MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

Electricity demand and generation scenarios

SCENARIO AND RESULTS SUMMARY

August 2016

New Zealand Government

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

ABOUT THIS REPORT

Published August 2016
By Ministry of Business, Innovation and Employment

15 Stout Street
PO Box 1473
Wellington 6140

Email: edgs@mbie.govt.nz
www.mbie.govt.nz

ISBN: 978-0-947524-28-9 (PDF)

Contents

1 Key Results

Both peak and total electricity demand is expected to grow out to 2050

- Total electricity demand growth averages between 0.4% and 1.3% each year in our scenarios out to 2050.
- Peak electricity demand is expected to grow, reaching between 6,560 MW and 8,060 MW by 2040 in our scenarios.
- The possible closure of New Zealand's Aluminium Smelter at Tiwai Point is a key uncertainty to the future of electricity demand. Total electricity demand would not return to current levels until the late 2020s in our modelling if the smelter closed in 2018.

The percentage of electricity generated from renewable sources is expected to increase

- Renewable electricity supply is expected to grow to meet increasing demand.
- More geothermal and wind generation capacity is built in all our scenarios and these technologies are the lowest cost options to meet additional new baseload demand in most scenarios.
- Up to 2,530 MW and 790 MW of new wind and geothermal capacity is built respectively between 2016 and 2040.
- In all our scenarios remaining large coal fired generation capacity is retired between 2020 and 2026.
- In a scenario with low cost and abundant gas supply and low carbon prices long term, the percentage of renewable electricity generation remains at a similar level as it is today. This is due to a mixture of renewable and gas fired baseload generation capacity being built to meet growing demand.

High uptake of electric vehicles and in home batteries can lead to increased renewable generation and reduced reliance on flexible gas fired generation

- Investment in solar PV systems with batteries could reach around 390,000 by 2040, in a scenario in which solar PV capital costs fall to NZD 3.16/W for a 3 kW system and battery costs fall to NZD 167/kWh.
- Charging electric vehicles predominately overnight, means little additional demand is added to peaks periods, as transport electricity demand increases with high electric vehicle uptake.
- Investment in residential solar panels with batteries can maximize household use of solar generation and shift household demand away from peak periods.
- Additional transport electricity demand from a high uptake of electric vehicles can be met by new geothermal, solar PV with batteries, and wind generation. There is less need for flexible gas fired peaking generation if the daily residential demand profile has lower peaks.

2 Purpose of the EDGS

The Electricity Demand and Generation Scenarios (EDGS) are created to be used by Transpower and the Commerce Commission to assess future proposals for planning for capital investment in the transmission grid. The role of the EDGS is set out in the Commerce Commission's Transpower Capital Expenditure Input Methodology Determination (Capex IM). Under the Capex IM, the EDGS provides a set of scenarios against which Transpower's proposals for major capital expenditure can be tested.

The scenarios are designed to investigate key uncertainties in the electricity sector including:

- The type and location of electricity generation supply, considering:
  - Technology costs (for existing and emerging generation technologies)
  - Resource availability and cost (particularly for natural gas)
  - The global response to climate change (particularly the price of carbon emissions).
- The characteristics and location of electricity demand, considering:
  - The size and structure of the economy
  - The future of heavy industry in New Zealand, particularly New Zealand's Aluminium Smelter at Tiwai Point
  - The size and structure of the population
  - The price of electricity compared with alternative energy sources
  - Energy efficiency and demand side participation in the electricity market
  - Uptake rate of new technology such as electric vehicles and Solar PV

Five scenarios have been developed to explore a plausible range of uncertainty about the future electricity system. The scenarios do not represent forecasts of the future and should not be interpreted as such. None of the scenarios are considered to be more likely, or less likely, than the others, and no significance should be attributed to their labels, which have been chosen to help users identify the scenarios and distinguish between them; they are not intended to convey a view that one scenario is better or worse than another.

This document is intended to provide a summary of the modelled scenarios and results while the Energy Modelling Technical Guide (see Reference 1) provides technical detail of the modelling approach.

3 Scenarios summary

The ***Mixed Renewables*** scenario has a mixture of geothermal and wind plant built, starting in 2020. This scenario assumes an average of 1% annual electricity demand growth, reflecting moderate GDP and population growth, and current views on relative technology cost and expected fuel and carbon prices.

The ***High Grid*** scenario assumes higher GDP and population growth rates leading to higher electricity demand across all sectors; with 1.3% per year growth in grid connected electricity demand. Higher gas exploration effort results in higher domestic gas supply with a flat wholesale gas price of around $6/PJ to 2040[1].

The ***Global Low Carbon*** scenario assumes a high carbon price and lower cost renewable technology (wind and solar) which leads to more renewable build. This scenario assumes high uptake of petrol hybrid vehicles and solar PV systems, and flat electricity demand per household due to efficiency measures.

In the ***Disruptive*** scenario a reduction in technology costs leads to high uptake of Solar PV with batteries and electric vehicles. Both total electricity demand and grid connected demand increases as the additional electric vehicle demand is only partially offset by solar generation. Peak and off peak retail electricity price signals lead to flattening of demand, with a lower peak demand through battery load shifting and off peak EV charging.

In the ***Tiwai Off*** scenario Tiwai shuts at the start of 2018 and lower GDP growth leads to lower electricity demand across all sectors, averaging 0.4% p.a. Some existing thermal generation retires due to the drop in energy demand in the short term. With less capacity on the system more flexible North Island generation is built in the early years to meet peak requirements.

[1] Scenarios are modelled and results are published to 2050. Uncertainty in assumptions and results increases the further in the future they occur. We have chosen to reference results and assumptions in 2040 instead of 2050 in this summary report.

Table 1 – Key Assumptions by scenarios

	Mixed Renewables	High grid	Tiwai Off	Global Low Carbon	Disruptive
Demand and oil and carbon prices					
GDP	Medium	High	Low	Medium	Medium
Residential demand per household	Medium	High	Low	Low	Medium
Tiwai load from start of 2018	572 MW	572 MW	0 MW	572 MW	572 MW
Carbon prices	$56 in 2030	$10	$56 in 2030	$152 in 2030	$104 in 2030
Oil price	Medium	High	Very Low	Low	Medium-Low
Population	Medium	High	Low	Medium	Medium
Electricity supply mix					
Gas supply availability	Medium	High	Medium	Medium	Medium
Retirement Huntly Rankin units	End of 2022	End of 2026	End of 2019	End of 2022	End of 2022
Cost of wind generation	Medium	Medium	Medium	Low	Medium
Hydro availability	Medium	Low	Medium	Medium	Medium
Technology uptake and peak demand					
Solar uptake	Medium	Low	Medium	High	Very High
EV uptake	Medium	Low	Medium	Medium – with high petrol hybrids	Very High
Peak demand projection	Medium	High	Very Low	Medium	Low

4 Electricity demand

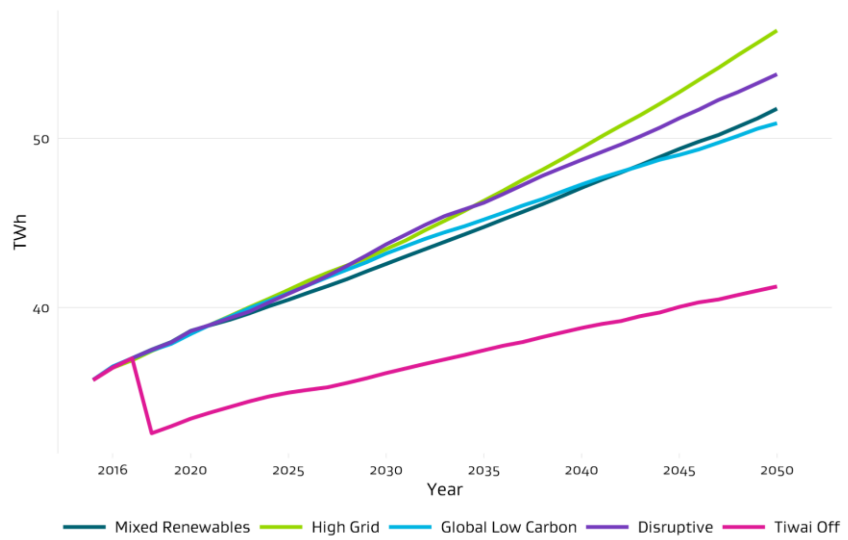
4.1 Electricity energy demand

Grid electricity demand growth ranges between 0.4% p.a. in our *Tiwai Off* scenario and 1.3%[2] p.a. in our *High Grid* scenario out to 2040. Demand growth is 1.0% p.a. in the *Mixed Renewable* scenario. Demand is expected to grow over time as our population, the economy, and household incomes grow[3].

