

Integrating renewable generation in New Zealand

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Canada

USA

**Central
America
& Mexico**

**South
America**

Caribbean

Europe

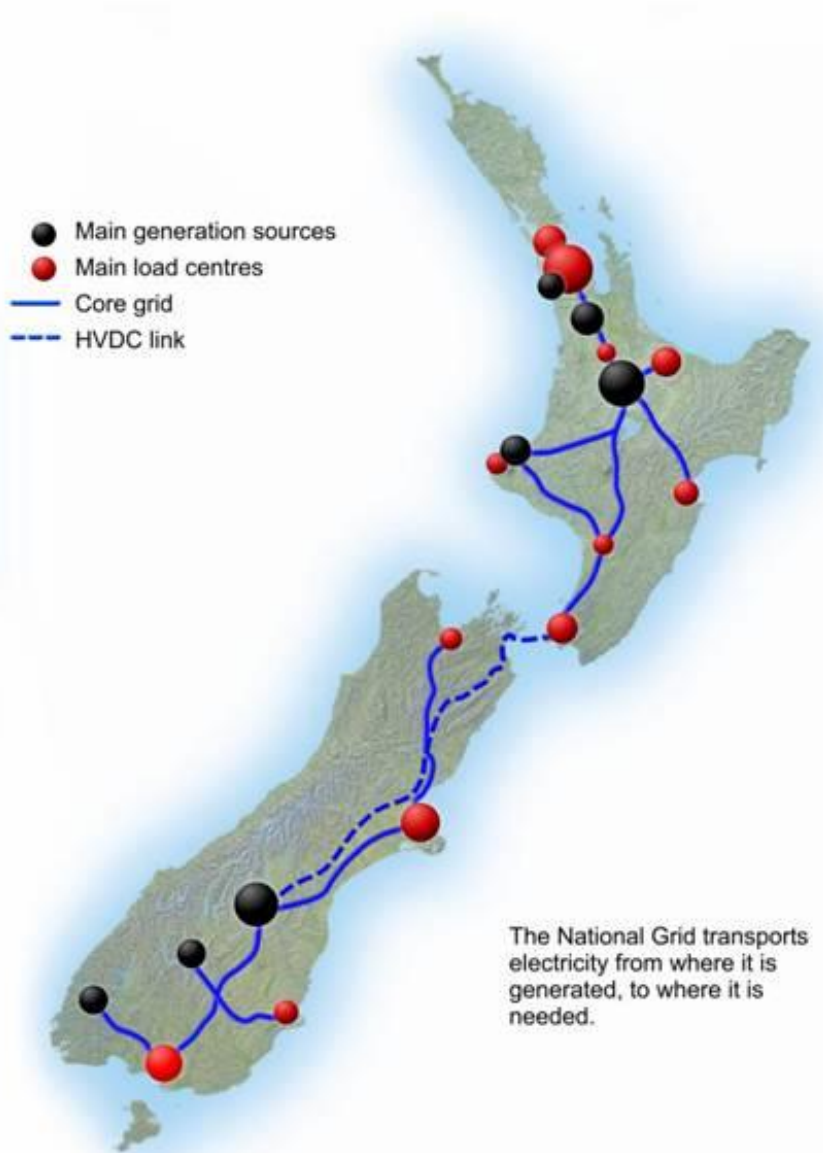
Africa

Asia

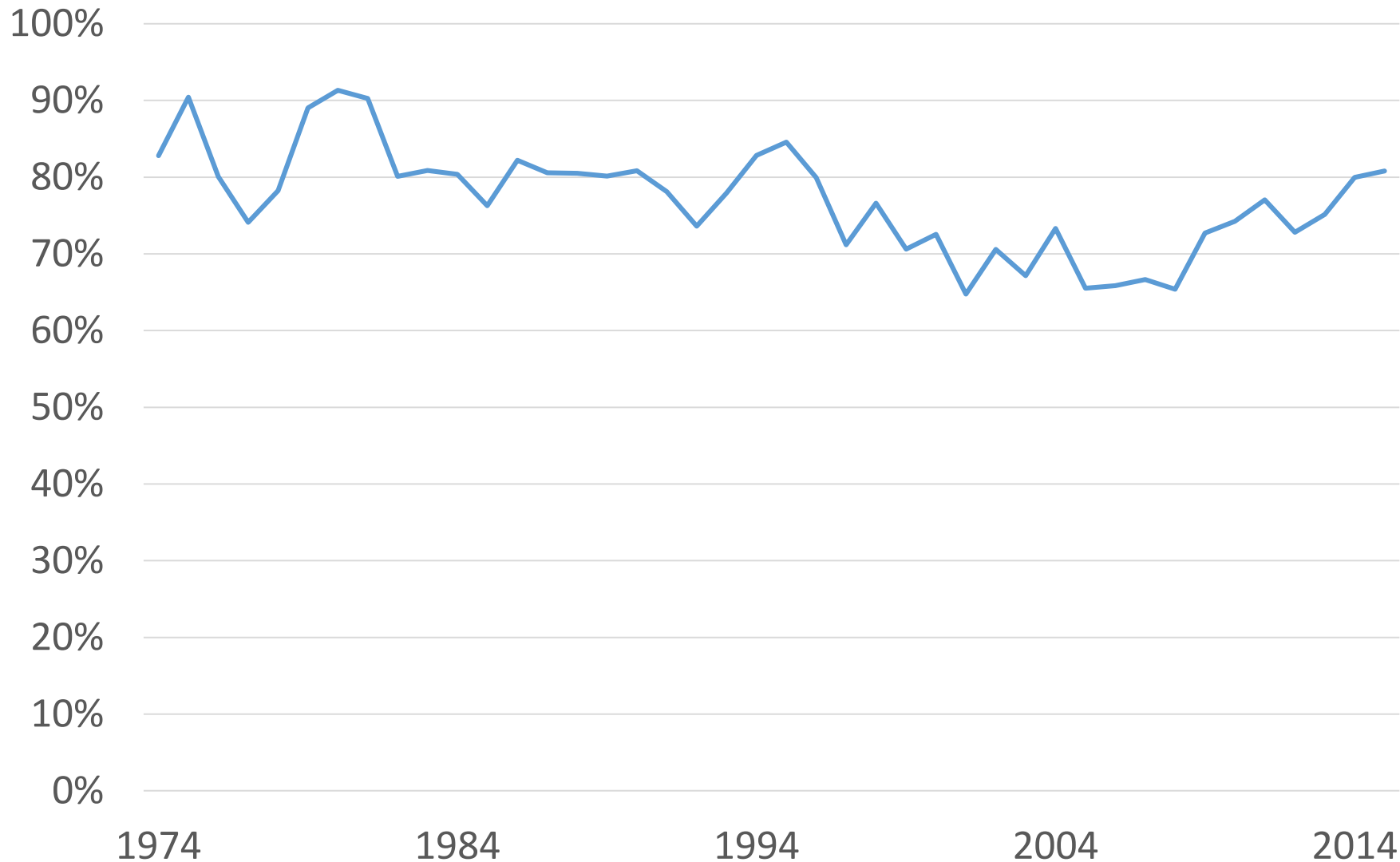
**Australia &
New Zealand**

New Zealand power system

- Two AC island power systems connected by an HVDC link – 1 000 MW capacity
- 6700 MW peak demand
- 220 kV, 110 kV transmission
- No interconnections to other power systems
- Peak/Minimum demand
 - North Island 4590/1580 MW
 - South Island 2975/1250 MW
- Installed capacity (generation)
 - North Island 5,794 MW
 - South Island 3,638 MW



