The economics of four future electricity system pathways for New Zealand

Media Briefing

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14th June 2023

Modelling prepared for the Parliamentary Commissioner for the Environment.

The opinions and views expressed in this presentation are the authors own and do not necessarily reflect the views of the Parliamentary Commissioner for the Environment.

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PCE communications on energy

- 11th March 2022 – Letter to Minister Woods, Shaw, Robertson.
  - Caution the development of green hydrogen industry for export
- 20th December 2022 – Letter to Minister Woods.
  - Urging government to move more swiftly with energy strategy
- 20th December 2022 – Note on need for energy strategy
  - Move forward with low regrets options
  - Develop deeper understanding of system wide impacts
  - More care needed before committing to projects with path dependence
- 2nd June 2023 – Submission on the national direction on renewable electricity generation and transmission
  - Specific needs of environment should be added
  - Effects management framework should not include compensation
  - Offsetting used in narrow circumstances

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NZ Battery Project

- Dry-year risk deficit is estimated at between 3-5 TWh
- NZ hydro lakes only have 4.5 TWh of storage, compared to 25 TWh of flows
- Two options to resolve the ‘dry-year’ risk problem
  - 1. Onslow (only single solution)
  - 2. Portfolio approach (including bioenergy, geothermal, curtailing green hydrogen)
- Climate change would provide some mitigation of dry year problem (only about 1-2%)

‘Failure to address dry year risk in an increasingly renewable electricity system will impose significant costs on New Zealand’

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Options considered by MBIE

Option 1 Onslow:

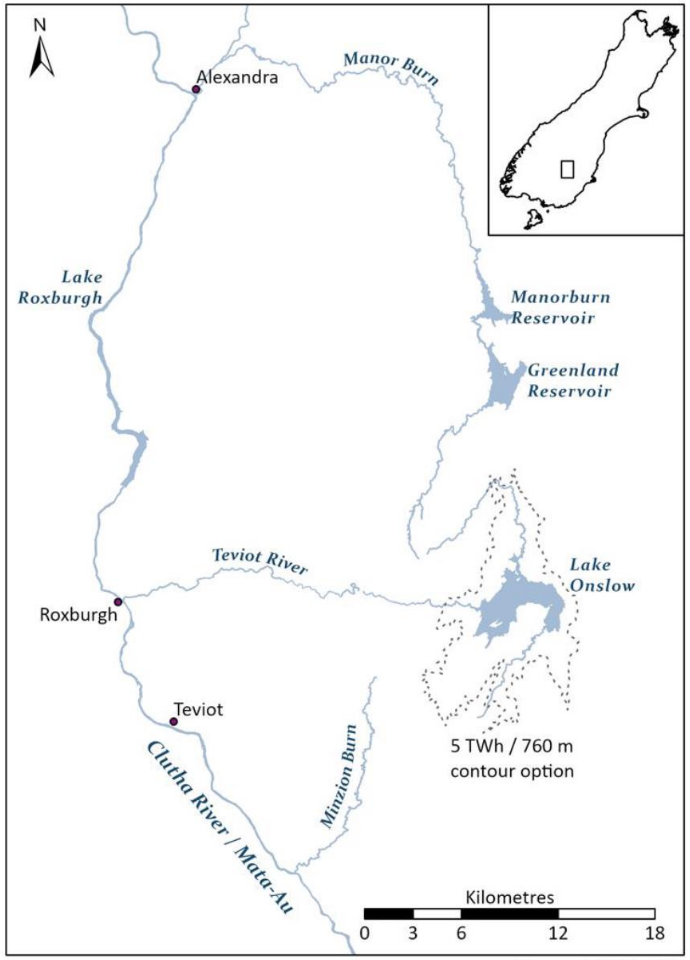
- 1 GW – 15% of peak demand
- 5 TWh – 12.5% of annual demand
- 8-10 year construction time
- 1.5 GW and 8.5 TWh option possible
- Technically feasible.

Option 2 Portfolio:

- 1.2 GW portfolio 2.4 TWh and
- Combustion biomass, geothermal, interruptible hydrogen w ammonia

Counterfactual:

- 100% ‘overbuild’ renewables
- 1,200 MW capacity
- 230 MW green-peakers



Source: MBIE, LINZ

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MBIE Comparisons

Criteria	Onslow	Portfolio option
Capex	$15,493 m	$13,275 m
Net Present Cost	$9,590 m	$13,550 m
42-year project expenditure	$28.7	$49 billion
BCR @ 5%	0.42	0.40
BCR @ 2% (with NZAS)	**1.12**	0.73

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The economics of four future electricity system pathways for New Zealand

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Electricity system pathways

Base case	Tiwai remains operational. New generation is built under prevailing economic and market conditions. Carbon prices rise in-line with meeting net zero targets going from $50 to $250 by 2050.
Pathway 1 **Tiwai Closes**	The Tiwai aluminium smelter is shutdown and electricity from Manapouri hydroelectricity dam flows into the grid. This lowers wholesale electricity prices and causes spill and other inefficiencies. Requires less growth in renewable energy over the short term.
Pathway 2a & 2b **Green Hydrogen**	Tiwai remains operational. A new 500 MW Southern Green Hydrogen facility (SGH) is developed. An ‘option’ fee is paid to the hydrogen plant to curtail production and provide flexibility to the grid. Hydrogen is exported overseas. New renewable generation is required to meet demand. Pathway 2a: fixed supply. Pathway 2b variable supply.
Pathway 3 **Onslow**	Tiwai remains and Onslow is built. Lake Onslow supports the grid in continuous operation mode by pumping when prices are low and generating when prices are high. Pumping and generation is optimized through water values in the Energy Link model.

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Energy Link Model

- Uses full range of 91 historical inflow-wind-sun scenarios available
- Uses E-market and I-Gen model to estimate prices and investment
- Daily wholesale electricity prices estimated to 2050
- Carbon prices increase from $50 to $250 by 2050
- LCOE for different technologies were provided as inputs by Energy Link
- Natural gas prices taken from latest natural gas forecast price used by Energy Link

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Model assumptions

- No hard renewable electricity targets for any pathway – pure market driven approach
- Base case represents BAU and is used as the counterfactual scenario
- Network infrastructure upgrade assumptions consistent across scenarios
- HVDC link upgraded to 1400MW.
- Assumptions about fossil fuel plant closures:

Plant	Status	Base Case	1: Tiwai Closes	2a: SGH Baseload	2a: SGH Dispatched	3: Onslow
TCC CCGT	Closure	Oct-23	Oct-23	Oct-23	Oct-23	Oct-23
Huntly 1^{st} Rankine Unit	Closure	Oct-27	Sep-24	Oct-27	Oct-27	Oct-27
Huntly 2^{nd} Rankine Unit	Closure	Jan-30	Sep-24	Jan-30	Jan-30	Jan-30
e3p (Unit 5) CCGT	Winter Mode	Oct-28	Apr-25	Oct-28	Oct-28	Oct-28
	Dry Year Mode	Oct-31	Apr-30	Oct-31	Oct-31	Oct-31
	Closure	Oct-37	Jan-34	Oct-37	Oct-37	Oct-37

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Pathway assumptions

Pathway 1: Tiwai Closes

- Tiwai closes in 2025
- Electricity flows to grid
- Standard market conditions

Pathway 2: SGH

- 2a: Fixed production
- 2b: Variable production
- Hydrogen exported
- Curtailed production
- Tiwai demand response
- 500 MW plant
- CAPEX of $750m
- OPEX of $7.5m per year
- Capacity factor of 77%
- Life of 30 years

Pathway 3: Onslow

- 8-10 years to build
- Can generate while pumping
- 1 GW and 5000 GWh
- Operates in continuous mode
- Uses "water values"
- CAPEX of $15 billion
- OPEX of $42 million per year
- Life of 100 years

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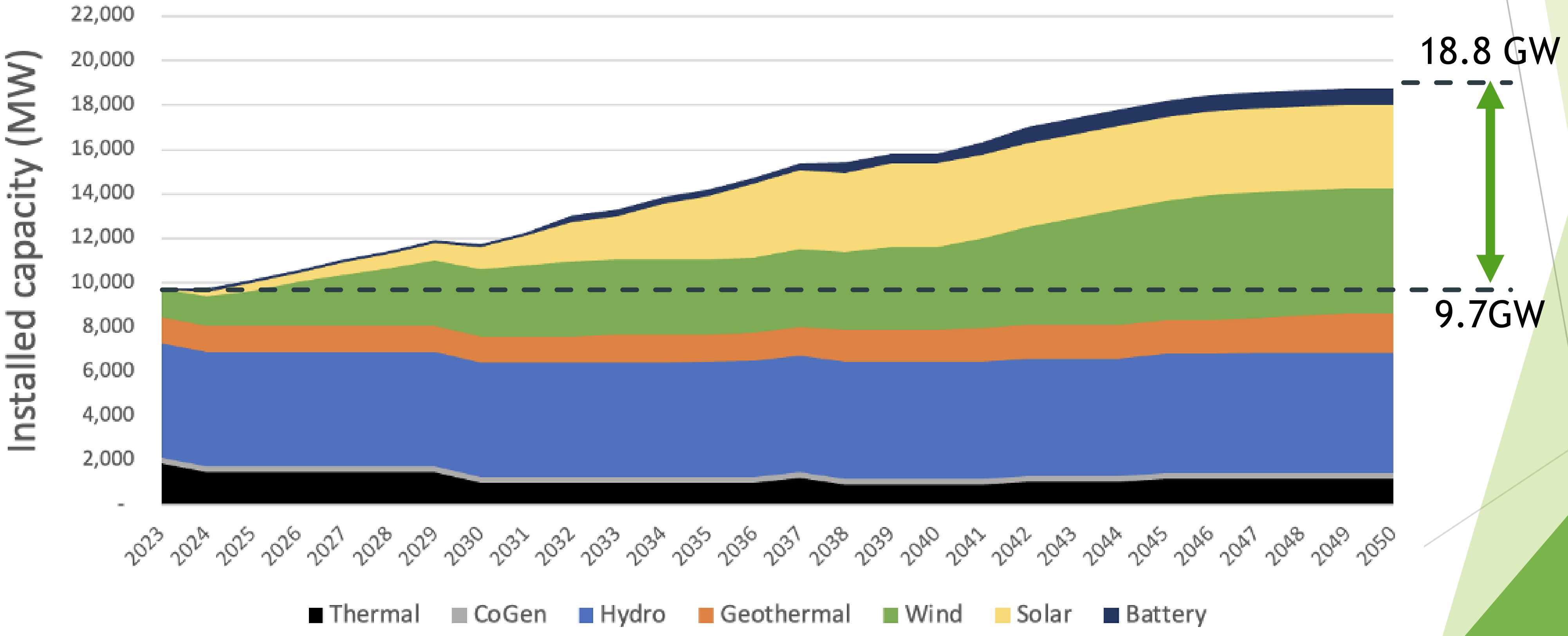
Demand projections

