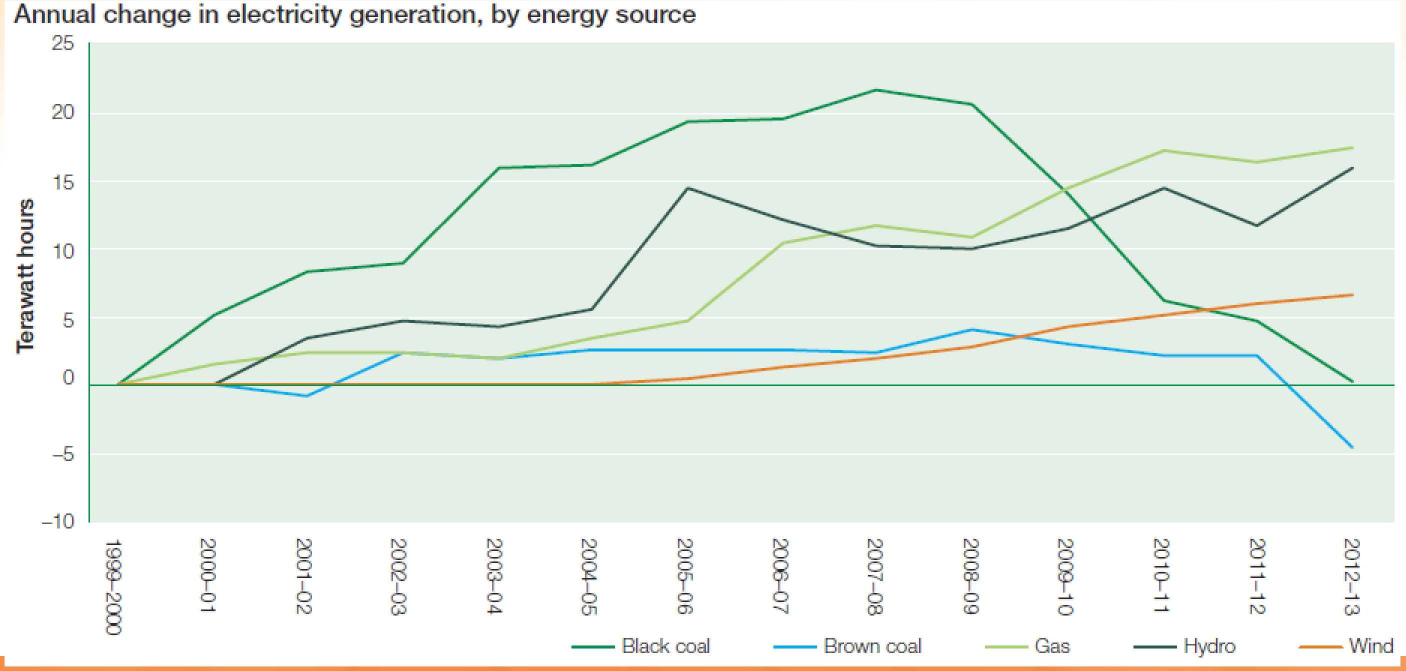
Electricity generation in the NEM



Aging generation fleet (and inefficient)

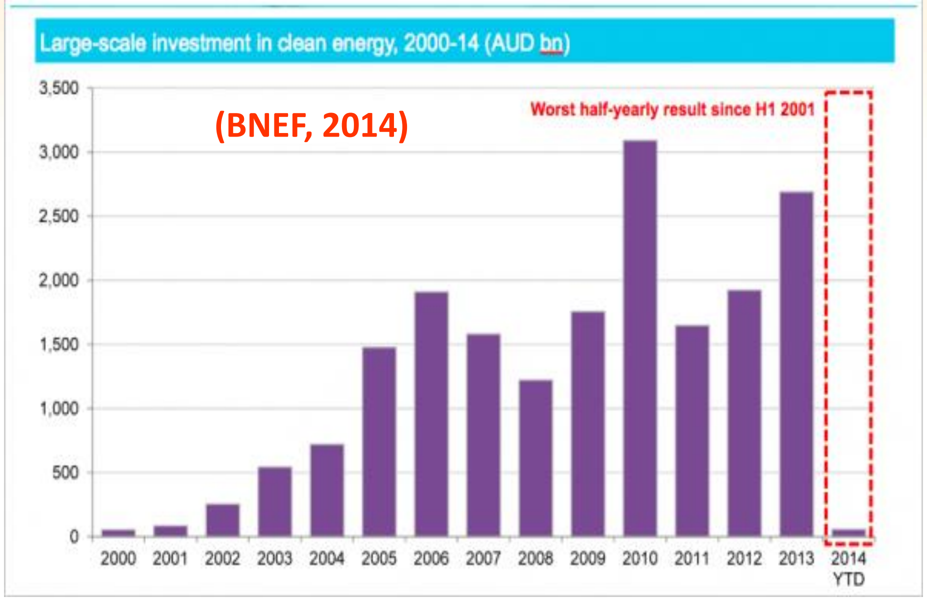
Future generation investment in the NEM

- 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.

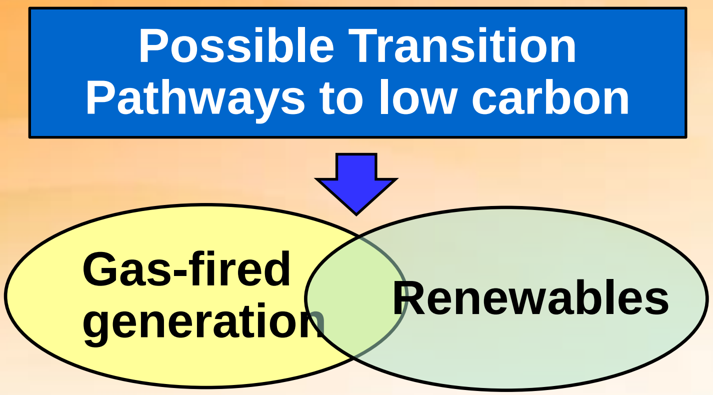


Interesting times in Australian Energy Policy

- 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
  - 41 TWh (20% based on 2010 demand) by 2020
  - RET is currently under review by the Government – high uncertainty.