Renewable generation as % of all generation in New Zealand



Installed generation capacity (MW)	
Hydro	5,252
Geothermal	723
Biogas	29
Wind	614
Diesel	164
Coal/Gas	1,000
Gas	1,397
Total	9,180

New Zealand Electricity Industry (i)

- Competitive wholesale electricity market and competitive retail market
 - Five large generator-retailers dominate the market
- Separation of lines and retail businesses
 - One transmission company
 - 27 distribution companies
 - Some grid connected industrial customers
 - Distribution companies can own some generation



Benmore dam <http://www.teara.govt.nz/en/hydroelectricity>

New Zealand Electricity Industry (ii)

Ownership



Ohaaki Geothermal power station

http://www.nzgeothermal.org.nz/nz_geo_fields.html

- Generation and retail
 - Vertically integrated by location
 - Partially privatised
- Transmission asset owner and system operator
 - Government owned
- Distribution
 - Mix of Trust owned and Publicly owned
- Two regulators
 - Electricity Authority
 - Commerce Commission

New Zealand Electricity Industry (iii)

Electricity Authority

- Oversees wholesale market
- Hires service providers for scheduling and dispatch, reconciliation, financial transmission rights
- Monitors industry adherence to rules and regulations

Commerce Commission

- Approves revenue proposals for transmission and distribution
- Monitors network performance for transmission and distribution

Electricity code (in legislation)

- Operation of wholesale market
- System operator obligations
- Asset owner performance obligations



New Zealand Wholesale Market (i)

- Operating for 20 years
- Bid based security constrained economic dispatch
 - Optimises energy and ancillary services costs
 - Nodal pricing with >280 trading nodes
 - 30 minute trading periods
 - Re-dispatch every 5 minutes
 - No AGC
- Nodal price – the system cost of increasing offtake at the node by 1 MWh
 - Nodal prices include costs of transmission losses and constraints
 - Load pays the nodal price for electricity consumed from the grid
 - Generation gets paid the nodal price for electricity injected into the grid
- New generation location takes nodal price into account
 - Build closer to load where there are higher prices
 - Less likely to build in constrained regions
 - Ongoing debate around having fewer price zones and having more trading nodes



<http://www.windenergy.org.nz/brooklyn-wind-turbine>

New Zealand Wholesale Market (ii)

- Financial Transmission Rights (FTR)
 - FTRs are financial hedges that help protect energy purchasers or generators from price uncertainty caused by transmission losses and constraints.
 - They confer the right to receive the difference between the prices at the nodes between which the hedge is written for a defined amount of megawatts and a defined period of time.
 - FTRs can be matched with an energy hedge to provide a high degree of price certainty.
 - FTRs are a standard component of the market design in most overseas electricity markets that, like New Zealand, are based on locational marginal (or nodal) pricing.
 - <https://www.ftr.co.nz/>
- Transmission planning is done by Transpower and overseen by Commerce Commission
- Generation investment is done by generators
- No capacity payments for generation

Ancillary Services in New Zealand

Ancillary Service	Provided by	Paid for by
Frequency keeping	Generators	Generators
Instantaneous reserves	Generators and load	Generation and transmission
Over frequency reserves	Generators	Transmission
Voltage support	Generators	Load in area
Black start	Generators	Transmission

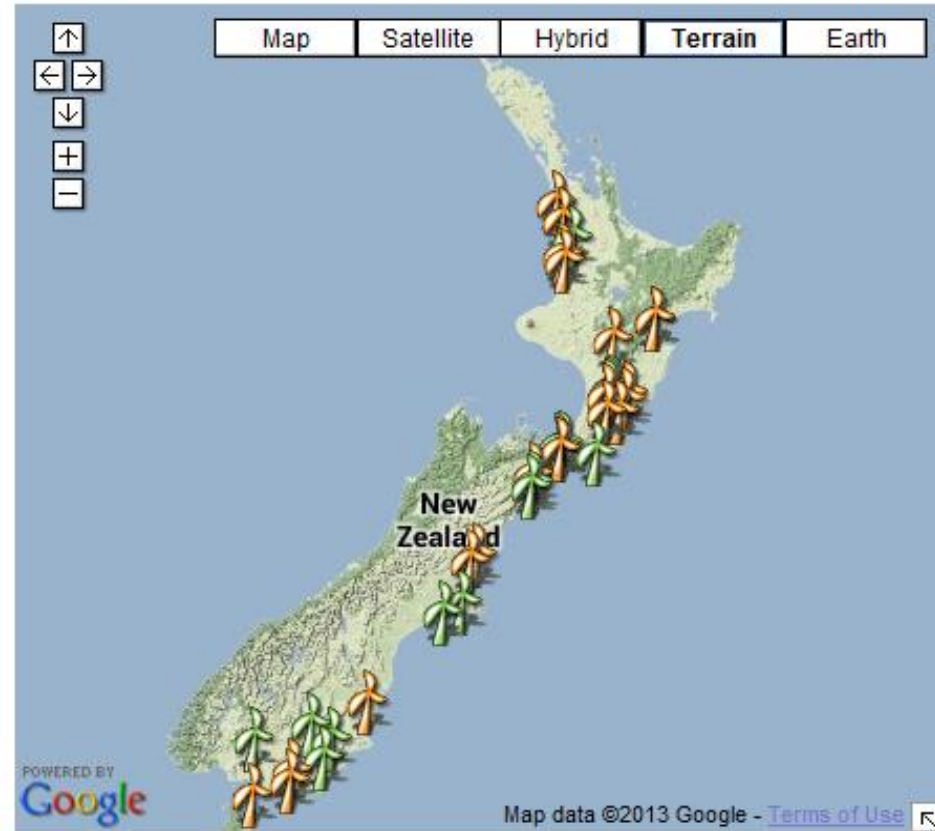
Frequency keeping and instantaneous reserves are managed as are part of economic dispatch every market trading period. Over frequency reserves and voltage support are dispatched at System Operator's discretion when certain conditions are met.

Integrating renewable generation

What's different?

