ETS settings 2023-27

Comment on Electricity price modelling

NZIER report to MEUG

6 October 2022

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Key points

Scope

This note comments on the modelling of the estimated impact of increases in carbon prices on electricity prices in Table 20 of the Climate Change Commission (CCC) advice on ETS settings for the period 2023 to 2027. Table 20 shows 2021 electricity prices for retail, commercial and industrial customers and the 'emissions component of price' at 'emissions prices' stated in dollars per tonne of carbon dioxide equivalent ($/t CO_2e also called NZU) of $50 to $250 in $50 increments.

Modelling does not present usable projections of price changes

There are three primary comments on the usability of the table as an indication of the impacts of increases in NZU prices on retail electricity prices (before considering the modelling of the impact of increases in NZU prices on wholesale electricity prices). These are:

- The NZU price impacts are not presented in a form that can be directly used as measure of price impact on consumers because they do not report the expected change in consumer electricity bills from the current cost of NZU (about $70 to $80).
- The modelling does not discuss the extent to which current retail prices reflect recent increases in wholesale prices. Our analysis suggests that the energy component of retail price has lagged increases in wholesale prices.
- The modelling and the accompanying commentary note there is a lag between a step-change in wholesale and residential analysis. However, the NZU price component is based on an average of past and future correlations between wholesale prices that are simulated for different NZU prices but roughly the same level of electricity demand.

Wholesale electricity price model assumes a painless transition to renewables

The modelling of the wholesale electricity prices during the ETS settings period does not credibly explain how a step reduction in the use of fossil fuels over the remainder of 2022 and a further reduction in the use of fossil fuels over the period 2023 to 2027 will coincide with a sharp fall in wholesale electricity prices. In particular:

- The modelling of the impact of NZU prices on electricity costs assumes a structural reduction in the use of coal and gas over the second half of 2022 (at the start of the modelling period). This materially reduces the direct exposure of wholesale electricity prices from NZU driven increases in thermal generation fuel costs in the short term. It is not clear how the modelling allows for the increased wholesale price risk from less controllable generation in the long term. The rationale for the structural shift assumption is not explained.
- The modelled emission reduction paths for coal and gas for the 'Fixed' NZU price path (continuation of NZU prices at current levels) are very similar to the emission reduction paths for coal and gas under the 'CCR' and 'Higher' NZU price paths. However there is a minimum 70 percent difference between NZU prices under the 'Fixed' and 'Higher'

NZU price paths. This suggests the structural shift assumption is unrelated to the NZU price path.

- The modelling of electricity prices seems to assume that average wholesale electricity prices will fall as wind generation and geothermal generation replace thermal generation which has a higher short run marginal cost. This is a more optimistic view than the modelling completed by the Electricity Authority (EA) Market Development Advisory Group (MDAG) on the shift to a 100 percent renewable generation system. It also does not reflect the recent experience of wholesale prices in the electricity market where a shortage of thermal generation capacity has led to hydro generator offers (rather than the cost of thermal fuel) setting wholesale prices and where development of wind and geothermal resource has not occurred quickly enough to lower wholesale price in off-peak and shoulder periods.

Reliance on averages rather than scenarios

The modelling and reporting focus on averages of wholesale prices from simulations of multiple weather patterns further scaling of NZU impacts on retail prices based on average over five years (2023 to 2027) or 13 years (2023 to 2035) is of limited use in identifying the ranges of price impacts that could occur over 2023 to 2027 if:

- The structural transition away from coal and gas is much less rapid than assumed in the modelling.
- Peak and shoulder period electricity prices are not pulled down by the long run marginal cost of wind and geothermal but instead remain high because of the need to conserve hydro generation capacity for peak periods – a continuation of recent market behaviour.

Potential for better use of information on current demand and retail charges

Secondary areas for improvement in the modelling are:

- Inclusion of the demand actuals that the model scenarios were aligned with or a source for that data. The current net generation volume reported by MBIE for the year to June 2022 (43,176 GWh) is 1,669 GWh above the modelling volume in 2023 (41,598 GWh). Up to 340 GWh of this difference could be attributable to the cessation of the oil refining at Marsden Point1. The remaining difference of 1.329 GWh is equivalent to about 160 MW of geothermal generation capacity 380 MW wind generation capacity.
- Complement the EA analysis of the residential electricity bill with the MBIE quarterly survey of residential sales-based electricity. The MBIE survey provides an indication of the change in the energy cost component of residential electricity bills over time. even though the MBIE survey does not separate the energy and other component into energy cost, retail margin and other costs.
- Changing the start date of the initial modelling period from 28 April 2022 to the beginning of a calendar quarter to make comparison of the model results with the latest actual data easier.

[1] We estimate NZ Refining used a maximum of 340 GWh of electricity per year before closing its refinery. The ‘REFINING NZ ANNUAL REPORT 2020’ page 18 reported electricity usage in PJ of 1.14 (2018), 1.23 (2019) and 0.92 (2020). which equates to usage in GWh of 317 (2018), 342 (2019) and 256 (2020).

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1 Scope

1.1 Terms of reference

The focus of the comment in this report is a critique of the modelling and analysis supporting Table 20[2] reproduced in Table 1 below.

