Price Formation and Investment in a 100% Renewable Electricity Market

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The literature around very high penetration of variable renewable energy (VRE) in the electricity sector is focused on technical feasibility and on the cost of the technology. But assuming 100% VRE is technically feasible, achieving a market with 100% VRE requires investment in sufficient plant to meet demand. New Zealand has an energy-only market in which expectations of future spot prices are a key driver of investment decisions by firms. This research looks at the question of how spot prices will be formed with 100% VRE under various physical configurations and government interventions, and the conditions that need to be met to ensure that the investment required to achieve 100% will be forthcoming.

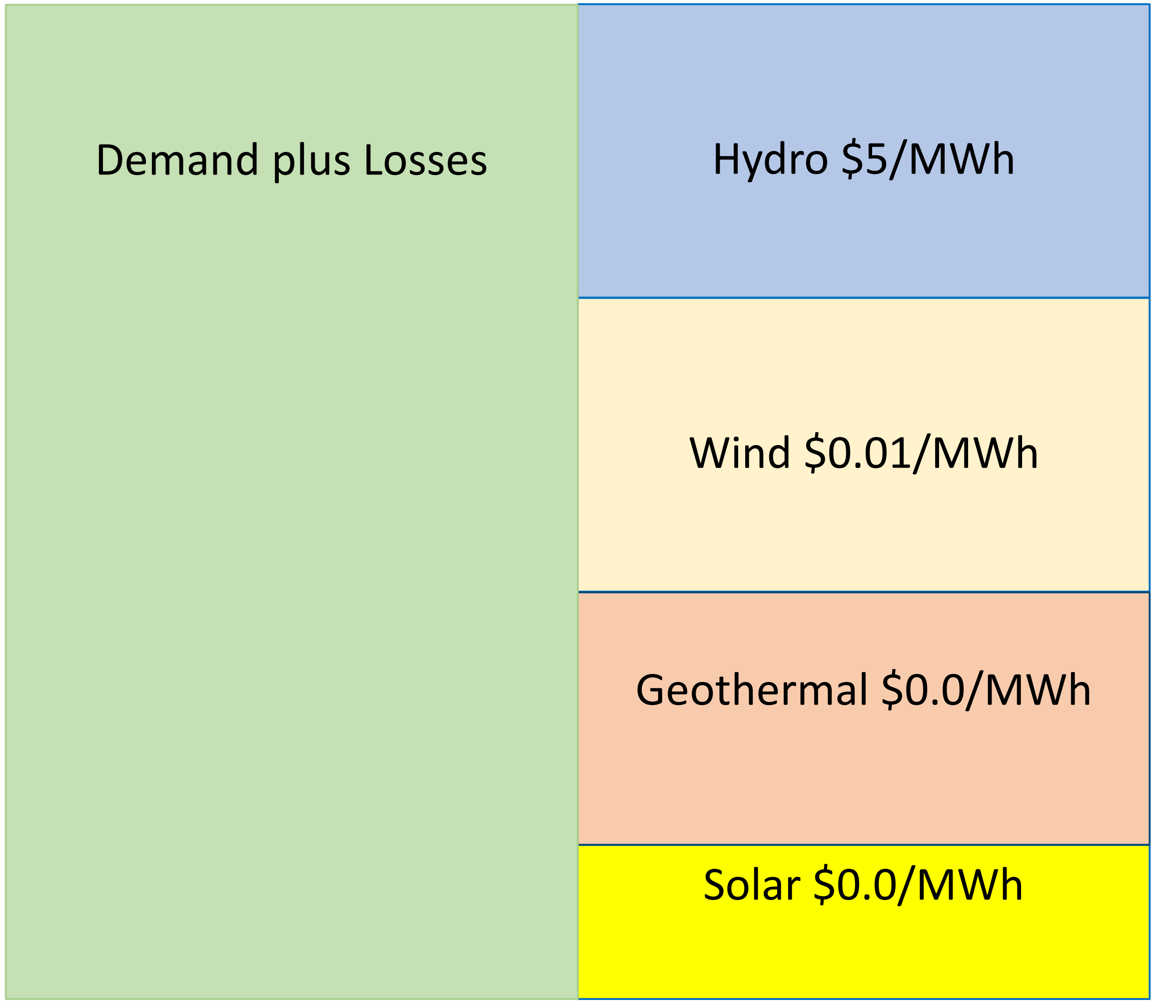
Motivation

- Our primary interests are the level and dynamics of prices, and the environment for investment in new generation with 100% renewables
- The literature has lots of papers showing that 100% renewables is technically feasible
- And lots of papers showing the technology is available at reasonable cost
- BUT, modelling we've undertaken in the last three years suggests there might be a problem:
  - we've sometimes found it difficult to achieve a stable market outcome at 100% renewables

The NZ Energy-only Market Simplified

- Generators offer to generate at a price in each half hour
- Assuming competition is at adequate levels, offer prices should reflect short-run marginal costs (SRMC, costs that vary with production)
- Price is set by the highest offer dispatched

