New Zealand Electricity Market (NZEM)

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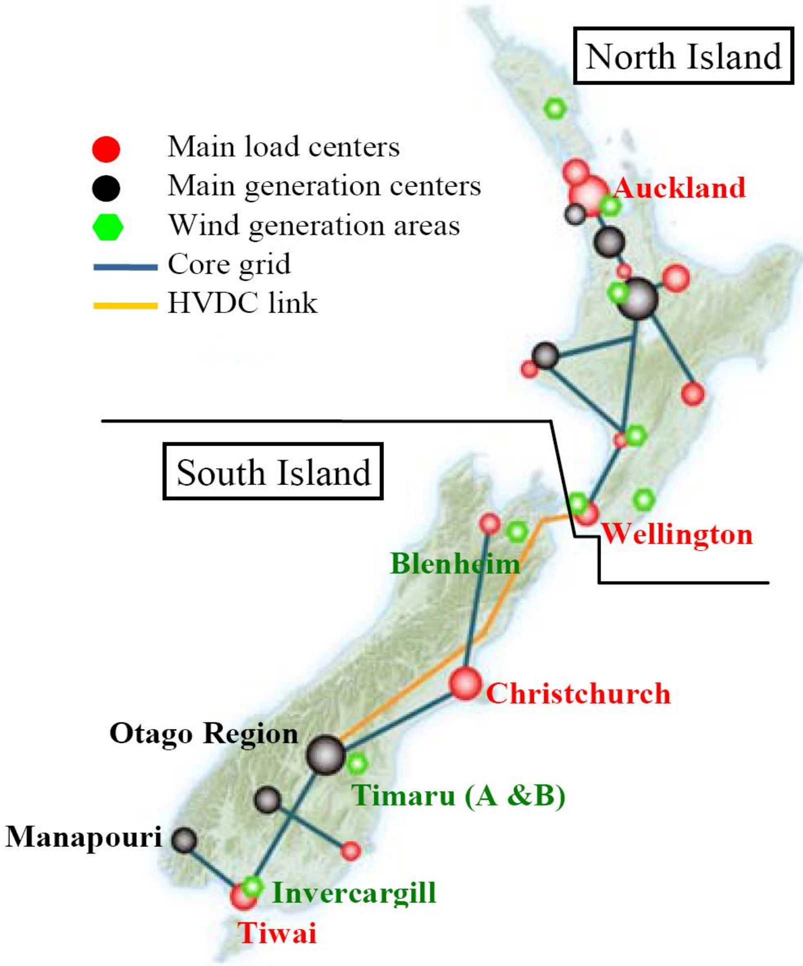
Overview of Presentation

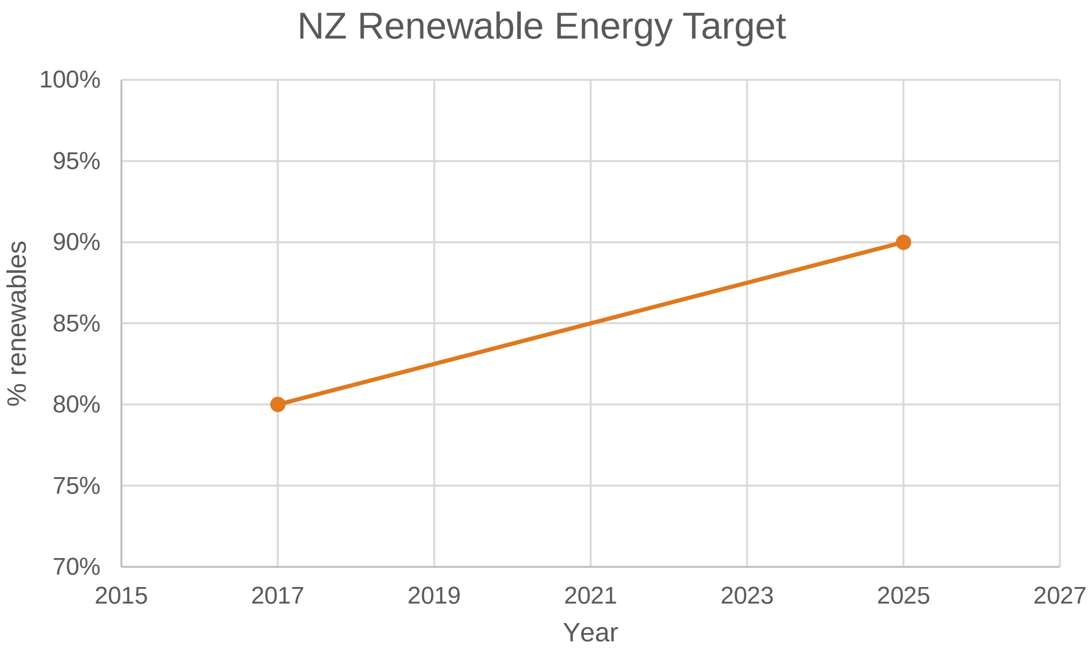
- NZ Power System
  - Power Systems
  - Renewables
  - Energy mix, Load
- NZ Electricity Market
  - Major characteristics
  - Different Dispatch Schedules
  - Security Constrained Dispatch Model
- Market Clearing Engine (SPD)
  - SPD in NZEM
  - LMP and issues in SPD
  - Risk-Reserve
  - Modelling of Branch Loss
  - Transmission Congestion
- Simultaneous Feasibility Test (SFT)
  - New Market System (June 2009)
  - AC and DC SFT
  - Thermal constraints by interaction of SPD and SFT
- Market Power Issues and Indices