Pathway 0: Base case (installed capacity)



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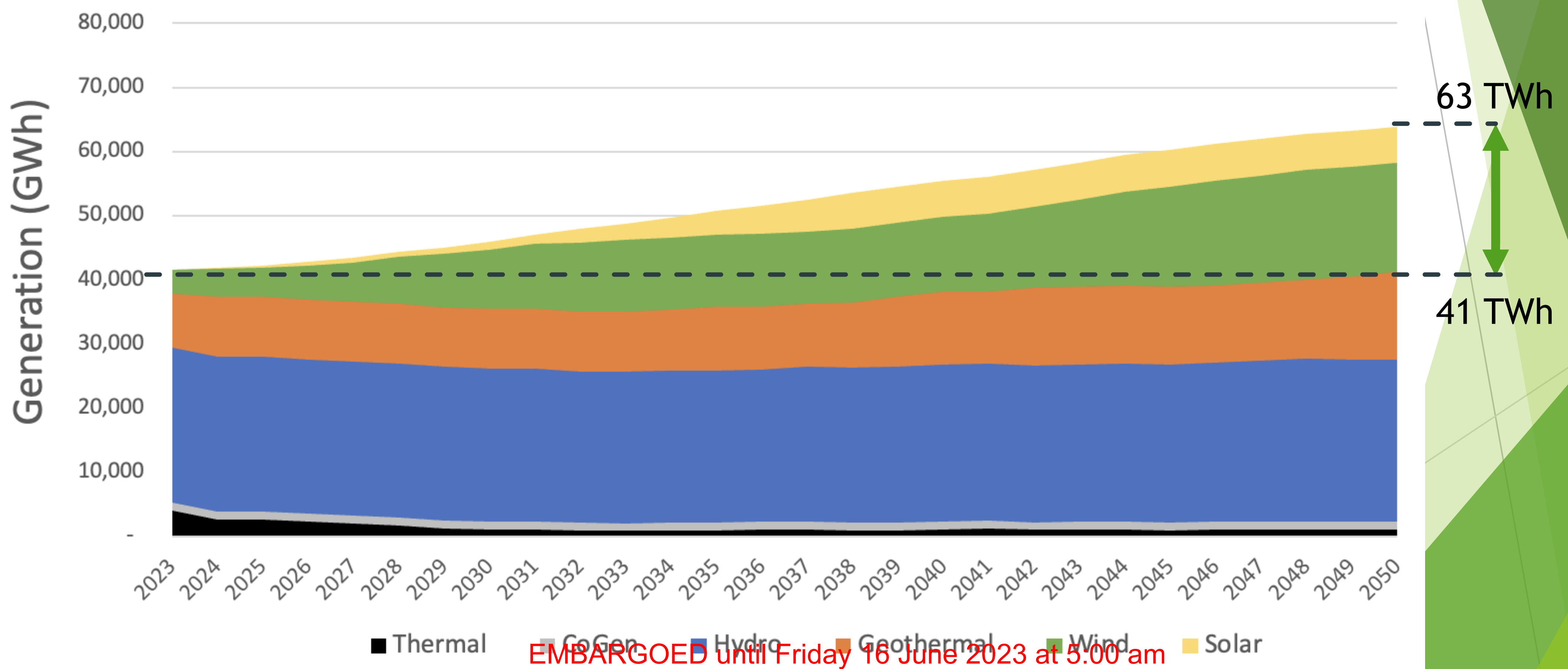
Generation projections

Pathway 0: Base case (generation)

- 22 TWh of new generation required by 2050
- Renewables supply 96% of demand by 2050



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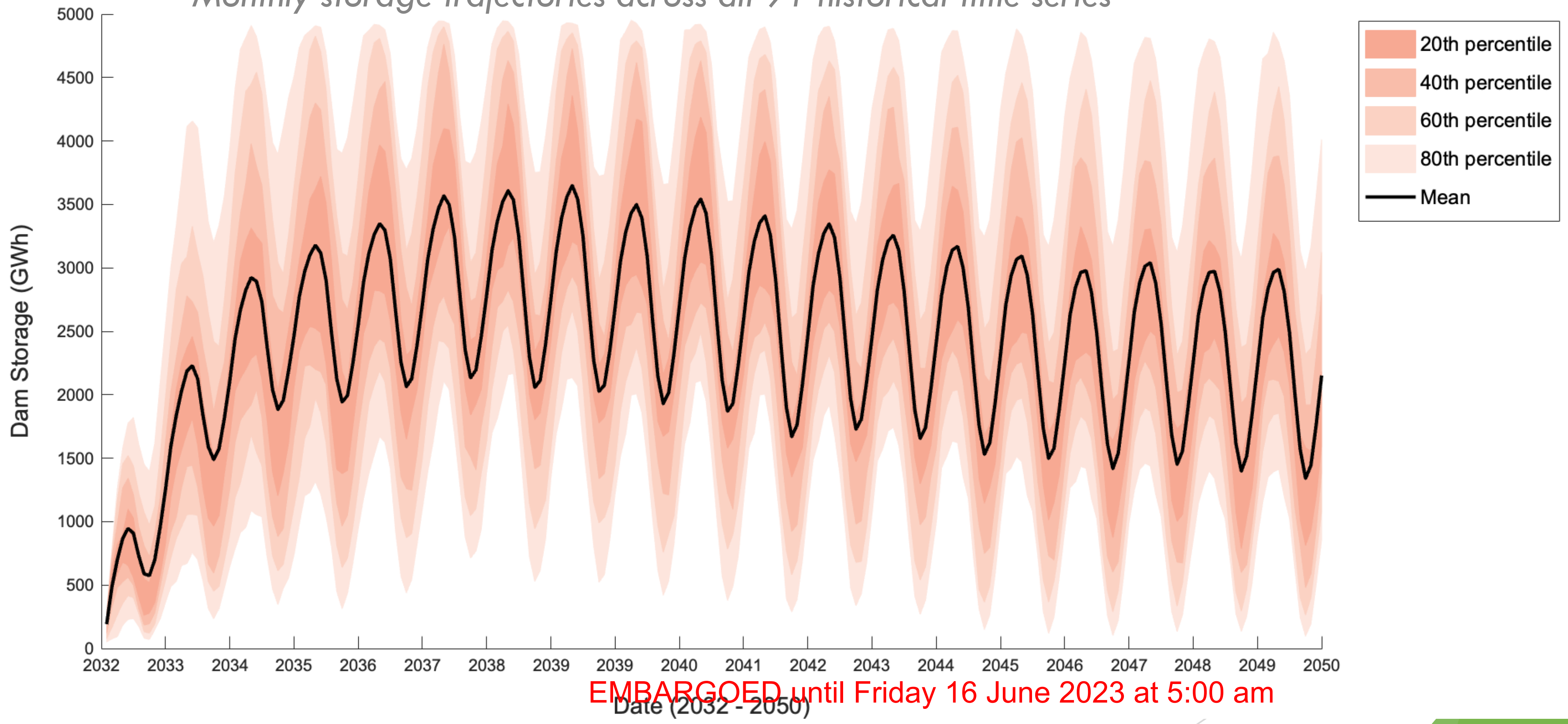
Operation of Onslow

- Onslow operating height between 2,000 – 3,500 GWh per year (1,500 GWh generation)

