Context:

- This pack was developed by the Climate Change Commission for internal analysis purposes and has been released as part of the consultation process. It is suitable for technical industry experts.
- This slide deck presents a summary of results from electricity market modelling of scenarios. The results were obtained used Energy Link's E-Market and I-Gen models. The purpose of the modelling was to complement our main modelling tool ENZ.
- This was an insight gaining exercise. There are limitations to this modelling piece and inherit uncertainties. Care should be taken in interpretation of the modelled results, particularly regarding long to term prices.
- There are short term market dynamics which are not reflected in this modelling. For example, market prices are currently being impacted by low hydro storage and high gas prices (as of February 2021) – these dynamics are not reflected in these results.
- This modelling exercise was completed in November 2020. Since this time the electrification scenarios developed in ENZ and presented in the 2021 Draft Advice and Evidence Reports have been further refined. The scenarios shown in this document bound the final scenarios shown in the advice report, but they are not exactly equivalent.
- The wholesale pricing result for the 'Central Pathway' shown in the 2021 Draft Advice Report is the modelled Tailwinds scenario shown here. The electrification scenarios are very similar and this is a valid approximation considering model accuracy and uncertainty.
- All prices are in 2020 real NZDs.

Electricity market modelling of CCC electrification scenarios

Completed Nov 2020

Updated for publication Feb 2021

He Pou a Rangi
Climate Change Commission

Context and purpose

The purpose of this work was to inform the Commission's evidence base and subsequent conclusions and recommendations regarding the build of new generation, retirement of assets, potential dry year solutions and a 100% renewable system, and the role of thermal generation in the electricity system. This was done with a view of understand the emissions consequences as the primary outcome, though security of supply and affordability considerations were included. Specifically, the purpose was to:

- Complement the basic electricity system of ENZ with Energy Link's more detailed market model.
- Include a detailed list of future generation projects.
- With dynamic demand modelling.
- Test electricity system with simulated hydro flows, wind and solar patterns.
- Validate ENZ market price and thermal operation.
- Gain insight into impact of Tiwai closure and Lake Onslow pumped storage scheme.

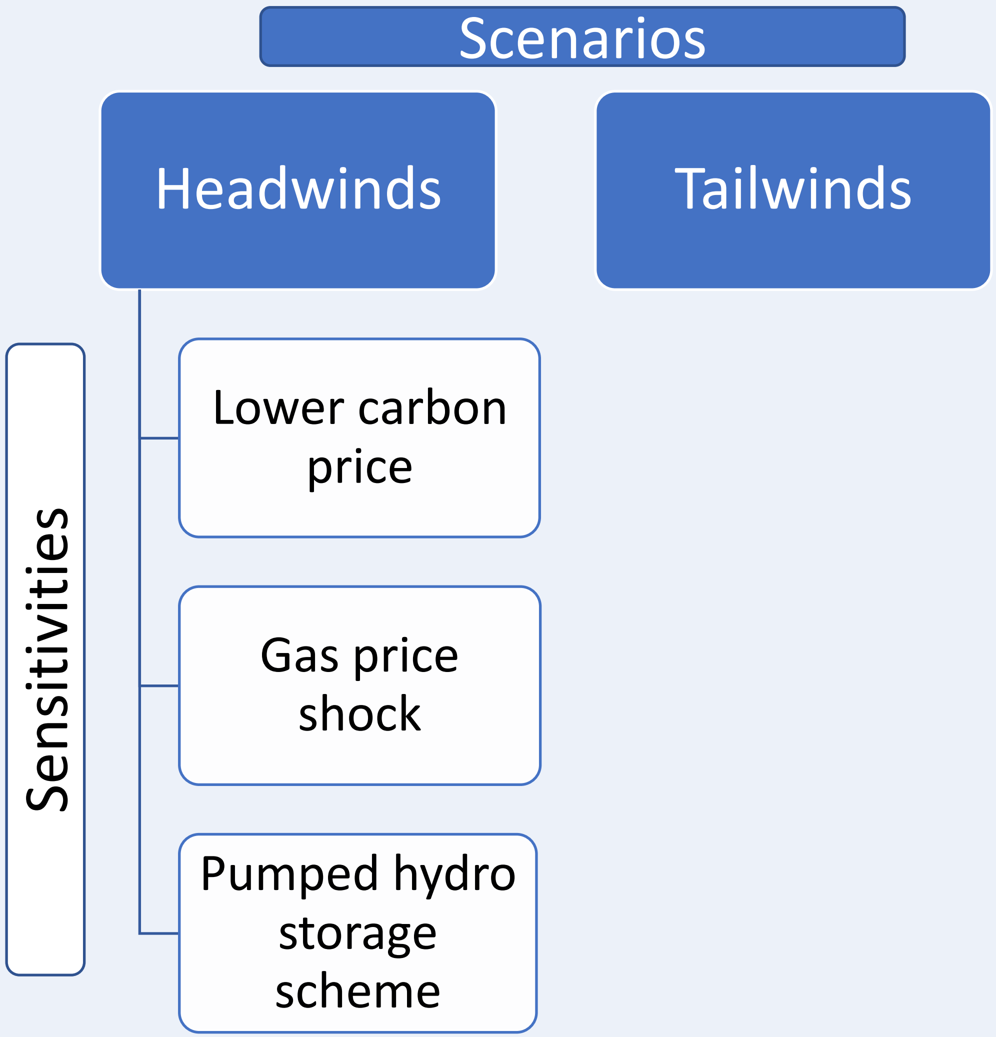
How the models were used

- E-Market and I-Gen models were used for Electricity inquiry by the ICCC. Model technical documentation available here.
- This work was a refresh of that exercise continuing all the way to 2050.
- Incorporates MBIE 2020 generation stack updates (Geothermal, Wind, Solar, Hydro).
- Revised generation cost reduction assumptions.
- Tiwai exit is central assumption, rather than sensitivity.

Scenarios and sensitivities

Headwinds and Tailwinds were modelled as scenarios.

- The modelled results of electricity demand from ENZ are used as inputs to the Energy Link models.
- This alignment was as of Nov 2020
- Regional demand profile provided for process heat electrification.
- Sensitivities to Headwinds scenario are:
  - a lower carbon price,
  - step increase in gas price and
  - integration of pumped hydro storage scheme.



Generation stack

- Includes 92 potential projects. Mixture of real scoped projects from MBIE generation stack, and some contrived projects.
- ROI= 8%

	Wind	Solar	Geothermal	Hydro	Peaker
Number of projects	47	11	15	12	6
Potential Total Installed capacity (GW)	5.60	1.73	1.11	0.65	0.86
Total generation (GWh)	19,640	3,330	9,060	3,380	750
Min 2020 LCOE ($/MWh)	57	91	73	105	268
Max 2020 LCOE ($/MWh)	90	114	117	128	290
Rate of CAPEX reduction	0.8% p.a to 2035, 0.5% p.a 2035-2050	3.0% p.a to 2035, 1.8% p.a 2035-2050	NA	NA	NA

Other assumptions/settings

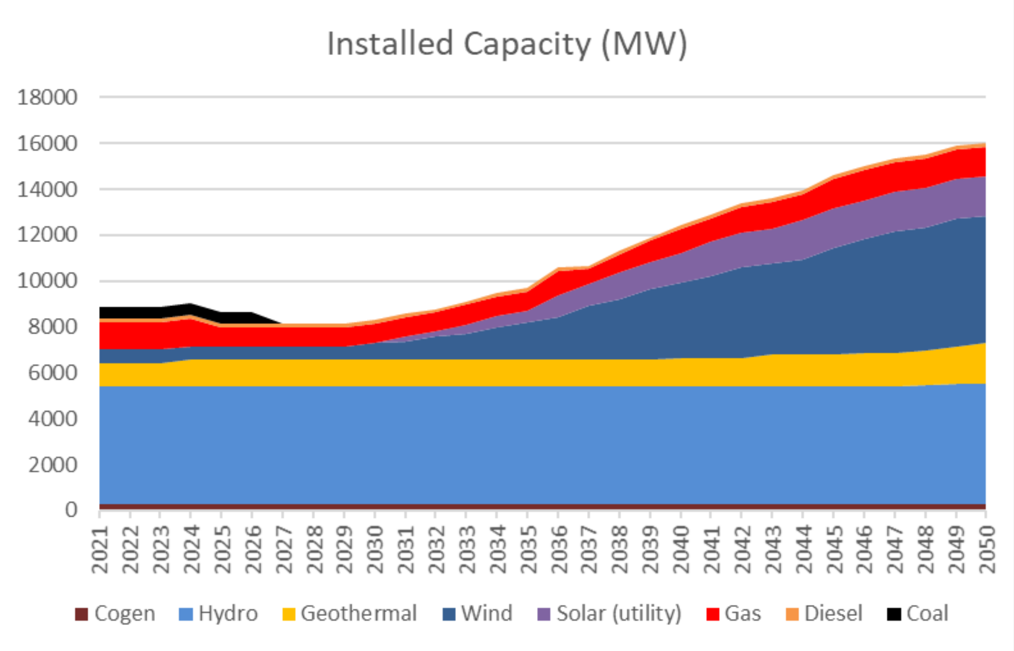
- Gas price rising from $8.6/GJ to $9.6/GJ by 2030.
- Emissions price rises to $250 by 2050.
- E3P gas generation plant closes in 2037.
- Distributed solar: 1.3 TWh by 2035, increasing to 3.2 TWh by 2050.
- E-market run with 3hour steps for 2035 and 2050 (reference years) and in day night mode for other years.
- Current market structure is unchanged.