NZ Power System and Electricity Market



- Operated by Transpower as Independent S.O
- North & South islands with HVDC interlink (1200 MW)
- 400 (Now Operated at 220kV), 220, 110 and 66 kV AC and ±350 kV DC
- Main bodies: Transpower , Electricity Authority and Commerce Commission
- LMP market, ½ hourly trading periods
- More than 700 market nodes in the MCE (SPD-LP)
- Thermal constraints generated near real time by ACSFT and SPD
- Energy and Operating reserves are co-optimized every 5 minute. FK regulating reserve are also co optimized every ½ hour
- Open Access to transmission
- Unit commitment: Generators are self committed
- FTR, DSP, and Scarcity price are in operation

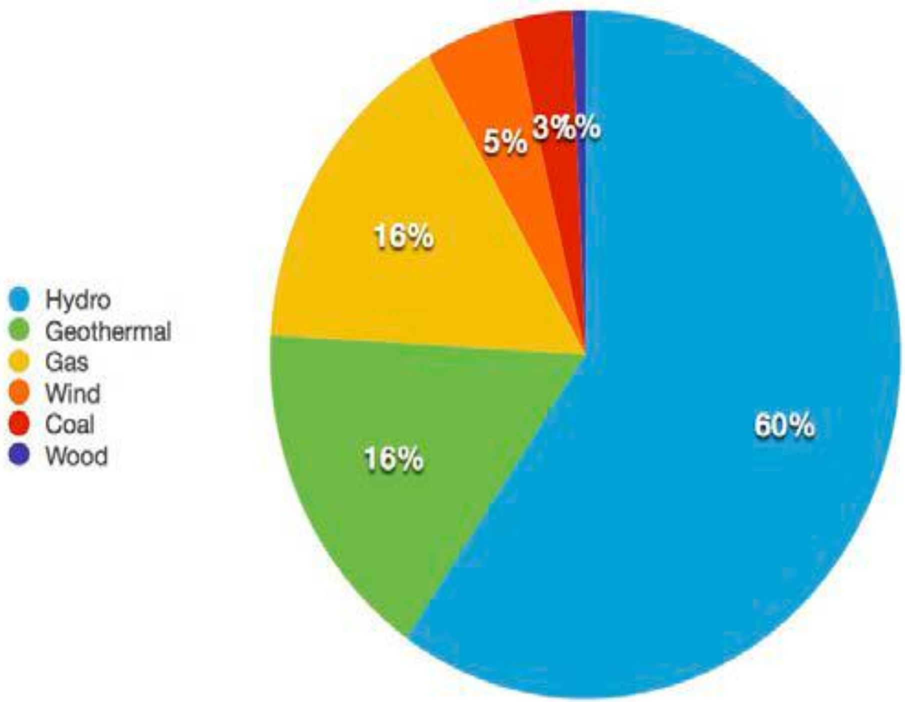
Renewable Resources in New Zealand



Energy Mix in NZEM- 2014

NEW ZEALAND'S ELECTRICITY GENERATION (12 months to Nov 2014)

