Embedded generation and gross demand analysis

July 2016

About us

scientia^{consulting} provides specialist modelling and analytical expertise to the energy sector.

This knowledge is based on extensive practical experience spanning operational and regulatory environments of the electricity industry in New Zealand and overseas.

Scientia's key areas of specialisation include electricity market design, analysis, market clearing engine development and testing, transmission pricing, transmission planning, load forecasting and generation expansion modelling.

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Outline

- Transpower requested us to:
  - Analyse half-hourly generation data provided by the Reconciliation Manager (RM) to provide an indication on the level of embedded generation on the system
  - Provide a high level estimate of the potential impact on gross demand considering the effects of embedded generation and demand response (DR) using DR data provided by distributors
- Our findings are presented in this presentation.

Findings I

- Non-grid (embedded) generation* has been increasing over the period 2009-2015:
  - Average output: 345MW in 2009 to 547MW in 2015 (58% increase)
  - Peak output: 544MW in 2009 to 850MW in 2015 (56% increase)
- This increase in embedded generation is due to:
  - Commissioning of new embedded wind generation and co-generation and/or load generation
  - Historically classified grid generation becoming non-grid generation
- The majority of the non-grid generation is in the lower North Island (LNI).
- Non-wind and non co-gen embedded generation shows the strongest response to winter peak load.

*Some embedded generation that is consumed on-site is not reported to the RM. Therefore we understand that the RM generation data does not include all potential non-grid (embedded/distributed generation) on the system. A list of some identified locations are shown in the Appendix however there may be others.

Findings II

- A total of 652MW of demand response was reported by distributors with 625MW (96%) reported as being used to manage peak load due to the current RCPD signal
- For the modelled period ~190MW of demand response was observed at the large direct connect consumers*
- A high level gross demand estimate** of 7170MW to 7545MW is calculated for the modelled period of 18:00 on 23 June 2015***. This is ~16% to ~22% above net load observed during this period****.
- The highest percentage increases were calculated for the Lower North Island (LNI) and Upper South Island (USI) due to the large amount of embedded generation and demand response in the LNI and distributor demand response in the USI:
  - UNI: 9-13%
  - LNI: 22-28%
  - USI: 17-30%
  - LSI: 15-18%

*New Zealand Aluminium Smelters, NZ Steel, SKOG, Carter-Holt Harvey, PanPac, Winstone