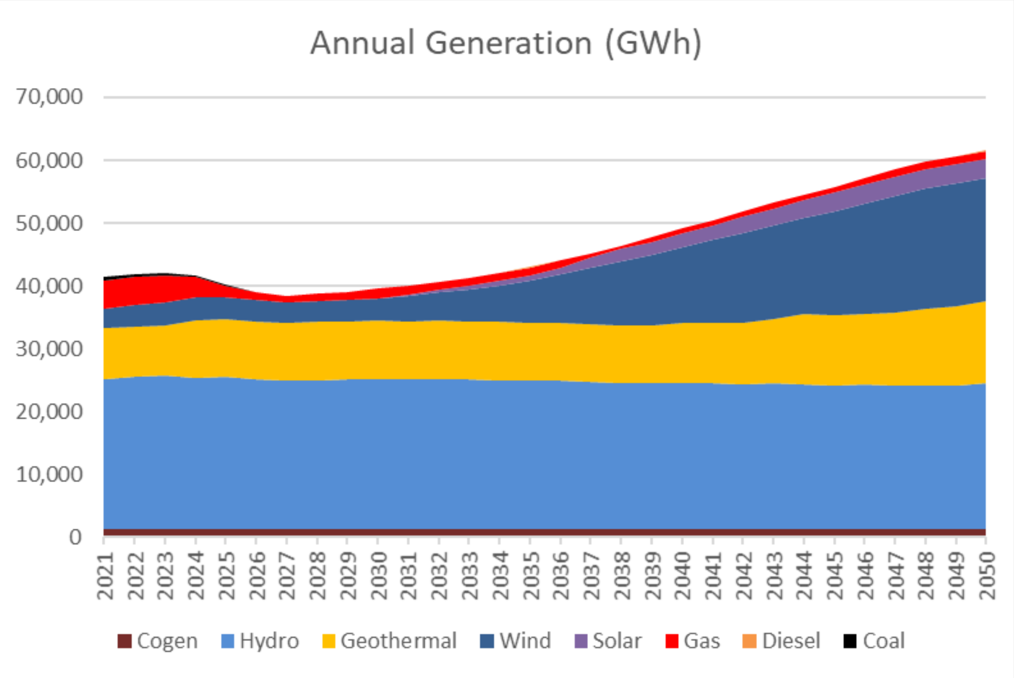
Results

Generation growth (Headwinds)

- New generation is geothermal, wind, solar, hydro and some gas peakers.
- No generation comes online between 2025 and 2030. This coincides with assumed Tiwai closure.
- Cogeneration remains. Some plants may not be viable at modelled emission prices, but model does not force closures.

Headwinds demand profile build schedule							
	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050	2050-2055
Total projects	**6**	**0**	**12**	**21**	**17**	**16**	**12**
Wind	4	0	9	15	8	8	3
Solar	0	0	3	4	3	1	0
Geothermal	2	0	0	0	3	5	3
Peaker	0	0	0	2	3	1	0
Hydro	0	0	0	0	0	1	6

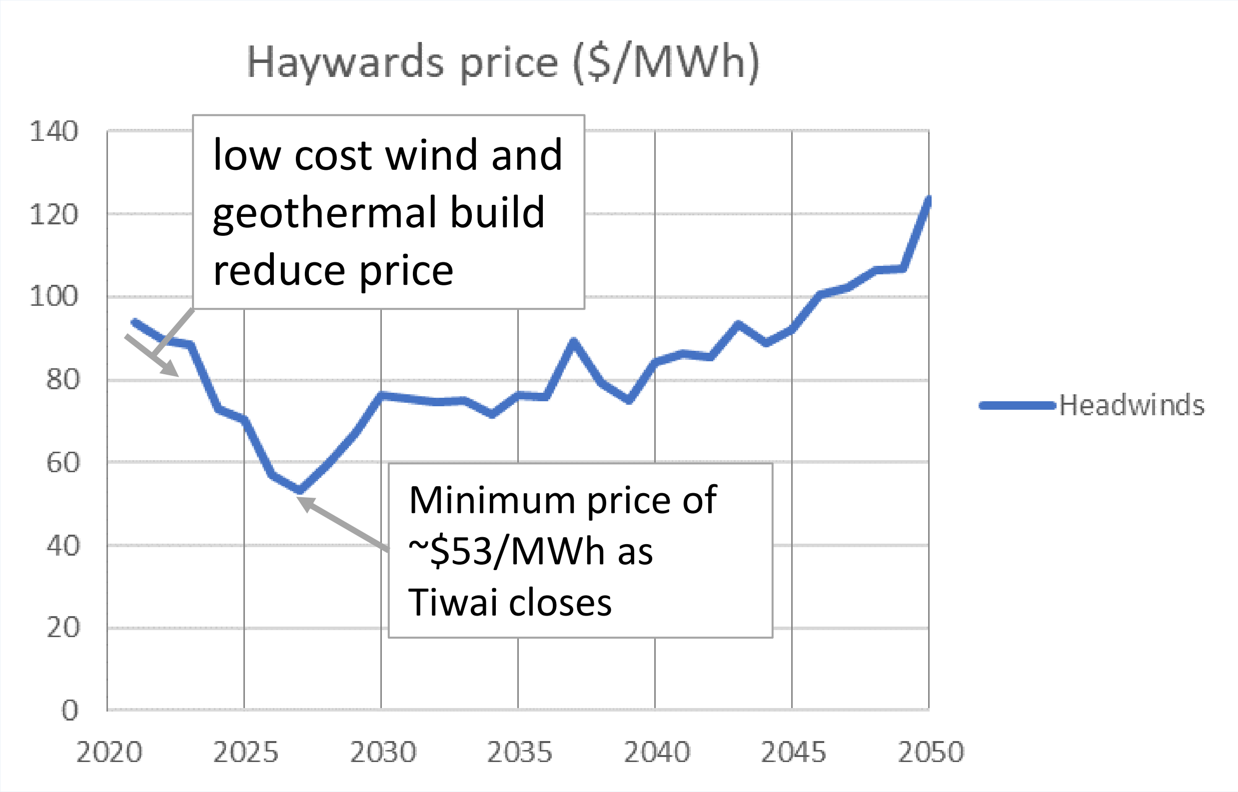




Wholesale market price (Headwinds)

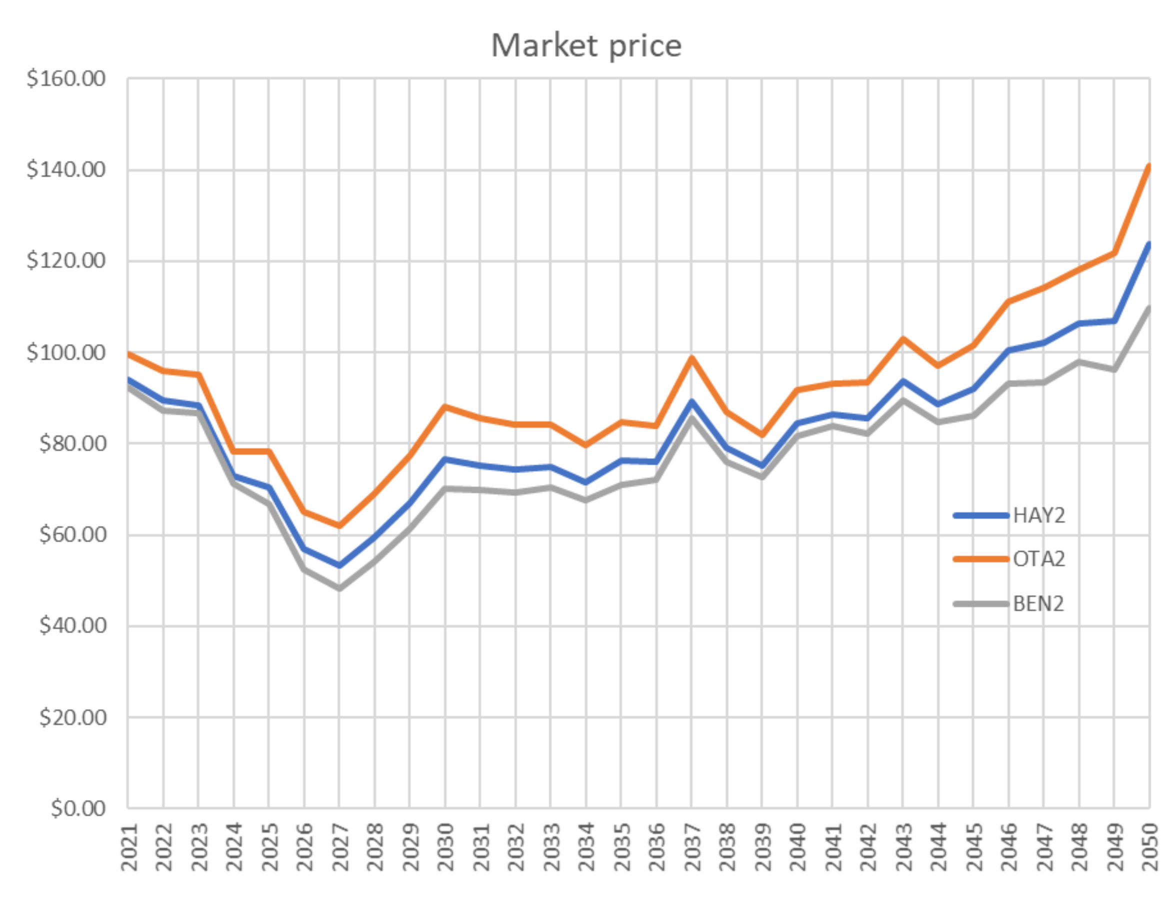
- Short term price reductions due to lower cost renewable build to displace baseload gas and assumed Tiwai closure.
- Prices stabilise from 2030-2040 at around $75/MWh. During this period the renewable cost reductions balance the use of higher cost generation sites and coincident generation penalty.
- Prices increase beyond 2040. This is due to:
  - CO_2 prices continuing to rise, impacting thermal offer prices and flowing through to wholesale prices.
  - Model runs out of low cost wind and solar projects. This is partly a limitation of modelled generation stack as could build more solar and wind. Instead the model starts building higher cost geothermal and hydro.
  - 2050 is a reference year, run in 3hr mode.