GENERATION TYPE	PERCENTAGE
Hydro	59.6%
Geothermal	16.3%
Gas	15.8%
Wind	4.6%
Coal	3.0%
Wood	0.7%



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New Zealand Electricity Market (NZEM) Major characteristics

- Independent System Operator
- LMP (locational marginal pricing) based dispatch
- Transparent constraint management
- Open access to transmission
- Co-ordinated ancillary services
- Energy Market
- FTR Market
- Reserve Market
- Market power Indices
- Mandatory system security standards

Major Characteristics…..contd
Market Place

- Sellers (Gens)
- Buyers (Consumers)
- Service Providers (Transpower, NZX)
- Market Operators SO, Transpower
- Regulators: Electricity Authority, Commerce Commission

Major characteristics …contd

- NZEM is the first among the 2nd generation LMP Electricity Markets. Operated since OCT 01, 1996

- It is a LMP market

- Energy and operating reserves and Frequency Regulating Reserve (FRR) are co-optimised. That means both energy and reserves could compete for the same resource (generators).

- Black-start and Reactive support reserves are procured off-line by contracts.

Major Characteristics…..contd

- Unit commitment: Generators are self committed.
- Gate closure occurs 1 hr before actual real time dispatch .

- Offers and Bids: Generators offer
  - energy bids ($/MWH) in up to 5 blocks (steps)
  - Reserve bids for both 6s and 60s reserves in up to 3 steps
  - Demand bids ($/MWH) in up to 10 blocks (steps)

- Demanders also bid for their load (MW, $/MWH). Demand bids are used only in one schedule (PRSS). Other schedules use forecasted /metered load.

- Dispatchable demand, are allowed in all schedules except real-time schedule.

Major Characteristics…..contd

- Network *Losses* are modeled inside SPD, approximating quadratic loss function using 6 linear loss segments.

- Static loss of each branch is modeled as load equally at each end.

- Dynamic loss for each branch is modeled at the receiving end only.

Different Dispatch Schedules (1)

The following schedules are run in parallel but with different periodicity. Some schedules have variable intervals. Periodicity include Daily, 2hr, 1/2hr and 5 minute. Runs like train of pulses.

- Weekly Daily Schedule (WDS)
- NRSS (Non-price Responsive Schedule, Short)
- PRSS (Price Responsive Schedule, Short)
- NRSL similar to NRSS but every 2 hrs, Covers Longer Period.
- PRSL similar to PRSS but every 2 hrs, Covers Longer Period.
- RTD (Real time dispatch)
- RTP (Real time pricing)
- FP (Final Pricing)

Market Clearing Engine: SPD in NZEM

SPD is a security constrained DC-OPF based application (works on Linear Program method).

BOX1

Input to SPD

- Network
- Bids and Offers
- Constraints

Input

BOX 2

SPD

- ***Objective Function***
- Minimise Generation and Reserve costs
- ***Subject to***
- Given Constraints
- Numerous Limits

Output

BOX 3

SPD Output

- Optimal and Secured Dispatch
- Nodal Energy Prices
- Island Reserve Prices

Major Constraints into SPD

Bus Injections	**Market Node Group Constraints**
AC & DC Branch Flows	**Mixed Constraints**
Branch Losses	**Ramping Constraints**
Branch Flow Constraints	**Risk-Reserve constraints**
Bus Power Balance Constraints	**FRR requirements**
Bus Group Generation MW	**N-1 Thermal constraints**
	Stability constraints

Power Balance and Branch Flow in SPD

$$P_{gi} - P_{di} = \sum_{j \in Ni} P_{ij} : \lambda_i ; \forall i.$$

$$P_{ij} = B_{ij}(\theta_i - \theta_j) + \frac{1}{2} P_{ij}^L : \tau_{ij} ; (\forall (i, j) \in L_{ij}).$$

- One of the most important power system control objectives is to keep the power balance in the system.
- At any moment, at any bus, the generation must meet load + Losses, and net line flows. Power balance at each bus(node) is used, and the corresponding dual variable gives the LMP at the bus.
- In NZ, we now balance the system through 5min dispatch.