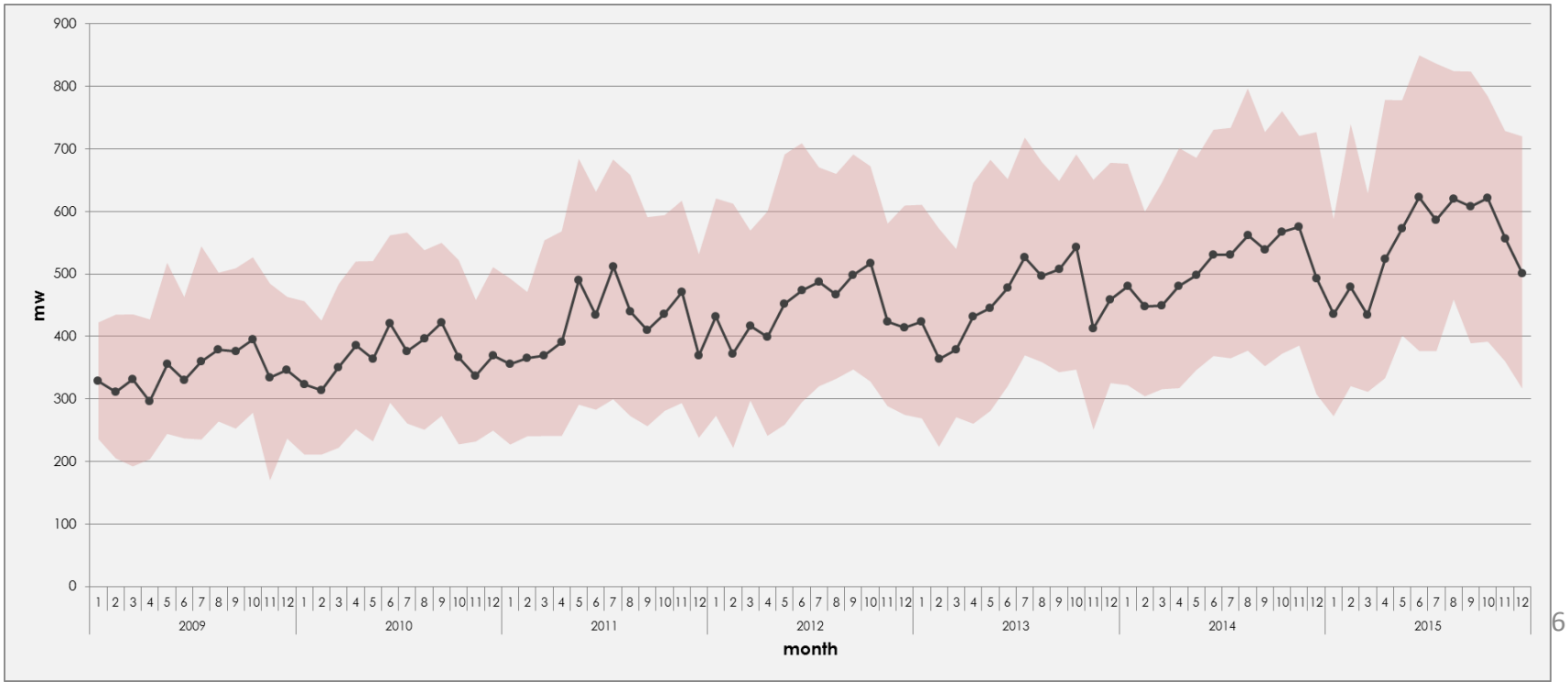
**This estimate is (a) based on the DR quantities provided by distributors, (b) does not include any adjustments for DR not reported by the distributors or at smaller direct connects, (c) does not include any adjustments for unreported embedded generation.

***In 2015, the 23 JUN at 18:00 was the period with the highest half-hour average gross generation.

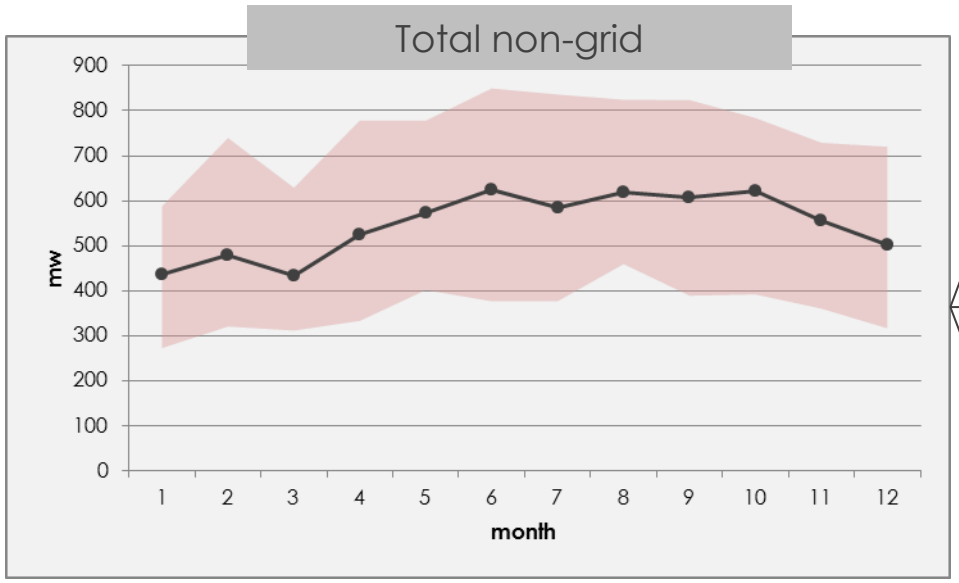
****The range is due to different modelled scenarios of DR from distributors and should not be interpreted as lower and upper bounds on gross load due to unreported response and generation as discussed above.