- Variability of output
- Predictability of output
- Physical characteristics and capabilities
 - Inertia
 - Ability to control output to a set level
 - Ability to support the power system during disturbances
 - Fault level contribution

Existing and proposed New Zealand wind generation



Existing and under construction (green)

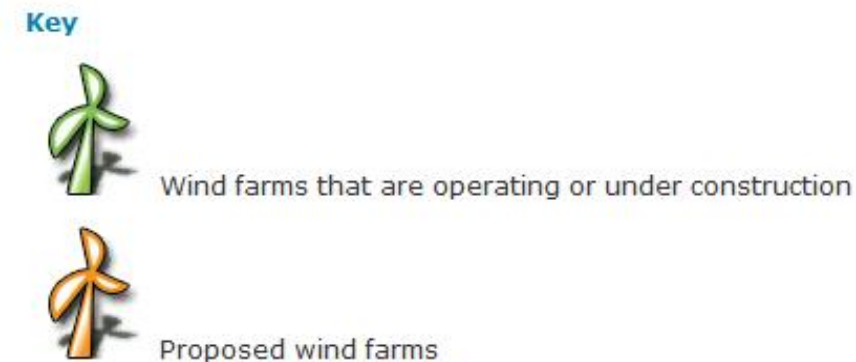
- 16 wind farms
- 0.25 to 142 MW in size
- 683 MW total installed capacity
- 482 turbines

In consenting process (orange)

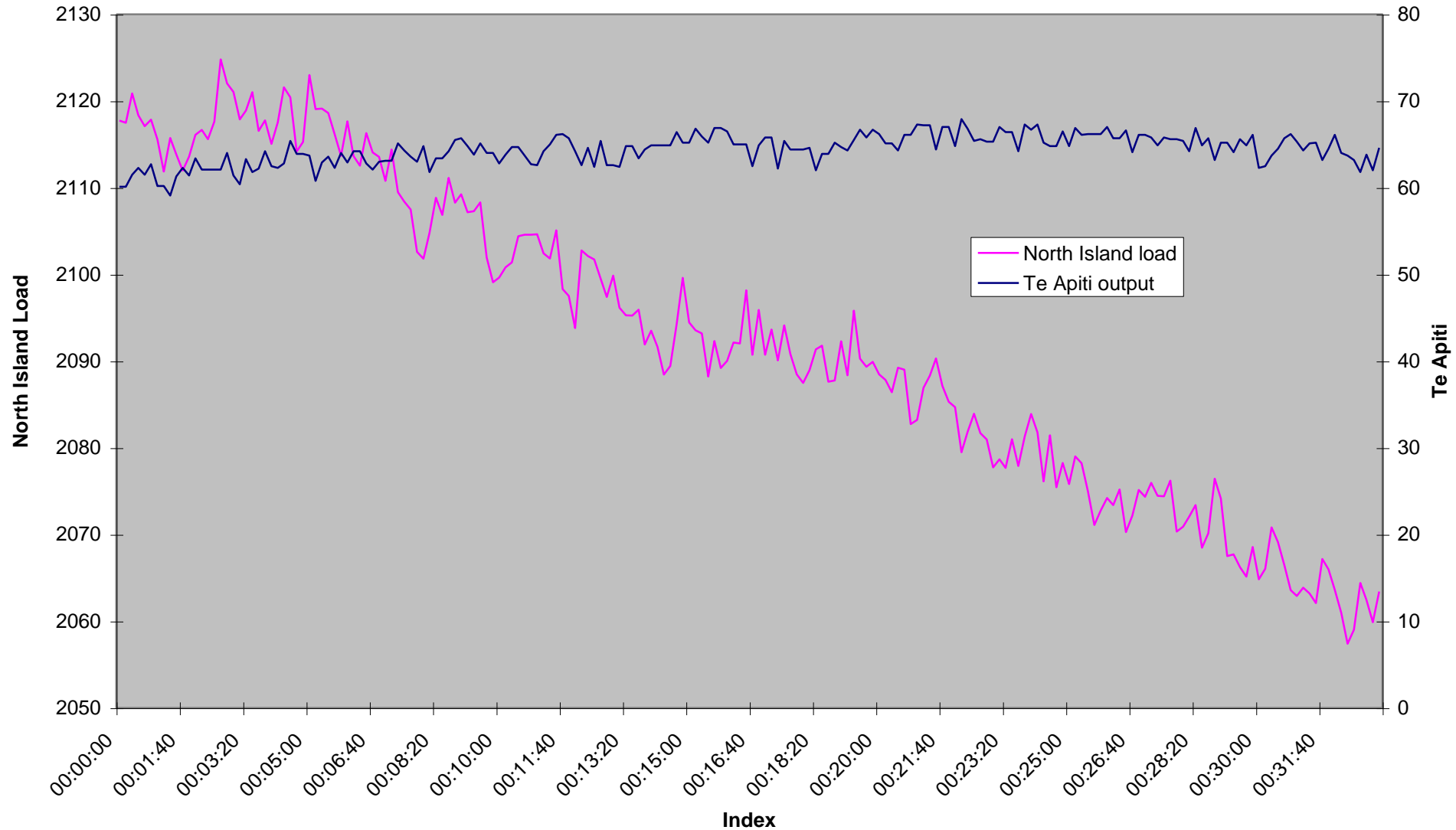
- 19 wind farms
- Up to 3300 MW installed capacity

Installed generation capacity (MW)