LMP Components

- **Energy Component –** Marginal generation price.
- **Loss Component -** is the marginal cost of additional losses caused by supplying an increment of load at the location.
- **Congestion Component -** equal zero for all locations if there are no binding constraints.

Nodal Price = Marginal cost of generation + Marginal cost of losses + Marginal cost of Transmission Congestion

Issues in SPD

- Multiple solutions
- Degeneracy
- Non-physical loss due to Circulating branch flow(CBF) and Loss tranche swapping
- Infeasibility

Reserve Modelling in NZEM

Generator Risk

$$\sum_i R_i \geq P_u + R_u \,;\ \forall u,\ u \in Risk\ units$$

P_u = Cleared Generation of Risk generator, u

R_u = Cleared Reserve of Risk generator, u

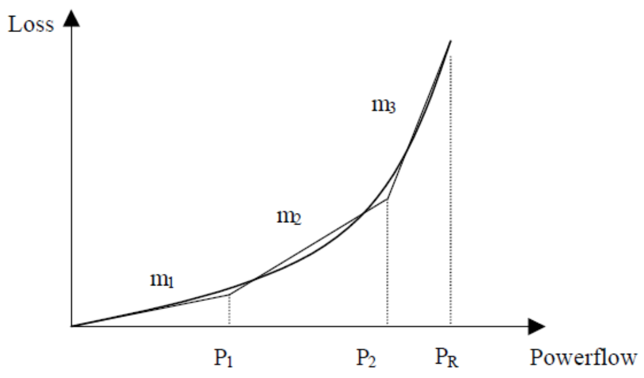
$\sum_i R_i$ = Total requirement of reserve from all generators

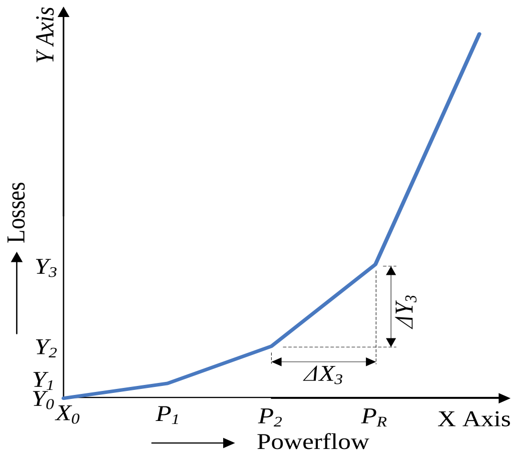
Reserve constraints

- Proportional constraint
  $R_i \leq x_i . P_i$
- Reserve upper bound constraint
  $R_i \leq R_i^{\max}$
- Generator joint capacity constraint
  $P_i + R_i \leq P_i^{cap}$
- Generator upper and lower bound constraint $P_i \geq 0$ $P_i \leq P_i^{\max}$