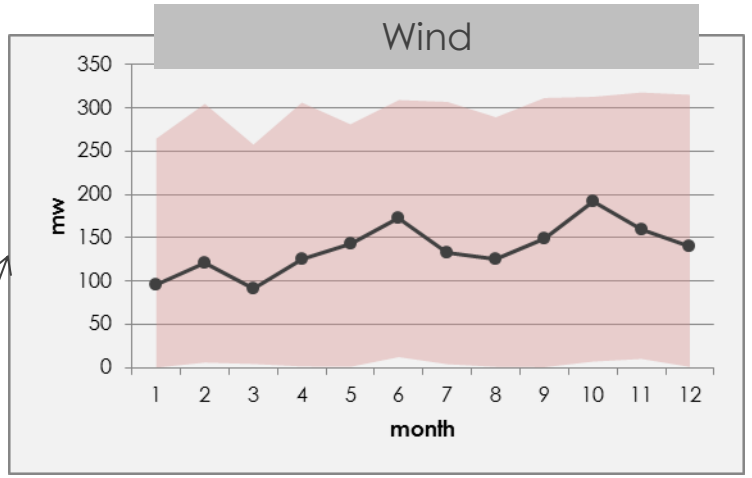
Aggregate RM non-grid generation data

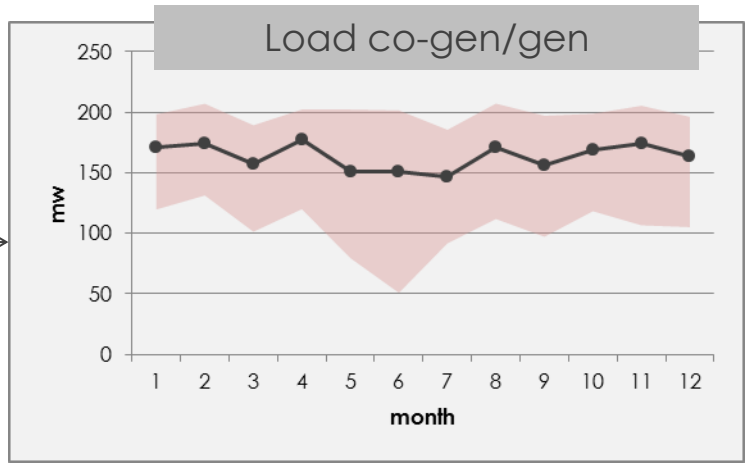
- The figure below shows monthly minimum, maximum and average of aggregate non-grid generation over the period 2009 to 2015.
- A consistent increasing trend in both average an peak non-grid generation is observed over this time. There are several contributing factors:
  - Increased amount of embedded wind
  - Increased amount of co-gen/load gen
  - Grid generation changing to non-grid