Monthly storage trajectories across all 91 historical time series



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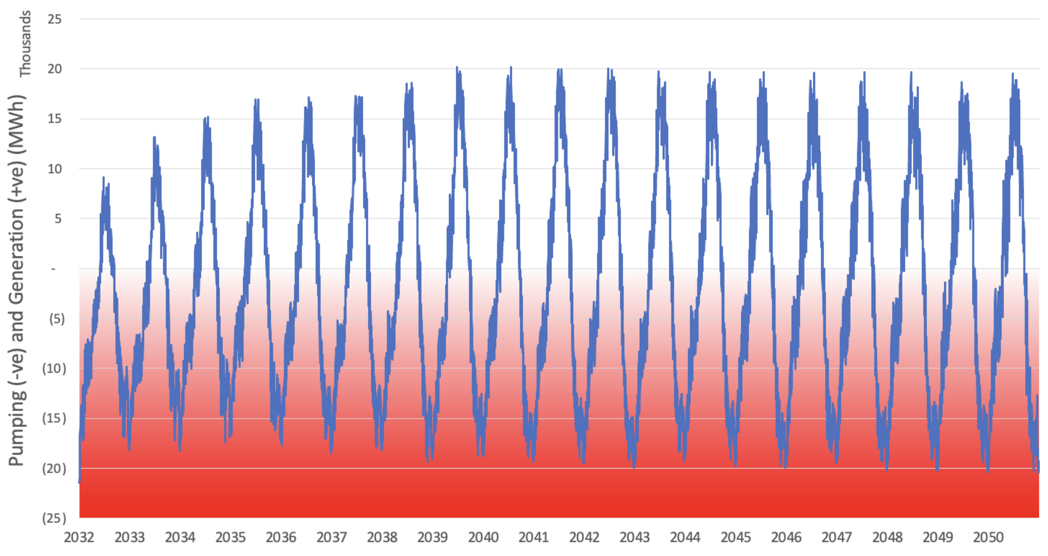
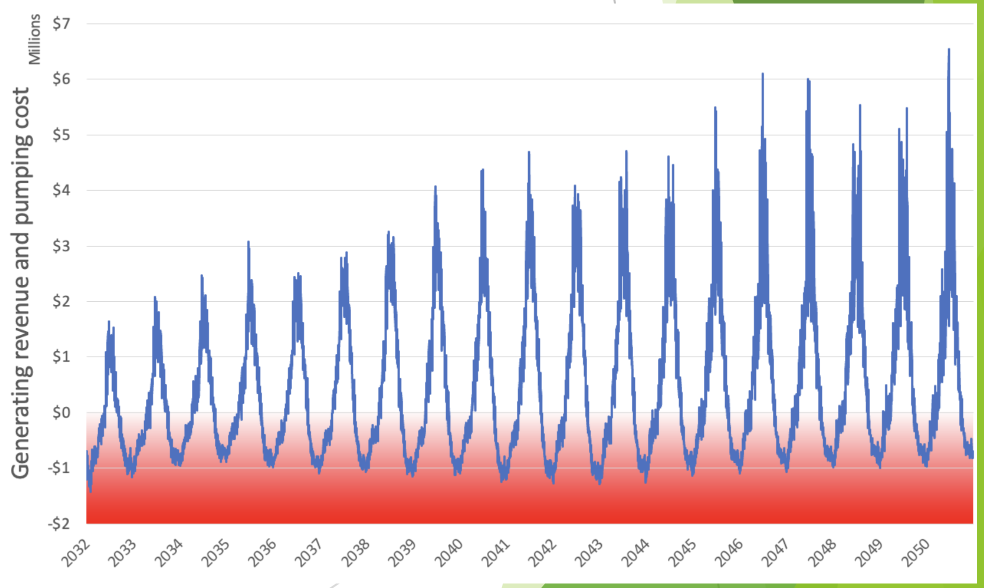
Onslow pumping and generation profile

- Onslow pumps Jan, Feb, March, Oct, Nov, Dec
- Onslow generates April, May, June July, August Sept
- Peak annual revenue increases from $2 to $6m per day
- Peak pumping costs bottom out at $1 m per day



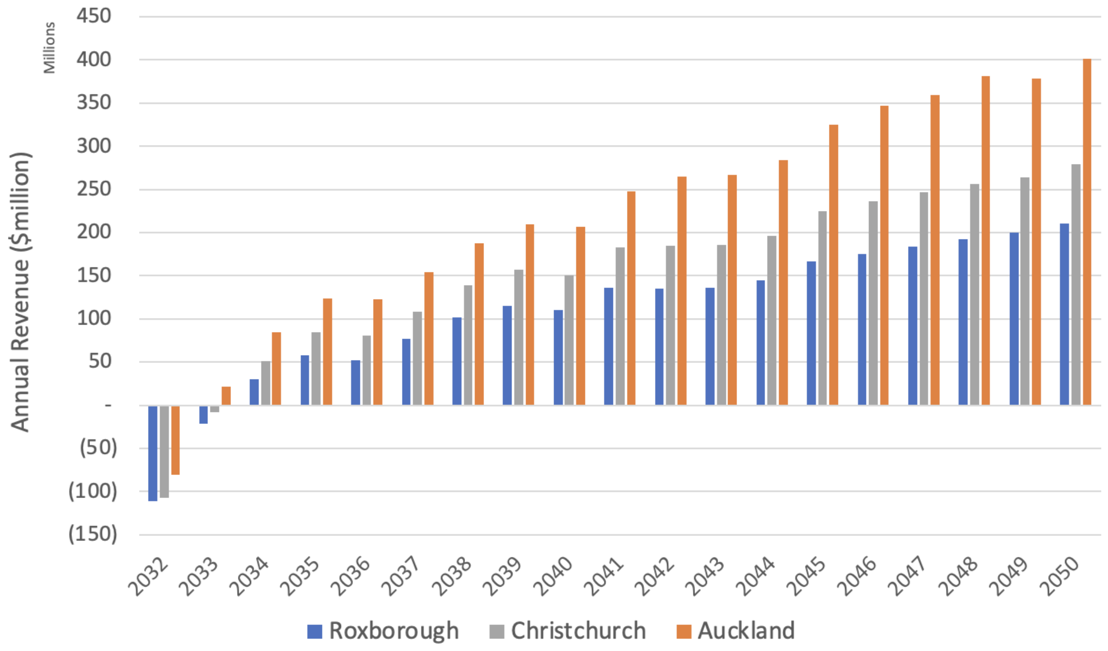
Onslow average daily pumping and generation cycles across all model runs



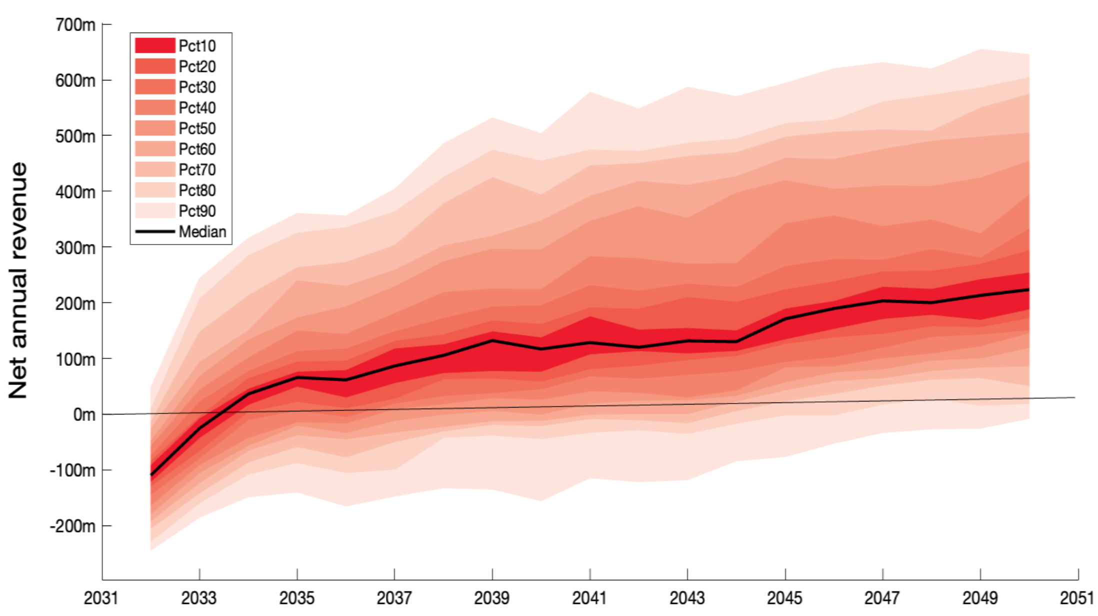
Daily generation revenue (white) and pumping costs (red) for Onslow

Onslow average annual revenue

- Negative revenues in 2032 and 2033
- In 2050 annual revenues range from $150 m to $400 m



Annual average revenue for Onslow by network node



Onslow annual net revenue variability (Christchurch)

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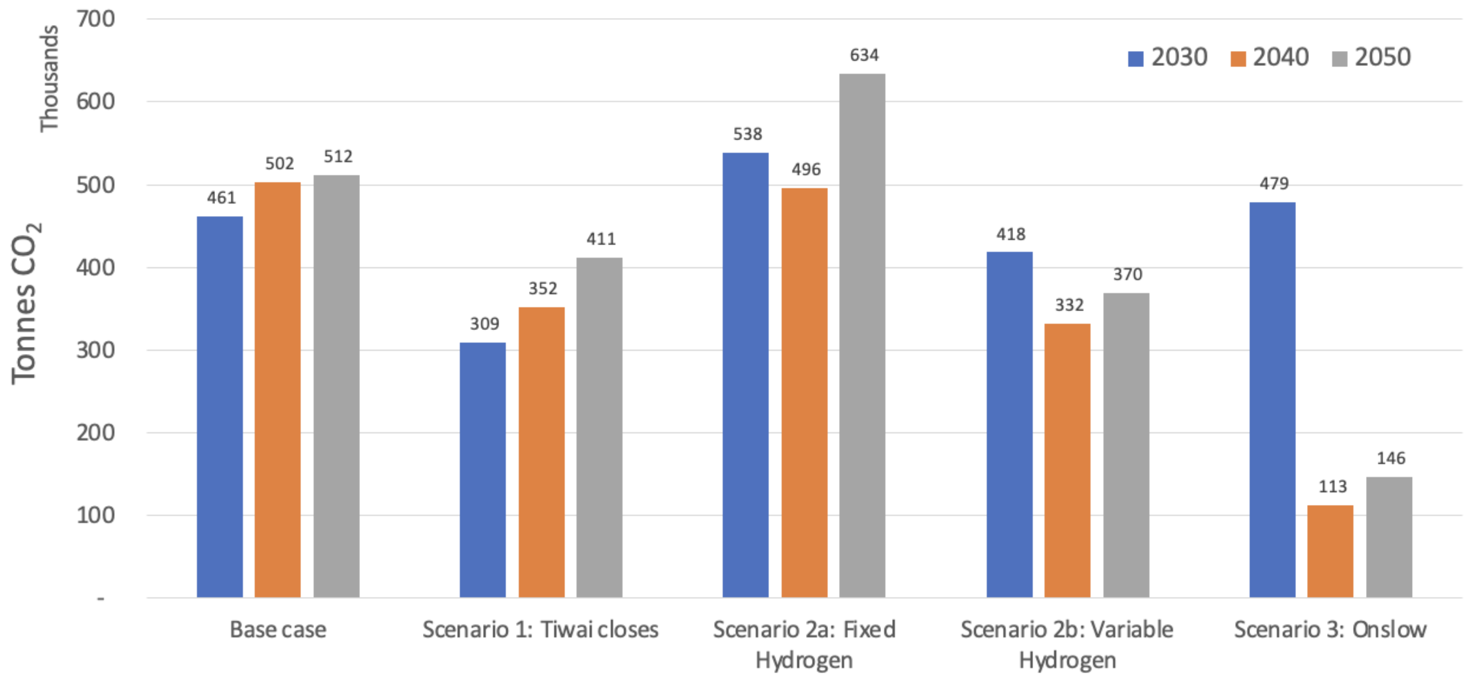
Annual emissions from thermal generation

- Ignores emissions from constructing Onslow
- Onslow emissions roughly 50,000 tCO2 per year (0.06% of NZ annual GHG emissions).