Linear Loss Model: 3 Seg Branch Loss

NZEM use 6 linear loss segments

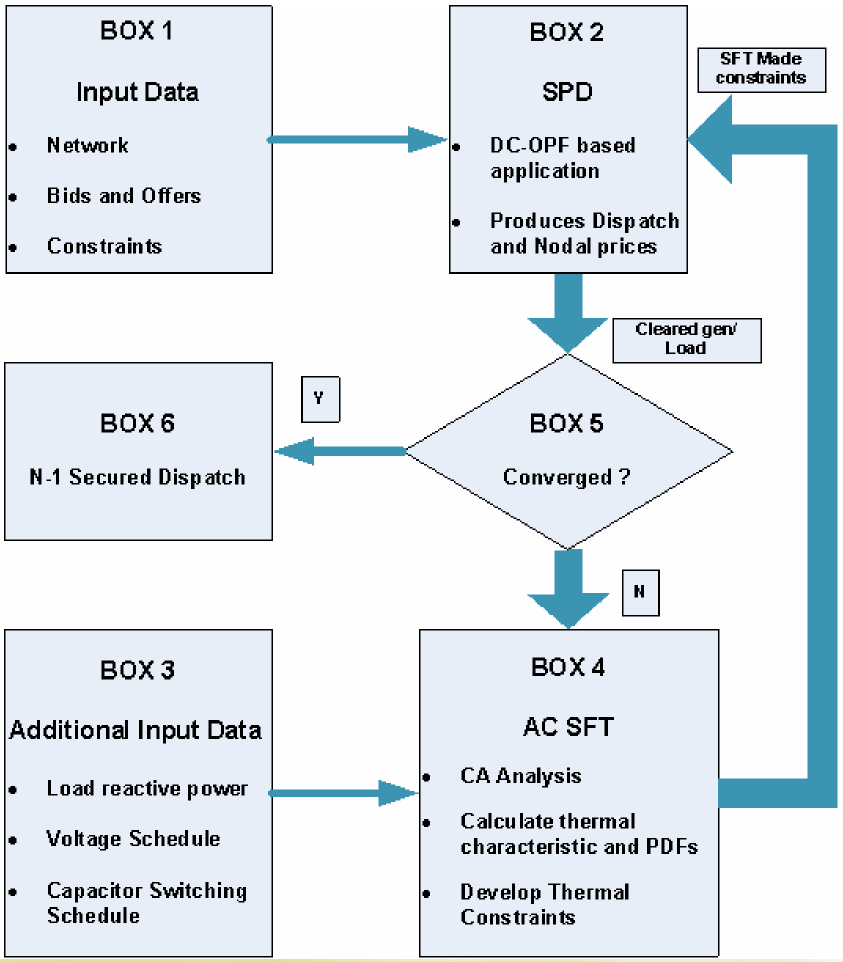




Thermal Constraints - SPD-SFT Iterations

$$DF_{pc} = \frac{P_P^{/} - P_P}{P_c}$$

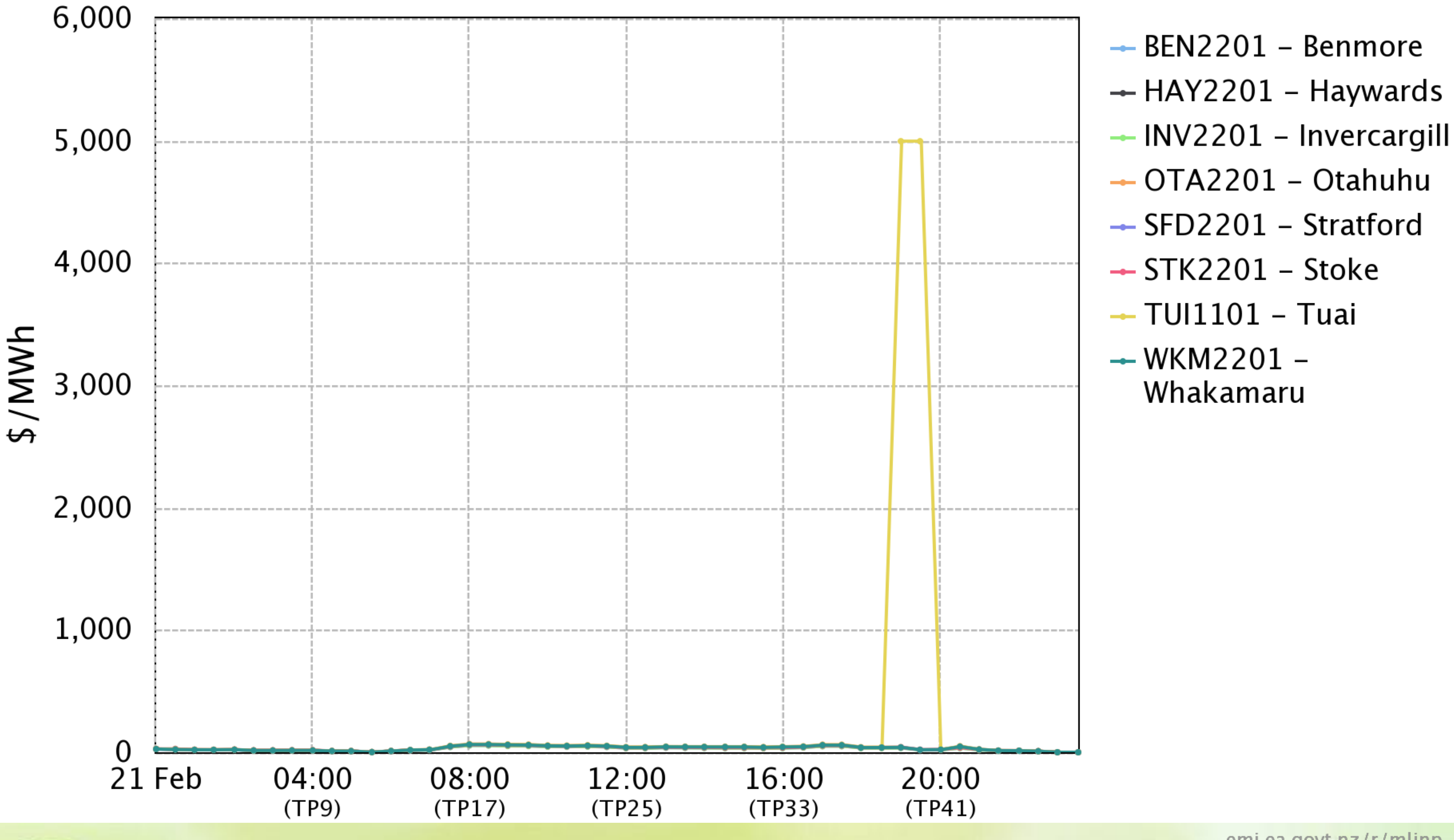
$$k_1 P_P + DF_{pc} . P_C \leq Rating_P$$