> *The impact of different emissions price on the price of electricity is summarised in table 20 of the consultation paper. Advice is sought from NZIER critiquing the analysis summarised in table 20.*
>
> *Feedback on the paper will form MfE advice to Minister. One factor the Minister must consider in s. 30GC (6)(a) is the impact of emissions prices on households and the economy*

Table 1 Impact of emissions price on the price of electricity

All prices in the body of the table are in c/kWh

Level of impact	Sector	Electricity price 2021	Sensitivity factor[1] ($/MWh per $/tCO2e)	Emissions component of price (c/kWh) for the emissions price ($ per NZU[2]) at the of each column				
				50	75	100	150	200
High	Residential	30.6	0.33	1.9	2.9	3.8	5.7	7.6
	Commercial	18.5	0.33	1.7	2.5	3.3	5	6.6
	Industrial	17.1	0.31	1.6	2.4	3.1	4.7	6.2
Low	Residential	30.6	0.19	1.1	1.7	2.2	3.3	4.4
	Commercial	18.5	0.19	1	1.5	1.9	2.9	3.8
	Industrial	17.1	0.18	0.9	1.4	1.8	2.7	3.6

Note:

1 The 'Sensitivity factor' is the product of:

- a The simple average of the slope coefficient of the linear relationship between the modelled wholesale electricity prices and the four emissions prices for each year of 2023 to 2027 – 'High impact' (0.28) or each year of 2023 to 2035 – Low impact (0.16).
- b A scaling factor for time weighted average wholesale prices (TWAP) to retail prices that is a product of three scaling factors: network losses (Ls), hedge premium (Hs), and a time of use factor (Rs). The total scaling factor for residential and commercial customers is 1.17 and for industrial customers it is 1.10.
- c Therefore the 'Sensitivity factor ($/MWh $/tCO2e)' for:
  - i High impact is 0.28 * 1.17 for Residential and Commercial customers and 0,28 * 1.10 for Industrial customers
  - ii Low impact is 0.16 * 1.17 for Residential and Commercial customers and 0,28 * 1.10 for Industrial customers

2 New Zealand Unit (NZU) represents one metric tonne of carbon dioxide equivalent (tCO_2e).

Source: NZIER

2 'Proposed changes to New Zealand Emissions Trading Scheme limit and price control settings for units 2022, Consultation document', page 38. Published in September 2022 by the Ministry for the Environment Manatū Mō Te Taiao.

The Ministry for Environment (MfE) consultation paper attributes Table 20 to work by the Climate Change Commission (the Commission) *'drawing on work undertaken by the Treasury.'* The Commission describes the approach to its electricity price modelling in 'Technical Annex 3'[3] and refers to the Commission modelling informing the Treasury's analysis of household impacts[4].

The purpose of the modelling is to assess the impact of the NZETS settings on retail energy prices (through the effect of ETS costs wholesale electricity prices). The modelling also comments on the estimated generation earnings based on spot market revenue.

1.2 Constrained critique

Our assessment of the model is limited by the lack of suitable detail to allow the us to credibly review the modelling process. We have not been able to either vary key assumptions or at least see the modelled results of a different set of assumptions about:

- Rapid retirement of thermal generation capacity.
- Seamless and timely expansion of wind and solar generation.
- Rapid mitigation of the price volatility and increased supply reliability risk that are expected as system dependence on wind and solar generation.

The model results we have assessed are largely "black-box" outcomes derived from complex models. Complex models are:

- Hard to quality assure – both as a structure and in particular runs; and
- Produce results that can be difficult to explain – as the intermediate steps causing the specific results are not accessible.

Accordingly our assessment focuses on testing the general "reasonableness" of the results.

2 Modelled price impacts

2.1 What is modelled

Table 2 presents the NZU price components in Table 20 as increases in the cost of NZU from an NZU price of $75 to indicate the type of price increase pressure implied by Table 20. The calculation of the percentage increase is a 'low' estimate of the increase as it assumes that the current NZU price of $75 is fully reflected in the current residential prices. The increase is calculated as the difference between the 'emissions component of price (c/kWh)' at the stated NZU price less 2.8 c/kWh divided by the 2021 price. The assumption that current retail prices fully reflect recent wholesale prices for residential consumers is not necessarily accurate as discussed in section 2.4 below.

[3] Advice on NZ ETS unit limits and price control settings for 2023-2027, Technical Annex 3: Electricity market modelling and retail price estimates, August 2022'

[4] Technical Annex page 14.

Table 2 NZU component increase estimate

Increase in NZU component from an NZU price of $75 as a percentage of the 2021 price.

Level of impact	Sector	2021 price (c/kWh)	Emissions price ($per NZU)			
			100	150	200	250
High	Residential[1]	30.6	3.1%	9.3%	15.5%	21.7%
	Commercial	18.5	4.5%	13.4%	22.3%	31.2%
	Industrial	17.1	4.5%	13.6%	22.6%	31.7%
Low	Residential[1]	30.6	1.8%	5.4%	8.9%	12.5%
	Commercial	18.5	2.6%	7.7%	12.8%	17.9%
	Industrial	17.1	2.6%	7.9%	13.1%	18.4%

Note:

1 Prices include GST of 15%

Source: NZIER

Combining this information with the high emission price path of an NZU price of $162.7 by 2027 suggests the model is projecting a price increase of residential bills of about 11 percent by 2027.