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Total	9,180



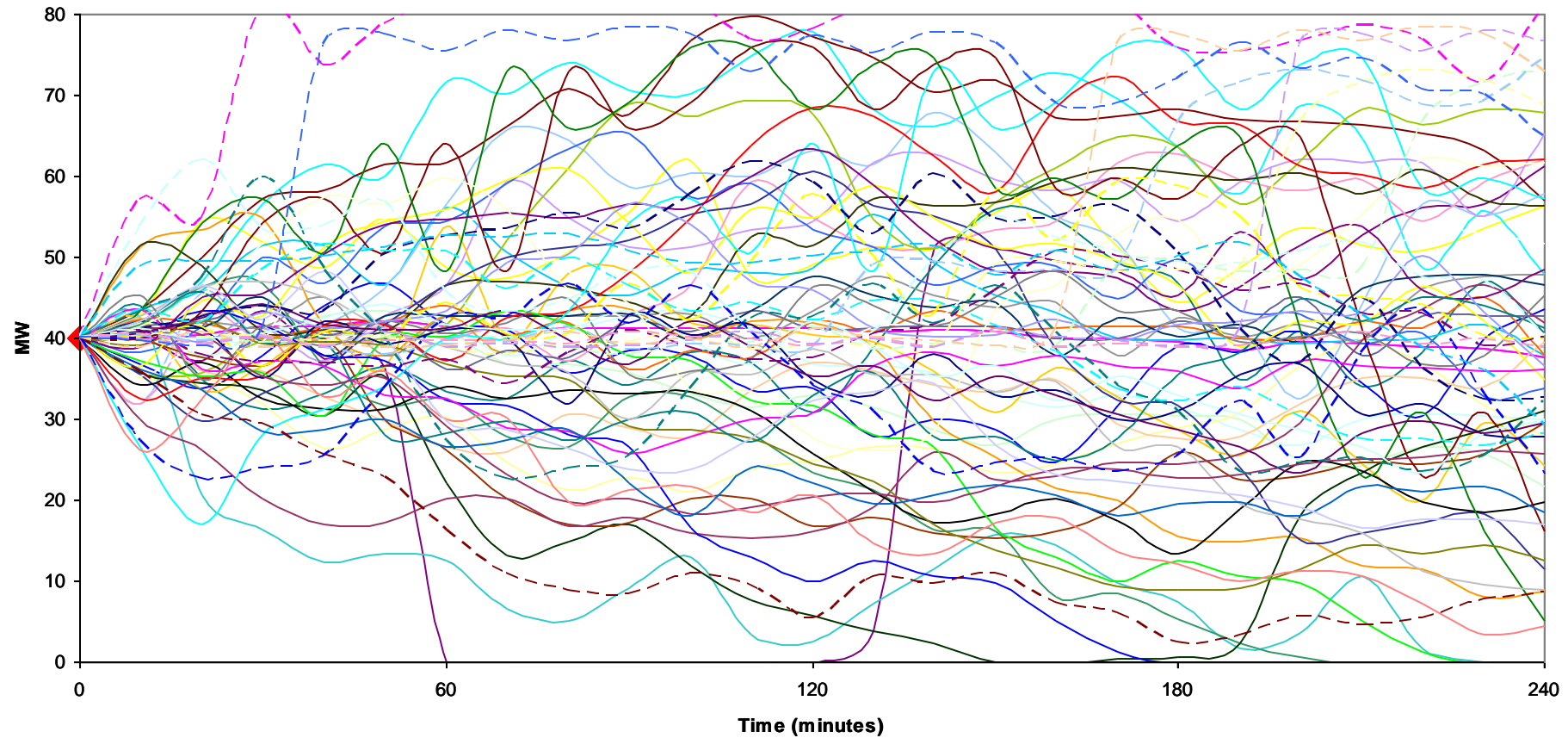
Output variability



Te Apiti is a wind farm in the North Island with an installed capacity of 90 MW.

Actual wind farm output, 90 MW installed capacity, initial output at 40 MW

Wind generation



New Zealand wind integration studies

Affected Area	Investigation
Pre dispatch processes	1: Effect of unpredictability of wind generation output on pre-dispatch processes
Dispatch processes	2: Effect of variability of wind generation output on dispatch processes
	3: Effect of variability of wind generation output on asset loading
Power System Stability	4: Effect of wind generation capability on steady state voltage management
	5: Effect of wind generation capability on management of frequency excursions
	6: Effect of wind generation capability on voltage stability
	7: Effect of wind generation capability on power system transient stability
	8: Effect of wind generation capability on oscillatory stability
	9: Effect of wind generation capability on dynamic voltage stability

Urgent further work

- Wind generation forecast
- Large change management
- SO tools and processes

Input into existing workstreams

Frequency keeping

- Normal frequency review
 - Cost allocation review
- Emergency management

Potential rule changes

- Fault ride through capability
- Voltage support requirements
- Frequency support requirements
- Instantaneous reserves cost allocation

How is the power system affected by renewable generation?

- **Increased uncertainty in scheduling**
 - Need forecasts for renewable generation
 - How much generation reserves need to be kept
- **Increased uncertainty in dispatch**
 - Increased frequency of re-dispatch
 - Increased need for ancillary services
- **Real time power system security may be affected**
 - Reduced resilience to disturbances
 - Reduced ability to control voltage
- **Power system reliability and adequacy may change**
 - To what extent can renewable generation be relied upon to provide security of supply
 - Will renewable generation be there at times of electricity shortage

Some industry models

- Vertically integrated
- Government owned or privately owned
- Separation of lines and energy
- Competitive wholesale electricity market
- Competitive electricity retail
- Merchant transmission
- Regulation by Government
- Regulation by self governance

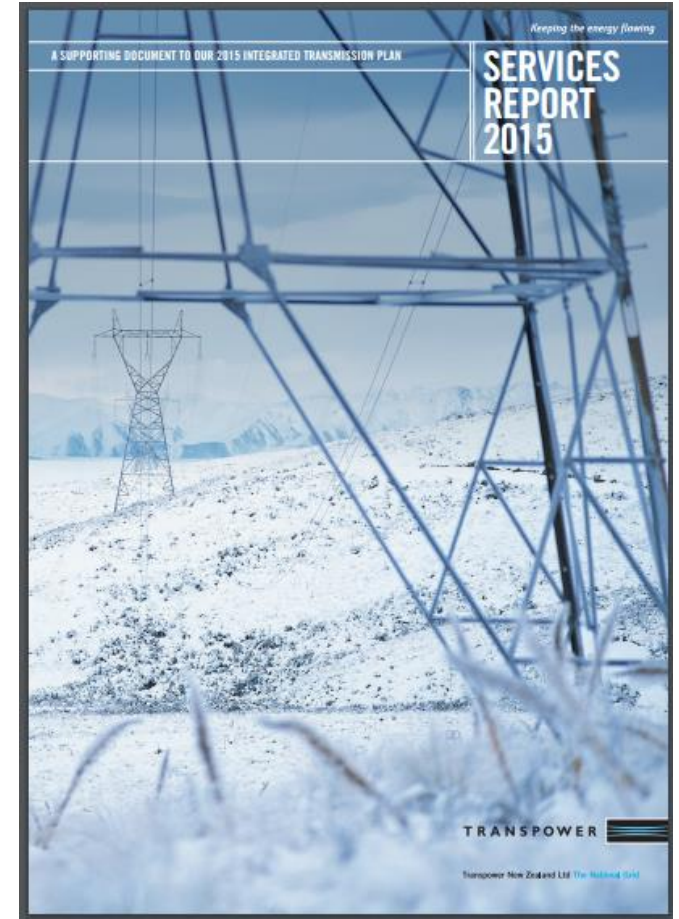


Huntly Power Station
https://en.wikipedia.org/wiki/Electricity_sector_in_New_Zealand

Service pricing and remuneration

Transmission service

- Transmission costs
 - Market costs (system losses and transmission constraints)
 - Capital and operating costs of transmission assets
- Service
 - Enabling an electricity market or access to remote generation or loads
- Performance measures
 - Reliability – energy not served
 - Asset availability – reduced reliability and market constraints



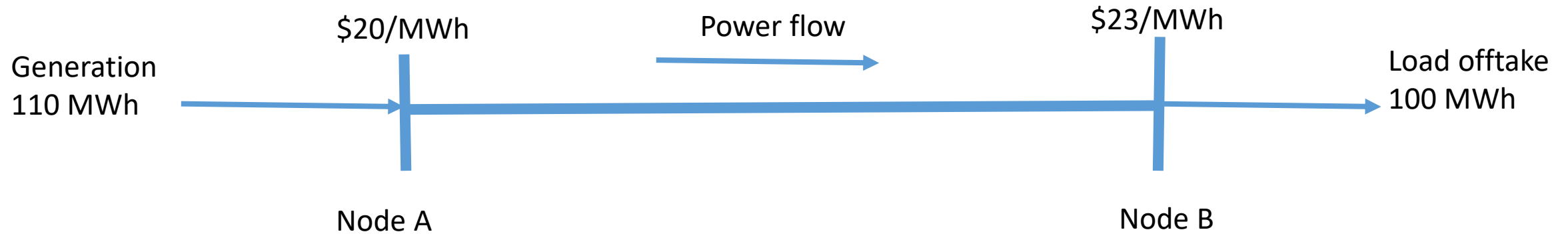
<https://www.transpower.co.nz/sites/default/files/plain-page/attachments/TP%20Services%20Report.pdf>