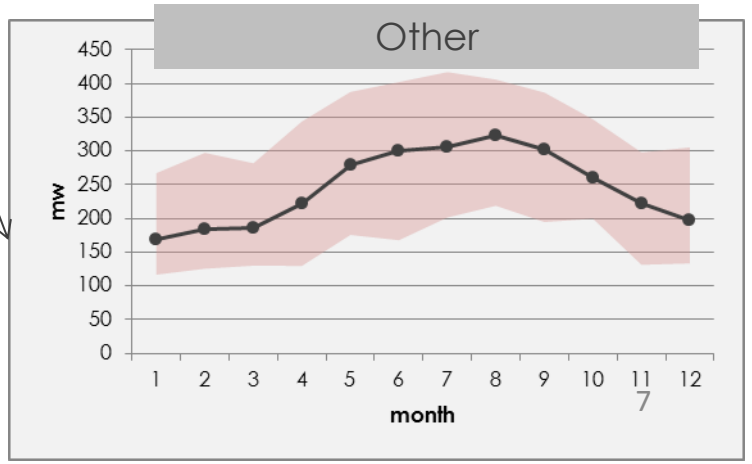


Non-grid generation breakdown into categories







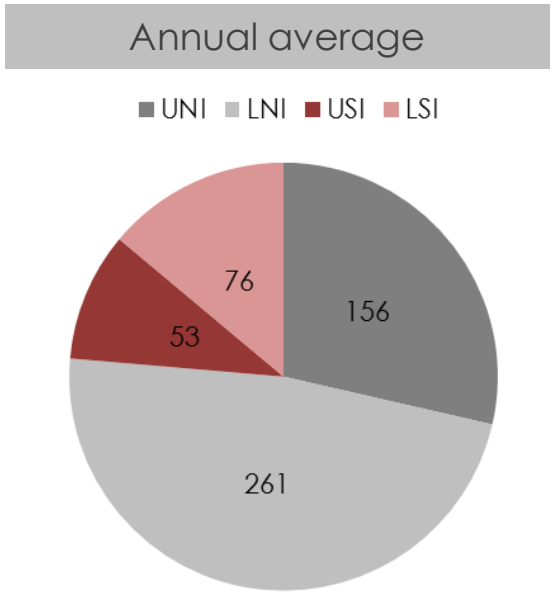


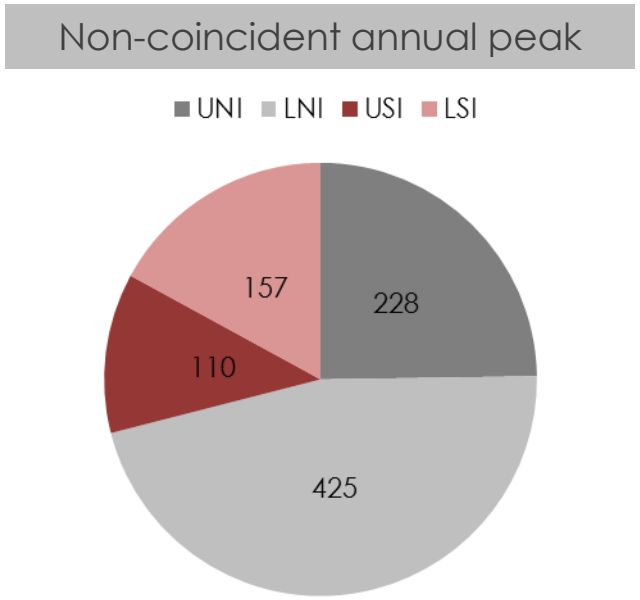
- Different types* of non-grid generation show different response to winter peak.
- Non-wind and non-load co-gen/load generation (categorised as "other") indicates the greatest response to the winter period which corresponds to peak system load.

*See Appendix for category types

Regional breakdown

- The annual average and non-coincident annual peak output from non-grid generation for 2015 is shown below.
- Here we see that the majority of the non-grid generation is in the LNI region.