The model spreadsheet and the accompanying report do not clearly state an assumption about the extent to which current wholesale prices are reflected in retail prices but instead make two contrasting comments:

- *Most electricity consumers are isolated from the spot market by retail electricity contracts which are based on the expectation of future wholesale prices.*[5]
- *We assume wholesale price increases will ultimately be fully passed onto consumers, but the timescale for this is uncertain and may vary by customer segment. For example, it is unlikely that current residential retail prices fully reflect the impact of the emissions price in the wholesale market as NZU price growth has been sudden and residential contracts are based on longer term trends. We expect a lag between a step change in wholesale prices and the change in retail prices.*[6]

2.2 How the model translates NZU prices into retail electricity prices

The model estimate of the increase in NZU prices is based on a three-step approach:

- For each year estimate the linear relationship between the simulated wholesale electricity prices and the NZU price and the slope of the line as the indicator of the of the price effect for that year. (This approach does not allow for the fact that from one year to the next some of the price change pressure is reflected by the change in the intercept term which is an estimate of the wholesale electricity price if the NZU price was zero.)
- Multiply the NZU slope coefficient by a scaling factor that reflects the different load profiles of the residential commercial and industrial customers.

5 'Technical Annex 3: Electricity market modelling and retail price estimates August 2022', page 13

6 'Technical Annex 3: Electricity market modelling and retail price estimates August 2022', page 14

- Average these factors over a period before applying them to the residential prices to calculate the emissions price component for a given NZU price.

The results of the regression analysis are shown in Table 5 of Appendix A. Three observations are worth noting:

- The factors used in Table 20 (see Table 1of this note) of 0.33 for the 'High' and 0.16 for the 'Low' impact lower the estimated effects of the NZU price increases on residential prices over 2023 to 2026 for the 'High' impact calculation and 2023 to 2027 for the 'Low' impact scenario.
- The way averaging is used in the retail price impact assessment implies retail prices are being set on the basis of expected future prices and is not consistent with the comment quoted above about a lagged pass-through of NZU price increases. (*We assume wholesale price increases will ultimately be fully passed onto consumers, but the timescale for this is uncertain and may vary by customer segment.).*
- The estimated wholesale electricity price (TWAP) with the NZU price set at zero in 2022 is $126.16 per MWh which is: $23.13 per MWh lower than the modelled TWAP for an NZU price of $70 ('Fixed' NZU price path) and $57.21 per MWh lower than the modelled TWAP for an NZU price of $120 ('Higher' NZU price path).

Credible and reliable estimation of price changes based on averages requires a high level of stability and predictability in the retail and wholesale markets. However the shift away from thermal generation and its assumed seamless replacement with wind and solar generation is a disruptive change that is likely to make wholesale market prices more volatile and increase the cost of delivering reliable supply both during and after the transition. These pressures are likely to increase risk margins in both wholesale and retail prices.

2.3 Direct comparison of wholesale prices

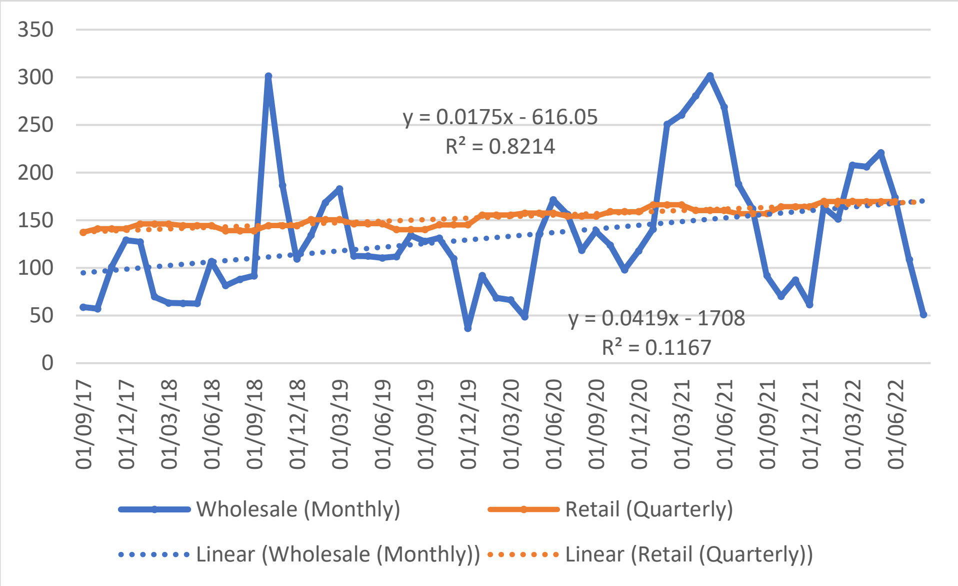
A simpler and more direct approach is to calculate the difference between the simulate prices in each of the years and use the difference as an indicator of the potential price pressure. This approach indicates the price increase pressure is more immediate than suggested by the by the modelling and separates the timing of wholesale price pressure from the assumptions about how and when it is passed on into retail prices. This analysis indicates that with the higher NZU prices residential bills would be about 10 percent higher over 2024 to 2026 but only 5 percent higher in 2027 than they would be if NZU prices remained at current levels. The reason for the reduction in price increase pressure from 2027 onwards is that thermal energy plays a much smaller role in the system than it does in 2023 (which again is much smaller than the role it plays in currently). (This analysis is based on multiplying the wholesale price increases shown in Table 3 of Appendix A by the adjustment factor of 0.33 used in the model.