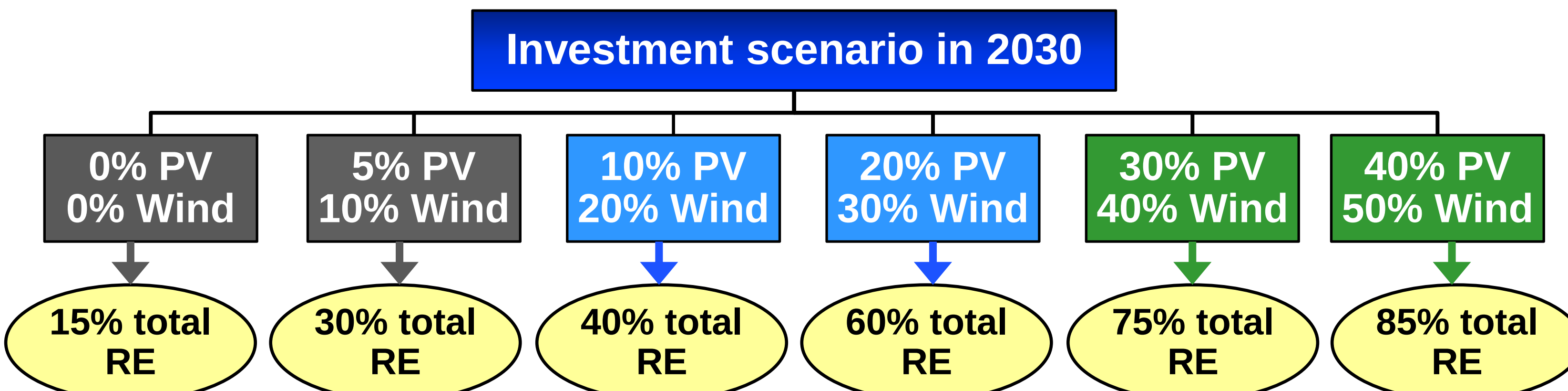


Modelling generation investment in 2030

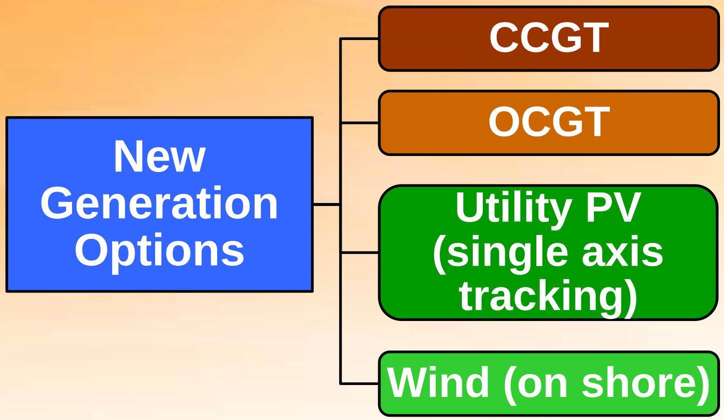


Examining different generation investment scenarios for 2030 in the context of high uncertainty.

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



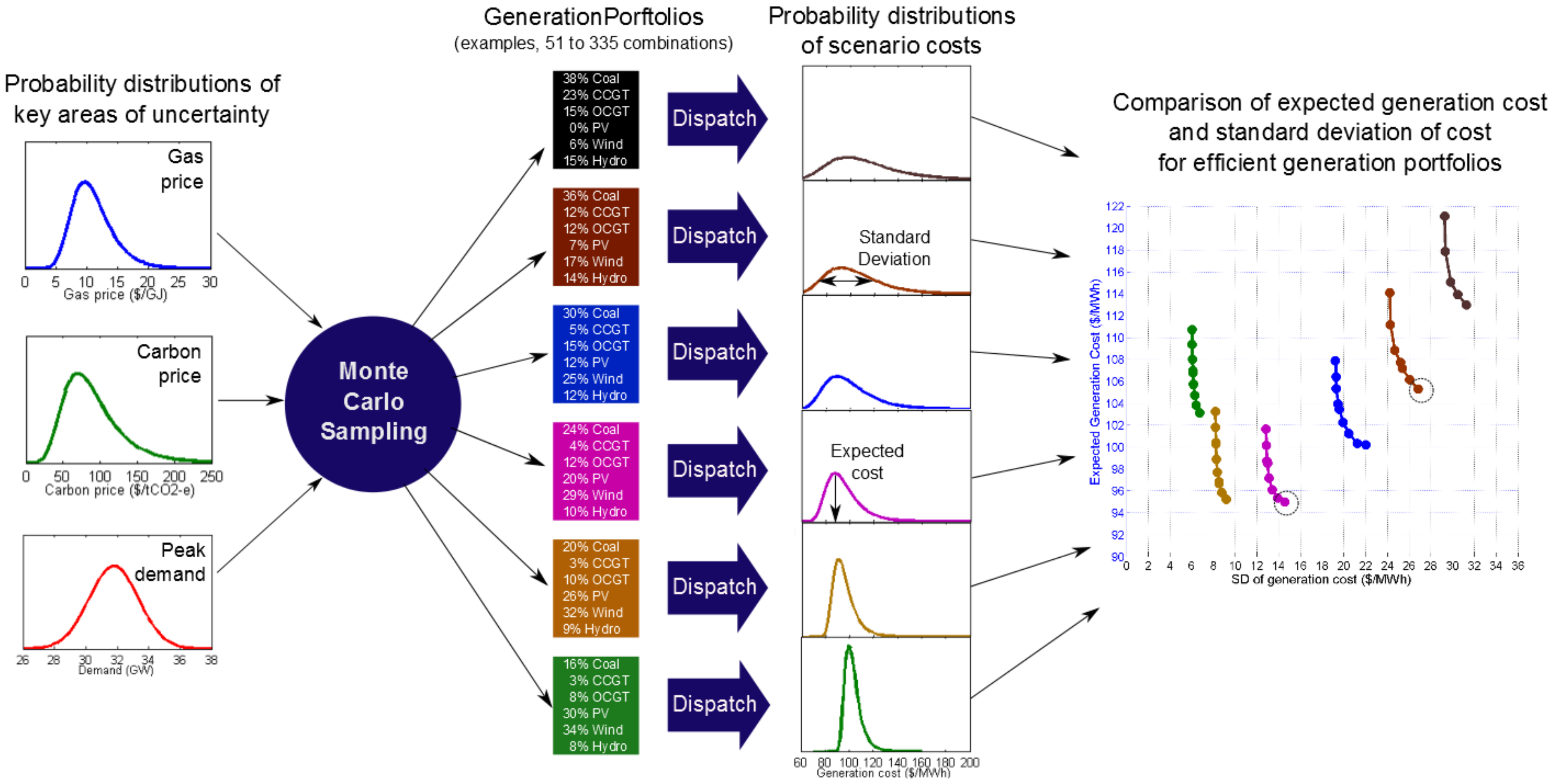
Modelling investment scenarios for 2030



- Four new generation options.
- Existing generation capacity (in 2013)
  - Coal, 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 coal (from zero to full retirement)

