TRANSPOWER

ELECTRICITY AUTHORITY
TE MANA HIKO

Reserve shortfall modelling using simplified worked examples

COMPETITION • RELIABILITY • EFFICIENCY

Contents of this pack

These illustrative results were obtained using a simplified Excel model

The first section shows the flaws in using the current reserve deficit constraint model under RTP (ie, in trying to use ‘real’ CVP values)

The second section shows similar conditions using the risk-violation curves

Worked examples of the (failed) reserve deficit approach

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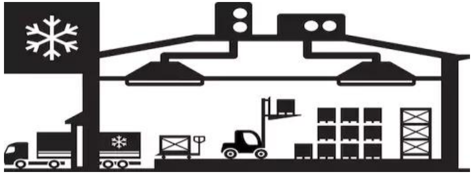
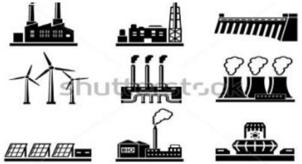
Market Scenario Example
one risk setter and both reserve classes constrained

North Island
Demand : 1650 MW



IL FIR : 100 MW @ 100 $/MWh
IL SIR : 100 MW @ 200 $/MWh



ENRG: 1500MW @ 100$/MWh
FIR : 200MW @ 20 $/MWh
SIR : 250MW @ 30 $/MWh

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP = 10k
SIR CVP = 10k

South Island
Demand : 1000 MW

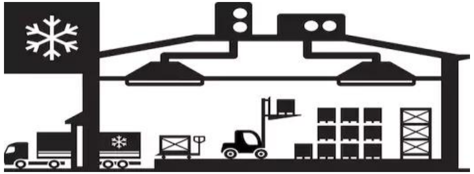
ENRG: 3000MW @ 0.01$/MWh

Market Scenario Example

one risk setter and both reserve classes constrained

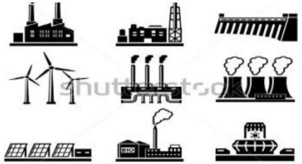
North Island

Demand : 1650 MW



IL FIR : 100 MW @ 100 $/MWh → 100 MW

IL SIR : 100 MW @ 200 $/MWh → 100 MW



Energy price: $10k/MWh

FIR price: $100/MWh

SIR price: $9899.99/MWh

ENRG: 1500MW @ 100$/MWh → 1300 MW

FIR : 200MW @ 20 $/MWh → 200 MW

SIR : 250MW @ 30 $/MWh → 200 MW

HVDC

NI ← SI

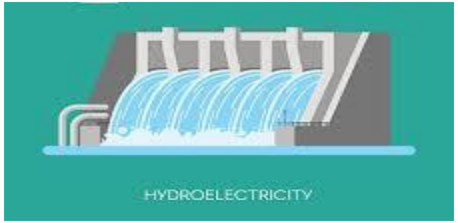
300 MW

South Island

Demand : 1000 MW

ENRG: 3000MW @ 0.01$/MWh

→ 1300 MW

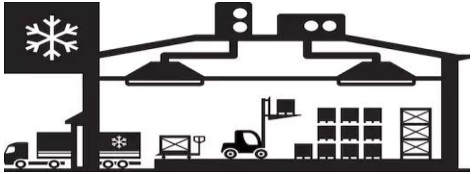


Energy shortage: 50 MW

Market Scenario Example
one risk setter and both reserve classes constrained

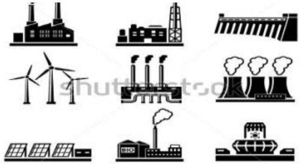
North Island

Demand : 1650 MW



IL FIR : 100 MW @ 100 $/MWh

IL SIR : 100 MW @ 200 $/MWh



ENRG: 1500MW @ 100$/MWh

FIR : 200MW @ 20 $/MWh

SIR : 250MW @ 30 $/MWh

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k

FIR CVP = 4.5k

SIR CVP = 4.5k

South Island

Demand : 1000 MW

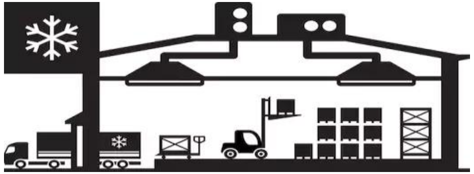
ENRG: 3000MW @ 0.01$/MWh

Market Scenario Example

one risk setter and both reserve classes constrained