2.4 Pent-up pressure on retail prices

The modelling of the price effects argues *'Most electricity consumers are isolated from the spot market by retail electricity contracts which are based on the expectation of future* *wholesale prices.'*[7] The paper also states there '*We expect a lag between a step change in wholesale prices and the change in retail prices.*'[8]

The above analysis assumes that the current residential electricity prices fully reflect recent increases in wholesale electricity prices. However, the comparison trends in the energy component of retail prices with wholesale prices in Figure 1 indicates the residential energy component has increase much more slowly than the wholesale market trend.

Figure 1 Wholesale spot energy price and average retail energy prices



Source: NZIER

2.5 Need for narrower focus on price passthrough mechanics

The approach to the comparison of NZU price changes on residential electricity prices could be made much easier to follow and test by:

- Stating clear assumptions about the model for pass-through of changes is wholesale prices to retail prices whether this is some form of value weighted lag, a moving average or an average of expected prices and whether there are constraints on the maximum rate of pass-through each period.
- Focusing the modelling on the pass-through NZU price changes rather than grafting it onto a model where the main assumption is a disruptive change in both the mix of generation fuel and the way in which the system can reliably meet peak and dry-year demand for electricity.

[7] Technical Annex 3: Electricity market modelling and retail price estimates, August 2022', page 13

[8] Technical Annex 3: Electricity market modelling and retail price estimates, August 2022', page 14

3 Wholesale price modelling

3.1 Comparison modelling approach and results with reality

The modelling is described as a continuation of the modelling in Ināia Tonu Nei The modelling is a transition for the CCC from reliance on a simple assumption that average wholesale electricity prices will fall in line with the long run marginal cost of wind generation to modelling based on the cost of the mix of generation during 3 hourly periods.

The CCC projections average wholesale electricity prices falling as lower marginal cost wind generation replace thermal generation has not matched recent conditions in wholesale electricity markets. Over 2018 to 2021 uncertainty about the price and availability of gas for generation and a shortage of peak capacity led to increased use of coal for generation and hydro generators setting the marginal price for generation above the cost of thermal generation in some peak periods. High wholesale prices were sustained after the gas supply uncertainty was mitigated. This demonstrated that wholesale prices can diverge from the short-run marginal cost of the marginal generator for extended periods (compared to for example the ETS setting period of 2023-2027).

3.2 Hard to critique because key links are opaque

Overall, the modelling is difficult to critique in and informed and logical way because the key modelling assumptions and two key modelling steps are opaque. The simulations are completed after an assumed major reduction in the use of coal-fired thermal generation without an explanation of how the shift is achieved.

The two key steps in the modelling are the simulations of electricity generation fuel and prices and the estimation of the sensitivity of electricity prices to carbon (NZU) prices.

The electricity generation simulations are based '*on a 91-year record of hydrological inflows and a 40-year dynamic estimate of wind and solar resource'*[9] for three demand paths The pricing distribution is reported in 5 bands with a mean. However, the generation fuel mix is only reported as mean.

The sensitivity of the simulated electricity prices to NZU prices is estimated from a linear regression of the simulated wholesale electricity price against the NZU price each year for the four scenarios used. This is a crude measure of the two NZU price effects that the model should measure:

- The contribution of NZU cost to the offer price of thermal generation when thermal generation is setting the market price by fuel type. (The model simulations should be able to provide this information as part of the output for the drivers of prices for each of the three-hour modelling periods.)
- The extent to which the lack of thermal generation capacity encourages higher hydro generation prices in dry years. (This has been a factor in the high wholesale prices over 2020 to 2022. This source of price pressure could be modelled by comparing scenarios with continuation of current use of thermal generation with the demonstration path switch to renewable energy.)

9 'Advice on NZ ETS unit limits and price control settings for 2023-2027, Technical Annex 3: Electricity market modelling and retail price estimates, August 2022' page

3.3 Modelled electricity price understates fossil fuel exposure

The modelling potentially understates electricity price exposure to carbon prices by:

- Assuming a rapid phase down in thermal generation without considering the effect of this phase down on wholesale electricity prices. The modelling projects that thermal generation will account for:
  - 10 percent of electricity generation in 2023 (less than 60 percent of the average share of thermal generation over 2018 to 2021).
  - 6 to 7 percent of generation over 2024 to 2027 (less than 30 percent of the average share of thermal generation over 2018 to 2021).
- Assuming coal will account for less than 10 percent of thermal generation from the second half of 2022 onwards when it has accounted for an average of 29 percent of thermal generation over 2018 to 2021 and 39 percent of thermal generation in 2022. The CO_2e emissions per GWh of electricity generated using coal averaged about twice the CO_2e emissions per GWH of electricity generated using gas.

The following charts compare the actual emissions from the main thermal and geothermal generation over the past five years with estimated emissions for 2022 and modelled emissions over 2023 to 2035 for the 'Fixed' NZU price path (Figure 2) and the 'Higher' NZU price path Figure 3.