The *Tiwai Off* scenario has the lowest demand with the assumption that New Zealand's Aluminium Smelter closes, reducing the grid connected demand by 12% in 2018. The *Tiwai Off* scenario also assumes the lowest GDP and population growth. The *High Grid* scenario has the highest grid demand by 2040 because of higher GDP and population growth in this scenario and low levels of distributed generation.

Grid demand is higher in the *Disruptive* scenario than all other scenarios except the *High Grid* scenario. This is due to charging of the 1.77 million vehicles in this scenario by 2040. However, this higher grid demand is partly offset by 1,600 GWh of household Solar PV generation in 2040. Total consumer demand, which includes the demand meet by household solar PV, is at a very similar level in the *Disruptive* and *High Grid* scenarios by the early 2040s.

Figure 1 –Electricity demand projections at grid exit point



Electricity demand in the *Global Low Carbon* scenario is higher than in the *Mixed Renewables* scenarios for the majority of the 2020s and 2030s, despite having the same GDP and demographic assumptions. This is due to higher carbon price in the *Global Low Carbon* scenario leading to fuel switching away from higher carbon intensive fuels to electricity, particularly in the industrial sector, as shown in Figure 3.

---

[2] Grid connected demand grows by 1.3% in the High Grid scenario.

[3] Energy demand is modelled by sector, using a combination of econometric models, production based forecasts for high energy intensive industry and a vehicle fleet model for transport demand. Full details of the energy demand modelling is provided in the Technical Guide see Reference 1.

Residential demand is assumed to remain constant per household in the *Global Low Carbon* scenario. Total residential demand grows (due to increasing household numbers) at a lower rate than in the *Mixed Renewable* scenario (see Figure 3) and means consumer electricity demand is the same in the *Mixed Renewables* and *Global Low Carbon* scenario by the mid-2040s.

Grid connected demand in the *Global Low Carbon* scenario falls below that in the *Mixed Renewables* in the 2040s due to increasing household solar generation offsetting grid demand.

Figure 2 – Consumer electricity demand projections

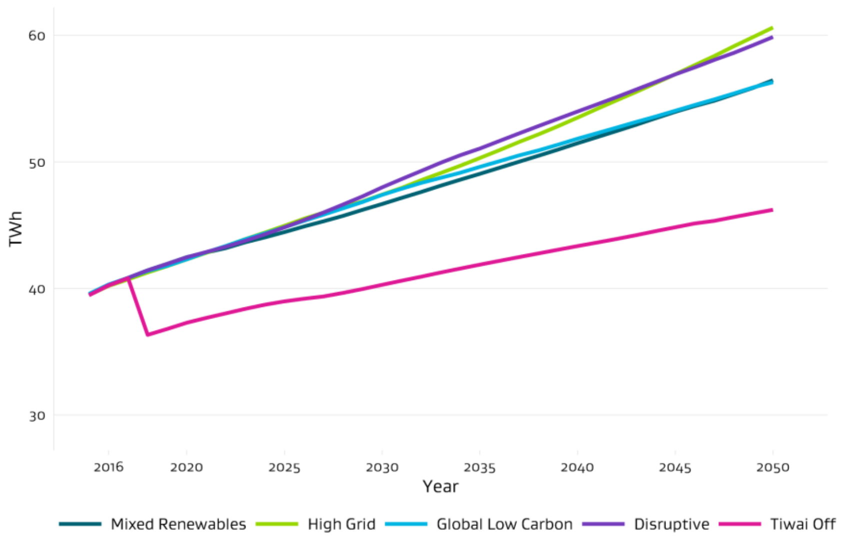
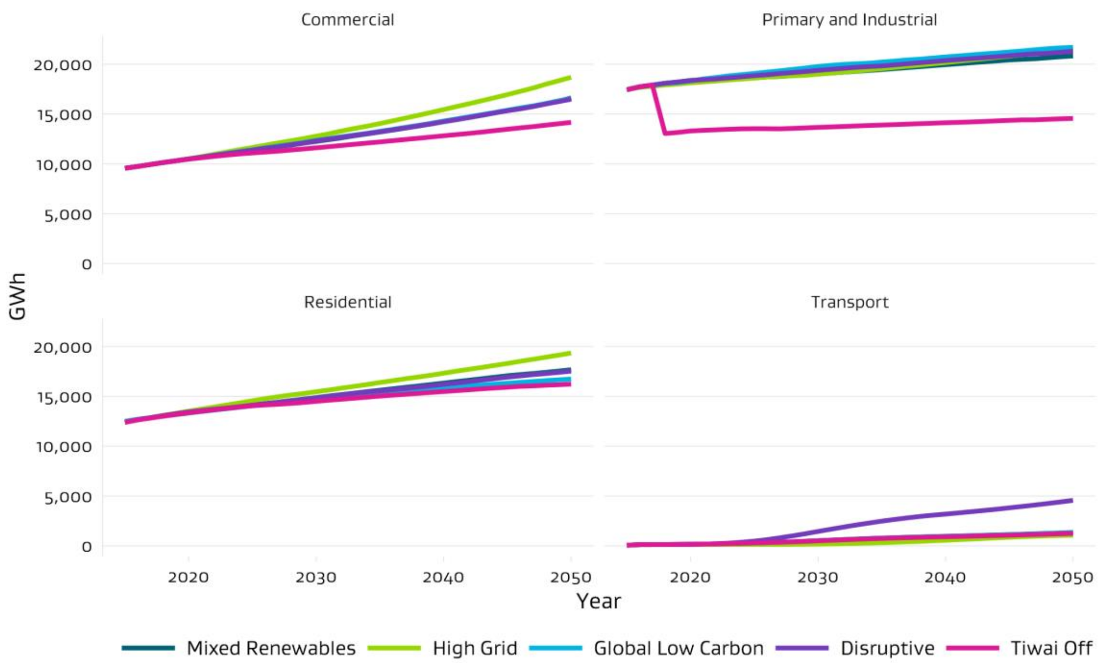


Figure 3 – Electricity demand by sector

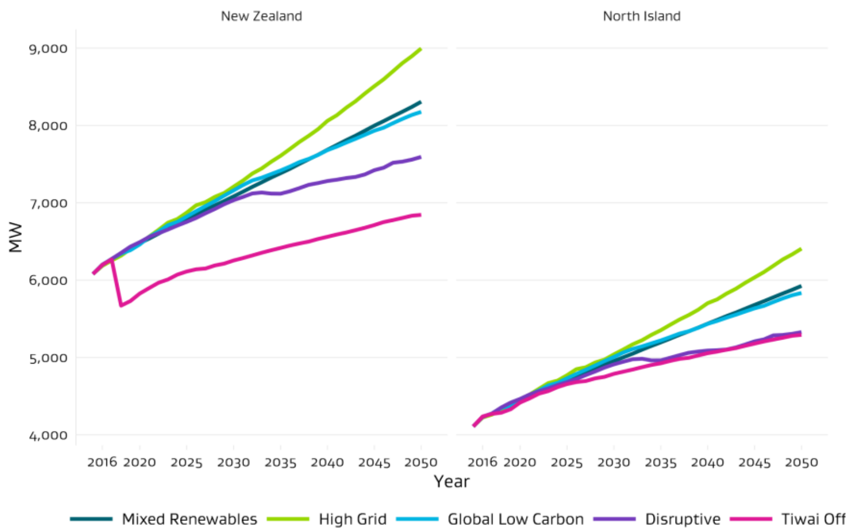


4.2 Peak electricity demand

Peak demand growth varies across all the EDGS scenarios by 2040, reaching about 8,060 MW in 2040 in the *High Grid* scenario, 7,685 MW in the *Mixed Renewables* scenario and 6,560 MW in the *Tiwai Off* scenario.