North Island

Demand : 1650 MW



South Island

Demand : 1000 MW

HVDC

NI ← SI

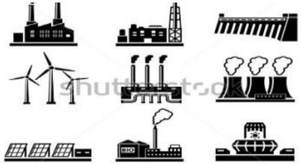
350 MW

IL FIR : 100 MW @ 100 $/MWh → 100 MW

IL SIR : 100 MW @ 200 $/MWh → 100 MW

ENRG: 3000MW @ 0.01$/MWh

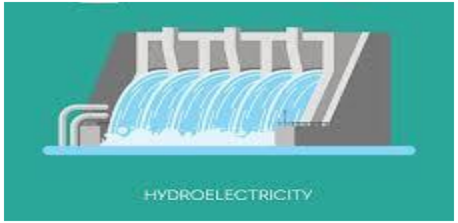
→ 1350 MW



Energy price: $9,000.01/MWh

FIR price: $4,500.00/MWh

SIR price: $4,500.00/MWh



ENRG: 1500MW @ 100$/MWh → 1300 MW

FIR : 200MW @ 20 $/MWh → 200 MW

SIR : 250MW @ 30 $/MWh → 200 MW

FIR/SIR shortage: 50 MW

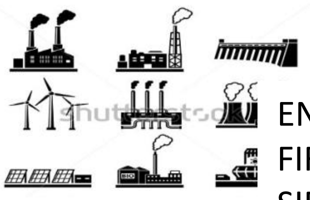
Market Scenario Example
three risk setters

North Island
Demand : 1510 MW

ENRG: 350MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 350MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 100MW @ 5k$/MWh



ENRG: 1000MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 300MW @ 3$/MWh

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP = 10k
SIR CVP = 10k

South Island
Demand : 1000 MW

ENRG: 3000MW @ 0.01$/MWh

Market Scenario Example

FIR shortage: 10 MW

rs

North Island

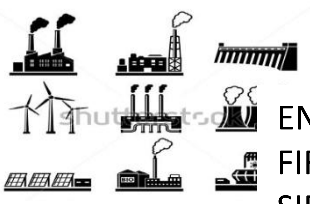
Demand :   1510 MW

ENRG: 230MW @ 0.01$/MWh
FIR   : 20MW @ 1$/MWh
SIR   : 30MW @ 1$/MWh

ENRG: 230MW @ 0.02$/MWh
FIR   : 20MW @ 2$/MWh
SIR   : 30MW @ 2$/MWh

ENRG: 0MW @ 5k$/MWh

Energy price: $3334.35/MWh
FIR price: $10k/MWh
SIR price: $3/MWh



ENRG: 800MW @ 100$/MWh
FIR   : 200MW @ 3$/MWh
SIR   : 200MW @ 3$/MWh

HVDC

NI ← SI

250 MW

South Island

Demand :   1000 MW

ENRG: 1250MW @ 0.01$/MWh

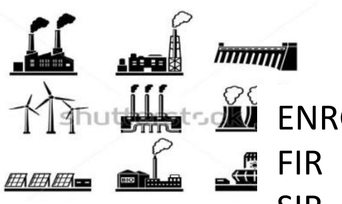
Market Scenario Example
three risk setters

North Island
Demand : 1510 MW

ENRG: 350MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 350MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 100MW @ 5k$/MWh



ENRG: 1000MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 300MW @ 3$/MWh

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP = 15k
SIR CVP = 15k

South Island
Demand : 1000 MW

ENRG: 3000MW @ 0.01$/MWh

Market Scenario Example
three risk setters

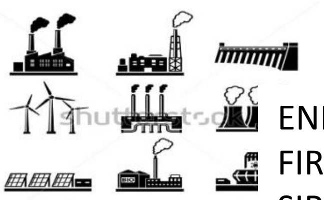
North Island
Demand : 1510 MW

ENRG: 220MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 220MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 30MW @ 5k$/MWh