Spot price set at $5/MWh – all generators receive this price



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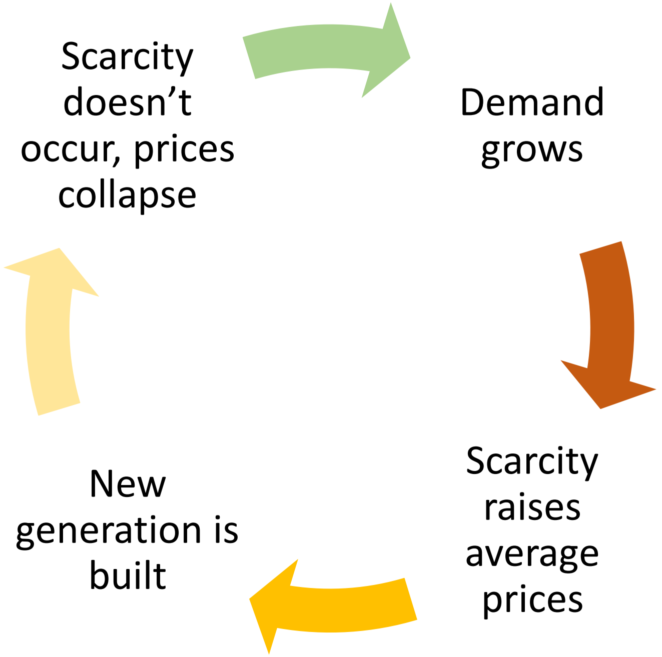
The Potential Problem

- **Prices could be very low, and too low to attract investment in new generation**

- **EXCEPT when there is a shortage, in which case prices can rise to $10/kWh and higher ("scarcity prices")**
  - **and some consumers have their lights turned off**

- **Potential for 'vicious cycle' and unstable market**



- **100% renewables may not deliver secure supply**

- **Consumers may be frustrated and generators deterred (from building new plant) by exaggerated boom-bust cycles**

Key Metrics

$\frac{\Delta\bar{S}}{\Delta G}$ is the change in the average annual spot price, $\bar{S}$, when the next cheapest increment of generation, ΔG, is added to the market.

$LCOE_{\Delta G}$ is the "levelised cost of electricity" of the next cheapest increment of generation, ΔG, and is the "constant average annual electricity price attained by the plant over its lifetime that just achieves target return on investment after covering all cash costs", e.g. $60/MWh for a new windfarm

SLR is what we euphemistically refer to as "supply of last resort" which could mean dispatching very expensive plant, but it could also simply mean non-supply (scarcity, lights out!)

Research Questions & Method*

1. Is the current structure of NZ's electricity market capable of delivering prices which reflect costs?
2. Will the risks and incentives on generators ensure that new plant is built in time to meet demand growth?
3. If not, what conditions must be met to achieve prices that are cost-reflective, at the same time as investment is feasible?

1. Simulate variations on the 100% renewables market
2. With and without pumped hydro storage in each island
3. With varying amounts of demand-response at varying prices ("dispatchable demand")
4. We're looking for configurations with
   1. "low" $\frac{\Delta \bar{S}}{\Delta G}$
   2. $\bar{S} \geq LCOE_{\Delta G}$
   3. $SLR = 0$

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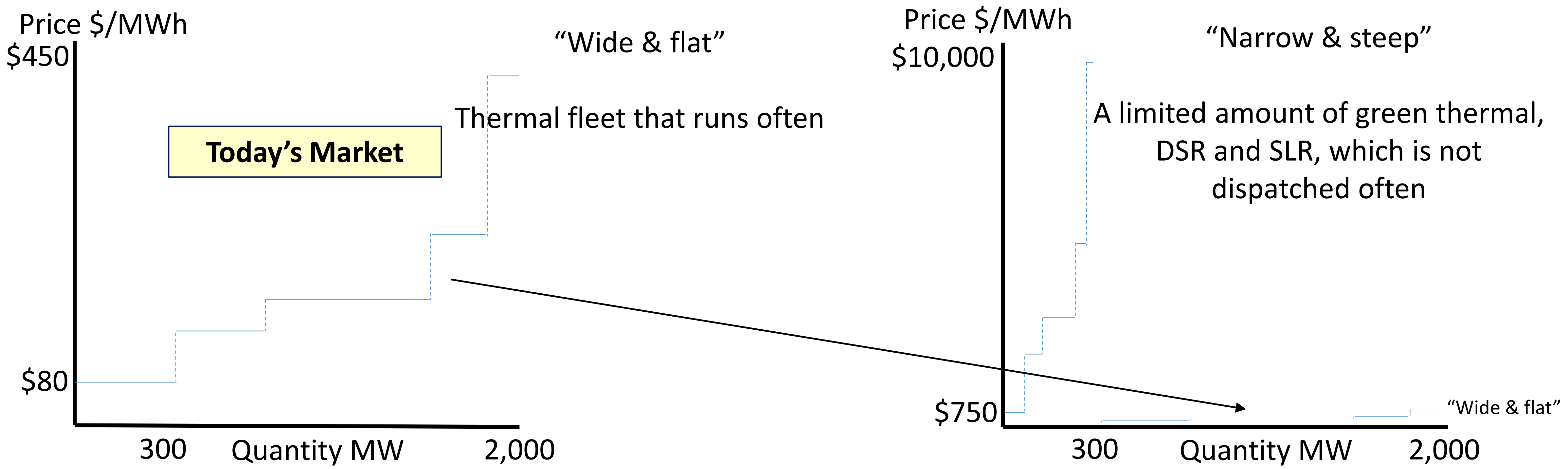
* *The Electricity Authority has a similar project running*