Probabilistic generation portfolio modelling

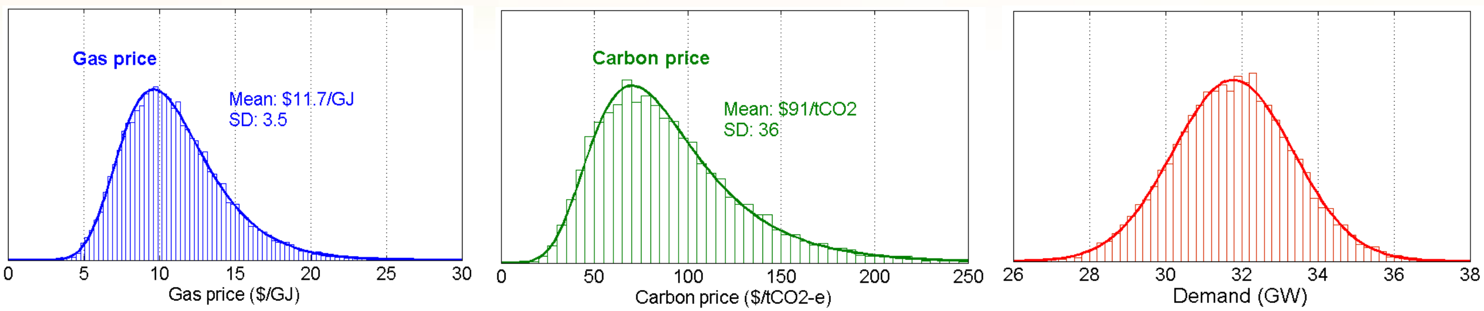


Modeling Inputs

Inputs

- **Generator data of each technology** — NTNDP (AEMO), AETA (BREE)
- **Hourly demand, wind & PV data for 2030** — AEMO 100% RE study
- **Prob. dist. of fuel prices, carbon price, demand** — Estimated from
  - AETA (BREE)
  - Australian Treasury modelling

- Lognormal dist. are applied to future gas and carbon prices.
- A normal distribution for electricity demand.