In the *Tiwai Off* scenario national peak demand reduces by 572 MW in 2018 due to the reduction in South Island baseload demand when the New Zealand Aluminum Smelter closes, as shown in Figure 4. North Island peak demand is not directly affected by the smelter closure; however both National and North Island peak demand growth in the *Tiwai Off* scenario is lower than in the *Mixed Renewables* scenario in later years, due to lower assumed GDP and population growth.

Figure 4 – Peak demand for New Zealand and the North Island



The *Disruptive* scenario has a lower peak demand than both the *Global Low Carbon* and *Mixed Renewables* scenario, despite having higher electricity energy demand. This is due to a higher uptake of both electric vehicles and solar PV with batteries.

The *Disruptive* scenario assumes that there is a within-day peak and off-peak retail price signal which incentivises charging of electric vehicles outside peak periods.

Total EV energy demand is allocated by hour of the day based on the following assumptions:

- 80% of charging occurs between 11pm and 5am
- 10% of charging occurs between 5pm and 11pm
- 10% of charging occurs during the day evenly allocated between 9am and 5pm

This means that little of the additional electric vehicle demand in the *Disruptive* scenario is allocated to the peak period, reducing the ratio between peak demand and energy in this scenario.

In the *Disruptive* scenario, there is a high uptake of residential[4] solar PV, the majority of which is installed with a battery, (over 580,000 solar and battery systems installed by 2050). Household solar and battery operation is modelled on an hourly basis[5] to maximise own use of

[4] Moderate commercial solar PV uptake is also assumed, with 3,268 commercial solar installations in 2040.

[5] The Technical Guide provides more details of solar and solar with battery modelling; see Reference 1.

solar generation and to shift demand from peak periods, allowing the battery to be charged from the grid in off peak periods, when solar is not generating, and supply the household in peak periods. Solar and battery systems reduce winter evening peaks by around 490 MW in 2040 and 800 MW in 2050 in the *Disruptive* scenario

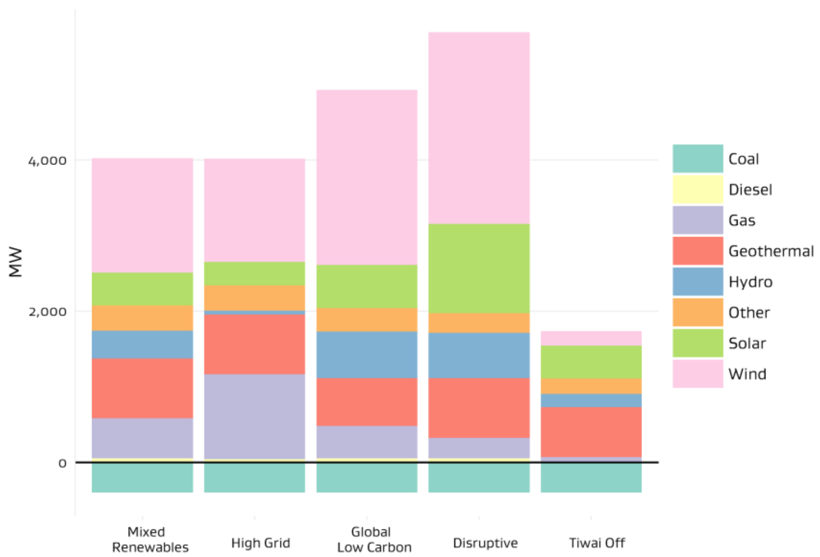
In the ***Global Low Carbon*** scenario there is significant uptake of solar PV systems (180,000 systems installed by 2040 and 360,000 systems by 2050), however investment in solar PV occurs predominantly without batteries and we do not see the effect of batteries shifting demand from the peak periods as we did in the *Disruptive* scenario.

5 Electricity Supply

Electricity supply is modelled using the Electricity Authority's General Expansion Model (GEM)[6]. More details of the supply side modelling methodology are available in the Energy Modelling Technical Guide[7]. Appendix A provides a summary of some of the key input assumptions to the GEM model. Full details of assumptions used in the model including the costs of new and existing generation technology are published by MBIE.[8]

By 2040 between 4,000 to 5,000 MW of new electricity capacity is needed in most scenarios to meet growing electricity demand, as shown in Figure 5. However, if New Zealand's Aluminium Smelter closes before 2040 then only 2,000 MW may be needed.

Figure 5 – Change in Electricity Capacity from 2016 to 2040



[6] The GEM model is made available on the Electricity Authority website, see Reference 2.
[7] See Reference 1.
[8] See Reference 3.

Geothermal and wind capacity increases in all scenarios between now and 2040. In most of the scenarios, geothermal and wind plant are the cheapest to build, with a long run marginal cost[9] (LRMC) ranging from $80 to over $100 per MWh[10] as shown in Figure 8.

Figure 6 shows the new build capacity by fuel type in the *Mixed Renewables* scenario. We can see there is both new geothermal and wind plant built in the scenario, from the early 2020s.

Figure 6 - New generation capacity built in the Mixed Renewables scenario[11]

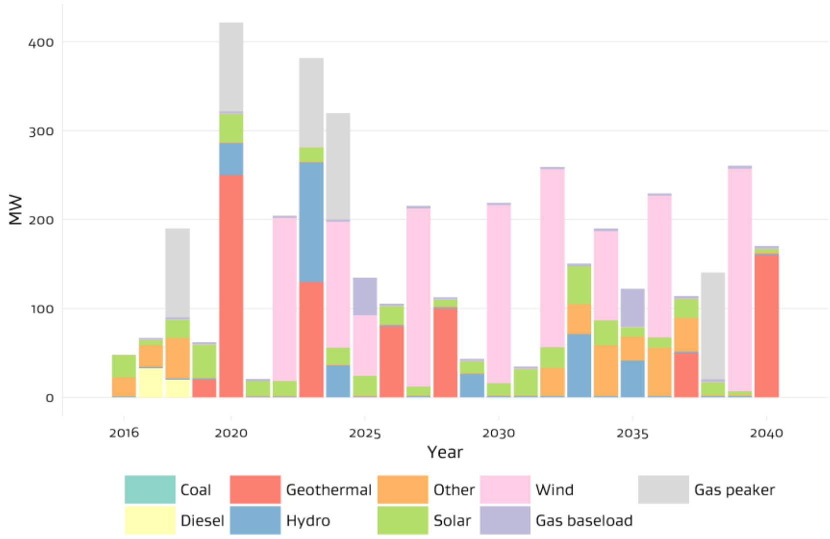


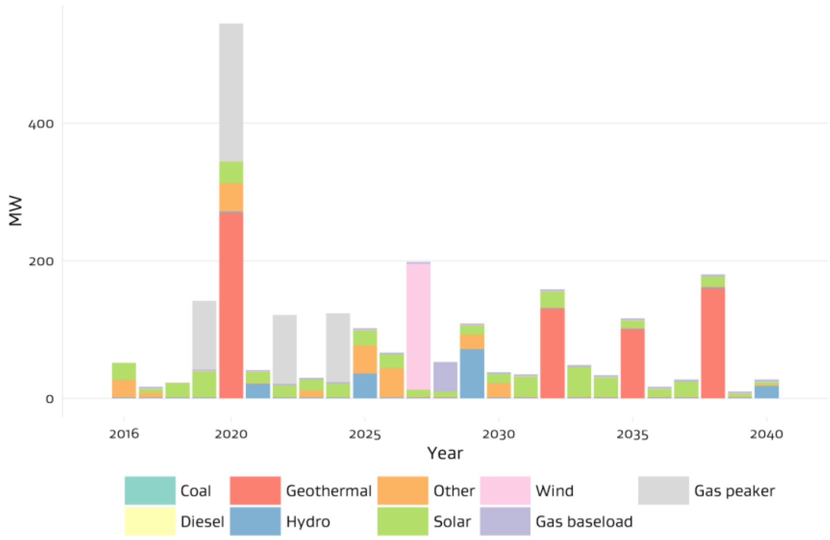
Figure 7 shows the new build in the *Tiwai Off* scenario. When compared to the *Mixed Renewables* scenario build in Figure 6 we can see little new capacity is required with the closure of New Zealand's Aluminium Smelter.