Energy price: $5000/MWh
FIR price: $14,996.96/MWh
SIR price: $3/MWh



ENRG: 800MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 190MW @ 3$/MWh

HVDC
NI ← SI
240 MW

South Island
Demand : 1000 MW

ENRG: 1240MW @ 0.01$/MWh

Worked examples of the risk-violation curve

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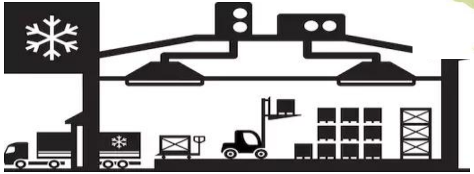
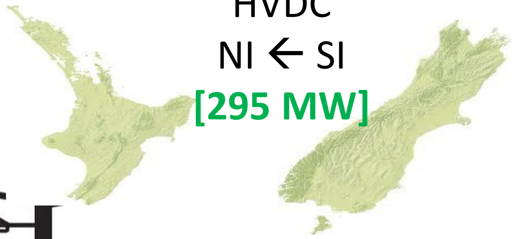
Market Scenario Example
(1 risk setter – No shortfall)

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

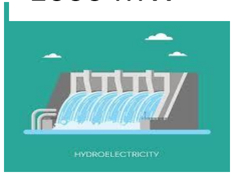
NI demand
1595 MW



HVDC
NI ← SI
[295 MW]



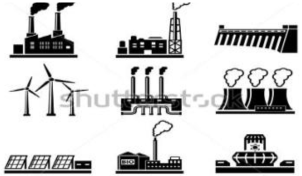
SI demand
1000 MW



ENRG: 3000MW @ 1$/MWh
[1295 MW]

	CE Risk Shortage			Energy shortage	
	MW	FIR price	SIR price	MW	Price
1	10	4.5k	4.5k	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

IL FIR : 100 MW @ 100 $/MWh **[95 MW]**
IL SIR : 100 MW @ 200 $/MWh **[95 MW]**



Energy price: $301/MWh
FIR price: $100/MWh
SIR price: $200/MWh

ENRG: 1500MW @ 100$/MWh **[1300 MW]**
FIR : 200MW @ 20 $/MWh **[200 MW]**
SIR : 250MW @ 30 $/MWh **[200 MW]**

The lowest cost supply of an additional MW in the NI would be via the HVDC @$301/MWh ($1/MWh + $100/MWh + $200/MWh). Reflected in the NI price.

Relationship between energy and reserve prices send consistent signals to market participants.

1MW offered into the energy market is more valuable than the same MW offered into NI FIR and/or SIR market.

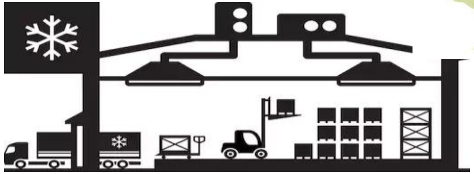
Market Scenario Example (1 risk setter – FIR risk shortfall)

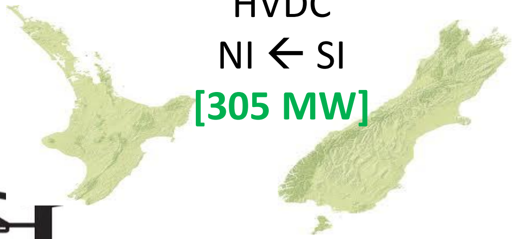
Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

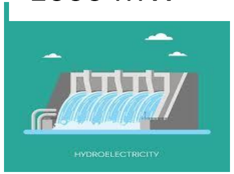
NI demand
1605 MW

HVDC
NI ← SI
[305 MW]

SI demand
1000 MW



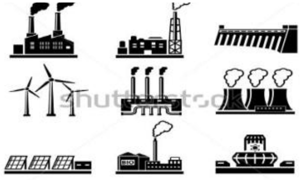




ENRG: 3000MW @ 1$/MWh
[1305 MW]

	CE Risk Shortage			Energy shortage	
	MW	FIR price	SIR price	MW	Price
1	10	**4.5k**	4.5k	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

IL FIR : 100 MW @ 100 $/MWh **[100 MW]**
IL SIR : 110 MW @ 200 $/MWh **[105 MW]**



Energy price: $4,701/MWh
FIR price: $4,500/MW/h [5MW]
SIR price: $200/MW/h

ENRG: 1500MW @ 100$/MWh **[1300 MW]**
FIR : 200MW @ 20 $/MWh **[200 MW]**
SIR : 250MW @ 30 $/MWh **[200 MW]**

The lowest cost supply of an additional MW in the NI would be via the HVDC @$4,701/MWh ($1/MWh + $4,500/MWh + $200/MWh). Reflected in the NI price.