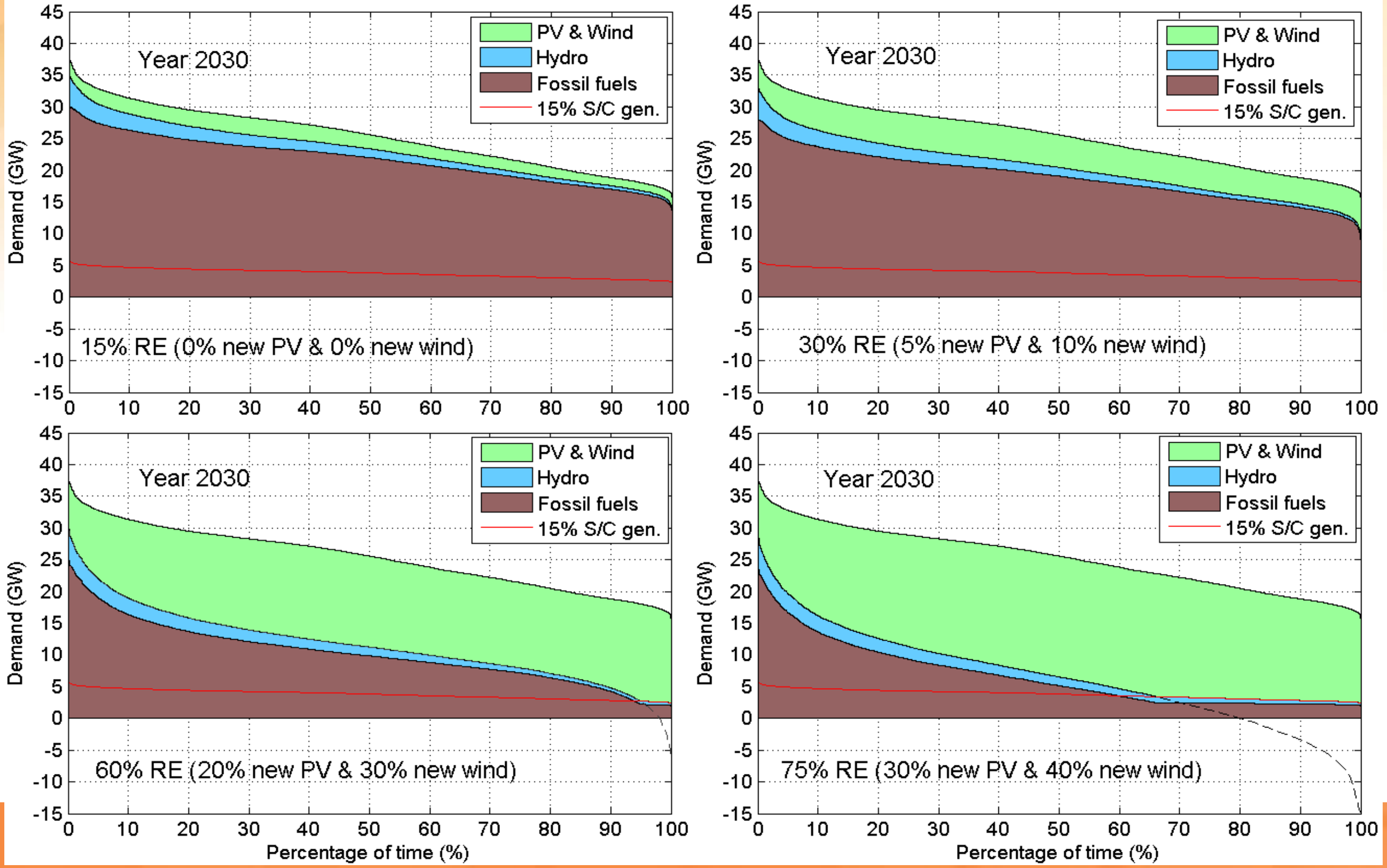


Histogram of gas price, carbon price and peak demand over 10,000 simulations

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

Generation dispatch

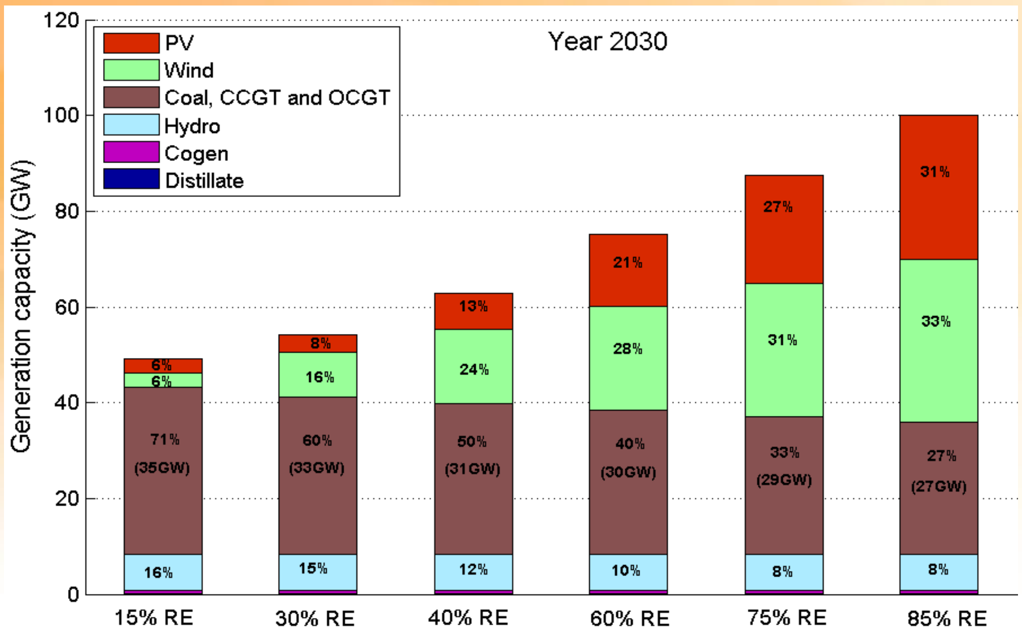
- Merit order dispatch in each period of the ***Load Duration Curve***.
- Priority dispatch for PV and wind – *treat as negative demand.*
- Minimum *synchronous generation* of 15% in any one hour period.



UC and operating constraints are not considered

Some spilled energy at high RE penetrations

Generation portfolios

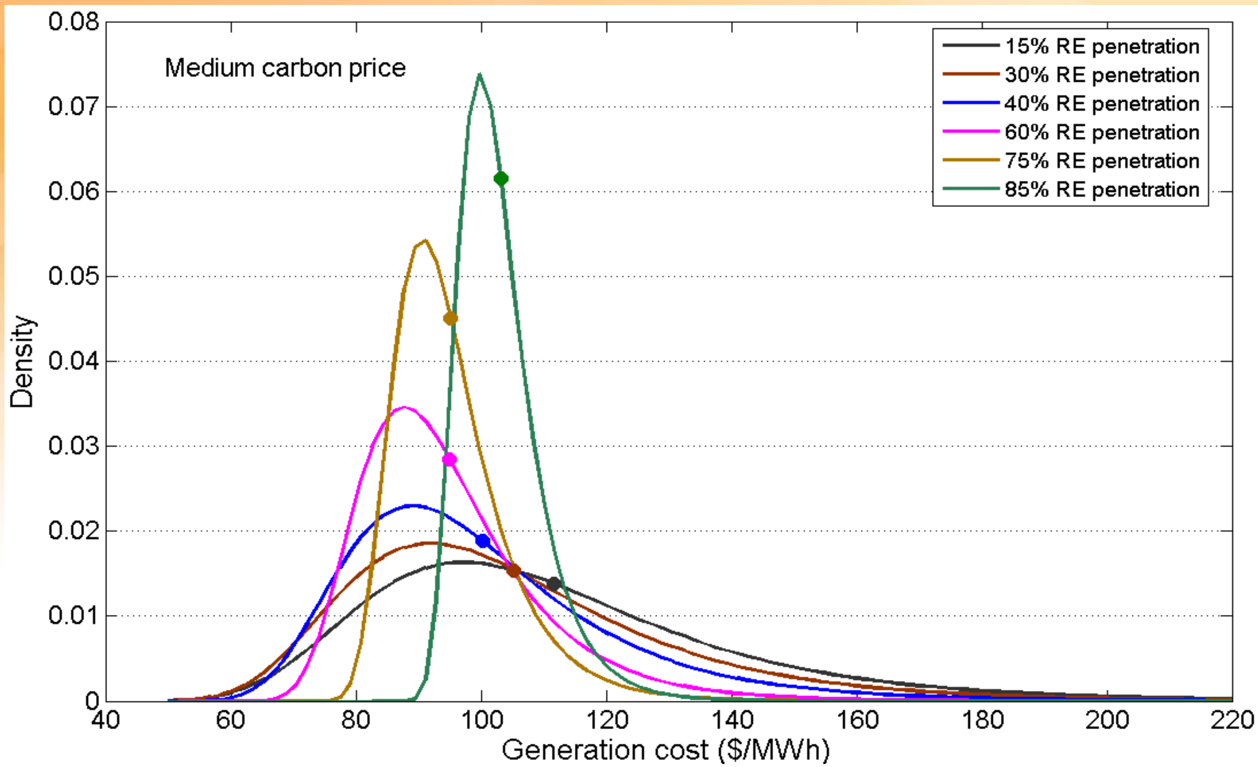


- PV and wind can displace fossil fuel generation (although lower capacity value).
- IC of fossil fuel (coal & gas) is determined based on NEM reliability standard (0.002% of unserved energy).

For each different investment scenario (each RE penetration)

- Analyse different possible permutation of 'fossil-fuel' generation mixes
  - *Vary the share of coal, CCGT and OCGT in 10% intervals (0% to 100%)*
  - *Max capacity of black coal in 2030 is capped at existing capacity (~20GW)*