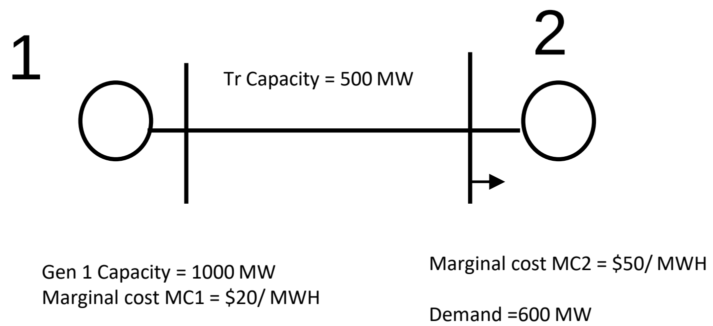
Transmission Congestion

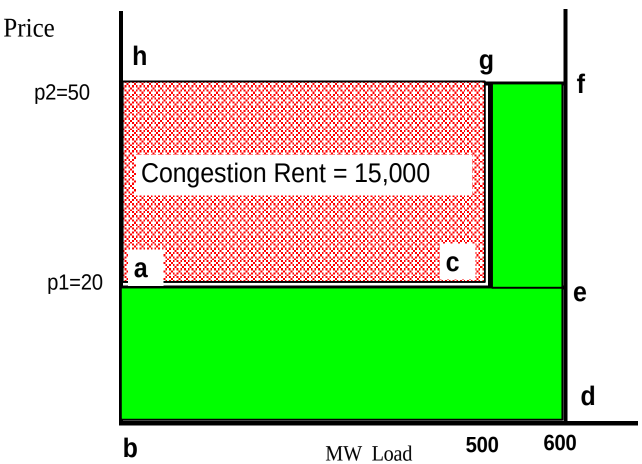
Price spike 21 February 2018

Congestion in 110 kV in Hawks Bay Area



Effect of Transmission Congestion





No transmission Congestion

Spot price (system marginal price) at node 1 & 2 $\rho_1 = \rho_2 =$ $20 / MWH.