[9] The LRMC is the average wholesale price per MWh of generation that a generator needs to earn to cover all plant costs (in this context including capital financing costs, carbon costs, fuel costs, O&M costs).

[10] Costs are real 2014 NZ dollars.

[11] Some small 10MW diesel reciprocating peakers are built in the early years in the modelling. This is an artefact of the electricity modelling to meet dry winter energy demand requirements. This is discussed in more detail in our Technical Guide, see Reference 1.

Figure 7 - New generation capacity built in the *Tiwai Off* scenario



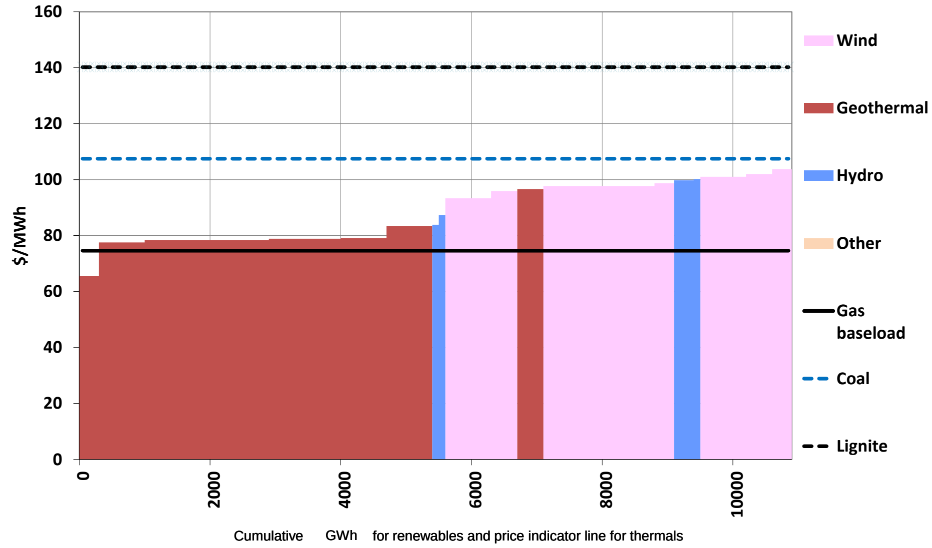
The GEM[12] model does not take account of revenue adequacy for existing plants when considering retirement and new build investment decisions. In the *Tiwai Off* scenario exogenous assumptions[13] were made to retire Taranaki CCGT (baseload gas fired plant) at the start of 2018 at the time New Zealand's Aluminium Smelter closes and to retire the remaining two Huntly Rankine units[14] at the start of 2020. Modelled results in Figure 7 show that 500 MW of new gas peaking plant is built by 2024 in the *Tiwai Off* scenario. The level of the peak demand is higher relative to the amount of electricity energy demand in the *Tiwai Off* scenario after closure of New Zealand's Aluminium Smelter. The shift from less flexible baseload gas generation to more flexible gas fired generation makes sense given the shift to a higher peak to energy demand ratio. However, it is relevant to note that short term pricing dynamics and revenue adequacy to cover the cost of investment for the new peaking plant in the *Tiwai Off* scenario has not been captured in the modelling. An alternative option to meet short term demand requirements could be to extend the life of existing coal and gas fired Huntly Rankine units, which could delay some of the new gas peaker build in the Tiwai Off scenario.

In the *High Grid* scenario, which assumes a low carbon and gas price and a higher domestic gas supply, new baseload gas fired plant[15] costs are competitive with geothermal and wind.

Figure 8 shows the LRMC assuming gas and carbon price of \$6/GJ and \$10/tCO_2e. The solid black line on the chart shows the LRMC of a new gas fired baseload plant at just below \$80/MWh, at a similar level to the lowest cost new geothermal plant. In most scenarios the gas and carbon price increase well above \$6/GJ and \$10/tCO_2e, meaning new gas fired baseload costs increase and these plant are not built in these scenarios.

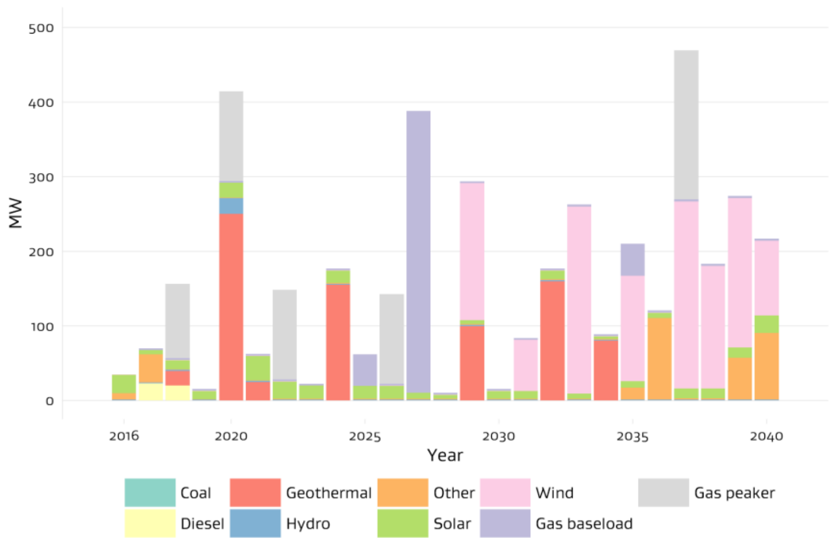
[12] GEM determines build and retirement decisions based on a least cost of electricity supply optimisation.
[13] Exogenous assumptions based on publically available information; however there is much uncertainty and alternative assumptions as to the operation or retirement of existing thermal plant is plausible.
[14] The Huntly Rankine units can generate using a combination of coal and gas.
[15] New gas fired baseload plants are combined cycle gas turbines (CCGT).

Figure 8 - Long Run Marginal Costs of new non-peak generation projects ($6/GJ gas, $10/tCO2e carbon



However, in the *High Grid* scenario abundant gas supply, flat gas price and low carbon price assumptions mean than new gas fired baseload costs remain competitive with geothermal and wind, and two 475 MW gas fired baseload plant are built in this scenario, one in 2027, the other in 2041. Figure 9 shows the High Grid scenario build profiles by technology type out to 2040. The retirement date for the existing Huntly coal and gas fired Rankine units is assumed to be later in the *High Grid* scenario (at 2026, compared with 2022 in the *Mixed Renewables* scenario). The Huntly units help to meet growing demand in the first half of the 2020s, deferring new build requirements.

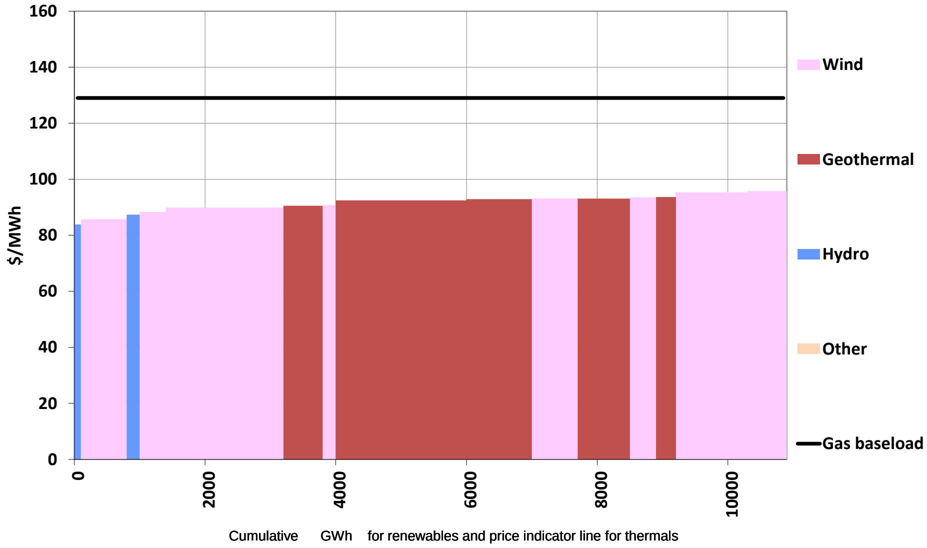
Figure 9 – New generation capacity built in the *High Grid* scenario



New wind capacity ranges from 190 MW to 2530 MW by 2040 across the scenarios. More wind is built in the *Global Low Carbon* and *Disruptive* scenarios, where there is a higher carbon price. However, less wind is built in the *High Grid* scenario, particularly in early years, where there is a lower carbon price and significantly more gas available for baseload generation and later retirement of the Huntly Rankine units.