Health warning: because of the limitations of the modelled generation stack, we are less confident in the modelled prices beyond 2035.



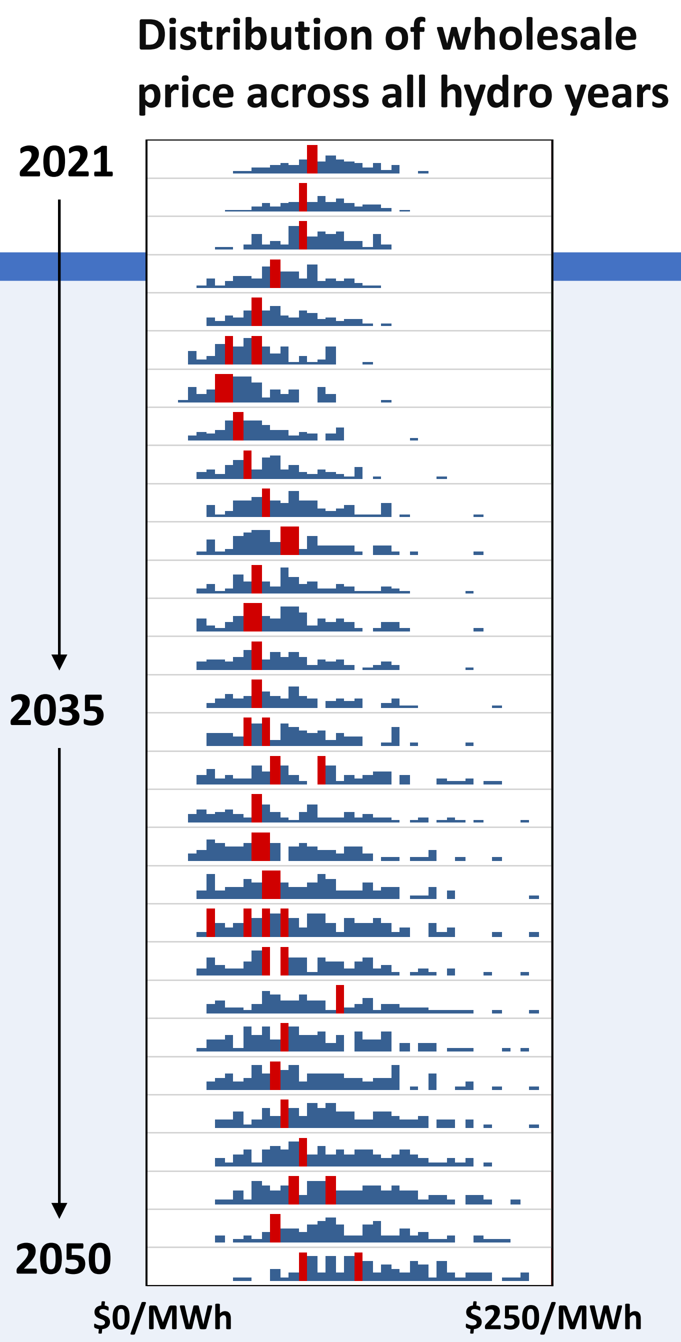
Regional pricing (Headwinds)

- The nodes plotted show the variation in wholesale price across NZ.
- Regional price difference increases when the aluminium smelter closes, as a greater proportion of generation is distanced from demand.
- Wholesale prices in the upper North Island are higher relative to the South Island and Central Aotearoa.



Distribution of prices

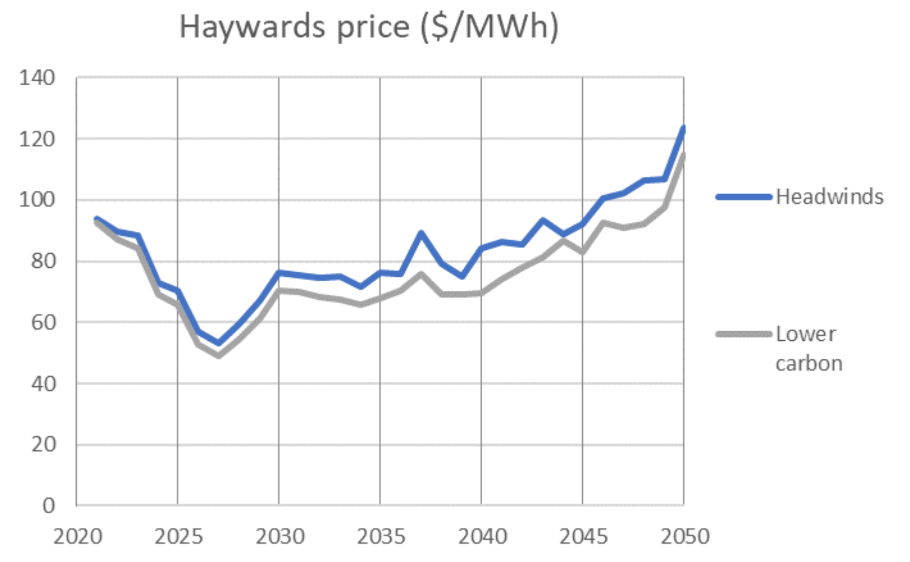
- The model simulates the electricity system with a 90 year record of hydro flows.
- The market price varies depending on the simulated hydrological inflow.
- **The spread in wholesale prices tends to increase as the model steps further into the future.**

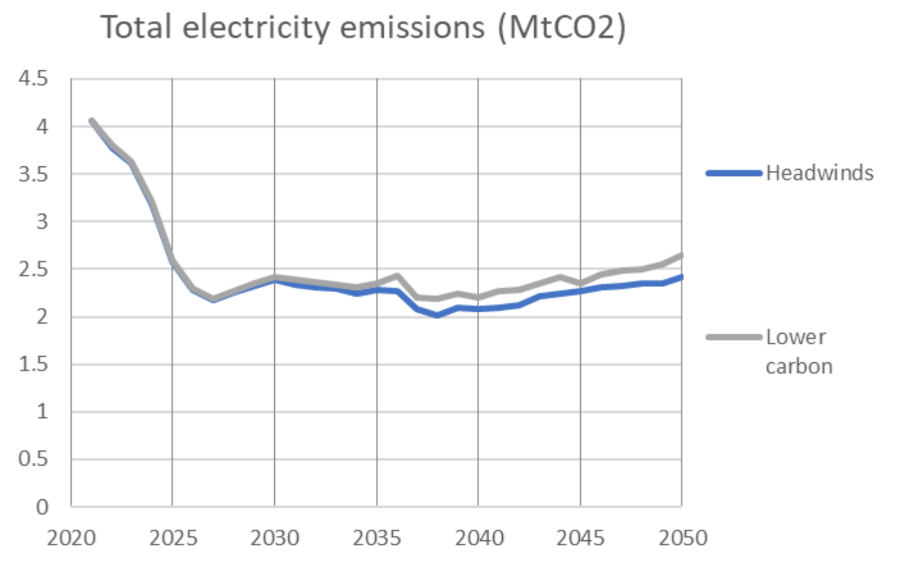


Sensitivity - Carbon price effects

Sensitivity test of a lower emission price path.