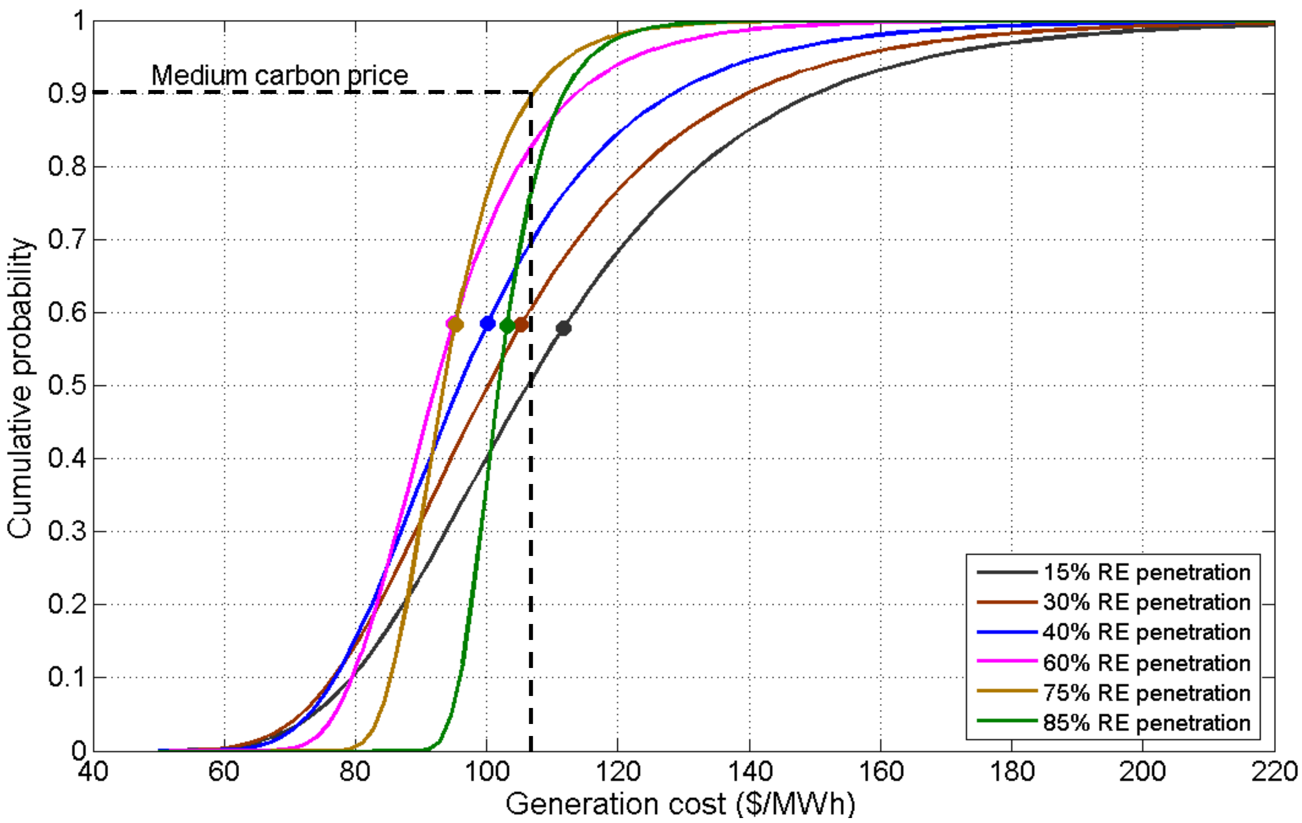
Comparing least-cost portfolios



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

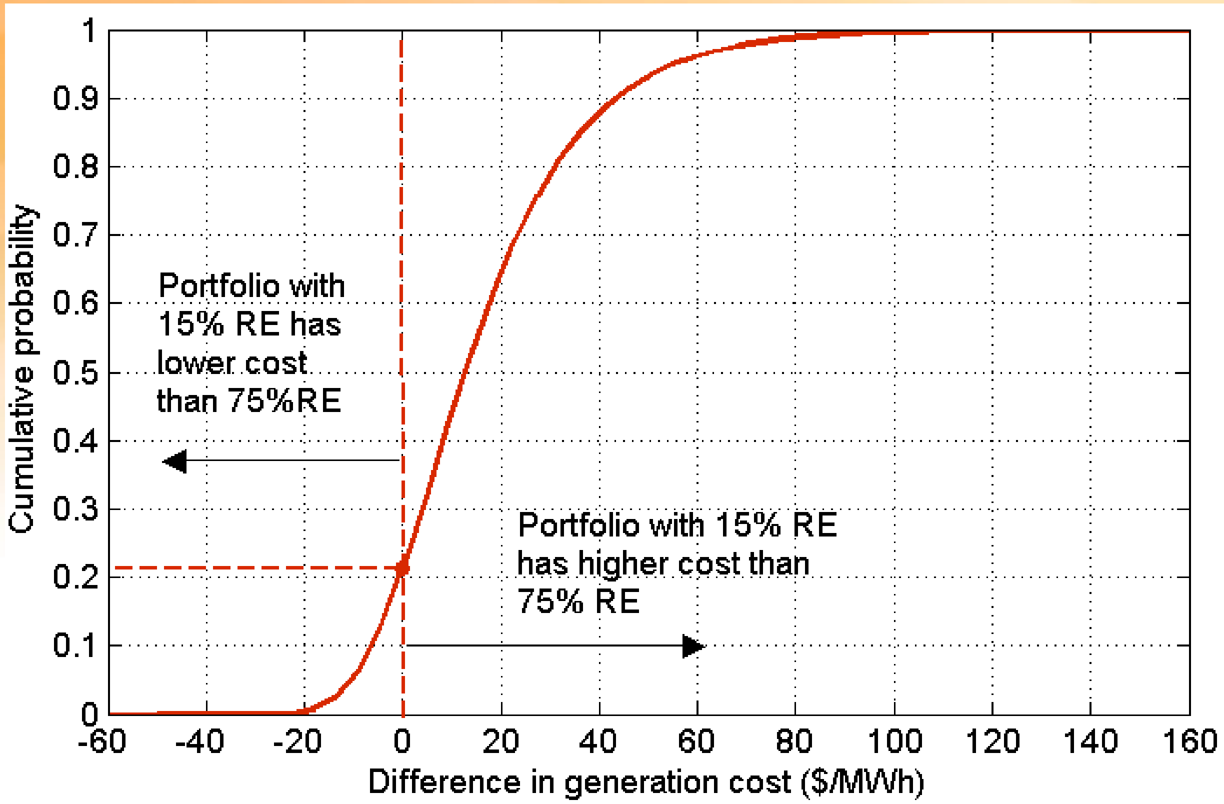
Comparing least-cost portfolios



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

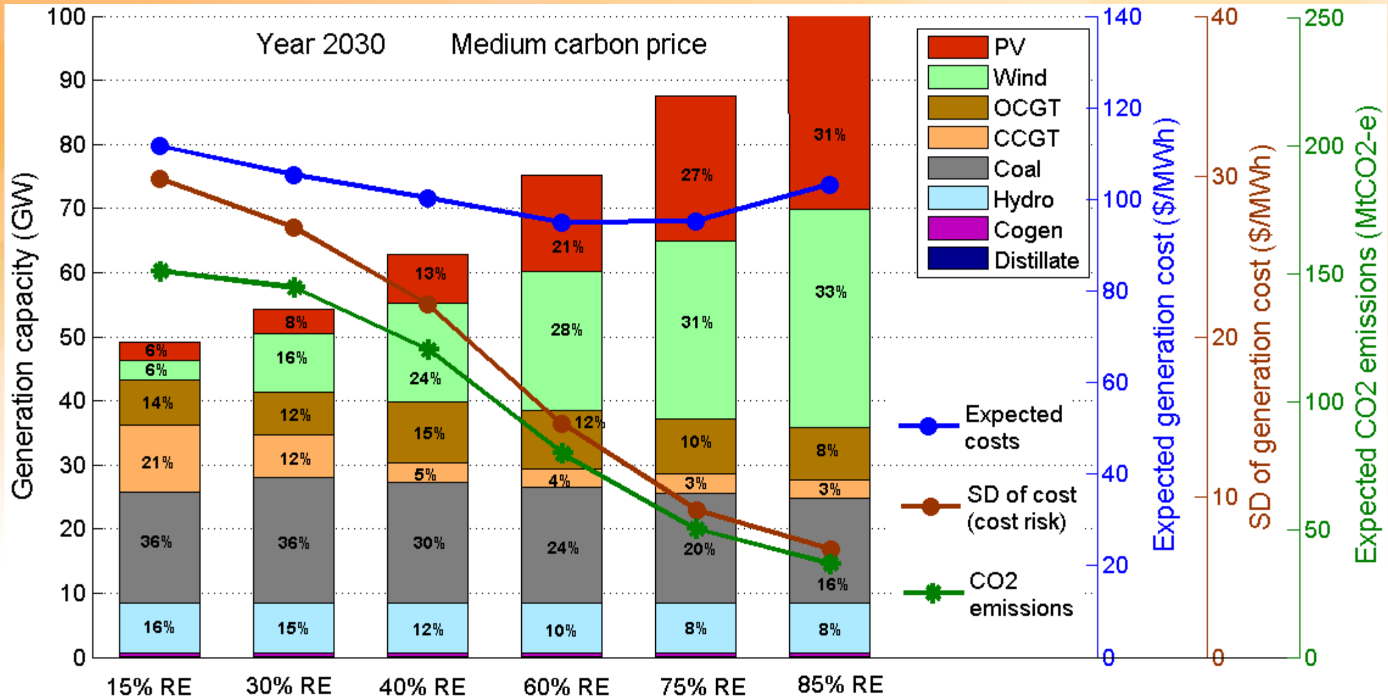


Risk associated with choosing between generation portfolios

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

Comparing least-cost portfolios