Figure 10 shows the LRMC of new non-peaking generation projects with a gas and carbon price of $7/GJ and $150/tCO2e, which are the prices assumed in 2030 in the Global Low Carbon scenario. In the *Global Low Carbon* scenario wind capital costs are assumed to be 10% below those in all other scenarios, which is also reflected in the LRMC in Figure 10.

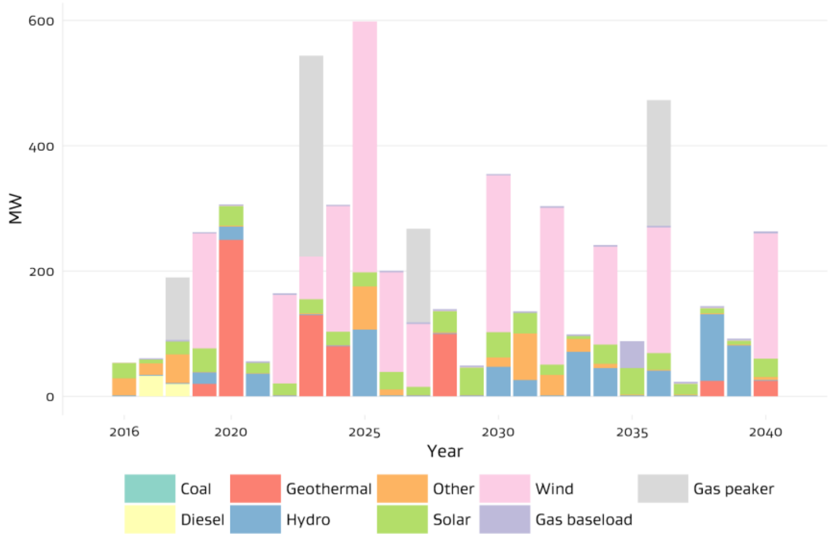
Figure 10 - Long Run Marginal Costs of new non-peak generation projects ($7/GJ gas, $150/tCO2e carbon, 10% lower wind capital costs)[16]



There is 1,500 MW of new wind capacity built by 2030 and 2,300 MW between 2016 and 2040 in the *Global Low Carbon* scenario. In the *Disruptive* scenario is 1,150 MW of new wind capacity built by 2030 and 2,530 MW between 2016 and 2040.

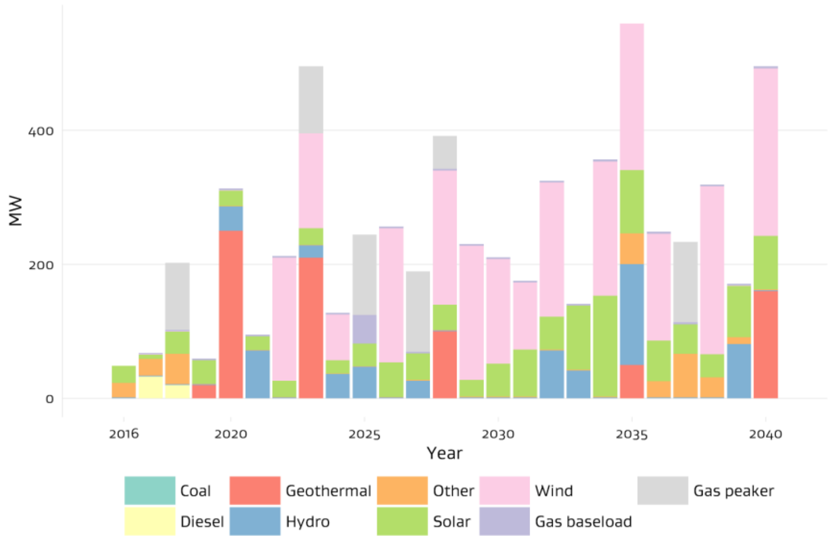
[16] Coal and Lignite LRMC are over $160/MWh and are not shown on the chart

Figure 11 – New generation capacity built in the *Global Low Carbon* scenario



Wind is intermittent and requires back-up plant at peak times. Gas peaking plant provides this security in the most scenarios. Less gas peaking plant is required in the *Disruptive* scenario because household batteries help to shift demand from peak periods.

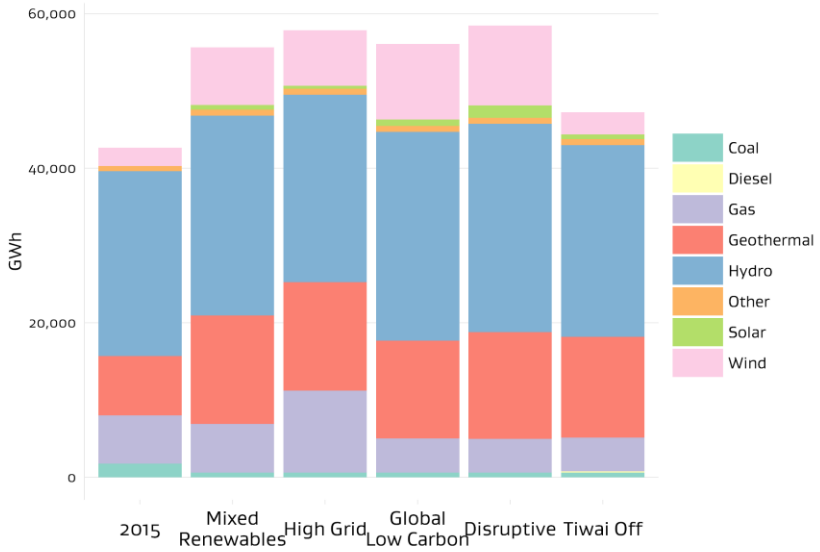
Figure 12 - New generation capacity built in the *Disruptive* scenario



There is 620 MW of new gas peaking plant built by 2030 and 820 MW between 2016 and 2040 in the *Global Low Carbon* scenario. In the *Disruptive* scenario 540 MW of new gas peaking plant is built by 2030 and 660 MW between 2016 and 2040.

Much of the additional transport demand in the *Disruptive* scenario is met by baseload geothermal and solar generation. This is possible as the demand profile is flatter in the *Disruptive* scenario. This is largely due to electric vehicles, which are predominately charged in overnight periods and because batteries installed with solar can maximise solar own use and shift demand to reduce peak demand.

Figure 13 - Electricity generation in 2040



Coal generation is likely to play a smaller part in electricity generation once the two remaining Huntly Rankine units close. In the year that these units retire, electricity generation from coal will fall to less than 600 GWh[17]. Greenhouse gas emissions will fall in the range of 700 to 1,556 kilotonnes of carbon dioxide equivalent (kt CO_2e) depending on the mix of generation that replaces them. Reduction in electricity generation emissions in the early 2020s is largely due to the retirement of the two Huntly units (see Figure 15).

Solar PV generation continues to grow, with between 100,000 and 390,000 residential and commercial solar units installed by 2040 in these scenarios. However this has a small effect on total generation as it will only make up 1% to 3% of electricity generation in 2040.

Baseload gas generation is likely to fall if the carbon price rises. The *High Grid* scenario is the exception where it is assumed that there is cheap gas available for electricity generation and the carbon price is flat at $10 per t CO_2e.

The percentage of electricity generated from renewable sources, shown in Figure 14, ranges between 81% and 91% across our scenarios in 2040. In the *Global Low Carbon* and *Disruptive* scenarios 90% renewable generation is reached by the mid-2020s and mid-2030s respectively. In both cases the renewable target is reached at the time that a baseload gas fired peaking plant retires in the modelled results.

[17] The remaining coal generation is mostly cogeneration in industry such as dairy.