Annual emissions from thermal generation (excludes geothermal and cogeneration)

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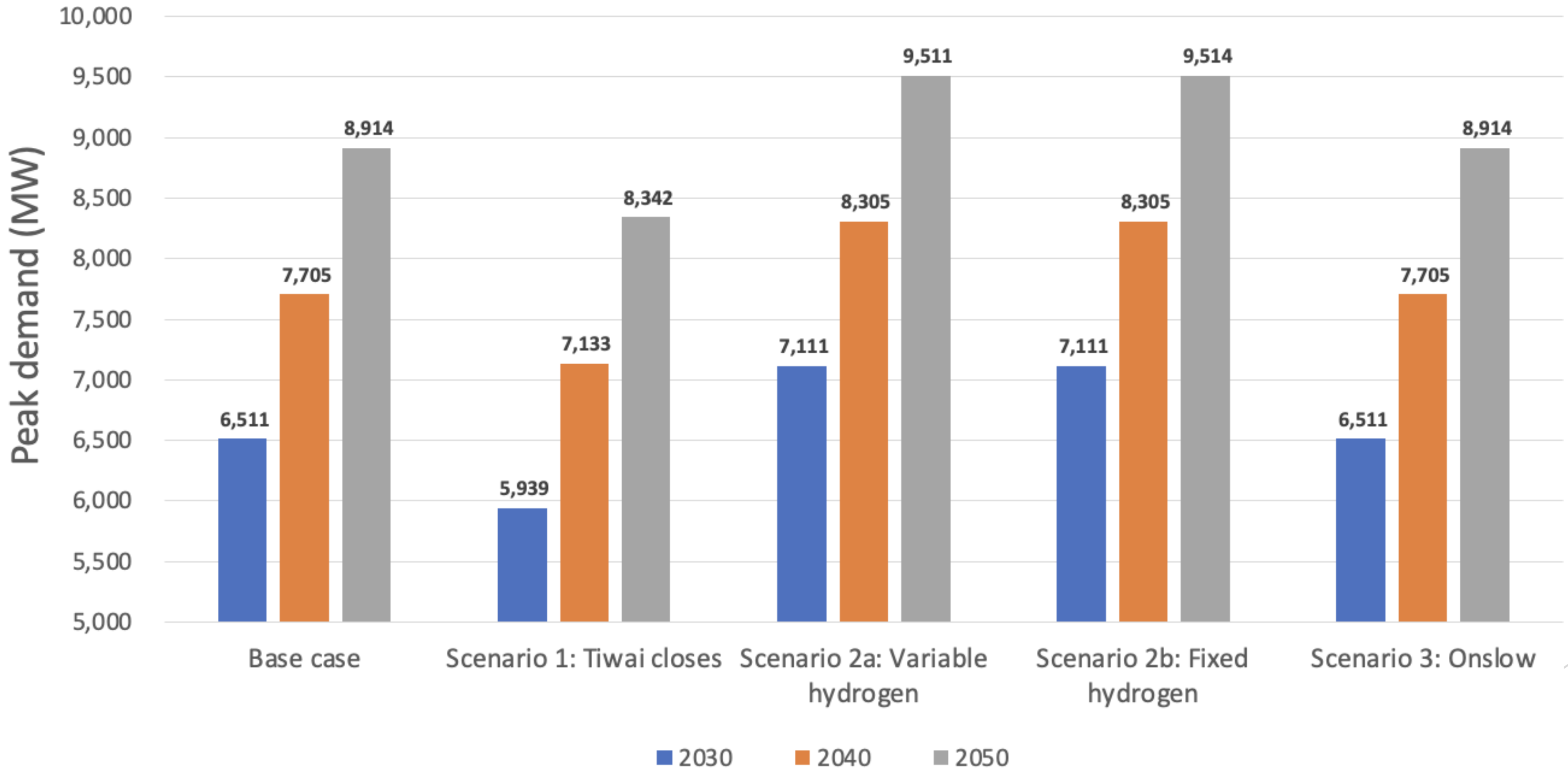
Peak demand (~network costs)

- Peak demand is same for base case and Onslow
- Hydrogen scenarios produce higher network peak demand



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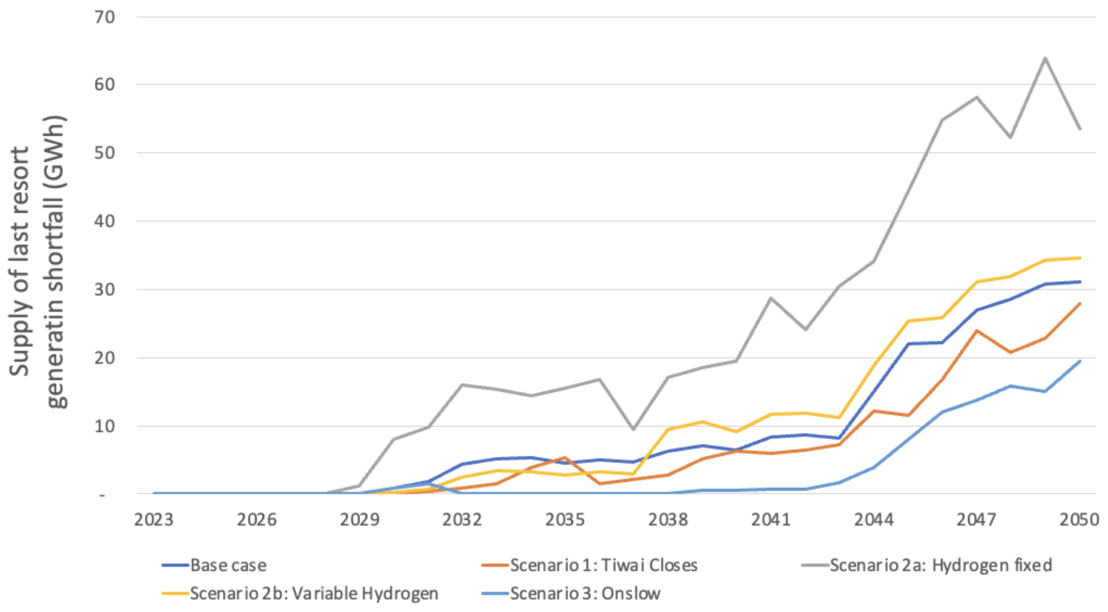
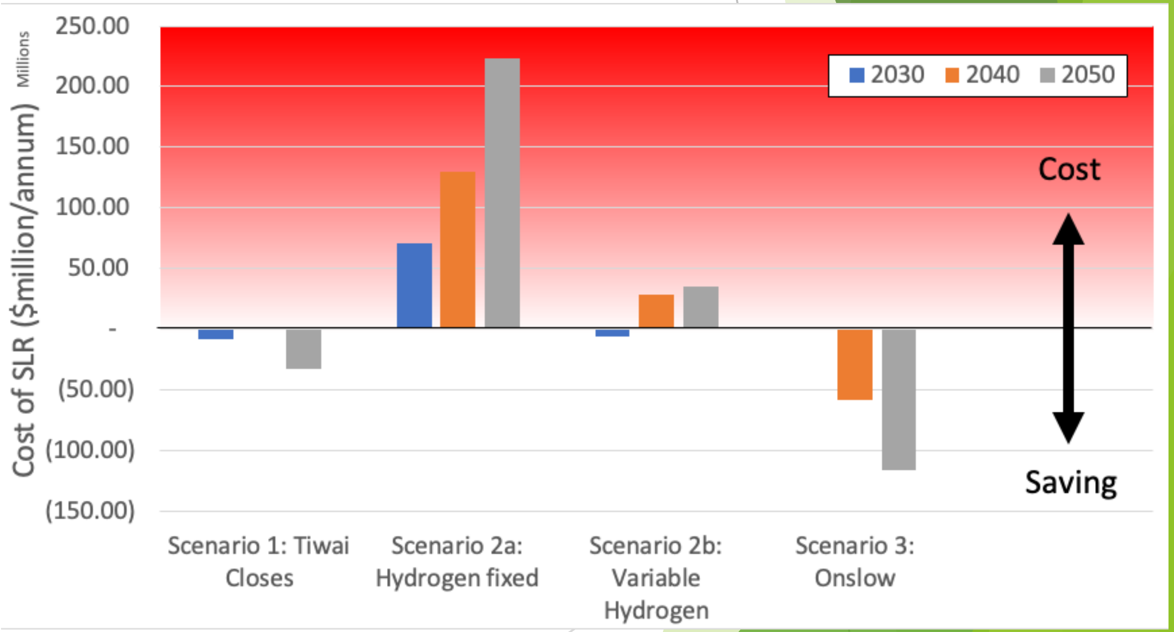
Peak electricity demand across entire network

Supply of last resort

- Hydrogen scenarios have highest SLR at 54 and 35 GWh per year
- Hydrogen scenarios cost $200m per year compared to base case
- Onslow has lowest SLR at 20 GWh per year saving $100m compared to base case