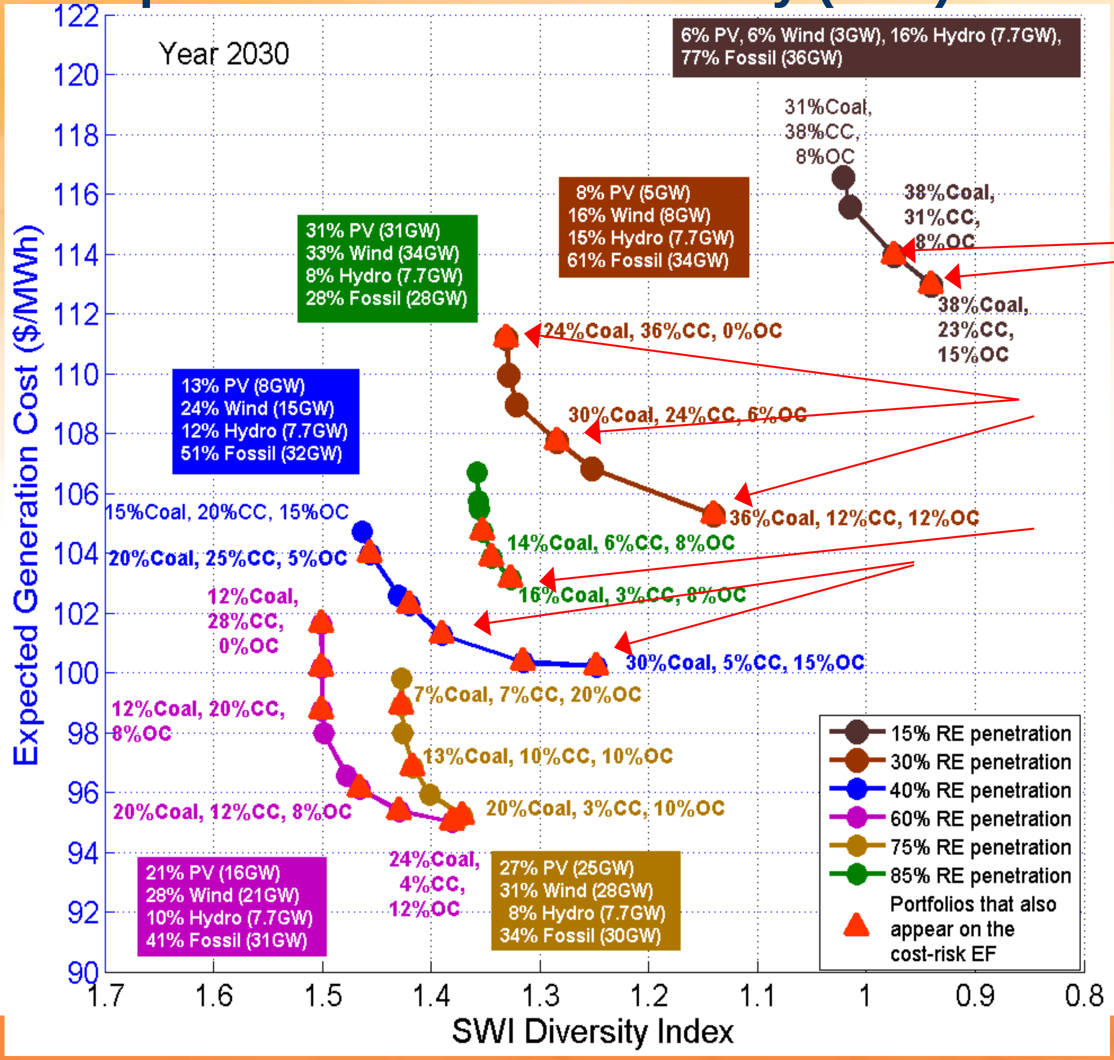
'Least cost' portfolios for each RE penetration

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

- System installed capacity increases considerably with higher RE.
- Capacity of coal and OCGT changes only very slightly.
- Significant decline in ***cost risk*** and ***emissions*** as RE increases.
- The overall cost is minimised at around 60% - 75% RE penetration.

Security of Supply – fuel diversity

Expect cost VS fuel diversity (SWI)