Approach to estimating the gross load

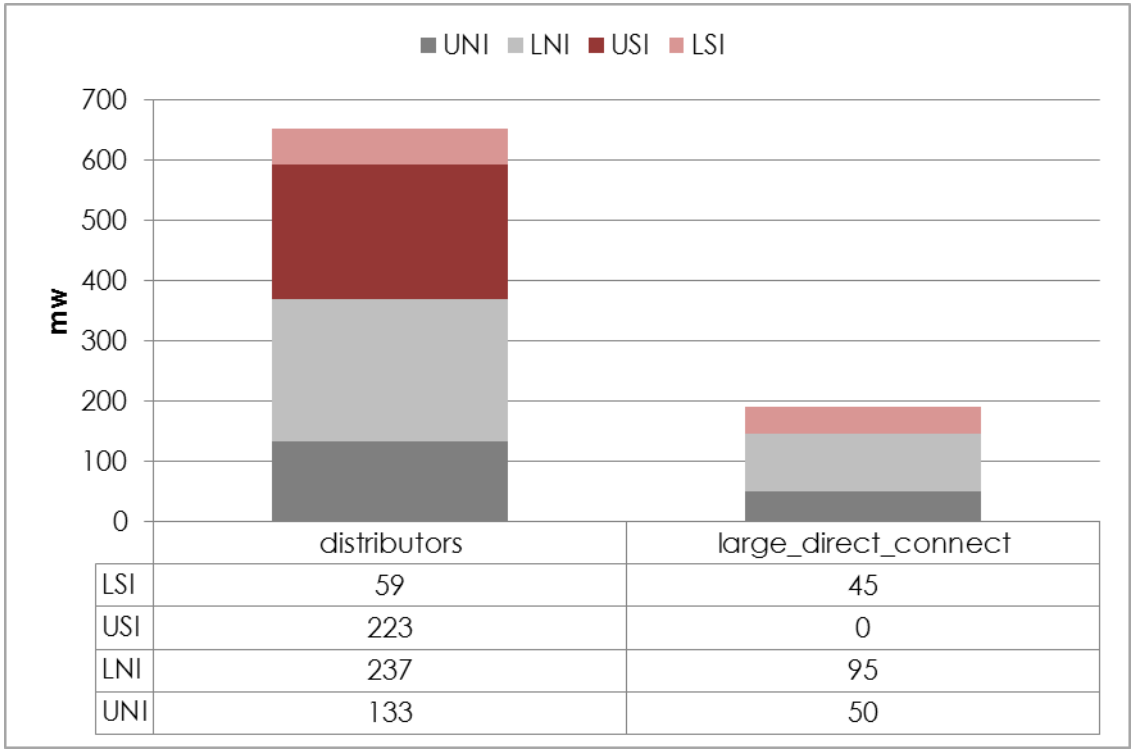
- To model the gross load estimate, we used the 2015 half-hour period with largest calculated gross generation based on the RM generation data*. This was at 18:00 on 23 June 2015.
- The following steps were used to create the "gross load" estimate:
  - Step 1: Aggregate the RM load data reported on the Authority's emi data portal into four RCPD regions
  - Step 2: Add back embedded generation at Kawerau. Some of this embedded generation was not included in the RM data.
  - Step 3: Add back observed demand reduction at large direct connects** during modelled period.
  - Step 4: Aggregate the provided distributor DR into regions and add back*** to the regional demand during the modelled period
- Given the uncertainties in the actual response by distributors, we considered sensitivities to their provided response.
- This high level estimate is based on the DR quantities provided by distributors and does not estimate what their actual response might have been during this period. It also does not include any adjustments for DR not reported by the distributors or at smaller direct connects and does not include any adjustments for unreported embedded generation. Further analysis would be required to assess the impact of these issues and make appropriate refinements.

*Note that it is possible that other periods with lower gross generation could actually have a greater gross load than the modelled period. To identify this, all half-hour periods would need to be assessed. For the purposes of providing a high level estimate the largest gross generation period was considered a reasonable period to determine the gross load estimate.

**Only reported RCPD response MW added back

***NZAS, NZ Steel, SKOG, CHH, PanPac, Winstone

DR data



	distributors	large_direct_connect
LSI	59	45
USI	223	0
LNI	237	95
UNI	133	50

- Distributors indicated 652MW of demand response (DR) with majority used for RCPD (625MW out of 652MW (96%))
- Approximately 190MW of demand response from large direct connects was observed during this period. Some of this response may have been influenced by higher spot prices during the modelled period (Spot prices on 23 June 2015 at 18:00 was ~$180/MWh).