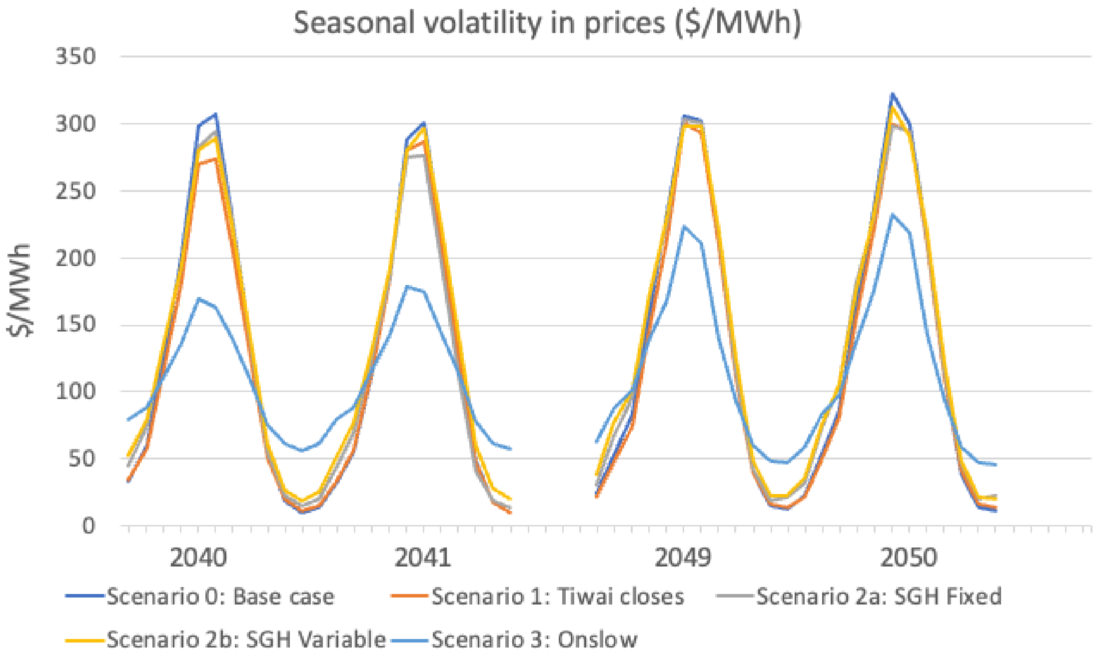




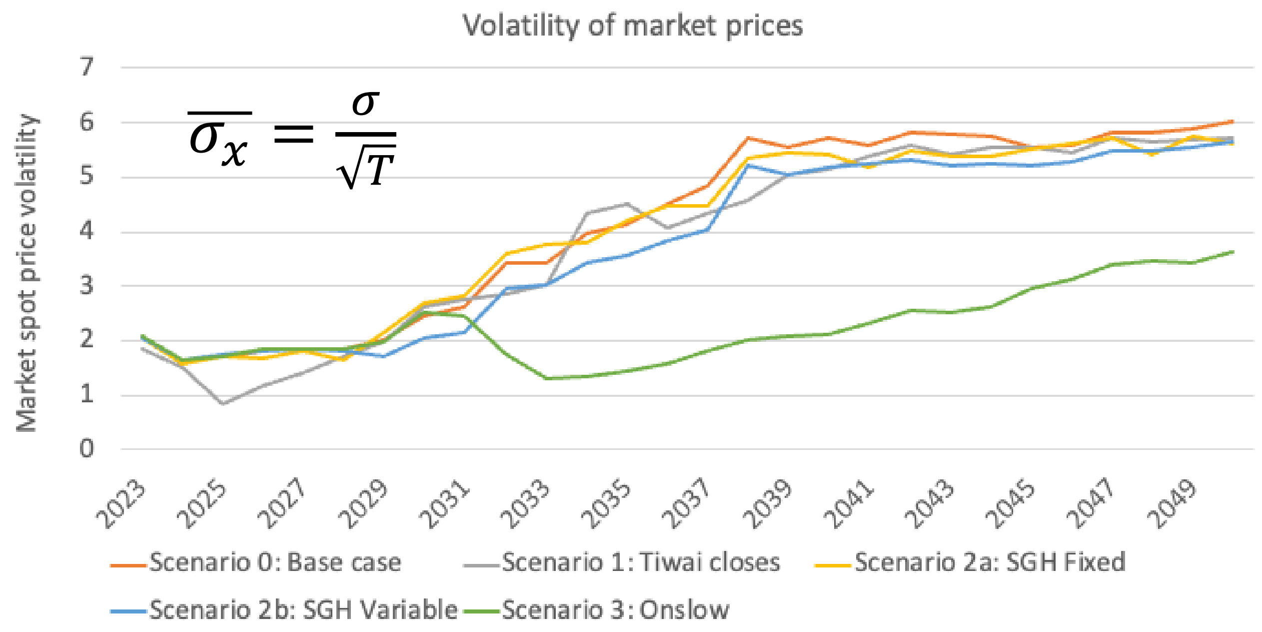
Supply of last resort (security of supply) (GWh)

Market volatility

- Onslow significantly supresses wholesale market price volatility compared to other scenarios
- Onslow caps seasonal high prices and raises the floor price
- This lowers cost of capital of renewable energy



Intra-annual spot price volatility



$$\overline{\sigma_x} = \frac{\sigma}{\sqrt{T}}$$

Average monthly price volatility for years 2039,2040,2049,2050

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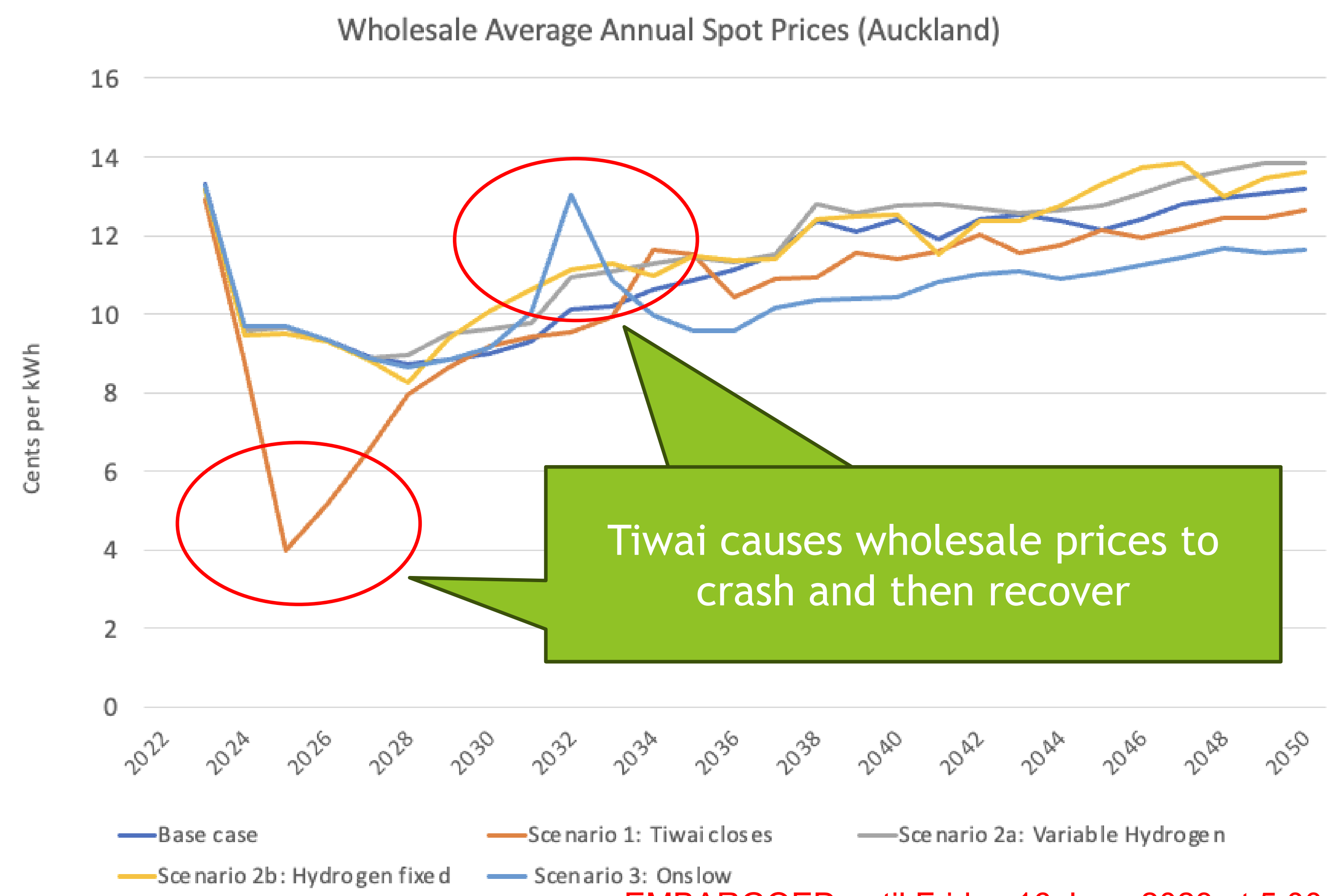
Wholesale average annual spot prices



- Tiwai causes prices to crash and then recover
- Onslow produces lowest wholesale spot price in 2050
- Potential spikes in wholesale prices requires system oversite

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Wholesale electricity prices

Auckland wholesale prices (cents per kWh)

	2020	2030	2040	2050	% Difference with Base Case in 2050
Senario 0: Base case	11.3	11.2	12.4	13.6	
Scenario 1: Tiwai closes	11.3	10.4	11.8	13.0	-1.9%
Scenario 2a: SGH Fixed	11.3	11.5	12.5	14.1	1.4%
Scenario 2b: SGH Variable	11.3	11.3	12.8	14.1	1.7%
Scenario 3a: Onslow	11.3	11.3	11.7	12.4	-3.7%

Christchurch wholsale prices (cents per kWh)

	2020	2030	2040	2050	% Difference with Base Case in 2050
Senario 0: Base case	11.0	11.8	13.8	15.7	
Scenario 1: Tiwai closes	11.0	10.3	11.9	13.4	-7.3%
Scenario 2a: SGH Fixed	11.0	12.2	14.8	17.7	6.1%
Scenario 2b: SGH Variable	11.0	11.9	13.9	15.7	0.1%
Scenario 3a: Onslow	11.0	12.0	13.1	13.7	-6.3%