The comparisons have the following common features:

- The actual emissions are estimated for:
  - Gas and coal by multiplying gas and coal energy used in generation (from the Ministry for Business Innovation and Employment (MBIE)) by CO_2e emission factors for these fuels (from the Ministry for Environment (MfE)).
  - Geothermal generation by multiplying generation in GWh by an emission factor of 76 t CO2e/GWh (MBIE geothermal generation stack report[10]).

  MBIE also reports CO_2e emissions for electricity generation by fuel. These values are similar to the estimates for coal and geothermal but higher for gas-fired generation. We have used our lower estimate for the actual emissions from gas generation to provide a conservative assessment of the difference between recent actuals and the emissions modelled by the CCC.

- The estimate for the year to 31 December 2022 is the sum of:
  - Actual emissions for the quarter ended 31 March 2022.
  - One third of the actual emissions for the quarter ended 30 June 2022.
  - Emissions modelled by the CCC for the remainder of 2022. '*The 2022 model year is for the period of 28 April to 31 December.'*[11]

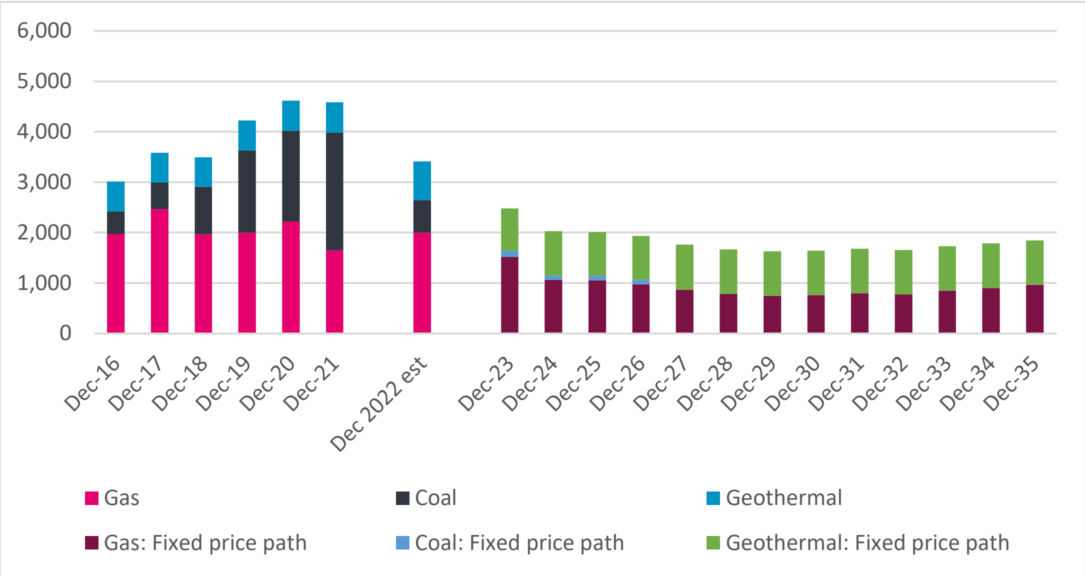
  The forecast for 2022 implies no further use of coal for generation from 1 July 2022 to 31 December 202.

[10] 'The present MW-weighted average emissions intensity for existing geothermal projects is 76 g CO2eq/kWh (2018), which has been steadily declining (91 g CO2eq/kWh in 2015) and is expected to continue to do so in the future' Source: Future Geothermal Generation Stack, A report for the Ministry of Business, Innovation and Employment' page 1

[11] 'Technical-annex-3-Electricity-market-modelling-and-retail-price-estimates-results-dataset.xlsx', 'Demonstration path scenarios', A8

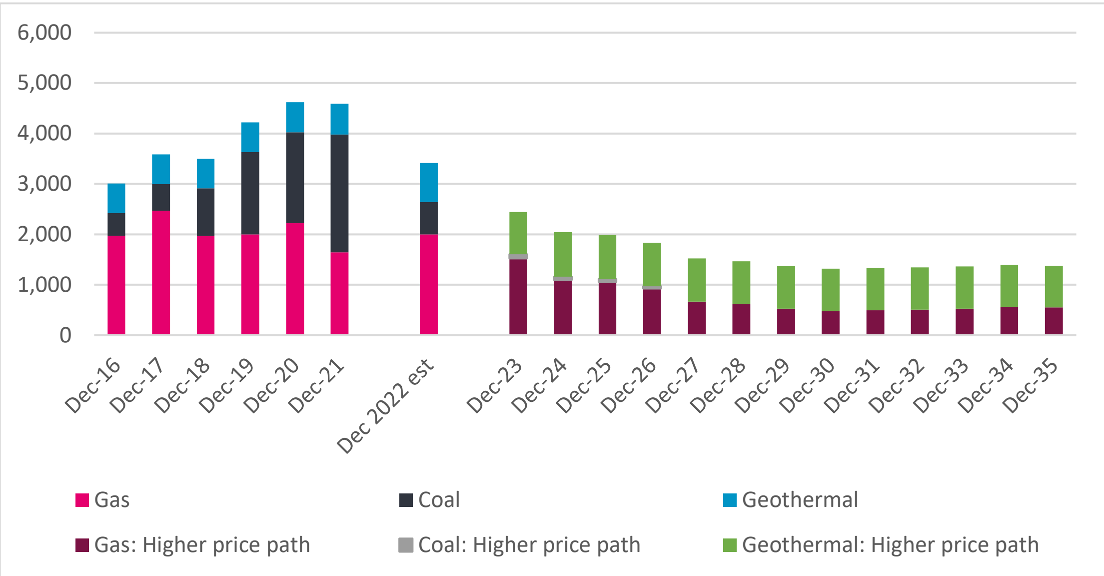
- The modelled reductions in thermal generation emissions do not seem to be correlated with the change in NZU prices. The 'Higher' NZU prices start at $50 (70 percent) above the 'Fixed' NZU price in 2022 and increase to $93 (132 percent) above the 'Fixed' NZU price by 2027. However, the modelled:
  - Gas emissions under the 'Fixed' and the Higher' NZU price paths are almost identical until 2026
  - Coal emissions fall 81 or 120 kt CO_2e in 2023 and are eliminated from the model by 2027.