Regulatory roles and responsibilities

- Market operation
- System operation
- Transmission asset owner
- Generation owners
- Distribution asset owners
- Distribution system operator
 - Future, to coordinate distributed energy resources
- Regulator
 - Allowed revenue and required performance of transmission and distribution
 - Oversight of market operation
 - Oversight of generation planning

End

Nodal Pricing

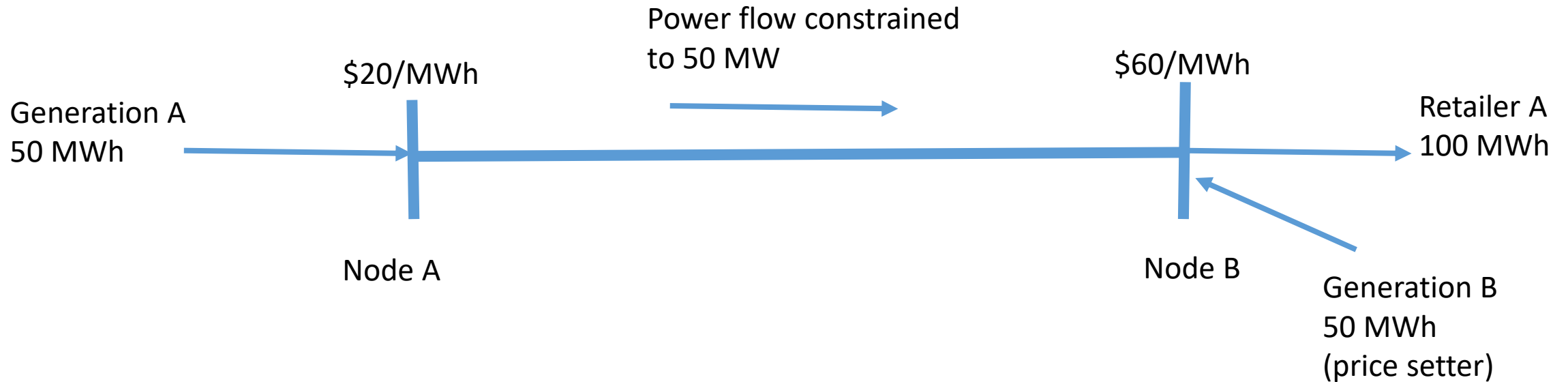


Generation paid
 $110 \text{ MWh} \times \$20/\text{MWh} = \2200

Load pays
 $100 \text{ MWh} \times \$23/\text{MWh} = \2300

Difference $\$2300 - \2200 is loss and constraint rental

Financial Transmission Rights



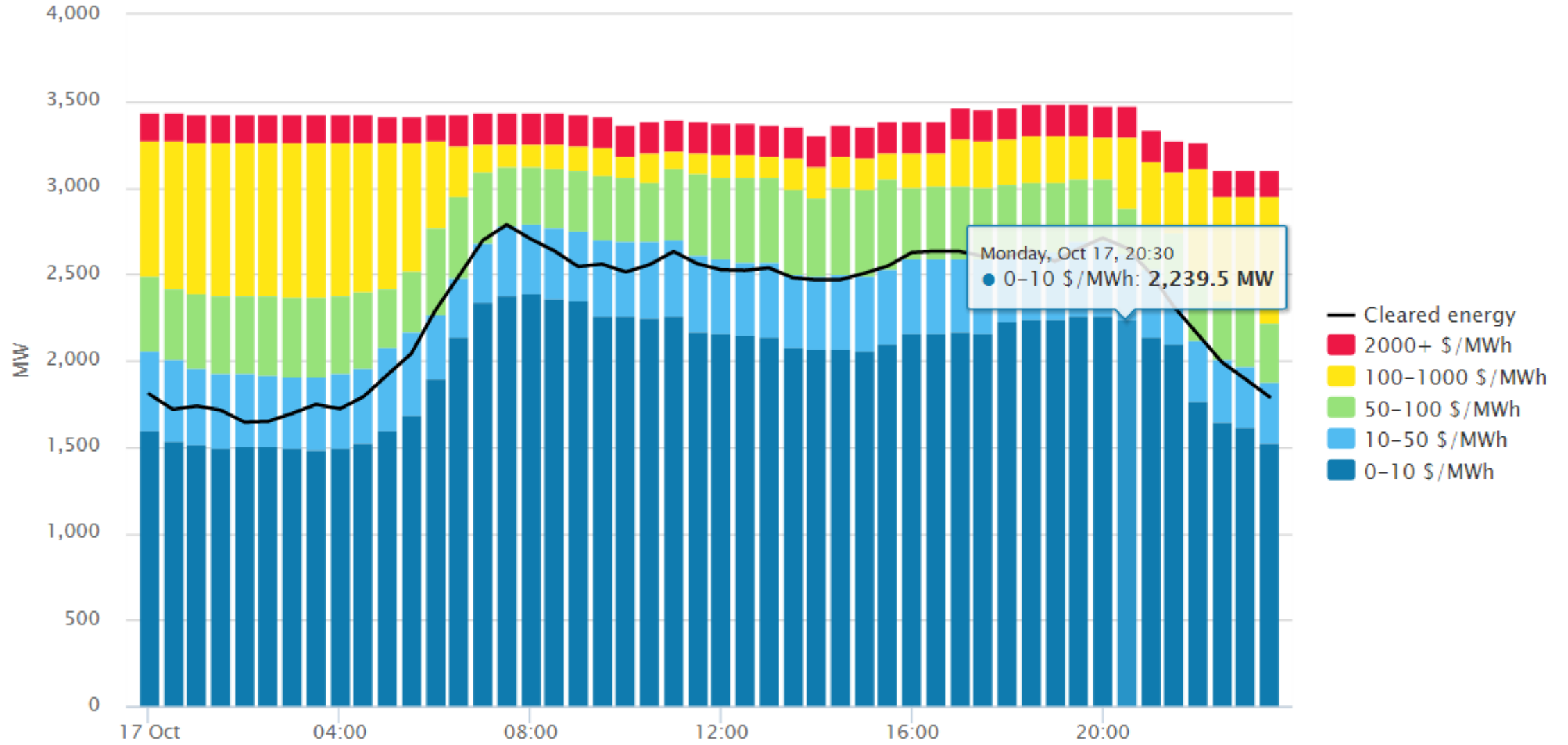
Generation paid
 $50 \text{ MWh} \times \$20/\text{MWh} = \1000