Total generation cost = area "abde" = 600 *20= $12000

Total bill paid by the customer = area "abde" = 600*20 = 12,000

With Transmission Congestion for a transmission capacity = 500 MW

Since transmission line is congested, a marginal electricity demand at node 2 can be met only by using expensive power generated at node 2.

Marginal price at node 2, $\rho_2 = 50$ /MWH.

Total generation cost =area "abdfgca" 500 * 20 + 100*50 = $15,000.

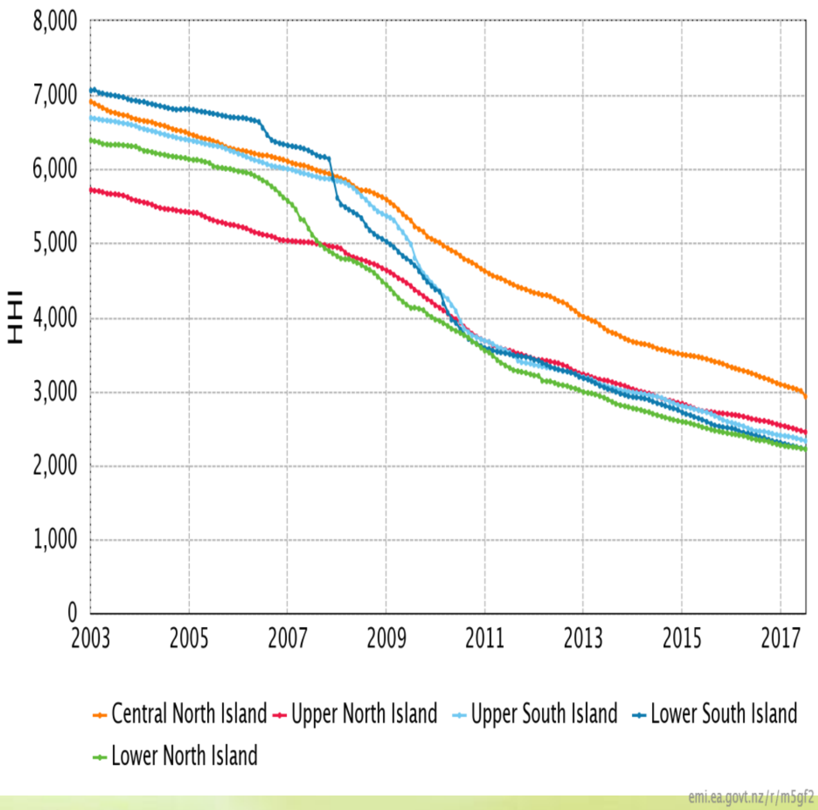
Total bill paid by the customer = area "bdfh" = 600*50 = 30,000

Cost of Congestion = area "cefg" = 15000 – 12000 = $3000 **&** Congestion Rent = area "acgh" = 30,000 -15,000 = $15,000