Uncertainties

- In addition to the unknowns around unreported embedded generation, there are some key uncertainties in regards to the demand response data used in the gross load estimate:
  - Distributors actual response to peak load periods:
    - A 100% distributor response can be considered extreme, however we are mindful that some distributor DR data might not be included. These may include some distributor customers who may have pass-through tariffs and would be incentivised to respond to a peak signal.
    - In using hot water load control, the distributor might not utilise the full load reduction capability as managing load "rebound" becomes an issue. We understand that for sustained usage (such as to manage peak demand over several periods), the distributor may only use around 40% of available demand response.
    - Some distributors might not use the demand response for a peak price signal but to manage constraints which may be coincident with peak load periods.
  - Direct connects actual response to peak load periods:
    - We have observed demand reduction during the modelled peak load period at the largest direct connects but there may also be reduction at the other smaller direct connects which have not been included in this high level estimate.
    - Some of the response from direct connect consumers may be influenced by spot prices in the wholesale electricity market which may coincide with peak load periods.

Sensitivities – results summary

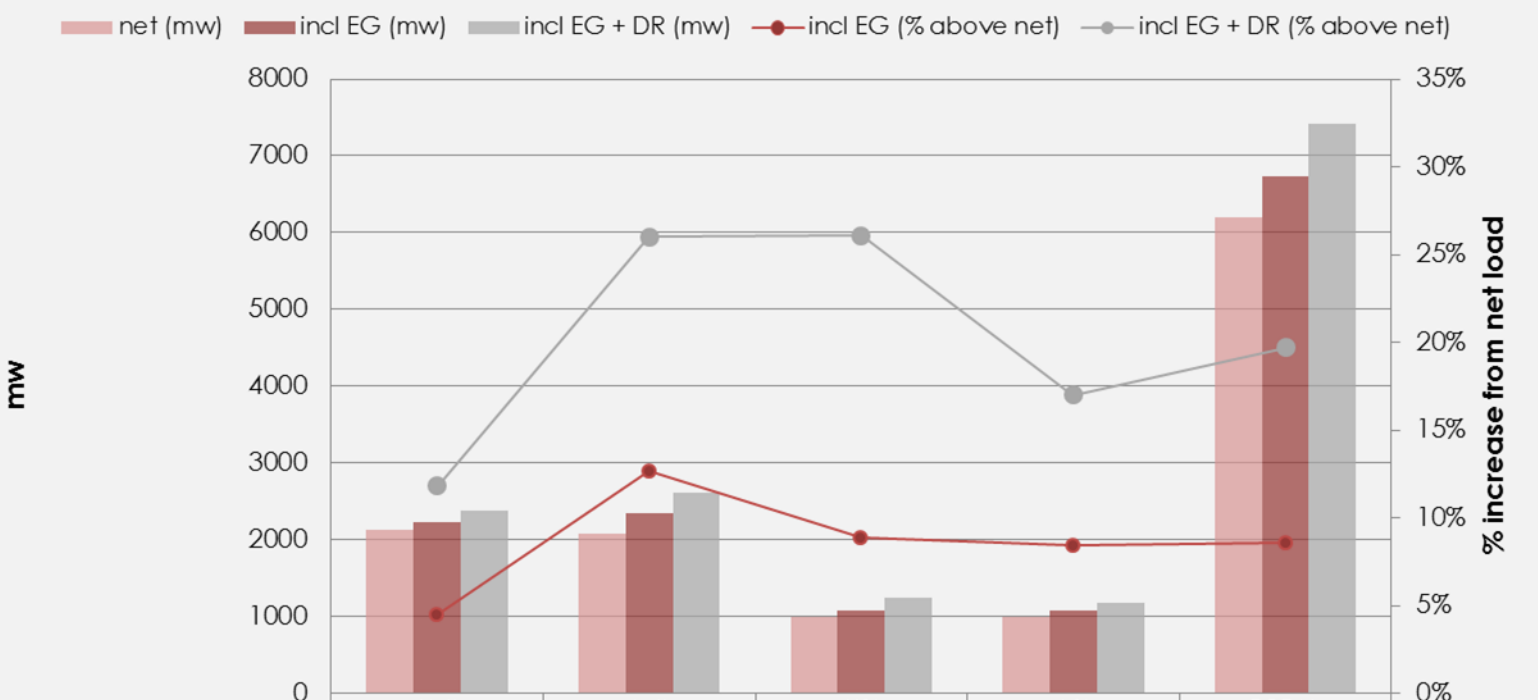
- We considered following sensitivities in regards to the provided distributor response:
  - 40% (250MW), 60% (375MW), 80%(500MW) and 100% (625MW)
- Sensitivity description (using sensitivity 1 example):
  - 40% distributor demand response: 40% of the reported distributor DR is active. That is this load is assumed to be disconnected during the modelled period and added back.