Figure 14 – Share of electricity generated from renewable sources

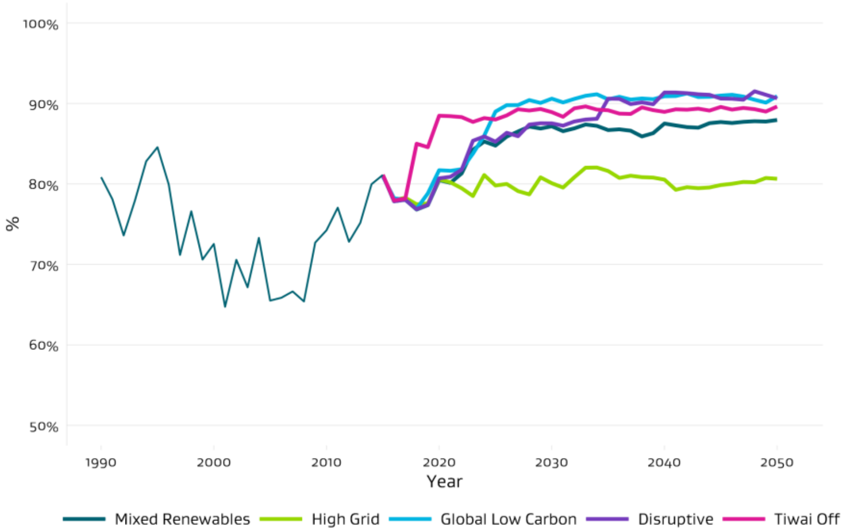
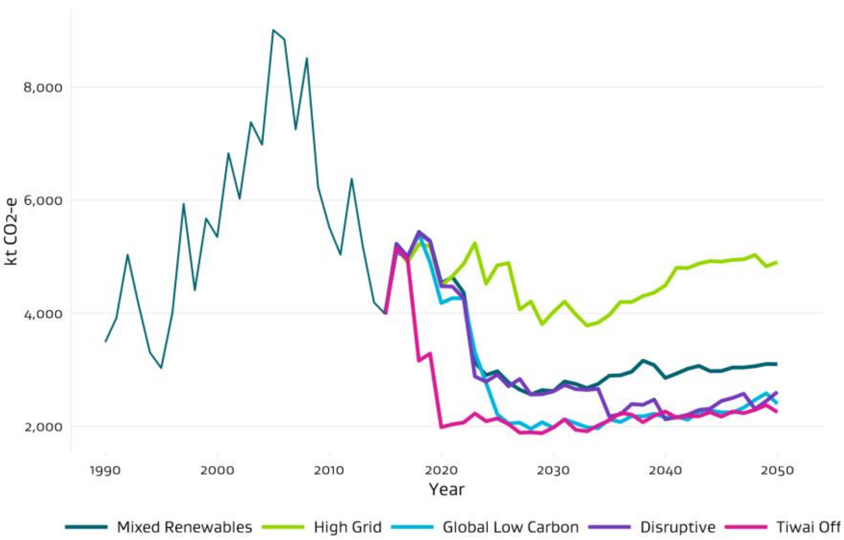


Figure 15 - Electricity greenhouse gas emissions



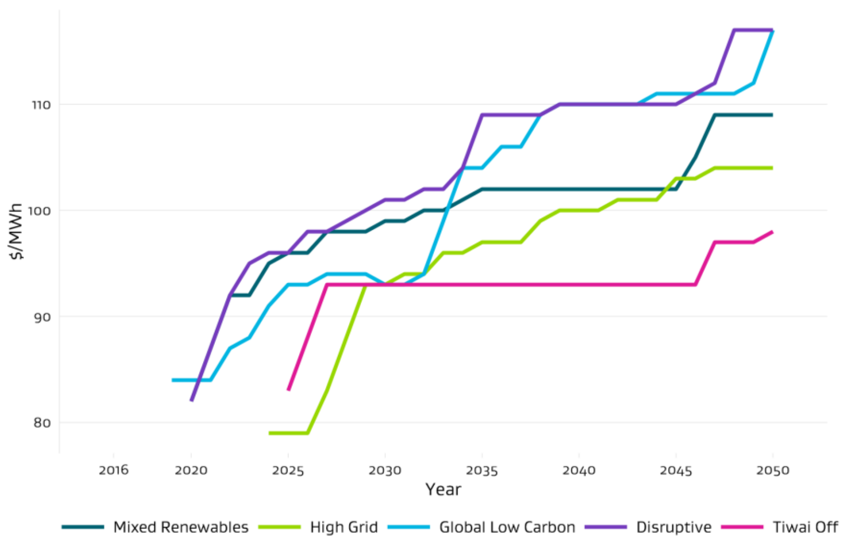
A wholesale electricity price indicator is determined for each scenario (see Figure 16). The price indicator is set based on the LRMC of the new build entering the market in each scenario. The methodology is based on the premise that investors are unlikely to build new generation unless they anticipate prices at or above LRMC when their plant is running in the future[18].

[18] This methodology does not consider short term dynamics of the electricity spot market where offers are largely based on SRMC as opposed to LRMC and should not be used as an electricity price forecast, particularly in the short term, as it does not take account of short term dynamics in the electricity market.

Lower cost plants are built first in each scenario and we can see that the wholesale electricity price indicator increases as more expensive plants are built in each scenario. In the *Global Low Carbon* scenario the price increases are lower than in the *Mixed Renewables* and *Disruptive* scenario in the 2020s. This is because the capital cost of new wind generation and hence LRMC (which is setting the price) is lower in this scenario.

In the *Tiwai Off* scenario, new baseload plant is not required until later in the scenario and hence the price remains flat for longer. In the *High Grid* scenario increasing baseload demand is met through additional generation from existing baseload gas and coal generators with a later retirement date for the Huntly Rankine units, new low cost geothermal and new baseload gas fired plant in the early years delaying build of more expensive plant and the increase in the wholesale electricity price indicator.

Figure 16 - Wholesale electricity price indicator



Appendix A - Scenario assumptions

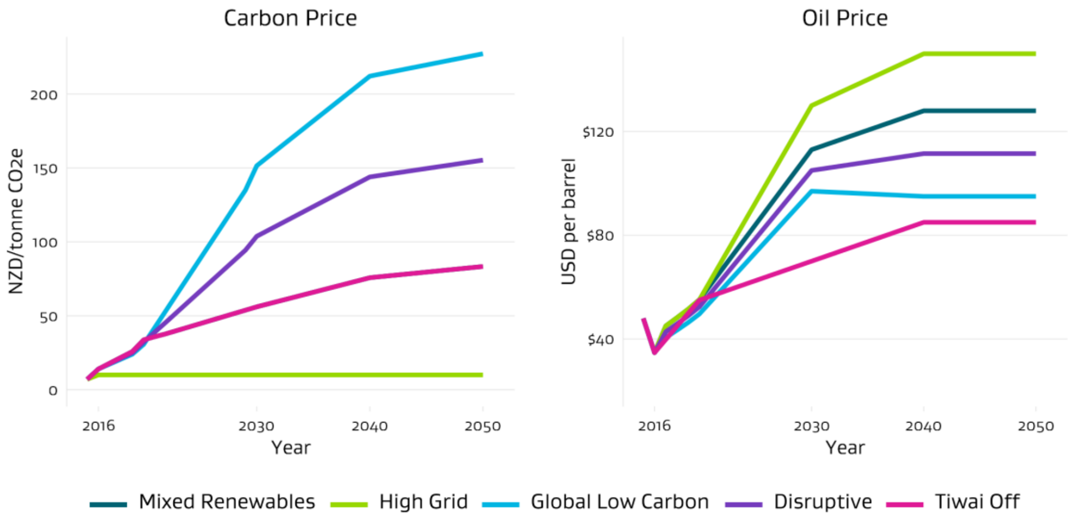
1 - Input price assumptions[19]

The crude oil projections from 2020 onwards are based on the International Energy Agency (IEA) World Energy Outlook scenarios (WEO 2015)[20]. Projections between 2016 and 2020 are based on World Bank commodity price forecasts (February 2016)[21] and trended to the 2020 IEA scenario values. Similarly, carbon price projections are based on the IEA scenarios, with the exception of the *High Grid* scenario in which the carbon price is $10 per tonne of carbon dioxide equivalents across the modelled period. Projections between 2016 and 2020 are interpolated from the 2016 price to the 2020 IEA value. Prices in the charts below are on a real 2014 basis.