Figure 2 Generation emissions (kt CO_2e)– recent actual vs fixed NZU price path



Source: NZIER

Figure 3 Generation emissions (kt CO_2e)– recent actual vs higher NZU price path



Source: NZIER

3.4 Disruptive change is difficult to model

The questionable assumptions that are necessary to come up with these results include:

- Rapid construction of wind, geothermal and solar generation – but all vital components are imported from suppliers likely to be beset by supply shortages and shipping problems.
- Sensible standby and reserves policies being implemented – at the moment this work seems to be in the problem definition/ conceptual stage.

3.5 Effect of NZU price increases on cost of electricity generation

The model does not provide sufficient information to independently calculate the termination of the use of coal or the reduction in gas use on the change in NZU impact on wholesale prices. An increase in the price of an NZU of $10 increases the price of electricity generated from coal by about $7 to $8 per MWh and from gas by about $4 to $5 per MWh.

Appendix A Data sources

This section contains data used in the above analysis.

A.1 CCC NZU price assumptions and modelled electricity prices

Table 3 Modelled NZU price paths

[insert caption subheading]

Year	Current auction reserve price (ARP)	Fixed price path	Current cost containment-reserve (CCR)	Higher emissions price path
2022	30	70	70	120
2023	32	70	77	127
2024	33	70	85	135
2025	35	70	93	143
2026	36	70	102	152
2027	38	70	113	163
2028	40	70	124	174
2029	42	70	136	186
2030	44	70	150	200
2031	47	70	155	205
2032	49	70	159	209
2033	51	70	164	214
2034	54	70	169	219
2035	57	70	174	224

Source: NZIER

Table 4 Modelled wholesale electricity time weighted average prices (TWAP)

Comparison of 'CCR' and 'Higher emissions price' paths to 'Fixed price' path

Year	Fixed price path	Current cost containment-reserve (CCR)		Higher emissions price path	
	Wholesale Electricity Price ($/MWh)	Wholesale Electricity Price ($/MWh)	Increase over Fixed price path	Wholesale Electricity Price ($/MWh)	Increase over Fixed price path
2022	159.30	159.99	0.4%	183.37	15.1%
2023	110.43	113.32	2.6%	131.89	19.4%
2024	88.43	98.59	11.5%	114.90	29.9%
2025	86.02	101.29	17.8%	112.60	30.9%
2026	87.14	103.34	18.6%	111.04	27.4%
2027	92.11	95.05	3.2%	104.60	13.6%
2028	88.89	97.26	9.4%	105.09	18.2%
2029	88.50	97.58	10.3%	100.69	13.8%
2030	91.11	97.84	7.4%	99.24	8.9%
2031	95.95	101.32	5.6%	103.14	7.5%
2032	94.52	104.46	10.5%	106.12	12.3%
2033	99.78	107.03	7.3%	108.74	9.0%
2034	104.69	111.03	6.1%	113.17	8.1%
2035	99.29	110.43	11.2%	112.75	13.6%

Source: NZIER

Table 5 Relationship between wholesale electricity TWAP and NZU prices

Results of linear regression analysis

Year	Sensitivity factor ($/MWh / $/tCO2e)	Estimated TWAP wo emissions pricing ($/MWh)	High impact ($/MWh / $/tCO2e)	Low impact ($/MWh / $/tCO2e)
2022	0.48	126.16		
2023	0.38	84.12	0.28	0.16
2024	0.36	66.03	0.28	0.16
2025	0.32	68.12	0.28	0.16
2026	0.25	73.57	0.28	0.16
2027	0.11	85.57	0.28	0.16
2028	0.14	80.38		0.16
2029	0.11	80.67		0.16
2030	0.07	85.75		0.16
2031	0.05	92.47		0.16
2032	0.08	89.35		0.16
2033	0.05	97.31		0.16
2034	0.06	99.88		0.16
2035	0.10	91.96		0.16

Source: NZIER

Table 6 Forecast generation by fuel – Current CCR path

Net generation in GWh for calendar years 2016 to 2021 and six months to June 2022