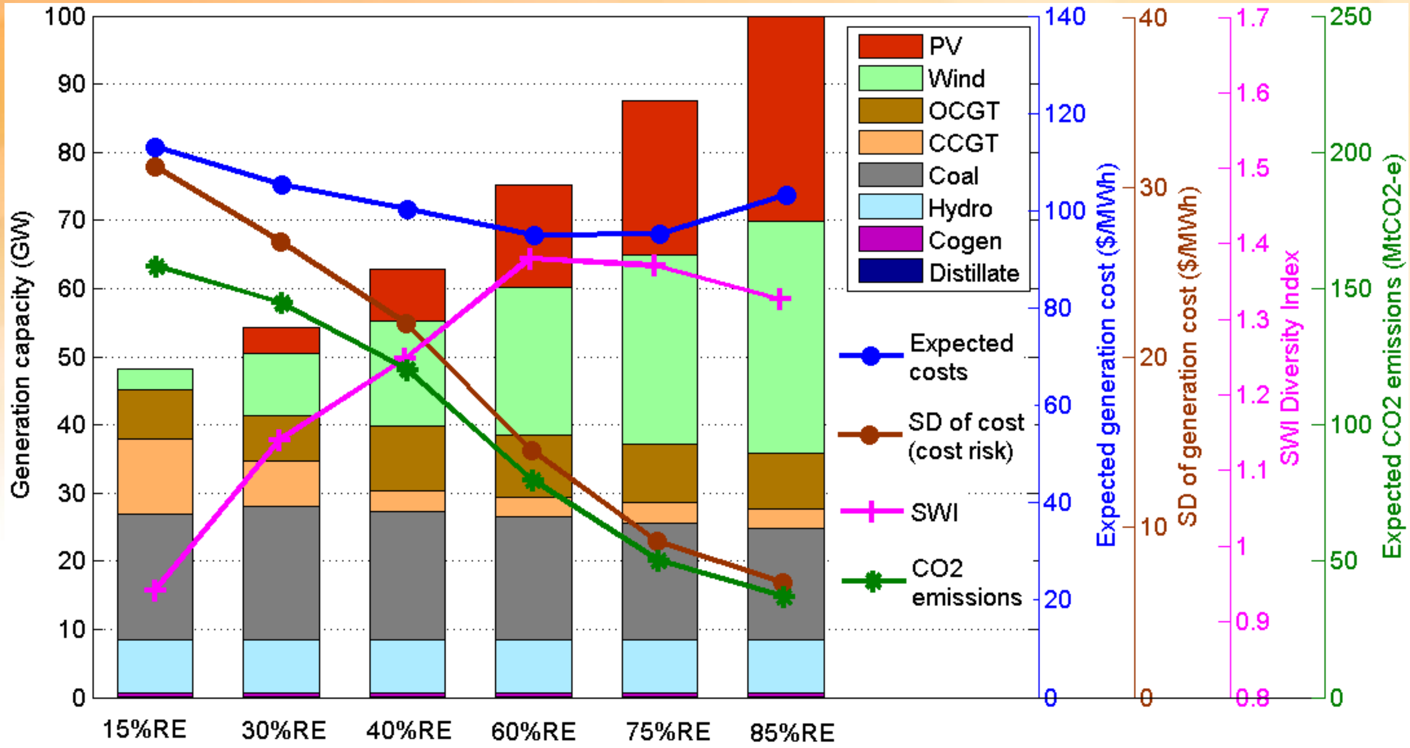


- Using ***Shannon Wiener Index (SWI)*** to measure fuel diversity (i.e. physical supply risk)

Reductions in both ***expected cost and fuel diversity (SWI)*** as RE increases from 15% to 60% ***(Downward movement of EF)***

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

Security of Supply – fuel diversity

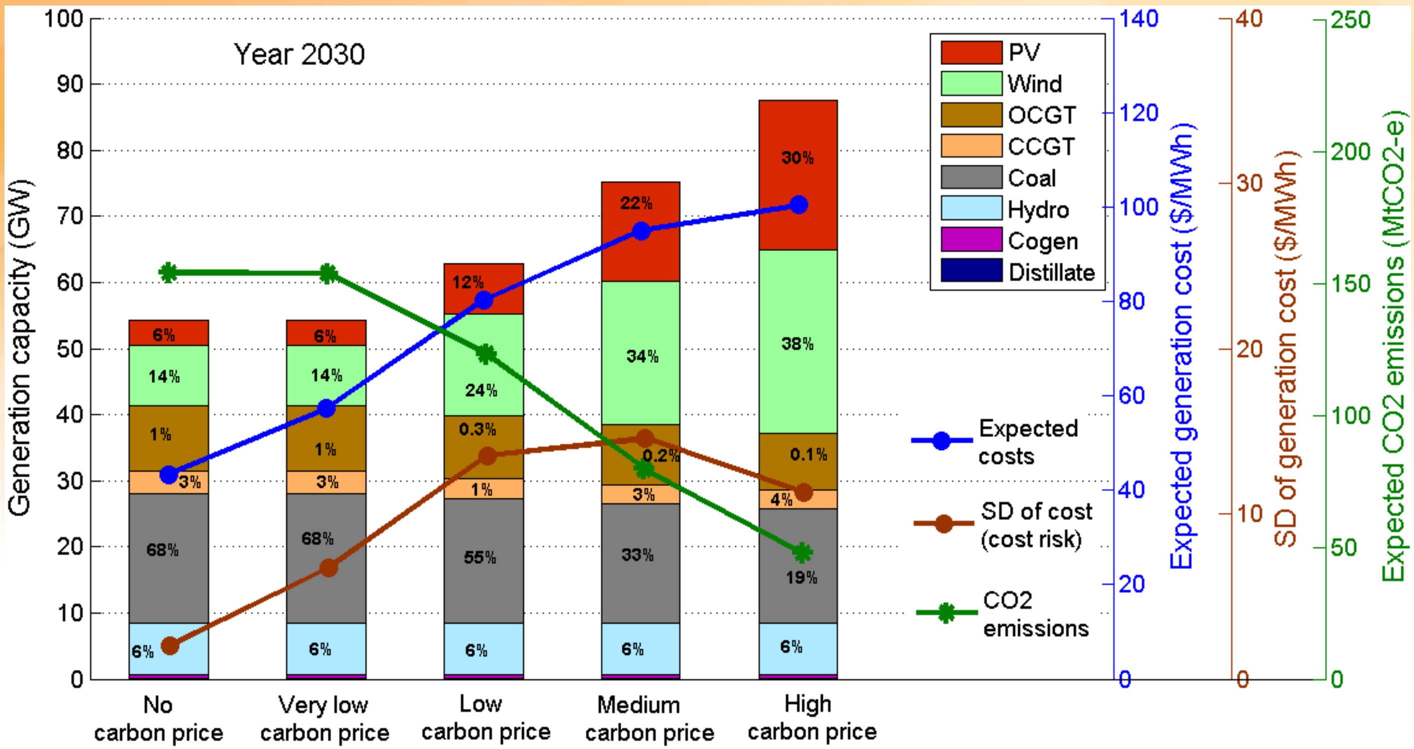


'Least cost' portfolios for each RE penetration

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

- Generation portfolios are well diversified at 60%-75% Renewables
  - Note this is in addition to low cost, associated cost risk and emissions