Table 2: Sources of input price assumptions

Scenario	IEA Oil Price Scenario	Carbon Price Scenario
Mixed Renewables	New Policies	IEA New Policies
High Grid	Current Policies	NZ Current Market
Global Low Carbon	IEA 450	IEA 450
Disruptive	Midpoint of Mixed Renewables and Global Low Carbon	Midpoint of Mixed Renewables and Global Low Carbon
Tiwai Off	Low Oil Price	IEA New Policies

Figure 17 - Input price assumptions



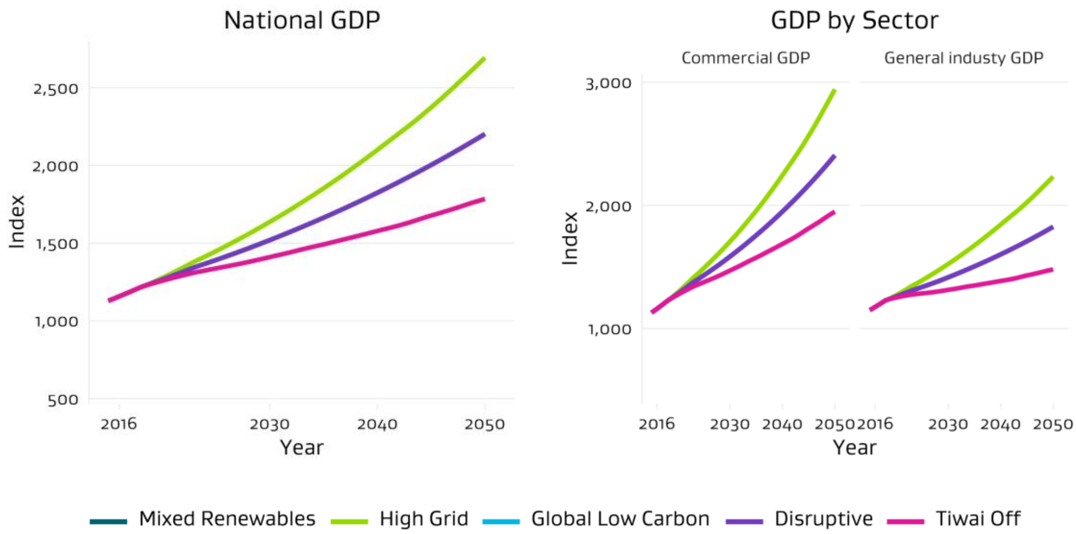
[19] All prices are quoted in real 2014 New Zealand dollars
[20] See Reference 4.
[21] See Reference 5.

2 - GDP projections

The central GDP projection is based on the New Zealand Institute of Economic Research (NZIER) projections. The average annual growth rates by industry in their 2015 Q4 report were used. This is a proprietary report and produced quarterly.

The Treasury Fiscal Growth Model[22] was used to determine the high and low GDP projections by changing the labour force input assumptions. High and low labour force projections were informed by Statistics New Zealand population projections.

Figure 18 - GDP projections at a national and sector level

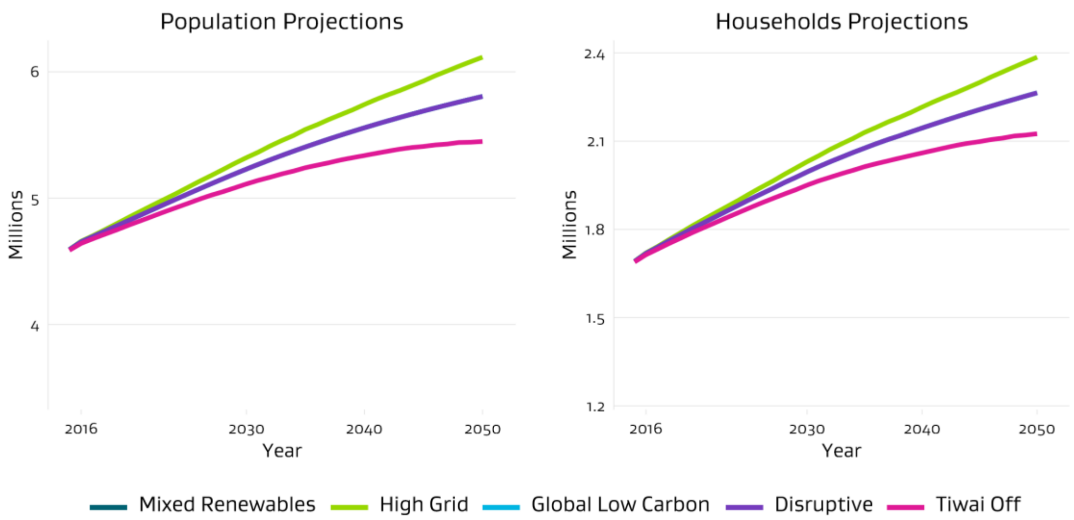


3 - Demographic projections

The population projections are from Statistics New Zealand. The 10th, 50th and 90th percentile correspond to the low, medium and high trajectories.

The household projections are also based on Statistics New Zealand projections.

Figure 19 – Demographic projections



[22] See Reference 6.

4 – Disruptive Technology uptake

Disruptive technology includes solar PV, solar PV with batteries and electric vehicles. Solar PV and solar PV with battery investment are modelled using a financial model which includes hourly solar PV and battery operation and household demand. The numbers of electric vehicles in each scenario are an output of the Ministry of Transport's *Vehicle Fleet Emissions Model*.[23]

Figure 20 – Solar PV uptake

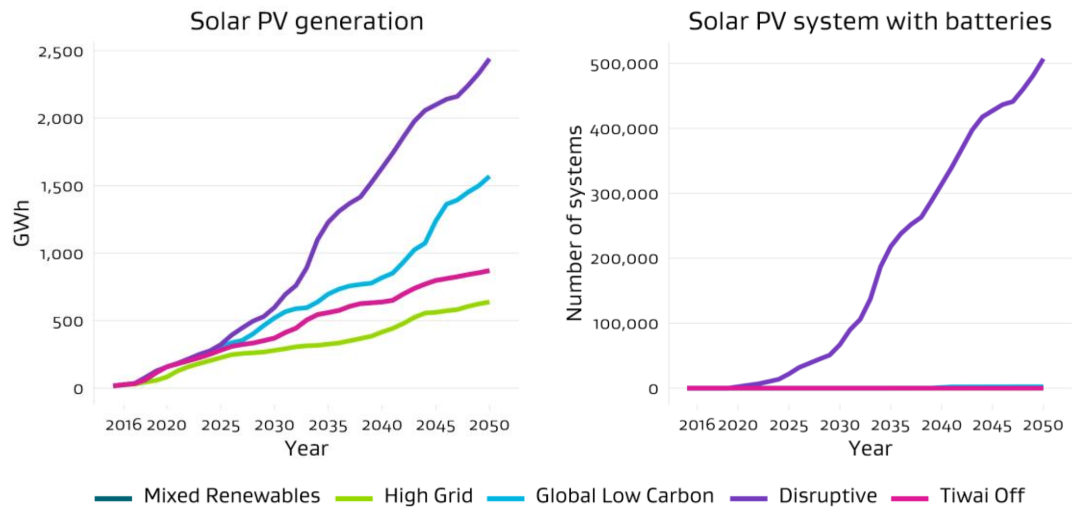
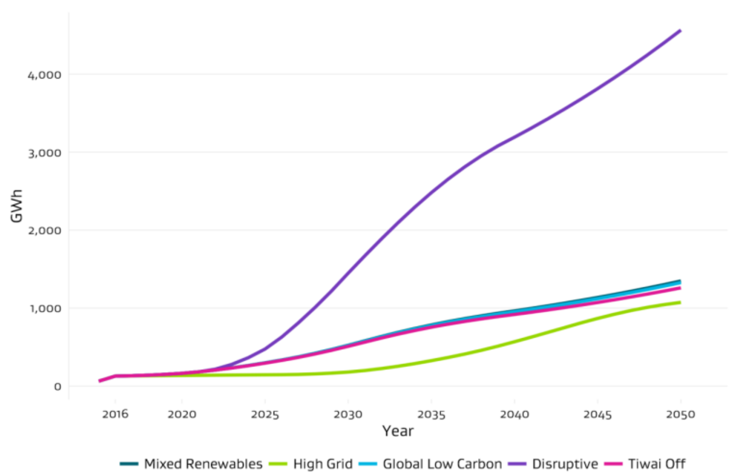
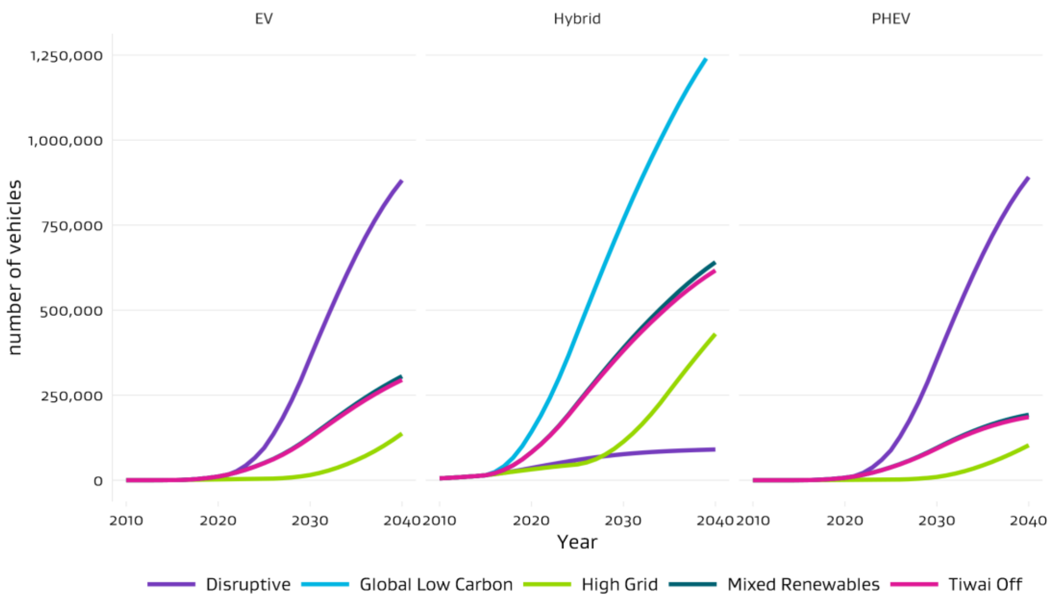