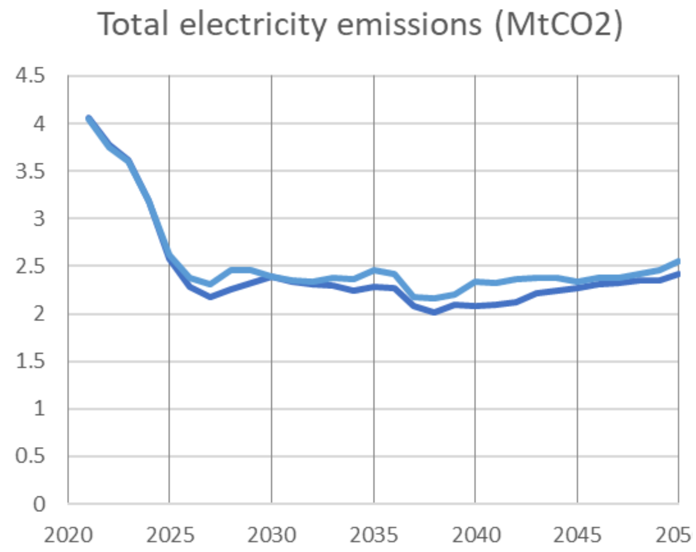
- Headwinds scenario emissions price rises to $250/TCO$_2$ at 2050.
- Lower carbon path reaches $125/TCO$_2$ at 2050.
- The higher carbon price translates to a $7/MWh higher electricity price (averaged across record).
- But with little impact on electricity emissions.
- Viability of some geothermal fields is uncertain at high emissions price though. This could alter the emissions if the fields were to close.

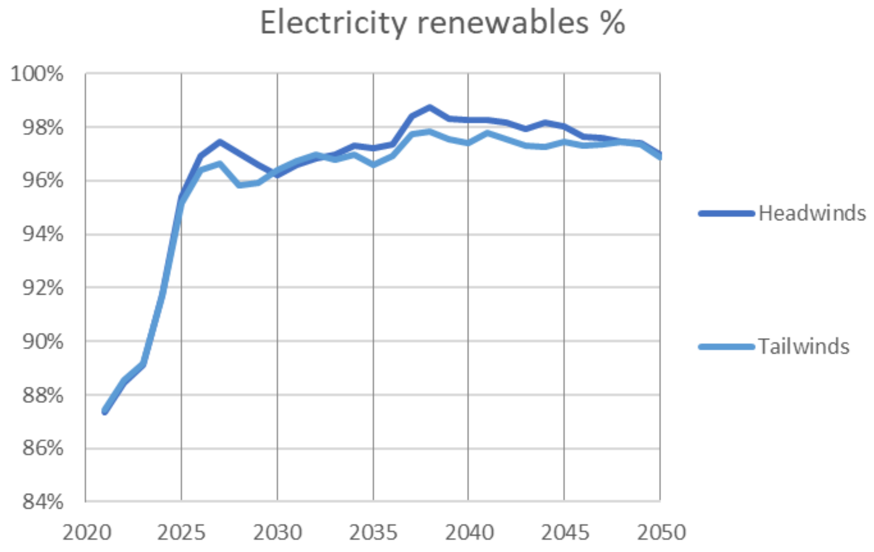


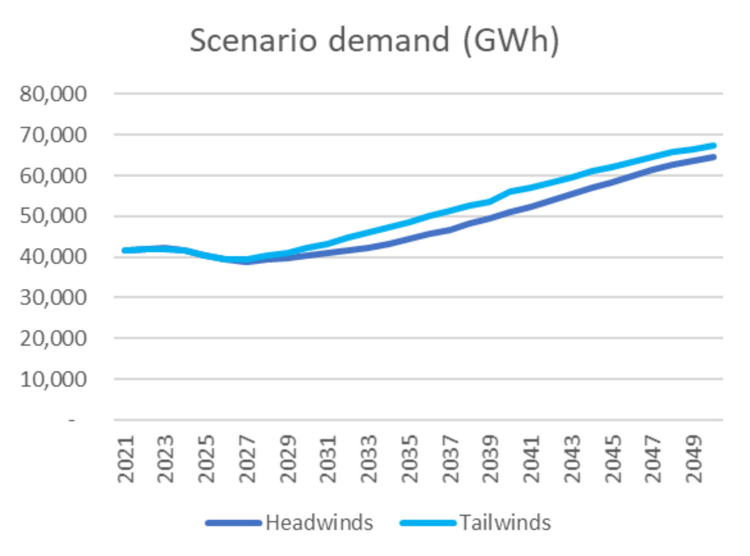


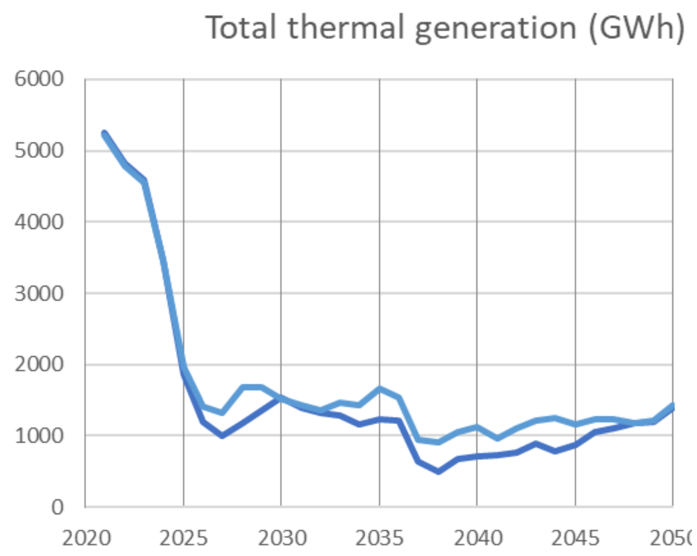
Tailwinds scenario – summary of outcomes

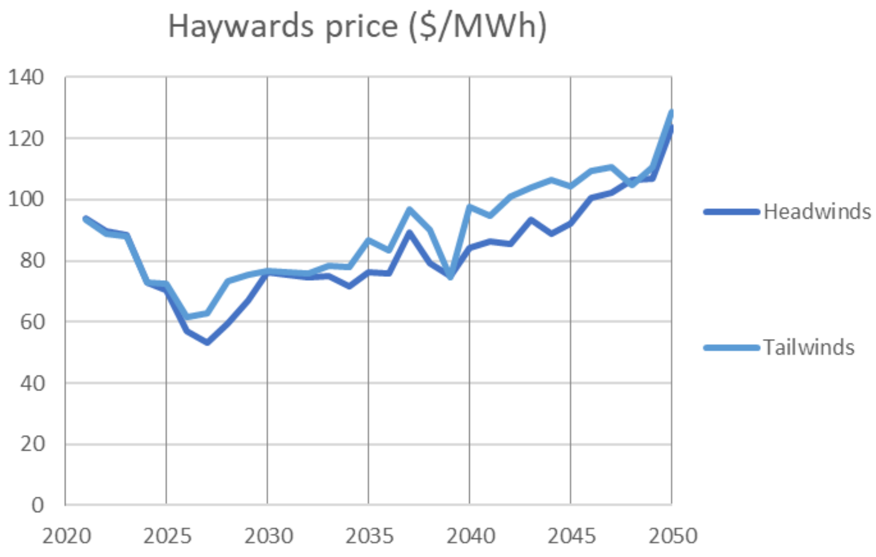
- Demand increases slightly faster in the Tailwinds scenario.
- Total electricity emissions across the two scenarios are similar (2-3Mt per year)
- Wholesale prices across the scenarios are similar.