	2022	2023	2024	2025	2026	2027	2028
Hydro	16,353	24,131	24,059	24,176	24,084	24,003	24,056
Geothermal	5,439	8,351	9,442	9,310	9,331	9,884	9,864
Wind	2,427	3,799	4,584	4,976	5,858	6,411	7,358
Cogen – renew	171	258	259	258	258	258	259
Soalr[1]	62	162	267	403	551	695	837
Cogen – fossil	659	964	966	964	964	964	967
Diesel	2	1	1	2	3	5	6
Fossil gas	3,264	3,819	2,604	2,568	2,362	2,082	1,875
Coal	238	139	92	106	109	0	0
Total	**28,614**	**41,625**	**42,274**	**42,762**	**43,521**	**44,304**	**45,222**

Notes:

1 Solar includes Home solar, Utility solar, Utility solar (with battery).

Source: NZIER

Table 7 Forecast generation by fuel – High emissions price path

Net generation in GWh for calendar years 2016 to 2021 and six months to June 2022

Fuel	2022	2023	2024	2025	2026	2027	2028
Hydro	16,329	24,124	24,109	24,265	24,186	23,907	23,920
Geothermal	5,438	8,351	9,449	9,328	9,411	9,878	9,877
Wind	2,427	3,799	4,365	4,632	5,430	6,756	7,233
Cogen – renew	171	258	259	258	258	258	259
Solar[1]	62	162	267	337	604	743	1,297
Cogen – fossil	659	964	966	964	964	964	967
Diesel	2	1	1	2	3	5	6
Fossil gas	3,282	3,831	2,743	2,783	2,552	1,797	1,641
Coal	243	132	104	124	115	0	0
Total	**28,613**	**41,622**	**42,264**	**42,692**	**43,523**	**44,307**	**45,200**

Notes:

1 Solar includes Home solar, Utility solar, Utility solar (with battery)

Source: NZIER

Table 8 Forecast emissions by fuel – Current CCR price path

Net generation in GWh for calendar years 2016 to 2021 and six months to June 2022

Fuel	2022	2023	2024	2025	2026	2027	2028
Fossil gas	1,319	1,527	1,128	1,147	1,055	746	681
Coal	210	114	90	107	99	0	0
Geothermal	567	836	886	868	871	893	888
Diesel	1	0	1	1	2	4	4
Cogen - fossil	221	221	221	221	221	221	221
Cogen - renew	204	308	309	308	308	308	309
Total	**2,684**	**3,348**	**2,977**	**2,993**	**2,898**	**2,513**	**2,447**

Source: NZIER analysis of Technical Annex 3[12]

Table 9 Forecast emissions by fuel – Higher emissions price path

Net generation in GWh for calendar years 2016 to 2021 and six months to June 2022

Fuel	2022	2023	2024	2025	2026	2027	2028
Fossil gas	1,337	1,525	1,098	1,055	925	667	615
Coal	149	81	61	63	45	0	0
Geothermal	567	836	885	866	864	859	853
Diesel	2	0	1	2	2	5	5
Cogen - fossil	221	221	221	221	221	221	221
Cogen - renew	204	308	309	308	308	308	309
Total	**2,642**	**3,314**	**2,918**	**2,857**	**2,707**	**2,400**	**2,346**

Notes:

1 Solar includes Home solar, Utility solar, Utility solar (with battery)

Source: NZIER analysis of Technical Annex 3[13]

Table 10 Emissions from generation – value used in CCC forecasts

Emissions in t CO_2e/GWh for the calendar years 2016 to 2021 and six months to June 2022

Fuel	2022	2023	2024	2025	2026	2027	2028
Gas	401	398	410	411	413	419	418
Coal	864	864	864	864	864		
Geothermal	104	100	94	93	91	90	89

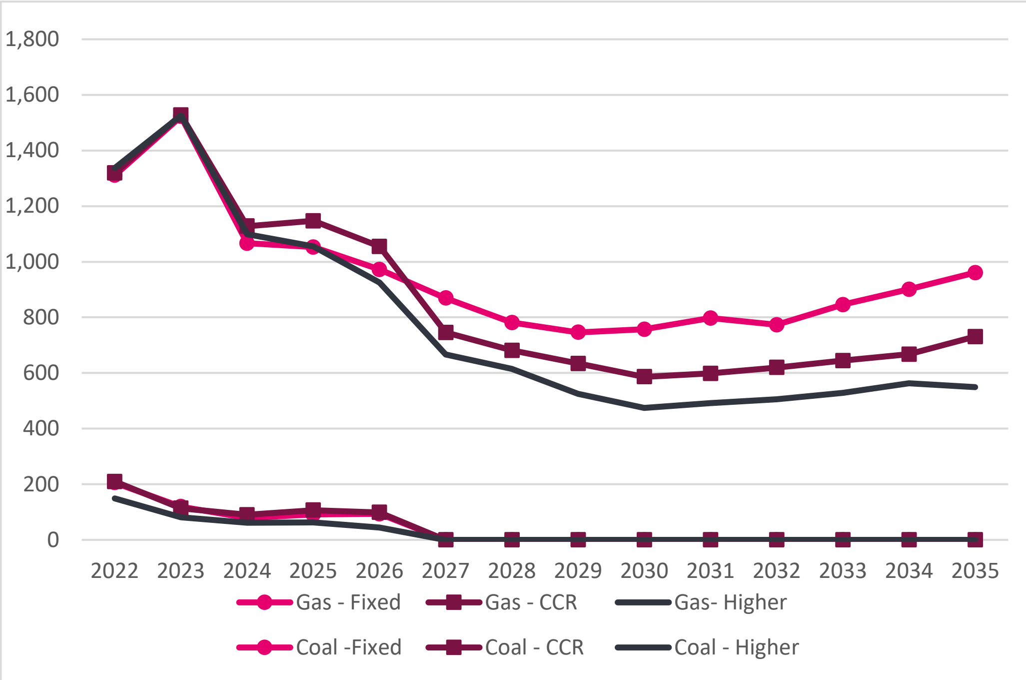
Source: NZIER analysis of Technical Annex 3[14]