Retailer A pays
 $100 \text{ MWh} \times \$60/\text{MWh} = \6000

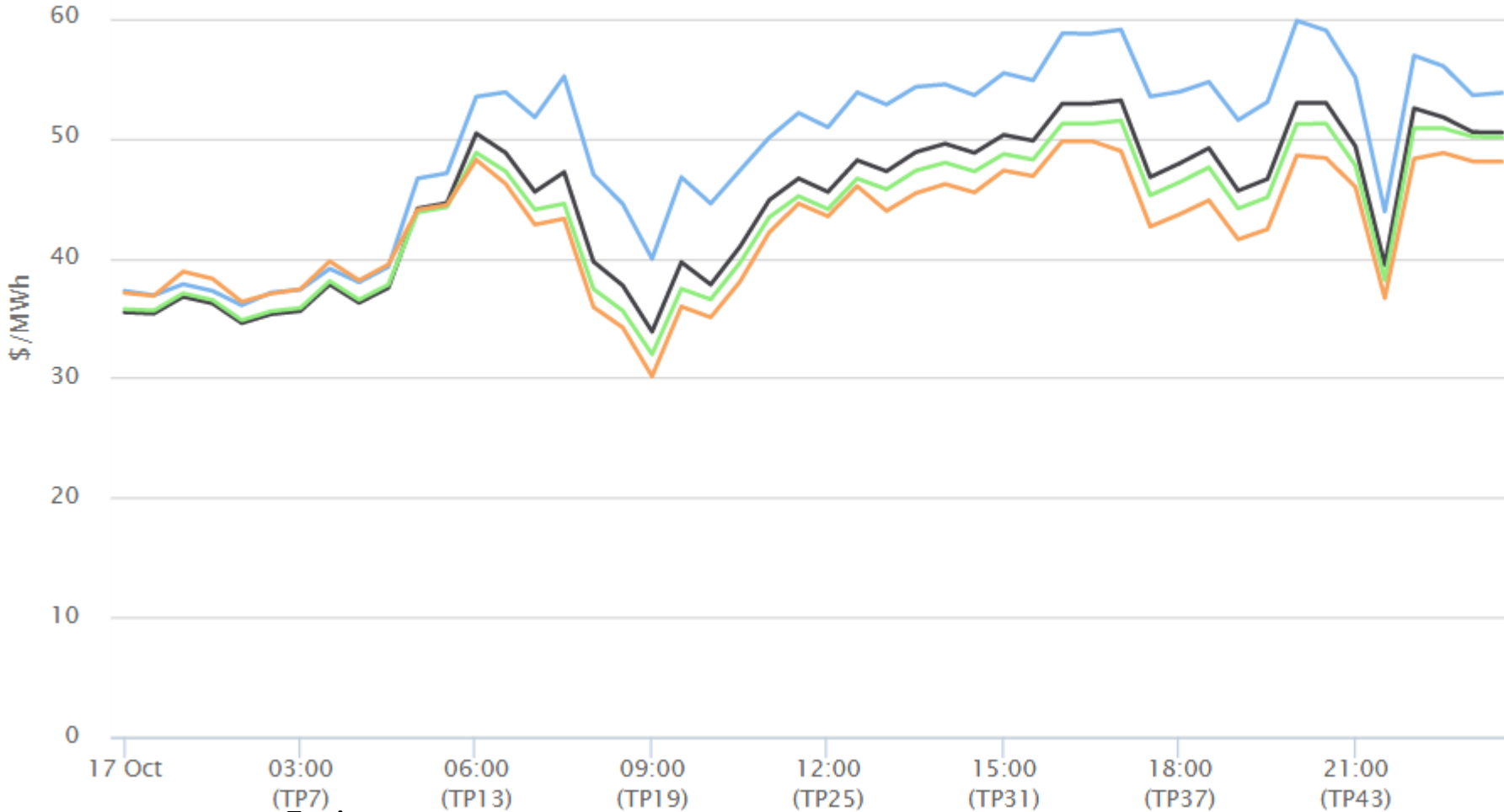
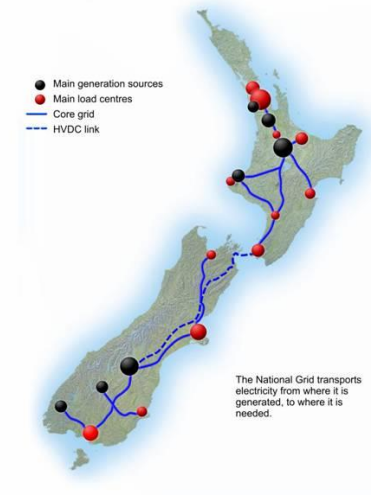
Difference $\$6000 - \5000 is loss and constraint rental

If Retailer A has an FTR for 100 MW across Nodes A and B then Retailer A is paid $100 \text{ MW} \times (\$60 - \$20) = \$4000$