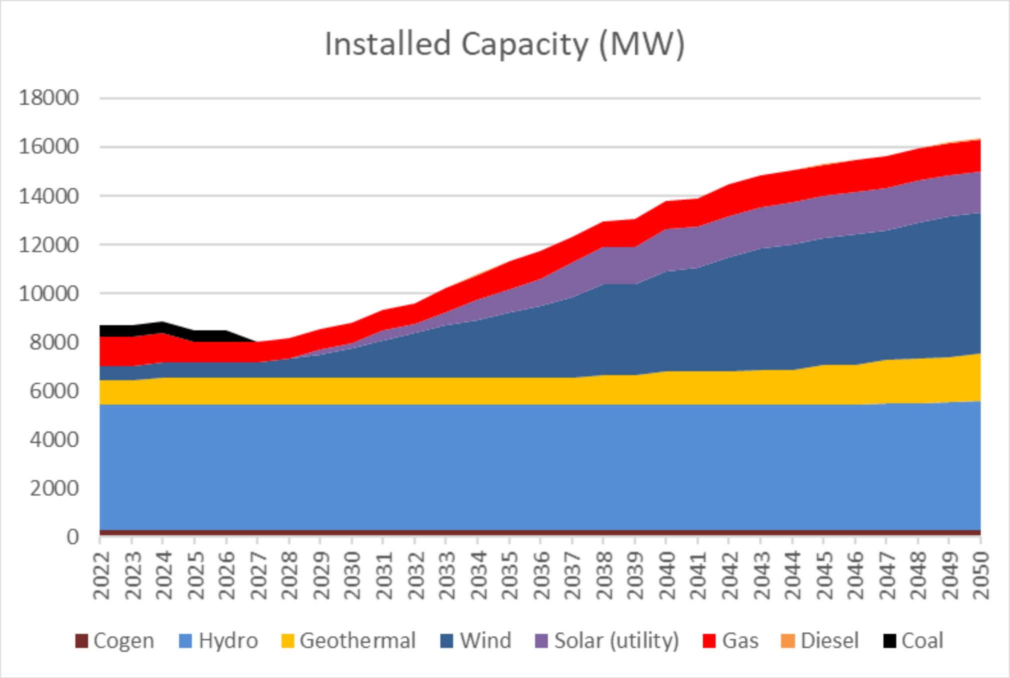






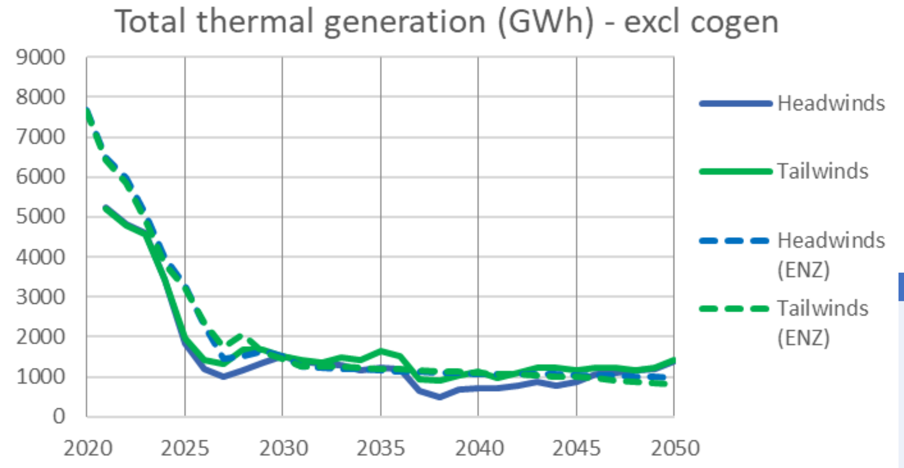
Tailwinds scenario – installed capacity

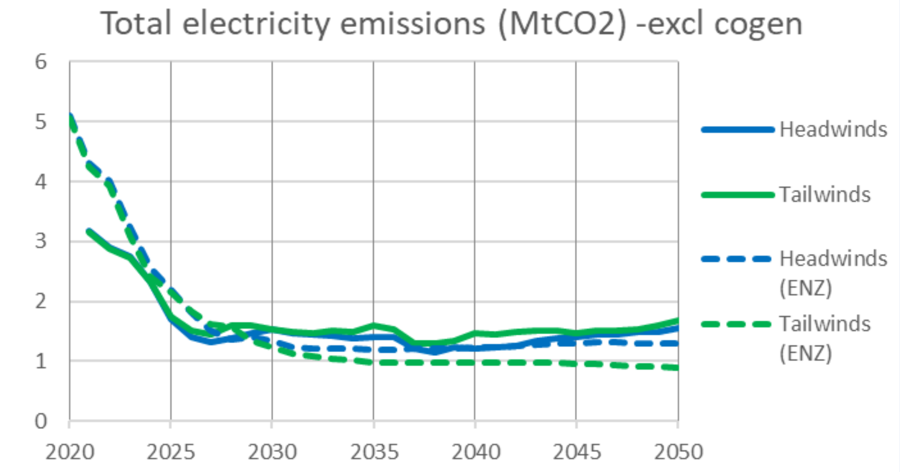
Tailwinds demand profile build schedule							
	2020-2025	**2025-2030**	**2030-2035**	**2035-2040**	**2040-2045**	**2045-2050**	**2050-2055**
Total projects	6	4	17	24	15	12	6
Wind	4	3	14	13	8	4	1
Solar	0	1	2	6	2	0	0
Geothermal	2	0	0	1	4	5	1
Peaker	0	0	1	4	1	0	0
Hydro	0	0	0	0	0	3	4

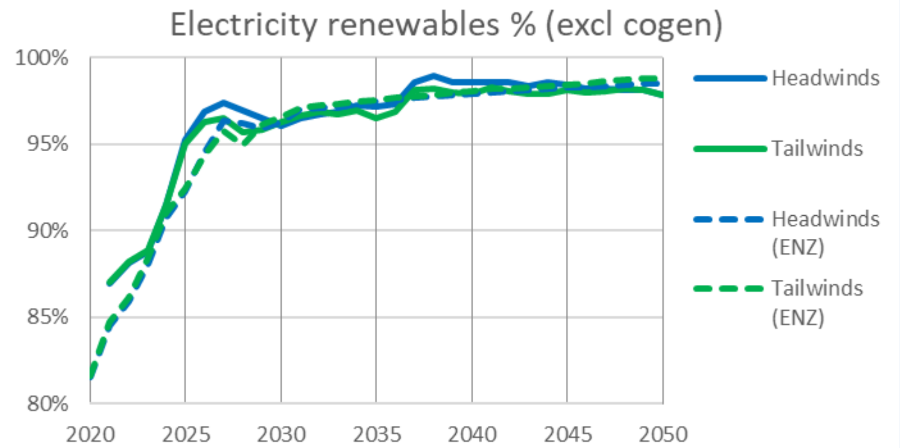


Comparison with ENZ (Headwinds and Tailwinds)

- ENZ estimates higher levels of thermal generation in short term. This is due to differences in base year generation and immediate build schedule.
- ENZ has lower total emissions beyond 2030. This is because high emissions geothermal fields close and geothermal re-injection is applied (Tailwinds).
- Setting aside cogeneration, both models give similar projection of renewables % (above 96% by 2030 and peaking at around 98%).

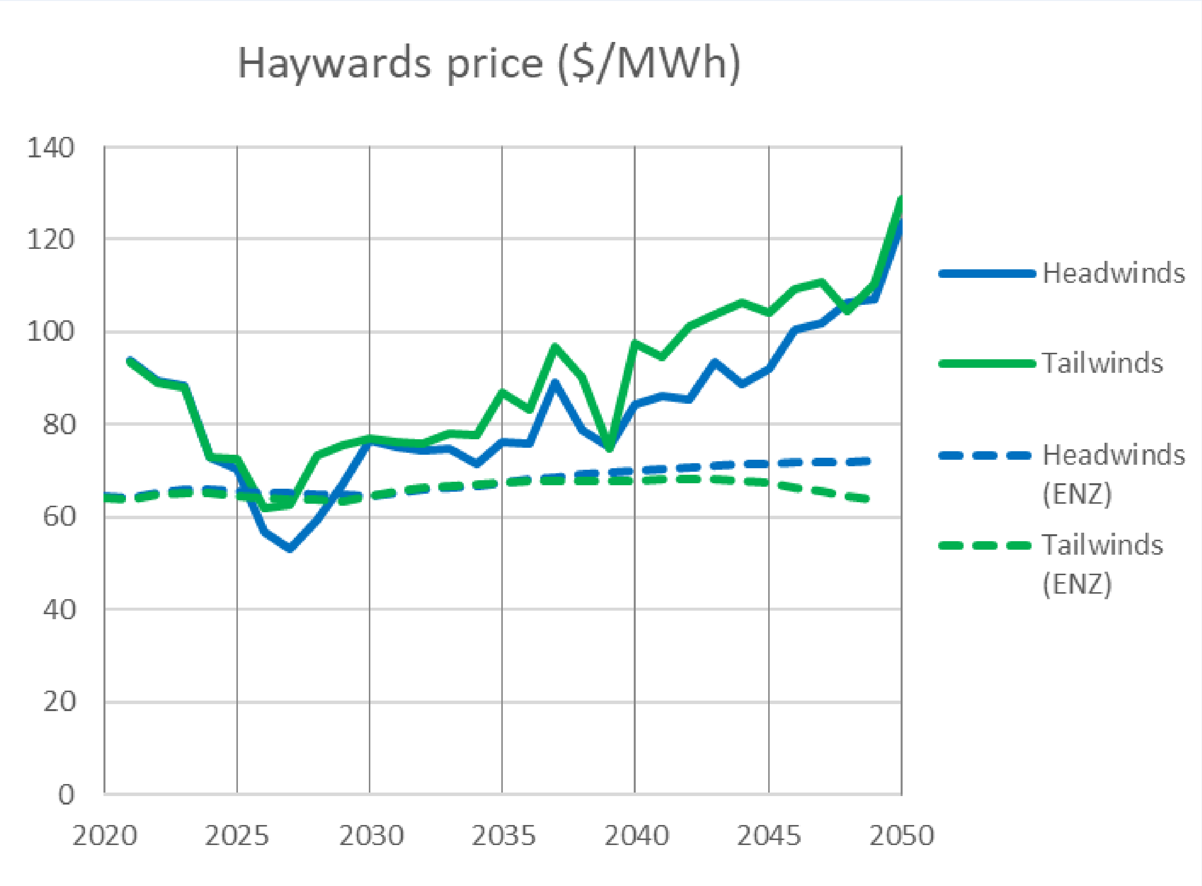






Comparison with ENZ (Headwinds and tailwinds)

- ENZ market price is determined by LCOE of next cheapest project on idealised supply curve. Penalties are applied as renewables increase penetration and a short term correction is made (not shown) based on futures market.
- E-market model has a much more detailed generation stack with location and weather factors.
- Builds are manually deployed and revenue thresholds are checked.
- Higher prices in E-market beyond 2040 in part due to assumed generation stack running out of low-cost renewable projects. Comparison is of limited usefulness at this point.