12 'Electricity market modelling and retail price estimates results summary', Demonstration path scenarios

13 'Electricity market modelling and retail price estimates results summary', Demonstration path scenarios

14 'Electricity market modelling and retail price estimates results summary', Demonstration path scenarios

Figure 4 CCC emissions (kt CO_2e)– ‘Fixed’, ‘CCR’ and ‘Higher’ NZU price paths



Source: NZIER

A.2 MBIE generation by fuel and emissions estimates

Table 11 Generation by fuel

Net generation in GWh for calendar years 2016 to 2021 and six months to June 2022

Fuel	2016	2017	2018	2019	2020	2021	Jun 2022
Hydro	25,676	24,924	25,992	25,343	24,024	23,992	11,382
Geothermal	7,738	7,779	7,729	7,793	7,834	7,968	4,054
Wind	2,317	2,070	2,047	2,233	2,282	2,616	1,329
Wood	496	485	463	472	460	483	229
Biogas	265	264	262	267	271	265	127
Solar[1]	56	76	99	126	159	203	125
Waste Heat[2]	51	46	49	45	40	43	22
Oil	3	6	11	4	13	26	3
Gas	5,338	6,527	5,287	5,412	5,932	4,650	2,843
Coal	979	1,133	1,479	2,118	2,159	3,020	955
Total	**42,919**	**43,311**	**43,419**	**43,814**	**43,173**	**43,267**	**21,069**

Notes:

1 Distributed Solar PV Generation has been estimated using Electricity Authority data.

2 Waste heat includes heat from chemical processes - e.g. fertiliser industry.

Source: NZIER analysis of MBIE net electricity generation data[15]

[15] 'Electricity graph and data tables, Table 1, Quarterly electricity generation and consumption', See workbook 'electricity', worksheet 'Table 1', Cells 'A12:A32', 'FL12:GL32'. Available at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/

Table 12 Emissions from generation – two estimates for natural gas

Emissions in kt CO_2e for the calendar years 2016 to 2021 and six months to June 2022

Fuel	2016	2017	2018	2019	2020	2021	Jun 2022
MBIE[1]							
Gas	2,610	3,096	2,527	2,571	2,700	2,140	1,306
Coal	448	525	946	1,643	1,818	2,358	695
Geothermal	721	673	614	602	568	583	279
Total	**3,779**	**4,294**	**4,087**	**4,816**	**5,086**	**5,081**	**2,280**
Estimate[2]							
Gas	1,974	2,469	1,965	1,998	2,220	1,646	1,076
Coal	448	526	945	1,633	1,804	2,336	689
Geothermal	588	591	587	592	595	606	308
Total	**3,011**	**3,586**	**3,498**	**4,223**	**4,619**	**4,588**	**2,073**

Notes:

1 Emissions from electricity generation reported by MBIE.

2 Estimate for coal and gas based on MfE emissions factor multiplied by fuel used for generation reported by MBIE. Estimate for geothermal based on emissions of 76 t CO2e/GWh from 'Future Geothermal Generation Stack' (report to MBIE) multiplied by geothermal generation reported by MBIE.

Source: NZIER analysis of MBIE net electricity generation data[16]

16 'Electricity graph and data tables, Table 1, Quarterly electricity generation and consumption', See workbook 'electricity', worksheet 'Table 1', Cells 'A12:A32', 'FL12:GL32'. Available at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/

Table 13 Emissions from generation – two estimates for natural gas

Emissions in t CO_2e/GWh for the calendar years 2016 to 2021 and six months to June 2022

Fuel	2016	2017	2018	2019	2020	2021	Jun 2022
MBIE[1]							
Gas	489	474	478	475	455	460	459
Coal	457	463	640	776	842	781	728
Geothermal	93	86	79	77	73	73	69
Estimate[2]							
Gas	370	378	372	369	374	354	378
Coal	458	464	639	771	835	773	722
Geothermal	93	77	87	79	74	79	81

Notes:

1 Emissions from electricity generation reported by MBIE.

2 Estimate for coal and gas based on MfE emissions factor multiplied by fuel used for generation reported by MBIE. Estimate for geothermal based on emissions of 76 t CO2e/GWh from 'Future Geothermal Generation Stack' (report to MBIE) multiplied by geothermal generation reported by MBIE.

Source: NZIER analysis of MBIE net electricity generation data[17]

[17] 'Electricity graph and data tables, Table 1, Quarterly electricity generation and consumption', See workbook 'electricity', worksheet 'Table 1', Cells 'A12:A32', 'FL12:GL32'. Available at https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/