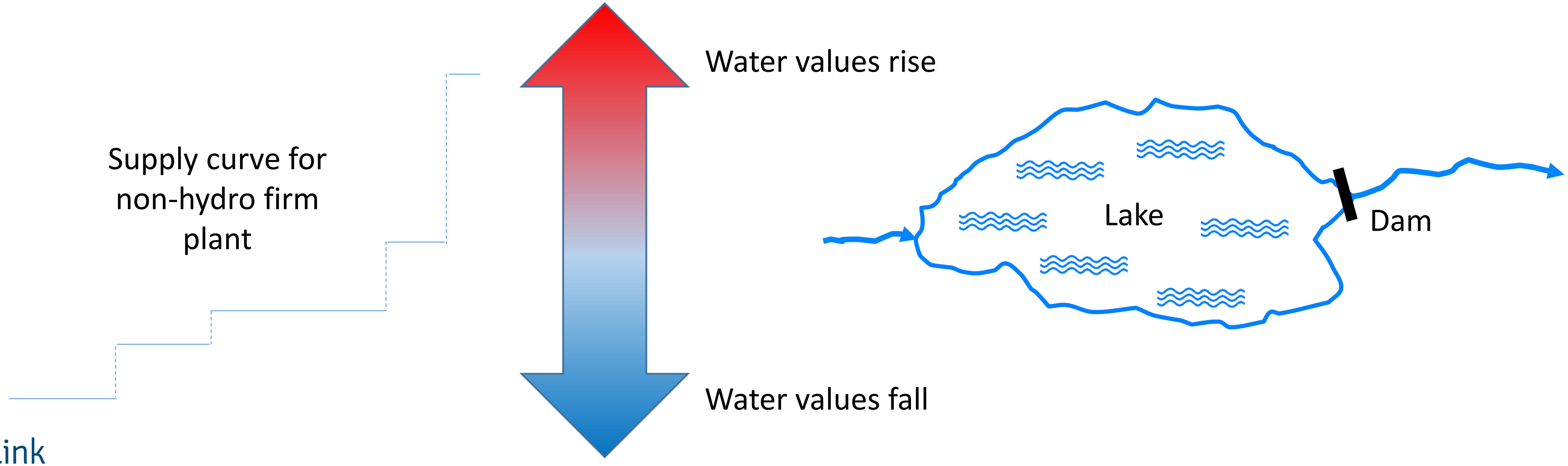
Delving Deeper - Supply Curve for "Firm, Flexible Plant"

- Today's market has a 'firm, flexible' thermal fleet that runs often at a relatively low price
- Most new VRE built in future will be uncontrollable and "non-firm", e.g. windfarms, solar, or "non-flexible", e.g. geothermal



Behaviour of Hydros with Storage

- Hydro generators with storage, value stored water with reference to (amongst other things) the supply curve for non-hydro firm, flexible plant:
  - if the supply curve doubles in price, for example, then water values have to double, otherwise the lakes will run low and shortage could result
  - if the supply curve halves in price, for example, then water values have to halve, otherwise the lakes will over-fill and excessive spill could result



Elements of the Simulated Market

- We use our *EMarket* market model:
  - market dispatch by hour with nodal spot pricing (current NZ market)
  - the grid - 220 nodes and 200 lines
  - demand and demand-side response (DSR and SLR)
  - hydro generators with storage lakes, river chains and water values
  - geothermal generators
  - windfarms
  - solar farms
  - BESS – battery energy storage systems
  - PHES – pumped hydro storage
  - green thermal plant, e.g. peaking generation powered by green hydrogen

Simulated Configurations

- **Initial modelling (in progress) consists of 50+ runs for 2040**
- **Three configurations:**
  - **100% renewables, no PHES**
  - **100% renewables, Onslow PHES (5,000 GWh storage)**
  - **100% renewables, Onslow PHES, 500 GWh PHES in the North Is**

New plant built (MW)	-50	+0	+50
Width of supply curve for non-hydro firm, flexible plant (MW)	-50	+0	+50
Steepness of supply curve (cents/kWh)	30 – 100	50 – 500	200 – 1,000

- **These runs will give us an initial set of** $\bar{S}, \frac{\Delta\bar{S}}{\Delta G}$**, and** SLR

Further Steps

- Initial 50+ runs will allow us to compare $\frac{\Delta\bar{S}}{\Delta G}$, in particular, to the current market using our model
- The next question will be: how much greater could $\frac{\Delta\bar{S}}{\Delta G}$ become before potential investors in new generation are deterred? What level of risk would cause them to seek returns elsewhere?
- Finally, what are the minimum requirements for the NZ market, with 100% renewables, to attract investment in new generation?
- We plan to complete by end of Q1 2022

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The End

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