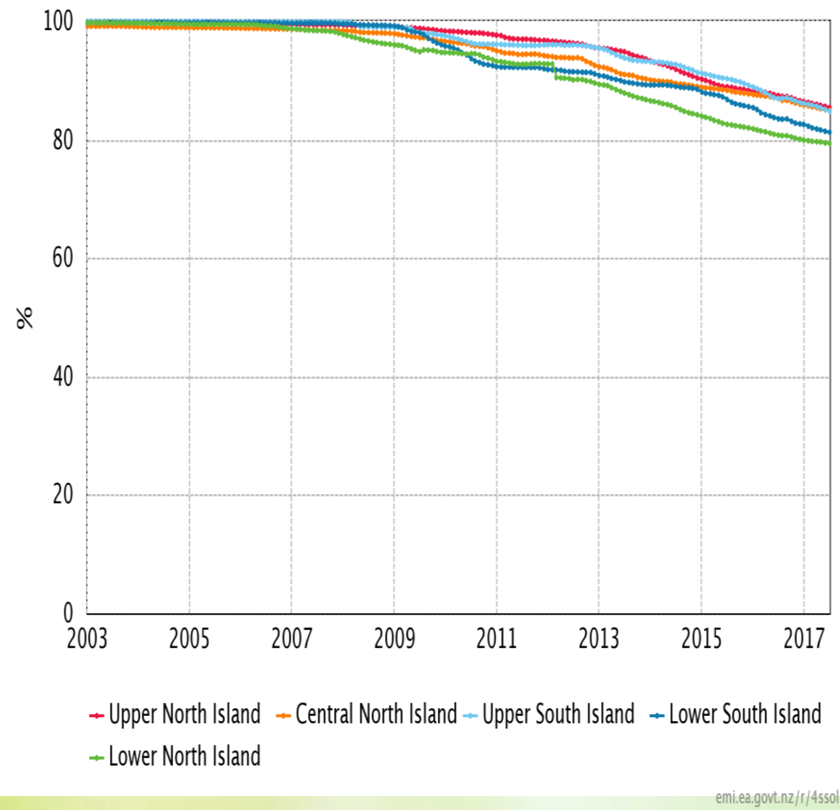
Market Power Monitoring - Retail

Electricity Authority publishes:

HHI (Herfindahl - Hirschman Index)

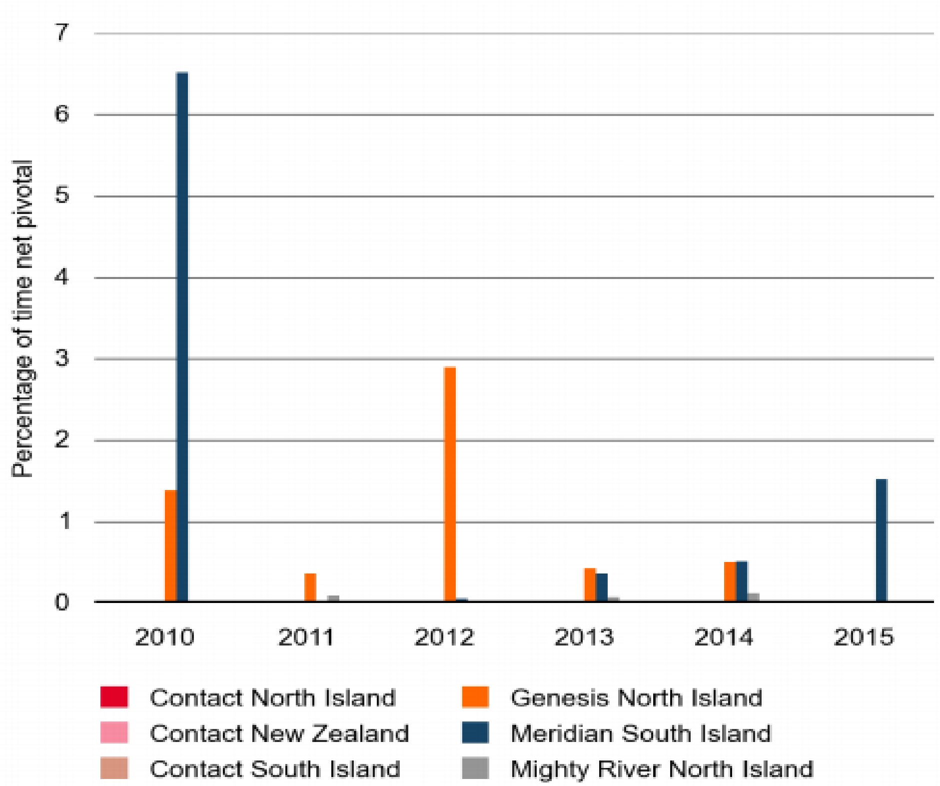


CR4 (Concentration Ratio)



Market Power Monitoring - Wholesale

Electricity Authority monitors how often large vertically integrated generator-retailers are nett pivotal



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[2] **FERC Market Monitoring Workshop**, Anjali Sheffrin DMA, CAISO, Dec 3-4, 2002

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[4] **Chapter 7 on Market Power and Competitiveness**, Annual report on market issues and performance, MSU CAISO, June 1999.

Disclaimer:

The views expressed in this talk do not necessarily reflect the views of Wintec, or Electricity Authority, New Zealand or the System Operator, Transpower New Zealand Ltd

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End of Presentation

Thank You

Questions?