Generation Stacks

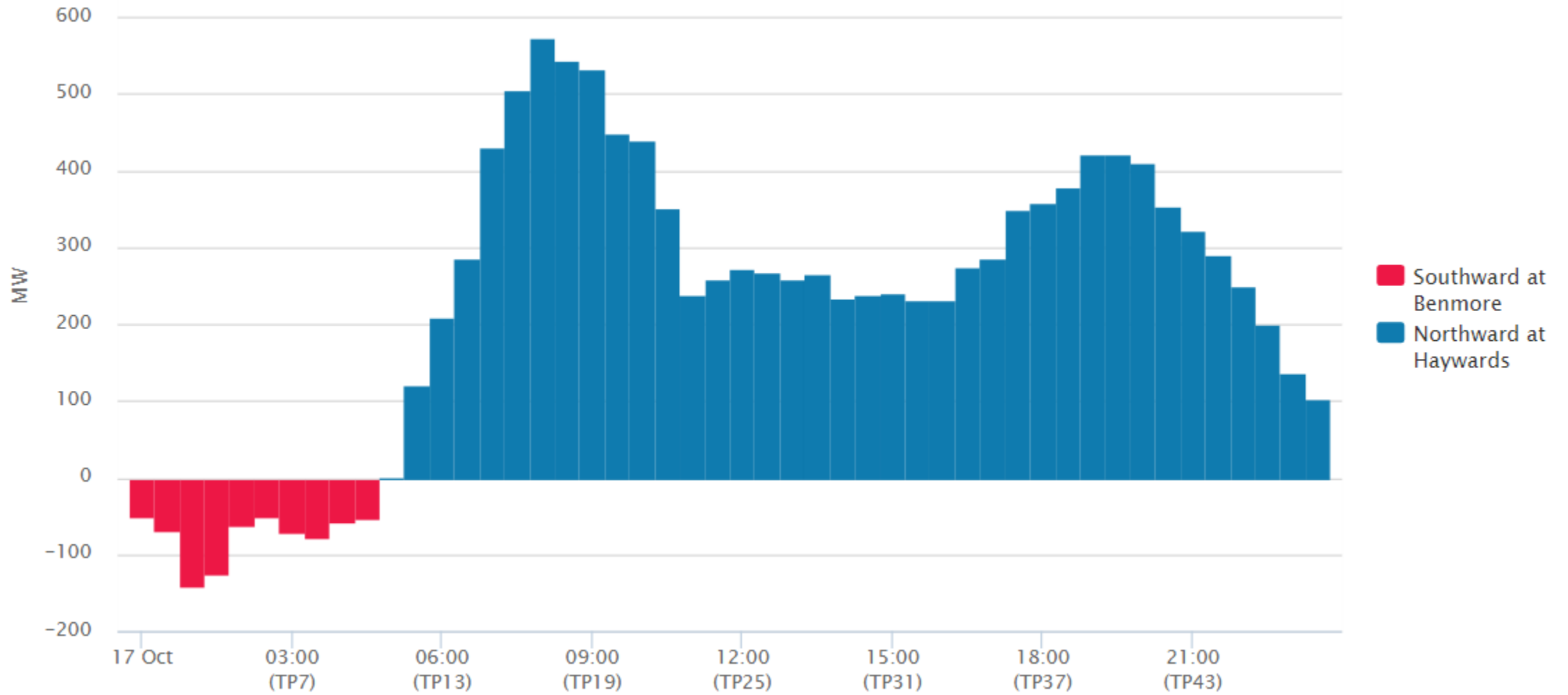


Spot prices across New Zealand

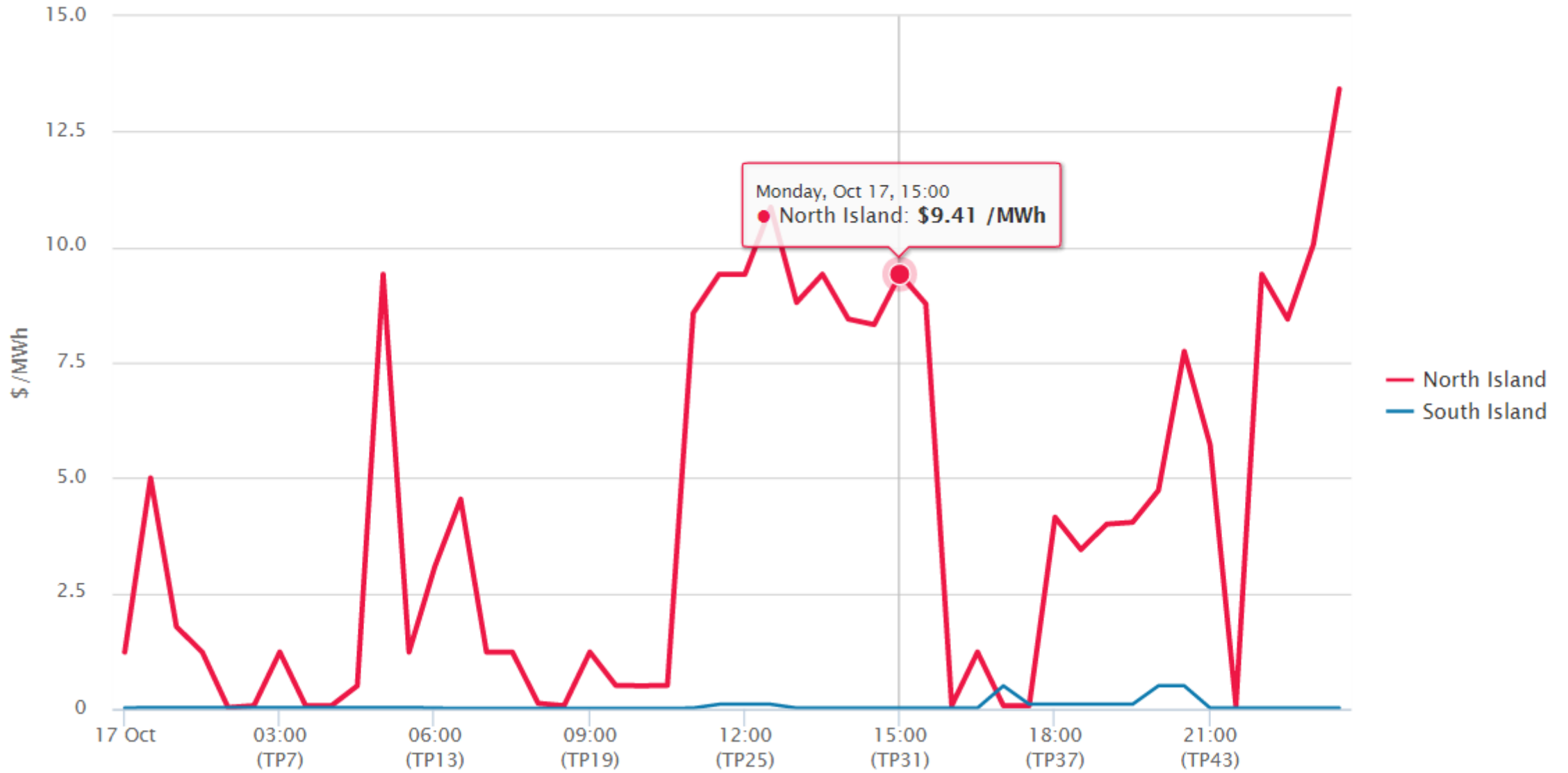


- OTA2201 - Otahuhu
- HAY2201 - Haywards
- BEN2201 - Benmore
- INV2201 - Invercargill