Figure 21 – Electricity demand from electric vehicles



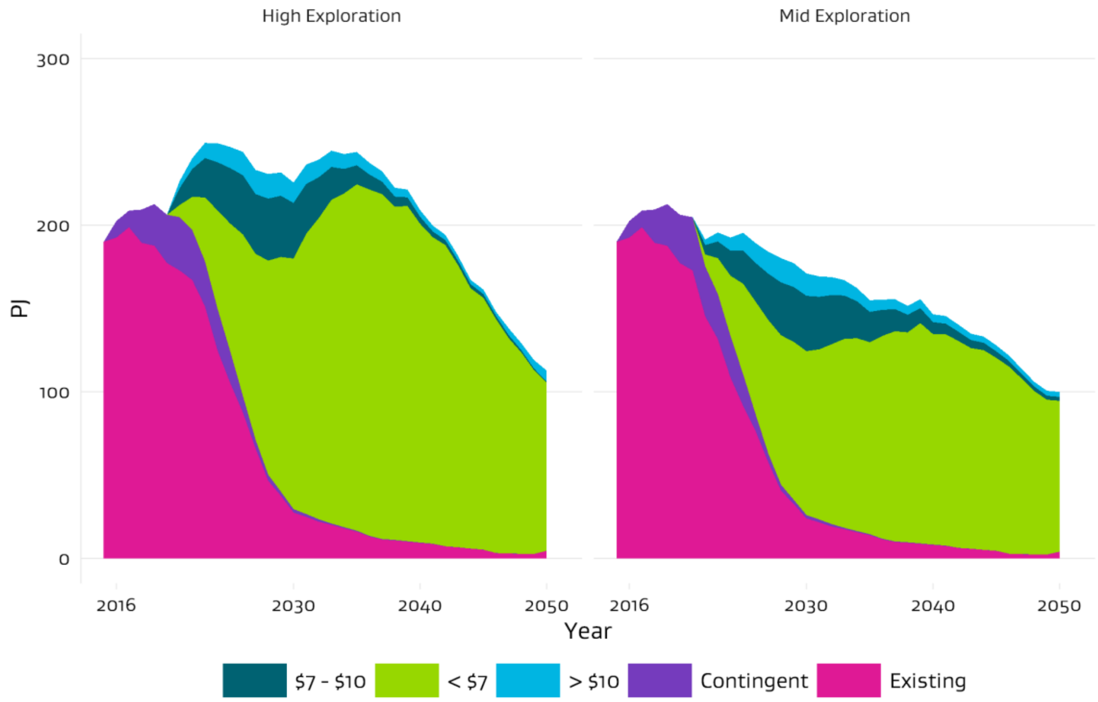
[23] More details of both the transport and solar PV modelling methodology is available in the Technical Guide, see Reference 1.

Figure 22 – Vehicle fleet composition



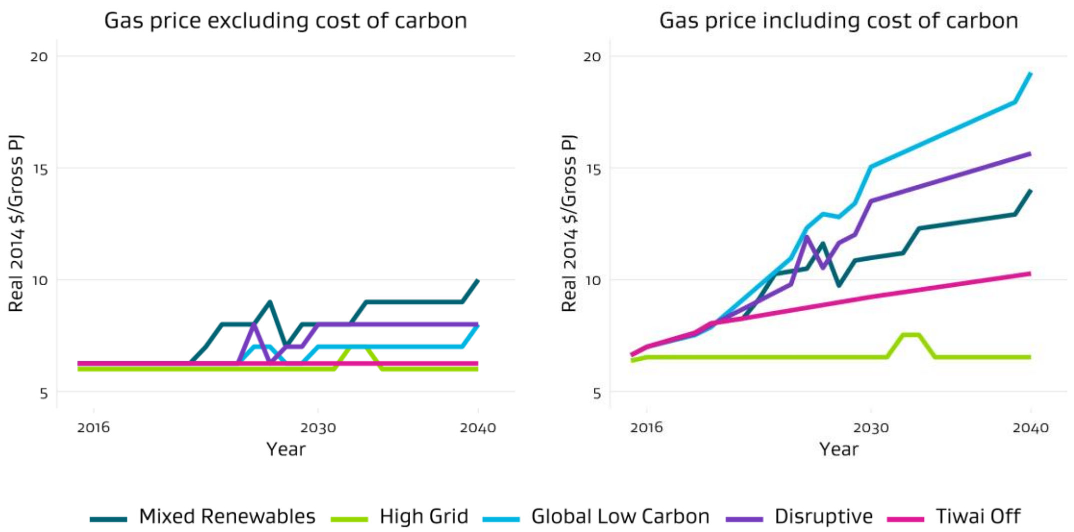
5 - Gas Supply and price

Figure 23 – Gas Supply



Gas price is modelled based on the gas demand and the cost of gas supply assumed in each scenario. [24]

Figure 24 – Gas price excluding and including the cost of carbon for each scenario



---

[24] More details of gas supply and demand modelling are available in the Technical Guide, see Reference 1.

References

1. *Energy Modelling Technical Guide*, 2016.
   Published online at: http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/technical-papers/energy-modelling-methodology

2. The GEM model is made available on the Electricity Authority website
   https://github.com/ElectricityAuthority/gem

3. Electricity Demand and Generation Scenarios assumptions and results published online
   http://www.mbie.govt.nz/info-services/sectors-industries/energy/energy-data-modelling/modelling/electricity-demand-and-generation-scenarios

4. IEA, World Energy Outlook 2015
   http://www.worldenergyoutlook.org/publications/weo-2015/

5. World Bank commodity price forecasts
   http://www.worldbank.org/en/research/commodity-markets

6. Treasury Fiscal Growth Model, New Zealand
   http://www.treasury.govt.nz/government/fiscalstrategy/model

MB13742_2558