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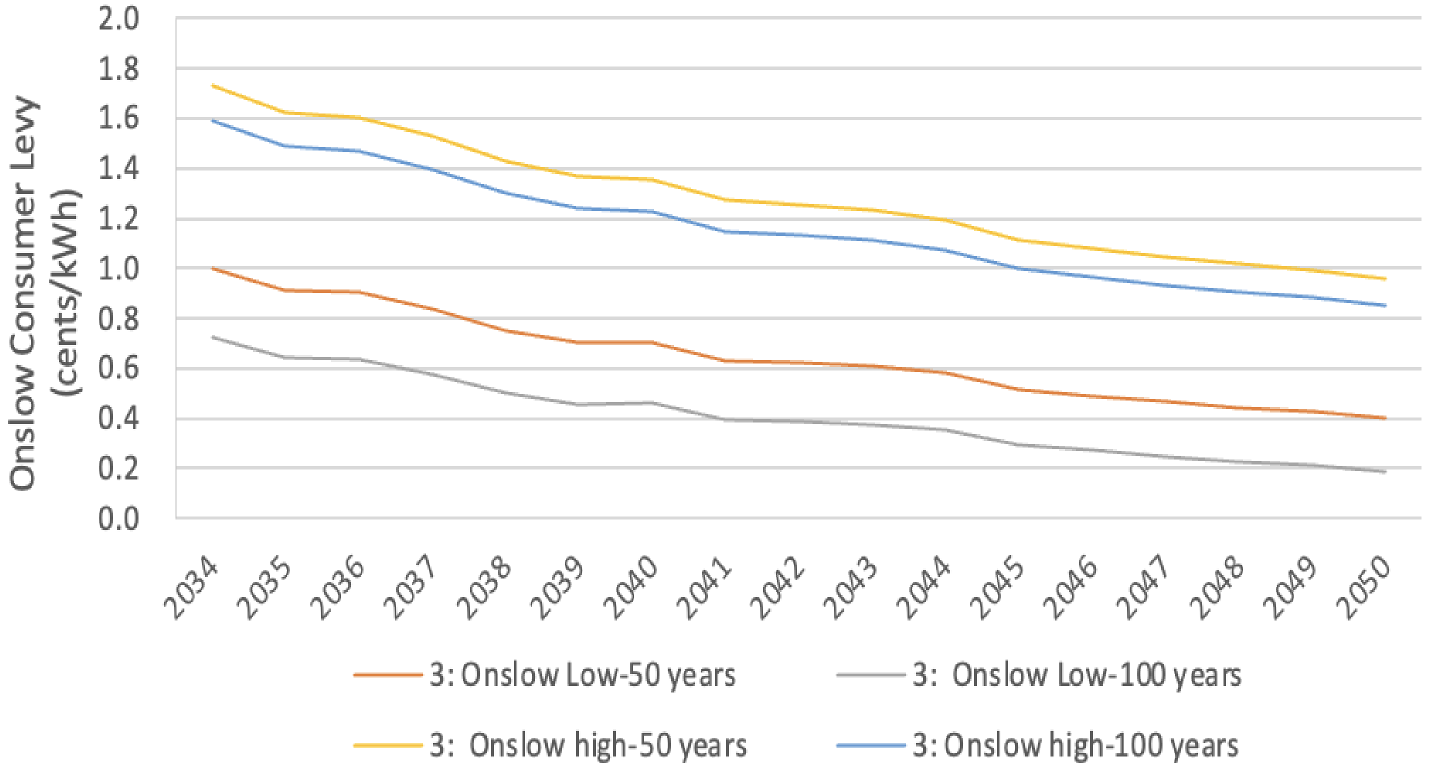
Onslow cost recovery consumer levy

- 2% WACC and 100 year life - $360 million per year cost of capital
- Consumer levy ranges from 1.8c kWh to 0.2 c/kWh



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Financial sensitivity assumptions

- All prices are in real $2020 dollars
- Real WACC of 2% and 5% (Commerce Commission recommend 3.78% and 4.13%)
- Discount rates of 2%, 5% and 7%
- Full asset lifetimes assumed (and 50 years for Onslow)

Sensitivity scenario	CAPEX $Billion	WACC (real)	Period
Pathway 2: SGH –low [11]	$0.75	2%	30 years
Pathway 2: SGH – high	$0.75	5%	30 years
Pathway 3: Onslow - low-50years	$15.0	2%	50 years
Pathway 3: Onslow - low-100years	$15.0	2%	100 years
Pathway 3: Onslow - high-50 years	$15.0	5%	50 years
Pathway 3: Onslow - high-100 years	$15.0	5%	100 years

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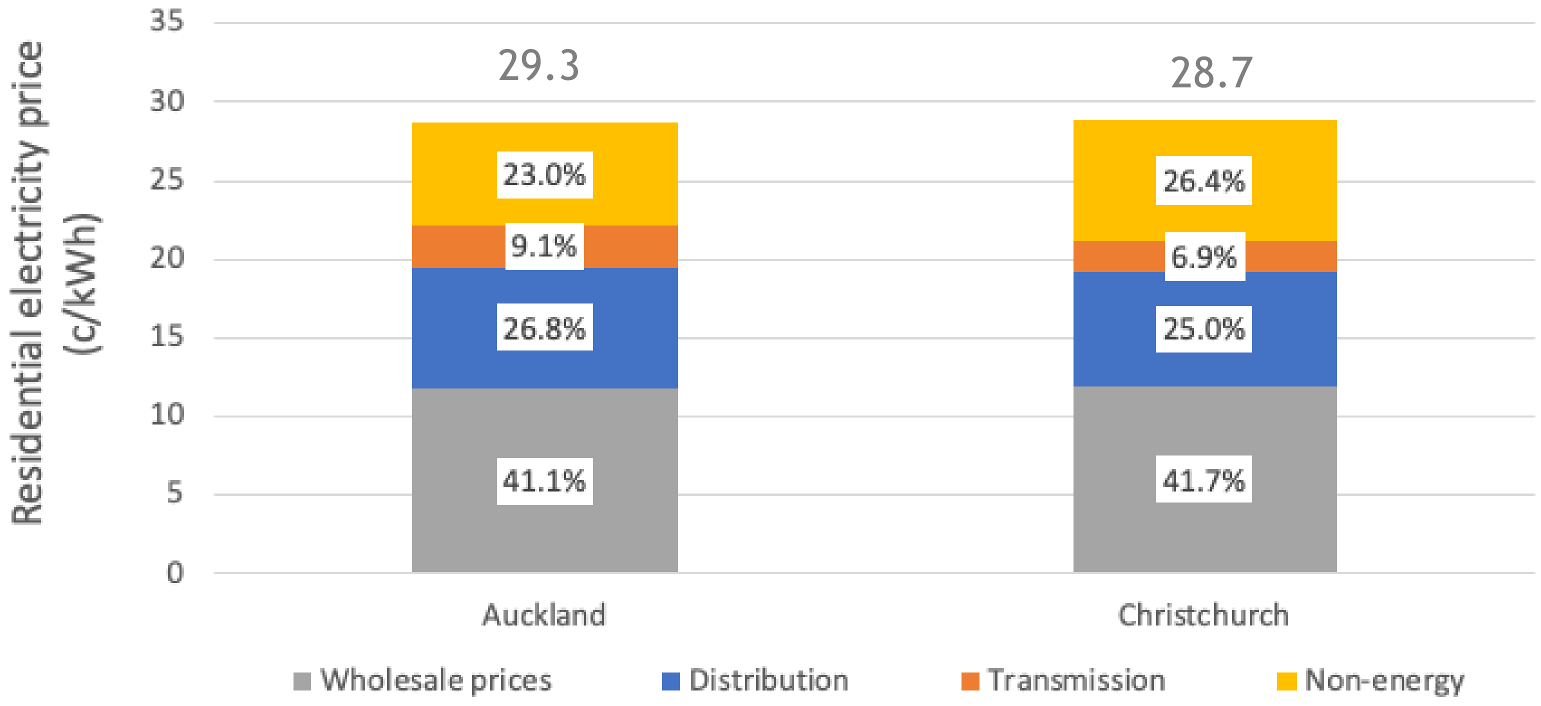
Residential electricity prices

Electricity Price = distribution + transmission + wholesale electricity + other (non-energy retail costs)