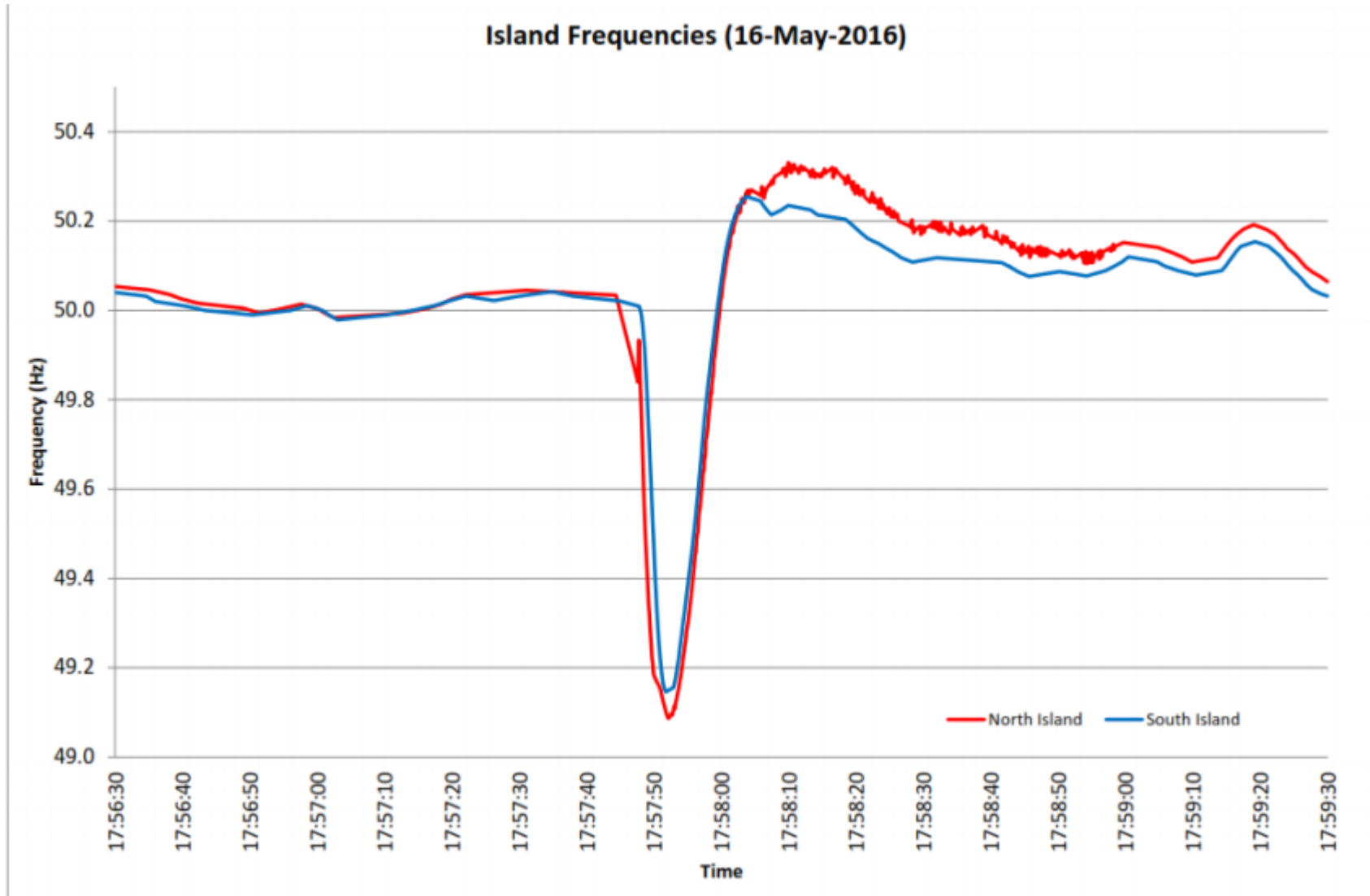
HVDC Transfer



Instantaneous Reserves Price



Under-frequency event following tripping of a generating unit – pre-event output = 366 MW



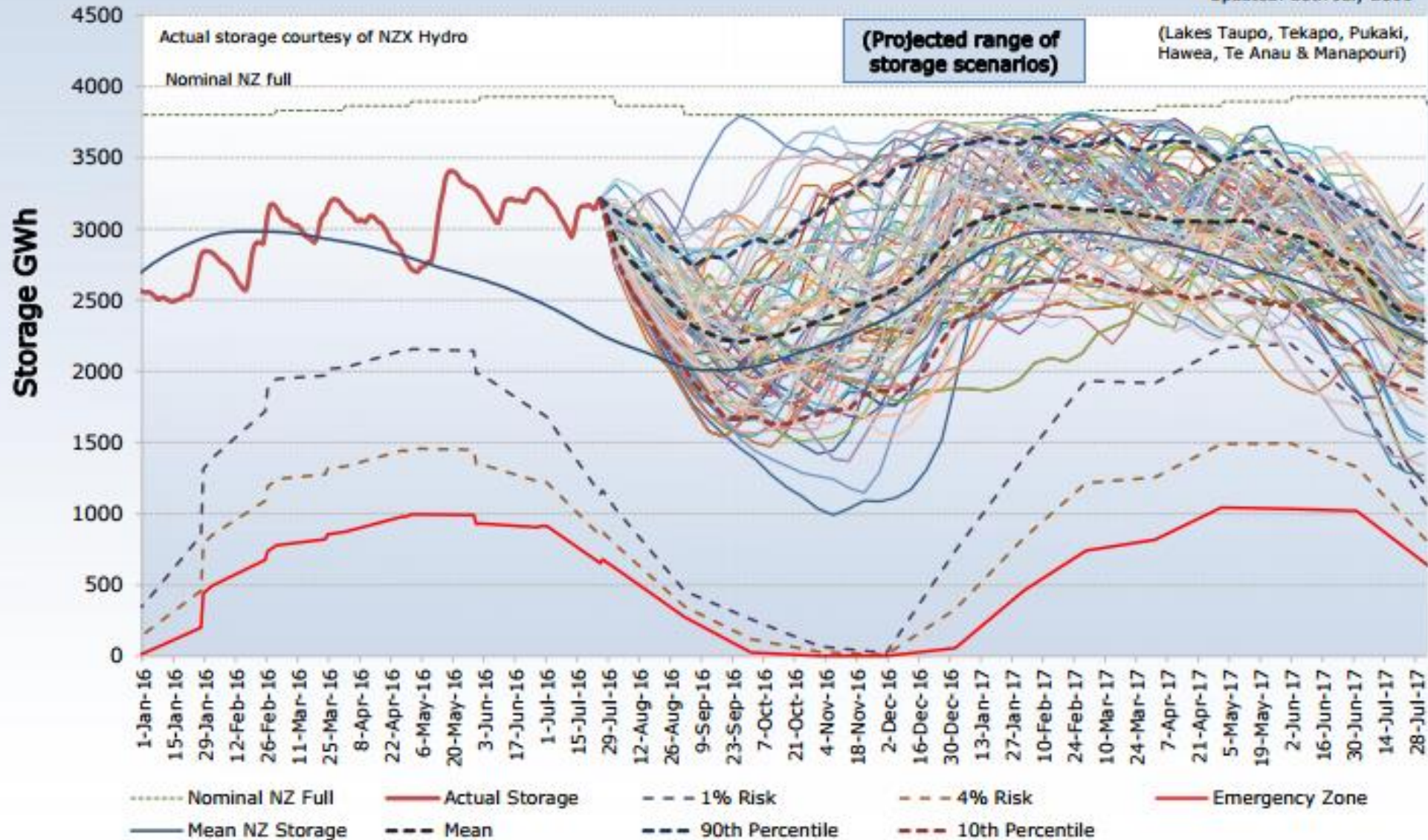
Frequency excursions 1 Sep 2014 to 31 Aug 2015

Frequency Band (Hz)	Annual rate	Performance target (legislated)
55.00 > Freq >= 53.75		0.2*
53.75 > Freq >= 52.00		2
52.00 > Freq >= 51.25	7	
51.25 > Freq >= 50.50	16	50
50.50 > Freq >= 50.20	2235	
50.20 > Freq > 49.80		
49.80 >= Freq > 49.50	2693	
49.50 >= Freq > 48.75	13	60
48.75 >= Freq > 48.00	1	6
48.00 >= Freq > 47.00		0.2
47.00 >= Freq > 45.00		0.2

Normal band 49.8 to 50.2 Hz

NZ Actual Controlled Storage and Risk Curve

Updated: 26th July 2016



Principles for regulation in New Zealand

- Competition with contestable services
 - Wholesale generation
 - Retail
 - Ancillary services
- Regulate non-contestable services
 - Transmission
 - Distribution
 - Separation of lines and energy businesses