Different carbon pricing scenarios

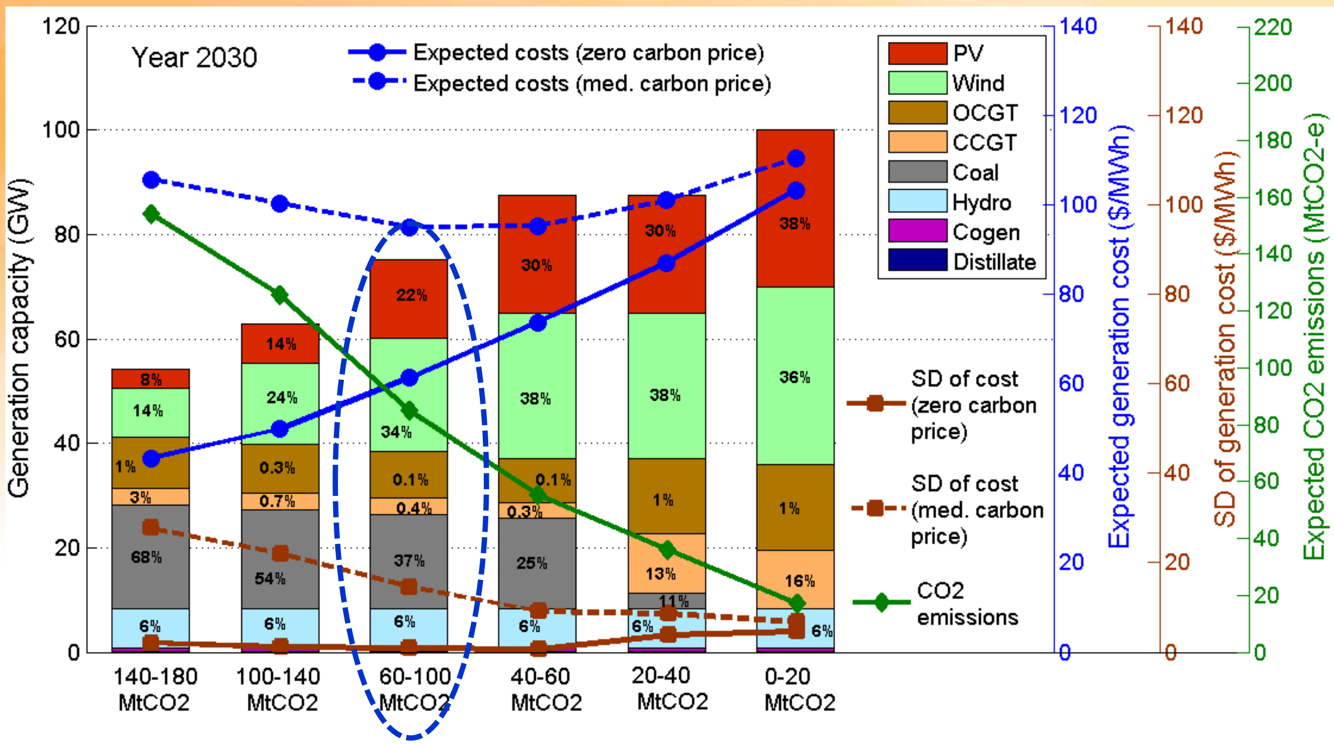


'Least cost' portfolios for different carbon pricing scenarios

- **Zero**
- **Very low ($20/tCO$_2$)**
- **Low ($54/tCO$_2$)**
- **Medium ($91/tCO$_2$)**
- **High ($115/tCO$_2$)**

- Coal and gas capacity remain the same for all carbon prices (existing capacity) - *No new CCGT installed for any carbon prices*
- RE still provide effective cost risk mitigation at low carbon prices
- Portfolio cost is heavily driven by the different carbon prices

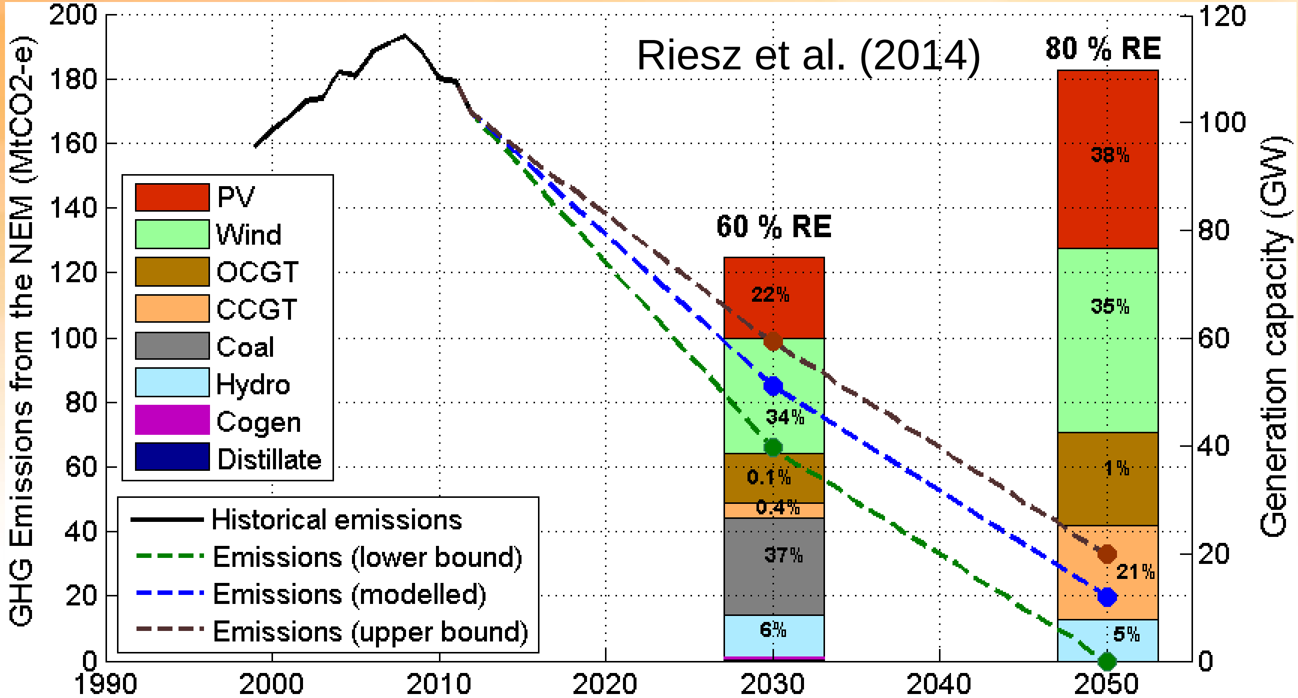
Options for achieving emissions targets



Least cost portfolios in achieving certain emission targets in the near term (2030)

- Role of base-load CCGT is minimal (except for very low emission targets)
- Emissions targets in 2030 is 40%-60% from the 2000 levels (i.e. need to reduce the emissions to around 60-100 $MtCO_2$ by 2030)
  - ➢ Large amount of RE, minimal CCGT, some existing coal (as peaking gen.)

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
- Investment in RE is preferable to gas-fired generation due to high gas and carbon price uncertainty
  - An expansion of RE target appears as a suitable policy response
- 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
- Flexibility from the perspective of short term operation will need to be considered

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