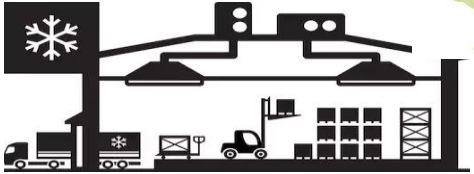
Relationship between energy and reserve prices send consistent signals to market participants.

A MW offered into the NI energy MW is more valuable than the same MW offered into the NI FIR and/or SIR market

Market Scenario Example
(1 risk setter – FIR and SIR risk shortfall)

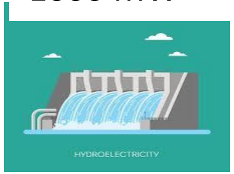
Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

NI demand
1610 MW



HVDC
NI ← SI
[310 MW]

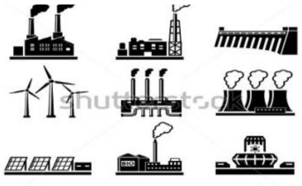
SI demand
1000 MW



ENRG: 3000MW @ 1$/MWh
[1310 MW]

	CE Risk Shortage			Energy shortage	
	MW	**FIR price**	**SIR price**	**MW**	**Price**
1	10	**4.5k**	**4.5k**	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

IL FIR : _100_MW @ 100 $/MWh **[100 MW]**
IL SIR : 100 MW @ 200 $/MWh **[100 MW]**



Energy price: $9,001/MWh
FIR price: $4,500/MW/h [10MW]
SIR price : $4,500/MW/h [10MW]

ENRG: 1500MW @ 100$/MWh **[1300 MW]**
FIR : 200MW @ 20 $/MWh **[200 MW]**
SIR : 250MW @ 30 $/MWh **[200 MW]**

The lowest cost supply of an additional MW in the NI would be via the HVDC @$9,001/MWh ($1/MWh + $4,500/MWh + $4,500/MWh). Reflected in the NI price.

Relationship between energy and reserve prices send consistent signals to market participants.

A MW offered into the NI energy MW is more valuable than the same MW offered into the NI FIR and/or SIR market

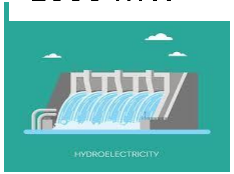
Market Scenario Example (3 risk setter – No shortfall)

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

NI demand
1580 MW

HVDC
NI ← SI
[240 MW]

SI demand
1000 MW



ENRG: 350MW @ 0.01$/MWh **[220MW]**
FIR : 20MW @ 1$/MWh **[20MW]**
SIR : 30MW @ 1$/MWh **[30MW]**

ENRG: 3000MW @ 1$/MWh **[1240 MW]**

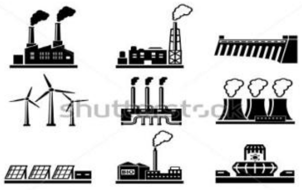
	CE Risk Shortage			Energy shortage	
	MW	**FIR price**	**SIR price**	**MW**	**Price**
1	10	4.5k	4.5k	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

ENRG: 220MW @ 0.02$/MWh **[220MW]**
FIR : 20MW @ 2$/MWh **[20MW]**
SIR : 30MW @ 2$/MWh **[30MW]**

Energy price: $100/MWh
FIR price: $296/MW/h
SIR price : $3/MW/h

ENRG: 100MW @ 9.5k$/MWh **[0MW]**

Marginal MW of FIR ~ 3 x marginal MW of energy (reflects the increased impact of a marginal MW of reserve versus energy on the system at the optimal solution)