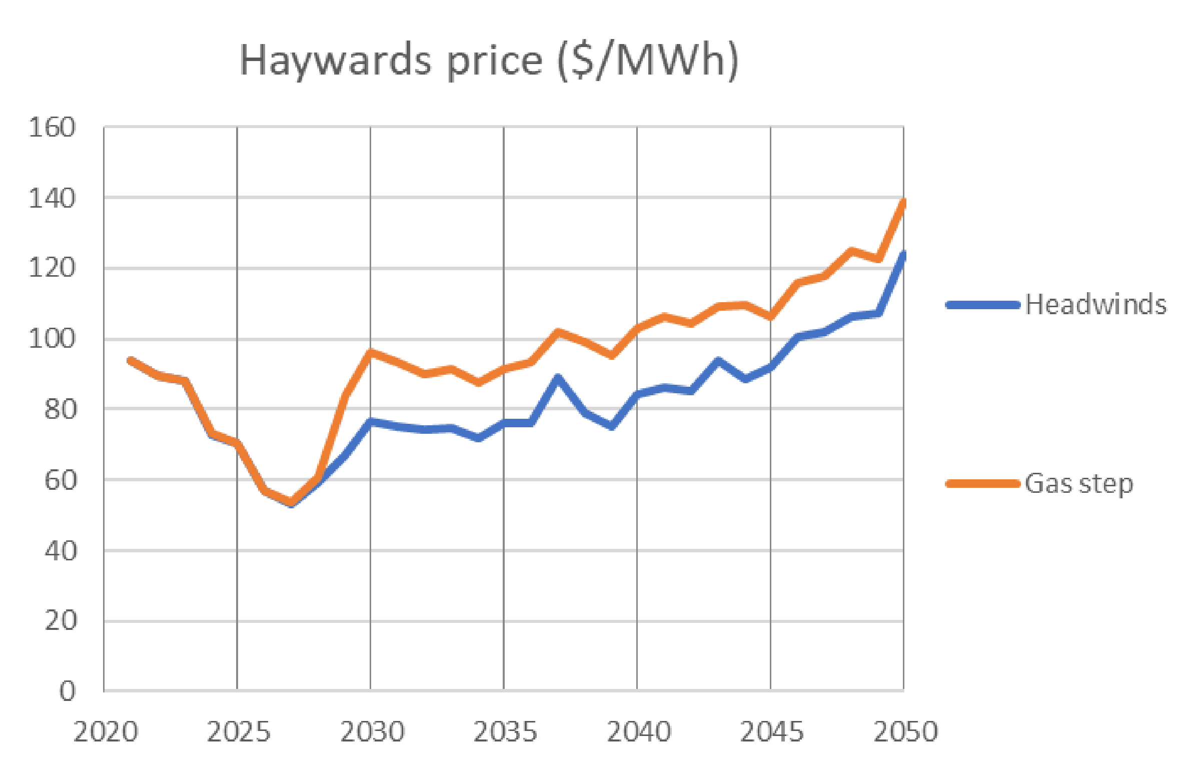


Gas price step sensitivity

- We are assuming that Methanex exit in 2029. This could have a significant impact on gas supply as Methanex provide flexibility and incentivise upstream investment.
- Gas for electricity generation could get more expensive. Either large amounts of gas need to be stored for occasional use or may require imported LNG.
- We have proxied this change in the model by a step increase in gas prices in 2029.
- Gas price steps from $8.6/GJ to $14/GJ in 2029.

Gas price step sensitivity

- Relative to the Tailwinds wholesale price, the change in gas price increases electricity costs by around $20/MWh.
- This is a significant increase which would impact industry electrification.



Investigating a pumped hydro storage scheme

- Modelled a ~5,000GWh scheme at Lake Onslow as a sensitivity for the Headwinds demand profile.
- The scheme becomes operational at around 2033.
- Runs at a 70% efficiency (pumping losses).
- Participates in market by purchasing electricity and on-selling later.
- Water values are assigned to resource to manage scarcity.
- Operates intra-day, intra-season and intra-year.
- Covers costs of operating but doesn’t try to pay for CAPEX.

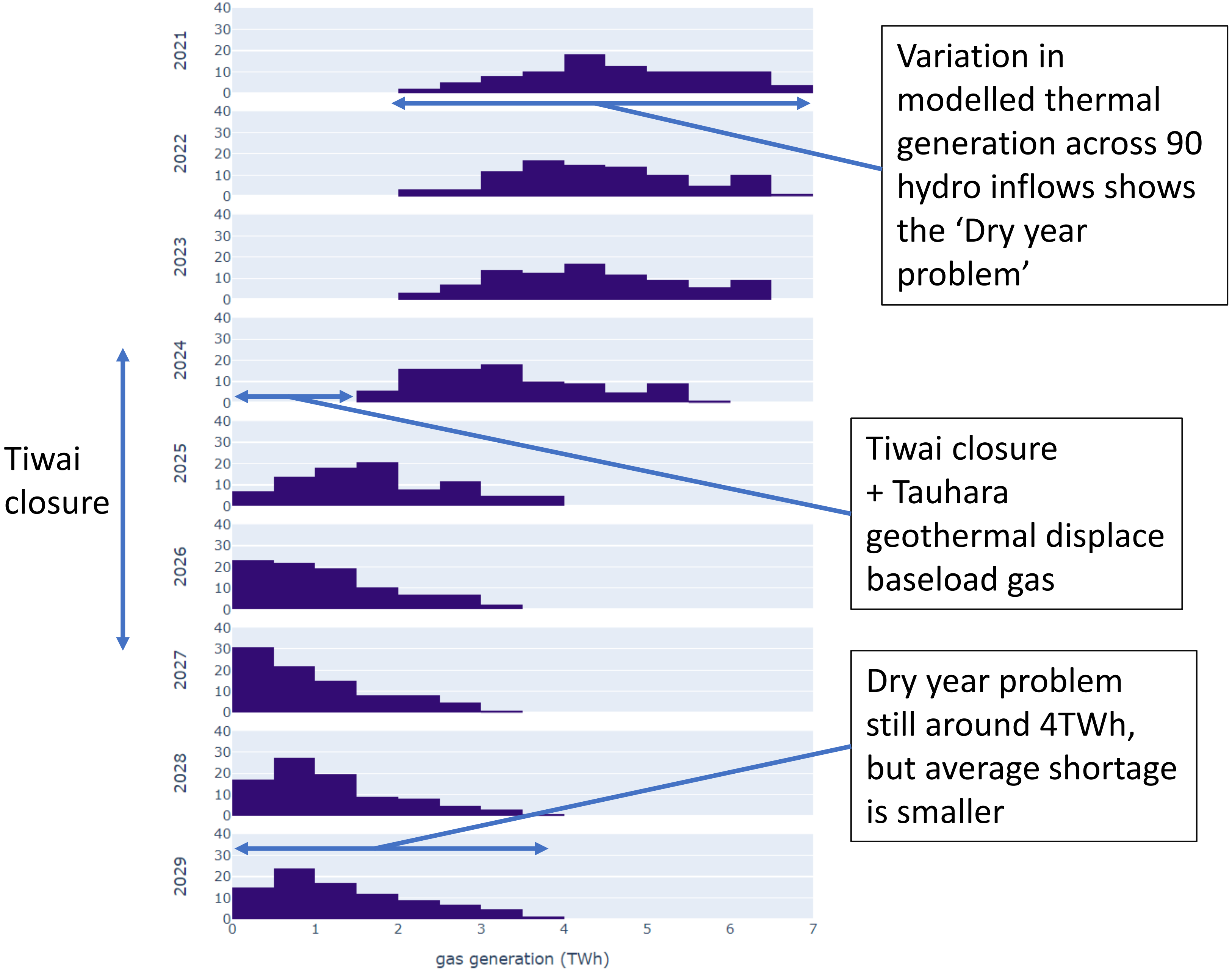
Does it solve the dry year problem?