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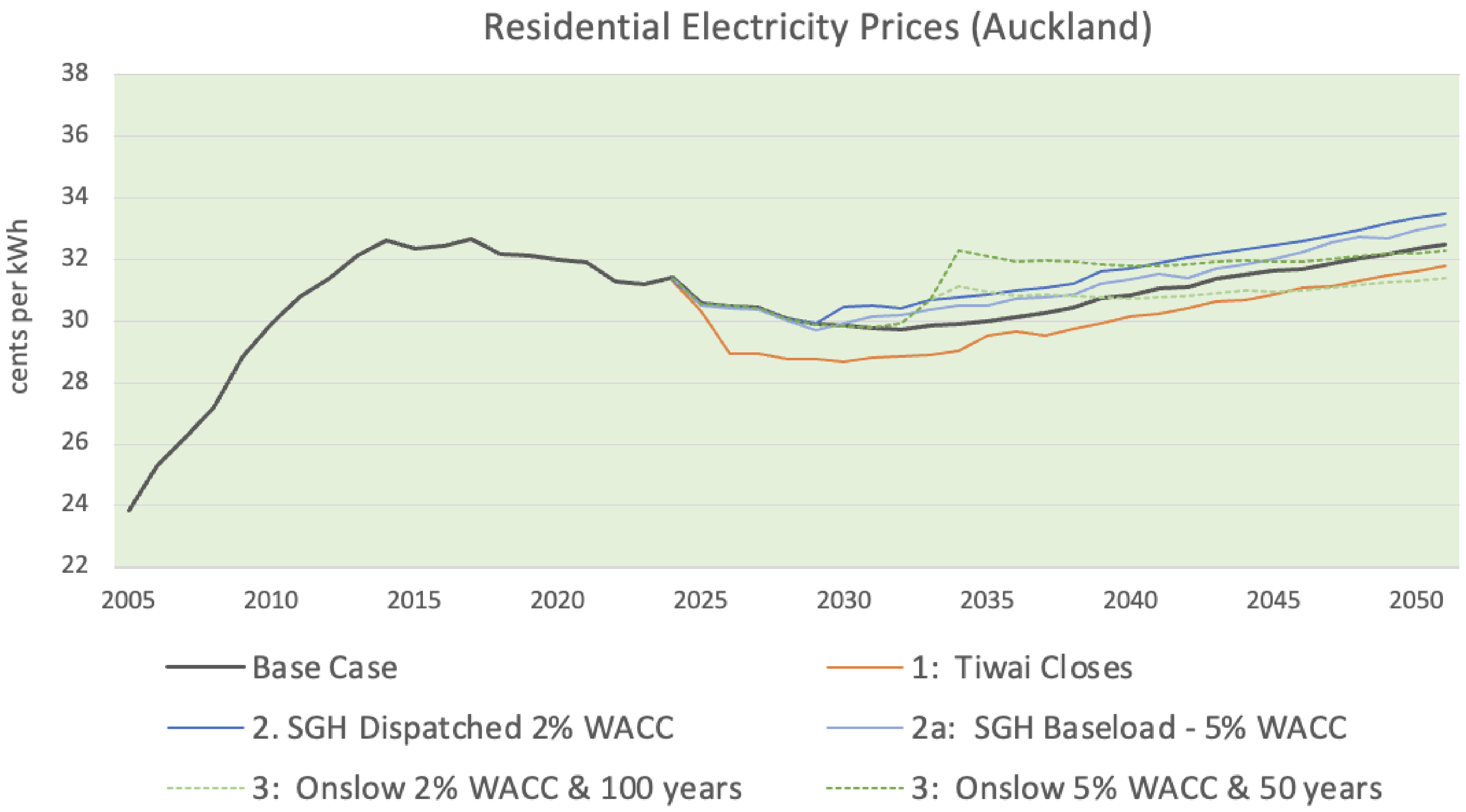
Residential electricity prices (Auckland)



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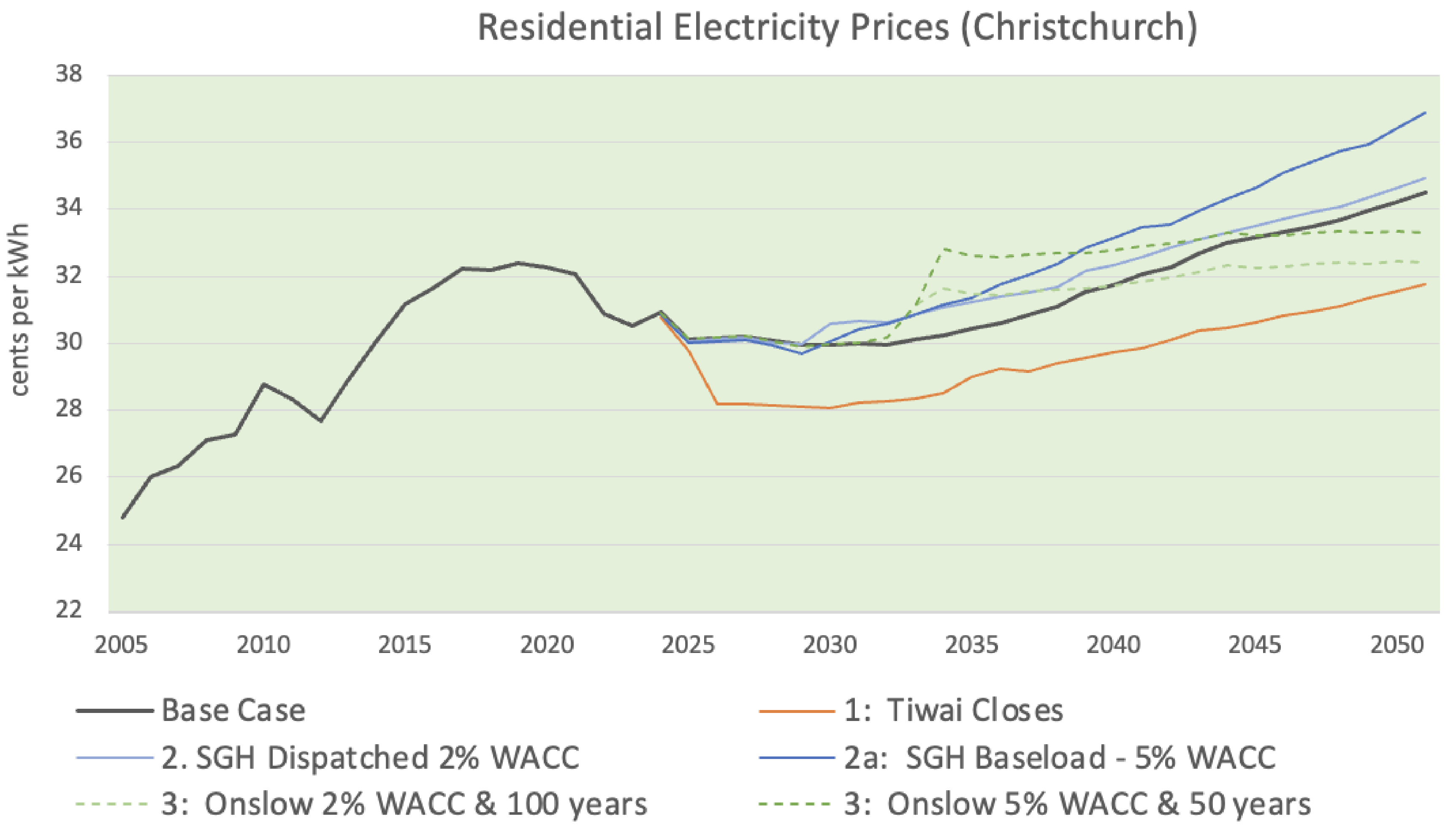
Residential electricity prices (Christchurch)



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Effect on residential electricity bills

Annual saving (cost) for average Christchurch residential electricity bill	2020	2030	2040	2050
Base case (average electricity bill for NZ household 7,261 kWh per annum)	$2,243	$2,175	$2,342	$2,505
Average annual savings compared to base case (red means reduction in electricity bill)				
Scenario 1: Tiwai closes	$0.0	-$123.0	-$157.7	-$197.5
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	$0.0	$42.6	$91.5	$170.6
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	$0.0	$48.6	$44.9	$29.8
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	$0.0	$45.1	$93.5	$172.4
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	$0.0	$50.7	$46.7	$31.4
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	$0.0	$16.7	-$0.3	-$132.9
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	$0.0	$16.7	-$20.3	-$150.5
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	$0.0	$16.7	$53.1	-$86.1
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	$0.0	$16.7	$42.9	-$95.0

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Effect on commercial, industrial and agricultural electricity prices

Electricity demand and electricity prices by sector in 2022

	Electricity Demand (TWh)	Percentage of demand (%)	Average price (2020) c/kWh
Residential	13.0	34	31.3
Industry	13.5	35	14.6
Commerce	9.4	25	18.5
Agriculture	2.4	6	22.8
Total	38.3	100	-

Auckland industrial, commercial and agricultural electricity prices

Industrial electricity prices (cents per kWh)	2020	2030	2040	2050	% Difference with Base Case in 2050
Senario 0: Base case	14.6	16.1	17.3	18.5	-
Scenario 1: Tiwai closes	14.6	15.3	16.7	17.9	-3.4%
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	14.6	16.5	17.5	19.0	2.8%
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	14.6	16.7	18.2	19.4	4.9%
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	14.6	16.5	17.5	19.0	2.9%
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	14.6	16.8	18.2	19.4	5.1%
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	14.6	16.2	17.2	17.7	-4.4%
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	14.6	16.2	17.0	17.5	-5.5%
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	14.6	16.2	17.9	18.3	-1.3%
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	14.6	16.2	17.8	18.2	-1.9%
Commercial electricity prices (cents per kWh)					
Senario 0: Base case	18.5	16.8	18.0	19.3	-
Scenario 1: Tiwai closes	18.5	16.1	17.4	18.6	-3.2%
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	18.5	17.2	18.3	19.8	2.7%
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	18.5	17.5	18.9	20.2	4.7%
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	18.5	17.3	18.3	19.8	2.8%
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	18.5	17.5	19.0	20.2	4.9%
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	18.5	17.0	18.0	18.5	-4.2%
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	18.5	17.0	17.8	18.2	-5.3%
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	18.5	17.0	18.6	19.0	-1.3%
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	18.5	17.0	18.5	18.9	-1.8%
Agricultural electricity prices (cents per kWh)					
Senario 0: Base case	22.8	20.6	21.8	23.0	-
Scenario 1: Tiwai closes	22.8	19.8	21.2	22.4	-2.7%
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	22.8	21.0	22.0	23.6	2.3%
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	22.8	21.3	22.7	24.0	4.0%
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	22.8	21.0	22.1	23.6	2.4%
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	22.8	21.3	22.7	24.0	4.1%
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	22.8	20.8	21.8	22.2	-3.5%
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	22.8	20.8	21.5	22.0	-4.4%
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	22.8	20.8	22.4	22.8	-1.1%
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	22.8	20.8	22.3	22.7	-1.5%

Economic analysis

Included in CBA analysis	Excluded from CBA analysis
Cost of capital for new generation and the resulting impact on electricity prices	Supply of last resort costs (SLR)
Operation and maintenance costs of different generation resources across the network	The cost of rolling blackouts or extended periods of insufficient generation supply
Transmission and distribution infrastructure (assumed same for all pathways)	The cost of market-based risk and cost of regulation
Onslow construction costs and the resulting impact on electricity prices	The effects of market power and rent seeking
Southern Green Hydrogen electrolyser costs and the impact on electricity prices	Demand response from the new TPM
Effects of price volatility on wholesale electricity prices	Changes to LCOE (e.g. lower cost of capital for renewables)
The effective carbon price to achieve net zero targets as recommended by the CCC	Differences between pathways in transmission and distribution infrastructure
	The sale revenue from hydrogen or aluminium
	Tax and dividend payments to government (aluminium, hydrogen and electricity)
	Optimisation of Onslow based on improved inter-annual climate predictions