ENRG: 1100MW @ 100$/MWh **[900MW]**
FIR : 200MW @ 3$/MWh **[200MW]**
SIR : 300MW @ 3$/MWh **[190MW]**

Market Scenario Example (3 risk setter – FIR shortfall)

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

NI demand

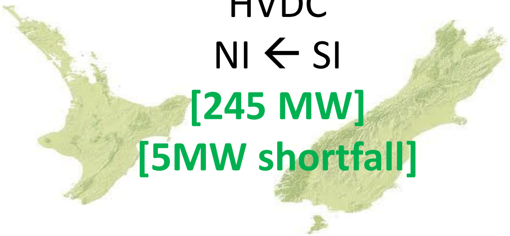
1585 MW

HVDC

NI ← SI

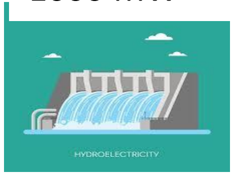
[245 MW]

[5MW shortfall]



SI demand

1000 MW



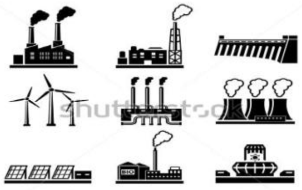
	CE Risk Shortage			Energy shortage	
	MW	FIR price	SIR price	MW	Price
1	10	**4.5k**	4.5k	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

ENRG: 350MW @ 0.01$/MWh **[220MW]**
FIR : 20MW @ 1$/MWh **[20MW]**
SIR : 30MW @ 1$/MWh **[30MW]**

ENRG: 3000MW @ 1$/MWh **[1241 MW]**

ENRG: 220MW @ 0.02$/MWh **[220MW]**
FIR : 20MW @ 2$/MWh **[20MW]**
SIR : 30MW @ 2$/MWh **[30MW]**

ENRG: 100MW @ 9.5k$/MWh **[0MW]**



ENRG: 1100MW @ 100$/MWh **[900MW]**
FIR : 200MW @ 3$/MWh **[200MW]**
SIR : 300MW @ 3$/MWh **[190MW]**

Energy price: $4501/MWh
FIR price: $13498/MW/h
SIR price : $3/MW/h

Marginal MW of FIR ~ 3 x marginal MW of energy (reflects the increased impact of a marginal MW of reserve versus energy on the system at the optimal solution)

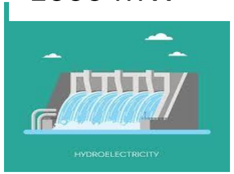
Market Scenario Example (3 risk setter – FIR + SIR shortfall)

Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

NI demand
1585 MW

HVDC
NI ← SI
[240 MW]

SI demand
1000 MW



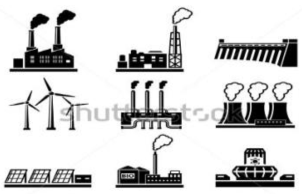
	CE Risk Shortage			Energy shortage	
	MW	**FIR price**	**SIR price**	**MW**	**Price**
1	10	**4.5k**	**4.5k**	80	10k
2	20	12.5k	12.5k	160	15k
3	100	17.5k	17.5k	1,3k	20k

ENRG: 350MW @ 0.01$/MWh **[225MW]**
[5MW FIR and SIR shortfall]
FIR : 20MW @ 1$/MWh **[20MW]**
SIR : 20MW @ 1$/MWh **[20MW]**

ENRG: 3000MW @ 1$/MWh
[1240 MW]

ENRG: 220MW @ 0.02$/MWh **[220MW]**
FIR : 20MW @ 2$/MWh **[20MW]**
SIR : 20MW @ 2$/MWh **[20MW]**

ENRG: 100MW @ 9.5k$/MWh **[0MW]**



ENRG: 1100MW @ 100$/MWh **[900MW]**
FIR : 200MW @ 3$/MWh **[200MW]**
SIR : 200MW @ 3$/MWh **[200MW]**

Energy price: $9000/MWh
FIR price: $13499/MW/h
SIR price : $13500/MW/h

Price of marginal FIR and SIR risk shortage tranch reflected in energy price.

Marginal MW of energy can reduce FIR and SIR shortage (reflected in price)

Marginal MW of FIR and SIR can reduce FIR and SIR shortage costs by 3 (reflected in price)