Thermal generation **2020-2029** across 90 year record of hydro flows

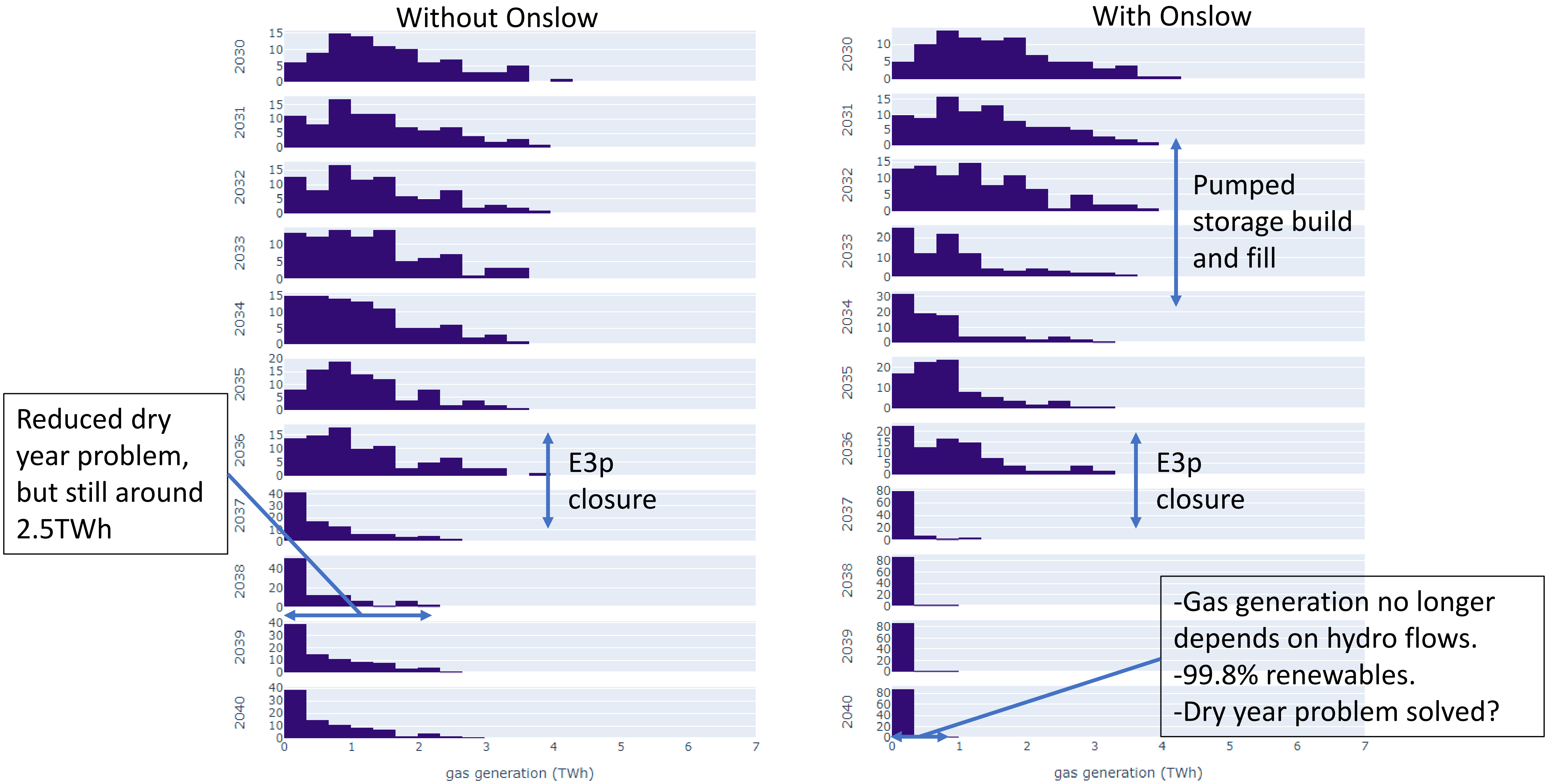
The charts show the variance in gas generation (in TWh) which runs in the system across the simulated hydrological years. We have used the hydro inflows of the last 90 years as proxies for what the size of the dry year problem could be.

The x axis shows gas generation in TWh and the y axis has the occurrence in number of hydro years.

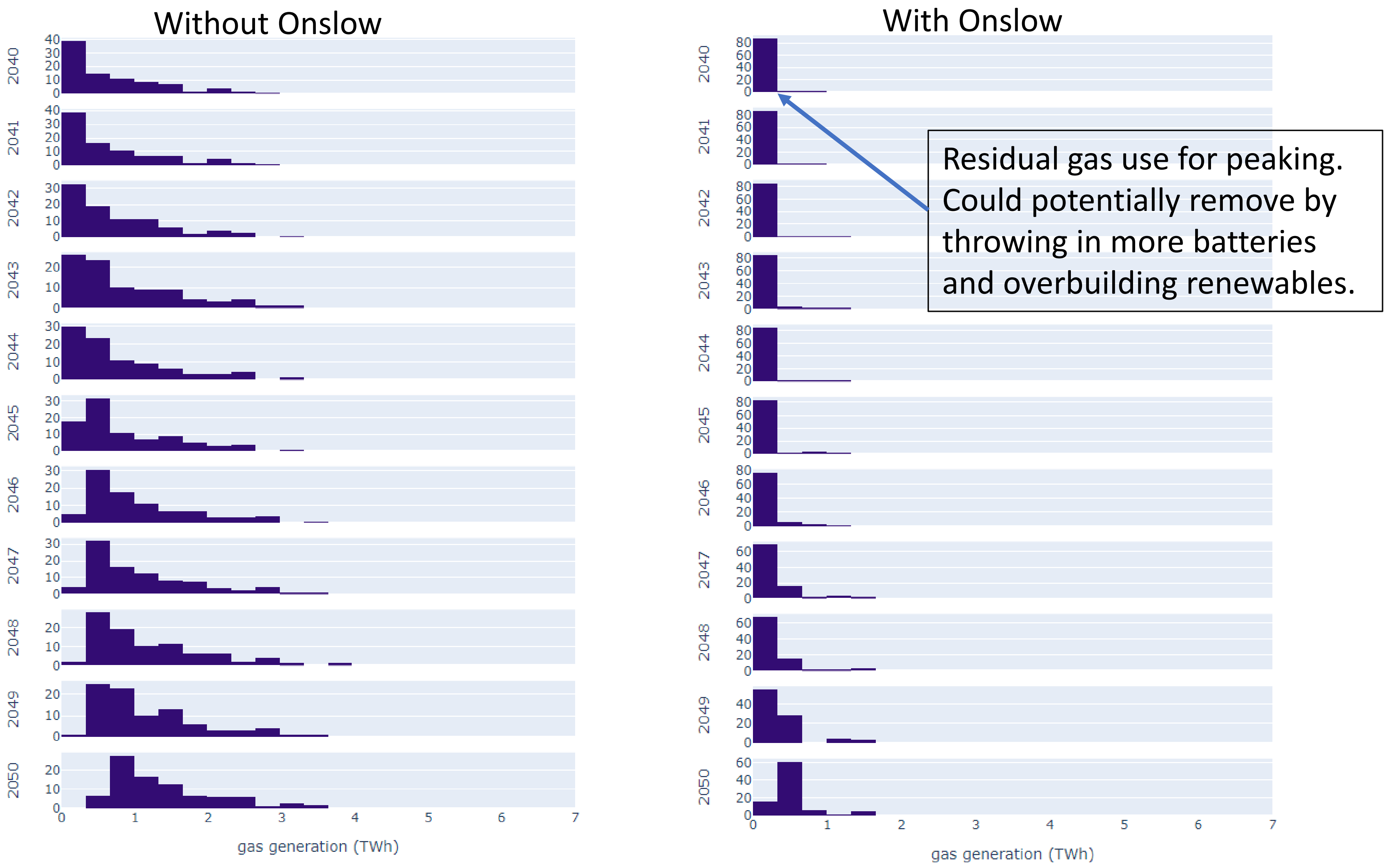
For years to 2050 under each scenario we run all 90 hydro flows to understand how much gas generation is required to meet demand. The stack of plots shows the results for the headwinds scenario. We assume Onslow is participating in the market in 2034.