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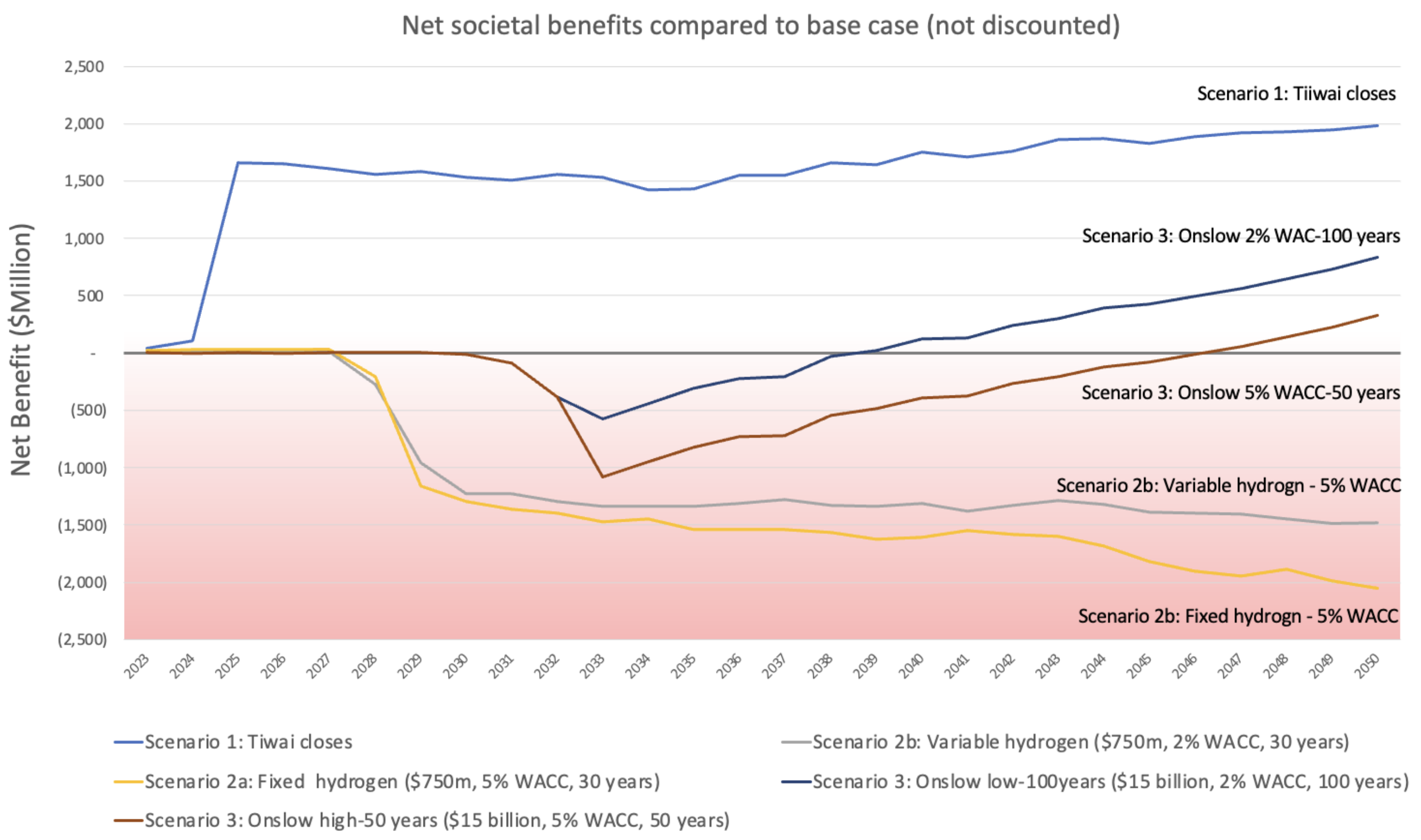
Undiscounted economic projections

- Tiwai has strongly positive benefit
- Break even points for Onslow:
  - Scenario 3 (Onslow Low): 2039
  - Scenario 3 (Onslow high): 2044
- Hydrogen has negative benefit



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Net Present Value (NPV)

Until 2073 (Discounted over 50 years)

Net Present Value (2022NZD $million) (red is negative NPV)	Constant exponential discounting 7%	Constant exponential discounting 5%	Constant exponential discounting 2%	Hyperbolic discounting 7%	Hyperbolic discounting 5%	Hyperbolic discounting 2%
Scenario 1: Tiwai closes	20,686	29,138	55,756	35,945	42,931	62,443
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	(14,946)	(22,849)	(48,648)	(30,077)	(36,631)	(55,401)
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	(12,382)	(18,536)	(38,185)	(23,794)	(28,854)	(43,184)
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	(15,081)	(23,051)	(49,063)	(30,335)	(36,945)	(55,870)
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	(12,499)	(18,712)	(38,550)	(24,020)	(29,129)	(43,596)
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	528	1,885	7,704	4,283	5,554	9,692
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	1,496	3,408	11,037	6,317	8,045	13,495
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	(2,052)	(2,174)	(1,178)	(1,138)	(1,083)	(442)
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	(1,560)	(1,400)	517	(103)	184	1,492

Until 2123 (Discounted over 100 years)

Net Present Value (2022NZD $million) (red is negative NPV)	Constant exponential discounting 7%	Constant exponential discounting 5%	Constant exponential discounting 2%	Hyperbolic discounting 7%	Hyperbolic discounting 5%	Hyperbolic discounting 2%
Scenario 1: Tiwai closes	21,943	33,614	91,416	61,550	76,599	126,364
Scenario 2a: Fixed hydrogen ($750m, 2% WACC, 30 years)	(16,236)	(27,444)	(85,254)	(56,361)	(71,192)	(121,018)
Scenario 2b: Variable hydrogen ($750m, 2% WACC, 30 years)	(13,319)	(21,872)	(64,765)	(42,879)	(53,949)	(90,829)
Scenario 2a: Fixed hydrogen ($750m, 5% WACC, 30 years)	(16,380)	(27,681)	(85,950)	(56,821)	(71,771)	(121,991)
Scenario 2b: Variable hydrogen (($750m, 5% WACC, 30 years)	(13,445)	(22,080)	(65,381)	(43,285)	(54,461)	(91,691)
Scenario 3: Onslow low-50years ($15 billion, 2% WACC, 50 years)	967	3,451	20,177	13,239	17,331	32,051
Scenario 3: Onslow low-100years ($15 billion, 2% WACC, 100 years)	2,023	5,285	25,993	17,056	22,165	40,303
Scenario 3: Onslow high-50 years ($15 billion, 5% WACC, 50 years)	(1,846)	(1,439)	4,681	3,069	4,449	10,061
Scenario 3: Onslow high-100 yeaers ($15 billion, 5% WACC, 100 years)	(1,309)	(506)	7,638	5,010	6,907	14,258

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Comparison of scenarios

Characteristic	Pathway 1: Tiwai closes	Pathway 2a: SGH	Pathway 2b: SGH	Pathway 3: Onslow
CAPEX ($billion)	Low	$0.75	$0.75	$15
OPEX ($million)	Low	$7.5	$42	$42
Peak demand by 2050. (GW)	8.32	9.5	9.5	8.9
Supply of last resort in 2050 ($million)	32	-233	-35	116
Emissions by 2050 mtCO2	0.4	0.6	0.4	0.1
Market volatility	5.7	5.6	5.6	3.6
Electricity prices in Auckland by 2050 - 2% WACC, full asset life	-2.2%	+1.8%	+3.1%	-3.4%
Net Present Value (100 years) - 2% WACC, 2% DR, full asset life ($billion)	+91	-85	-64	+26

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Key findings

- Tiwai closing reduces electricity prices with an expected benefit of $1.5 billion per year
- Onslow still economically viable with $15 billion CAPEX levied on consumers
- Southern Green Hydrogen uneconomic under a range of sensitivity tests
- Tiwai closing and Onslow were only scenarios to generate a positive NPV

- Wholesale price volatility is a key driver of cost in the electricity system
- Security of supply is an important driver of system wide costs
- High renewable penetration is achieved across all scenarios
  - When combined with security of supply strategy, cheaper than base case
- Results are highly sensitive to financial input assumptions

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Recommendations

- Full transparency and disclosure of all modelling assumptions, data and release of all models for public scrutiny.
  - Cost of capital, discount rates, asset lifetimes, capex and opex costs, network investment, future demand projections and other assumptions.
- Use of full asset life in financial and economic calculations
- Use hyperbolic or low discount rates when assessing long-lived assets
- Use cost of capital estimates consistent with investors expected rate of return
- Include **all** material costs and benefits in calculations:
  - Include cost estimates for outages and dry year risk
  - Assessment of likely impacts of market power
  - Estimate level of regulatory oversite and monitoring required
  - Assessment of changes to LCOE estimates for renewables
  - Costs and benefits of network upgrades under different scenarios
  - The optimisation of Onslow using medium range climate models

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Recommendations for MBIE battery project

- Undertake economic analysis on the full costs and benefits of security of supply and dry year risk for NZ.
  - Dry year deficit is assumed constant at 3-5 TWh but as aggregate demand and renewables increase, so will dry year deficit!
- Assess how different pathways will affect wholesale prices
  - Volatility and impact on final consumers
- Use the full life of the asset and appropriate cost of capital and discount rates – not 42 years.
- Use accurate estimates for the LCOE of green-peakers
  - Cabinet paper suggested costs were higher than modelled increasing from $480 per MWh to $1000 per MWh.

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Questions?

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