Thermal generation **2030-2039** across 90 year record of hydro flows

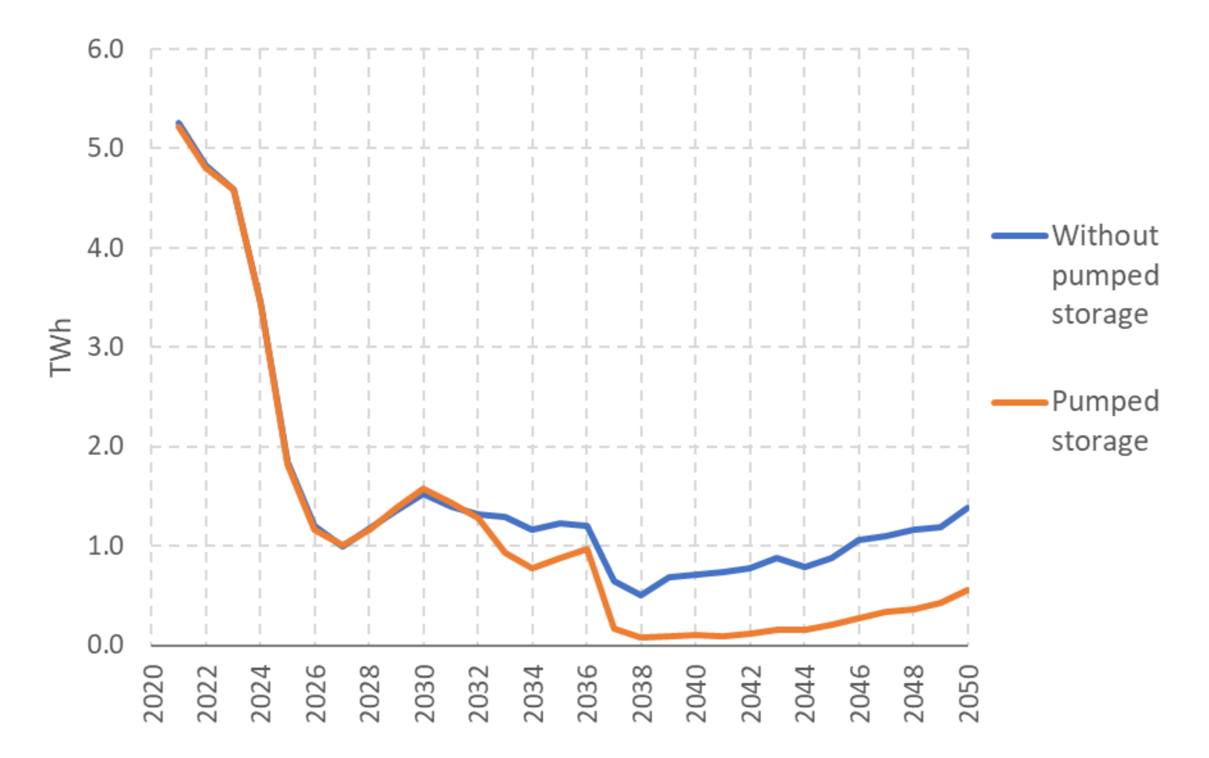


Thermal generation **2040-2050** across 90 year record of hydro flows



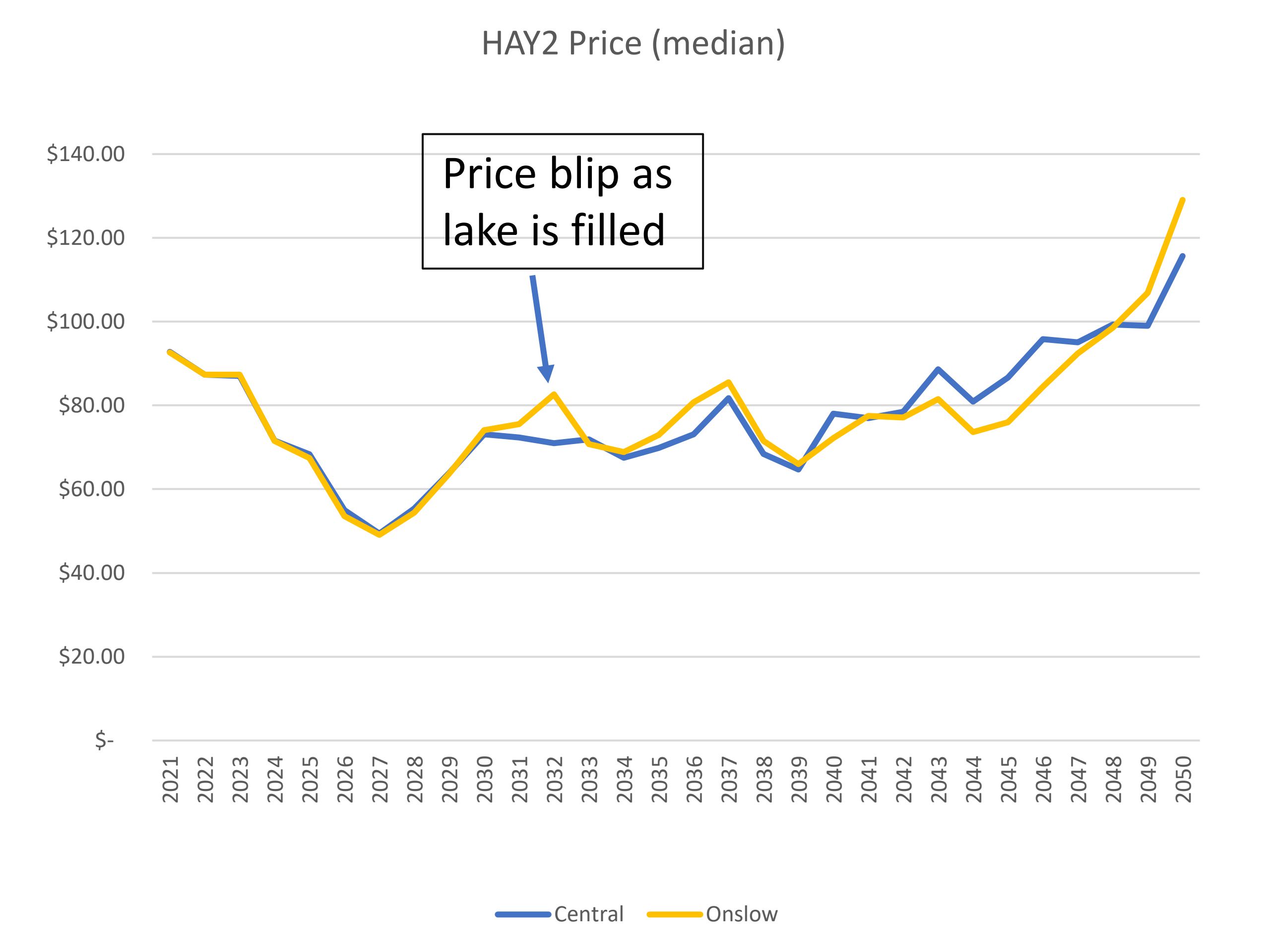
Investigating a pumped hydro storage scheme

- Once operational the scheme removes on average around 0.6TWh of thermal generation per year.
- This is equivalent to 0.3Mt CO2 of emissions per year.

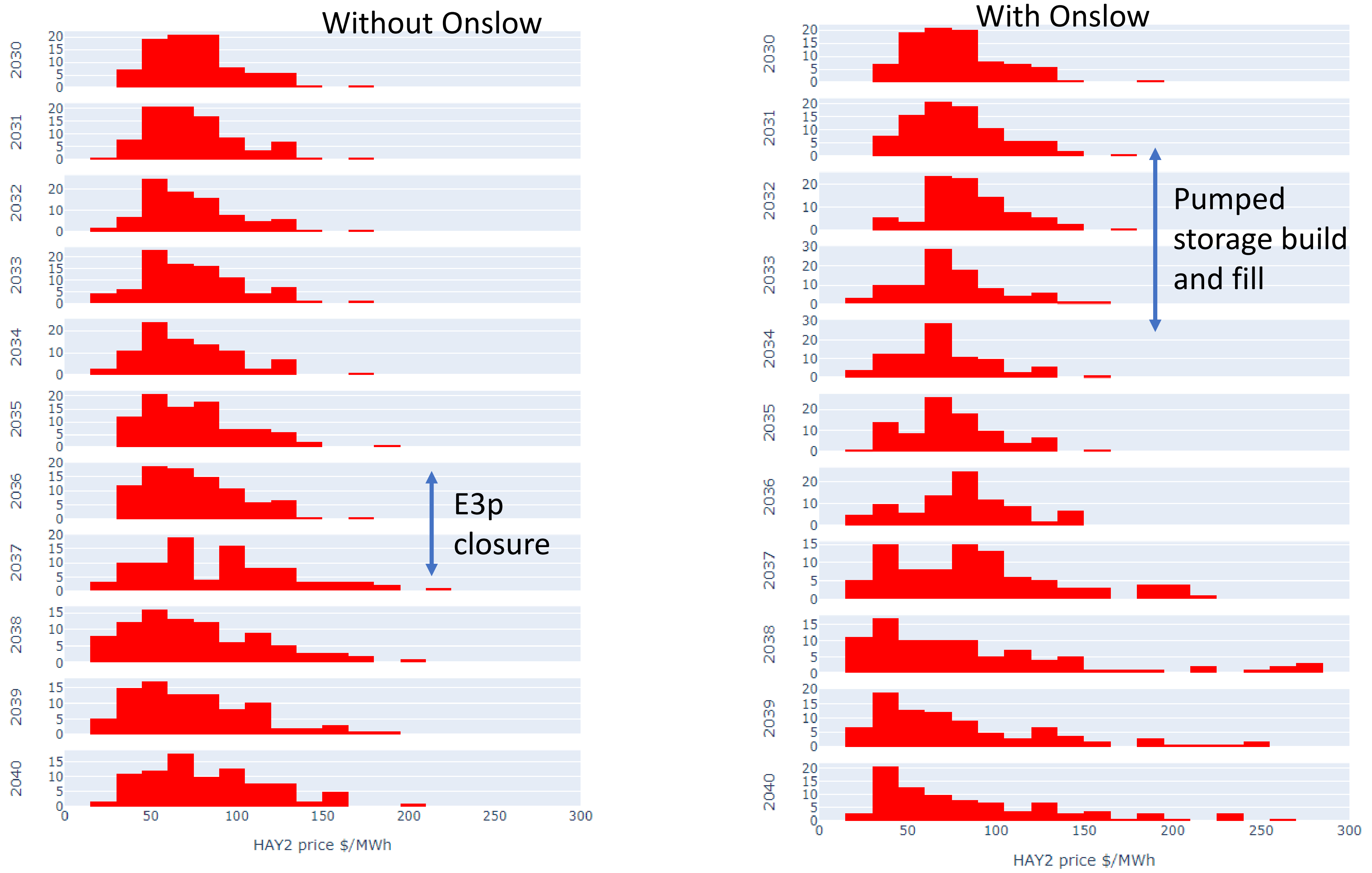


Market price effects

- There is considerable uncertainty in how a scheme such as a pumped hydro solution at Lake Onlsow would operate in the market.
- In this model implementation, in order to ensure all generators still make revenue, the gas price for thermal plants has been manually increased. Without this adjustment the modelled market price collapses and generators do not cover costs.
- With this adjustment the average market price is similar to a system without Onslow. (Median estimate of average).
- Have not included the CAPEX of Onslow or a HVDC upgrade.



Market prices **2020-2029** across 90 year record of hydro flows



Investigating a pumped hydro storage scheme

Summary:

- Model shows that a 5,000GWh pumped storage scheme largely decouples thermal generation from lake inflows (and wind and solar seasonal variation later).
- Gas is still in system for peaking purposes. Eliminating gas was not the purpose of this exercise. But have reached 99.8% renewables average.