Sensitivity	Distributor response	Gross load (MW)	% above net load
1	40%	7170	16
2	60%	7295	18
3	80%	7420	20
4	100%	7545	22

- Based on these sensitivities a high level estimate of the gross demand is 7170MW to 7545MW.
- This is ~16% to ~22% above net load during the modelled period.

Results - 80% modelled distributor response

- The figure below shows the net load, load including embedded generation (EG) and load including demand response (DR) for the 80% distributor response sensitivity (gross load).
- The estimated national gross load of 7420MW is ~20% above national net load with the USI and LNI calculated as having the largest proportionate increase above net load (26% respectively).
- Figures for the other sensitivities are included in the Appendix.



	UNI	LNI	USI	LSI	TOTAL
net (mw)	2132	2076	990	1002	6200
incl EG (mw)	2228	2338	1078	1086	6730
incl EG + DR (mw)	2384	2616	1248	1172	7420
incl EG (% above net)	4%	13%	9%	8%	9%
incl EG + DR (% above net)	12%	26%	26%	17%	20%

APPENDIX

RM non-grid generation observations

- RM generation at KAW0112 does not appear to include all co-generation/load generation at Kawerau. The maximum RM generation at KAW0112 is 36MW but the co-generation offered into market at Kawerau is ~60MW. We understand that only a portion of the load at Kawerau is being captured by the RM.
- RM generation does not appear to include the non-grid co-generation at Whareroa used to supply the Fonterra dairy plant (HWA1102).
- RM generation does not include any non-grid co-generation at PanPac (WHI0111).
- RM generation at HWB0331 does not distinguish between the wind generation at Mahinerangi (36MW) and the embedded hydro-generation at Waipouri (38MW) which also generates into the node at Halfway Bush (HWB). This split has been approximated by using a final pricing generation series for Waipouri at HWB to separate the embedded wind and embedded hydro generation at this node.

Non-grid large co-gen or direct connect load generation*

Station name	GXP	Type	Capacity (MW)
Glenbrook	GLN0332	Co-gen	112
Kapuni	KPA1101	Co-gen	25
Kawerau*	KAW0112	Co-gen/load gen	62
Kinleith**	KIN0112	Co-gen	41
Te Rapa	TWH0331	Co-gen	44
Kiwirail***	TMN0551	load gen	2.2
Kiwirail	TNG0551	load gen	2
Kiwirail	HAM0551	load gen	1.2
Kiwirail	SWN0251	load gen	0.7
Kiwirail	BPE0551	load gen	0.7
Kiwirail	PEN0251	load gen	0.5

*Some identified co-gen/load gen is not captured in the RM data. There may be some other smaller sites as well.
**Kinleith generation is modelled as non-grid from 2013.
***Capacity at Kiwirail GXPs are maximum injections from the RM data

Non-grid wind category

Station name	GXP	Capacity (MW)
Flat Hill	INV0331	6.8
Hau Nui	GYT0331	8.5
Mahinerangi	HWB0331	36
Mill Creek	WIL0331	60
Mount Stuart	BAL0331	7.7
Tararua Stage 1	LTN0331	32
Tararua Stage 2	BPE0331	36
Te Rere Hau	TWC2201	48
Te Uku	TWH0331	64
White Hill	NMA0331	58

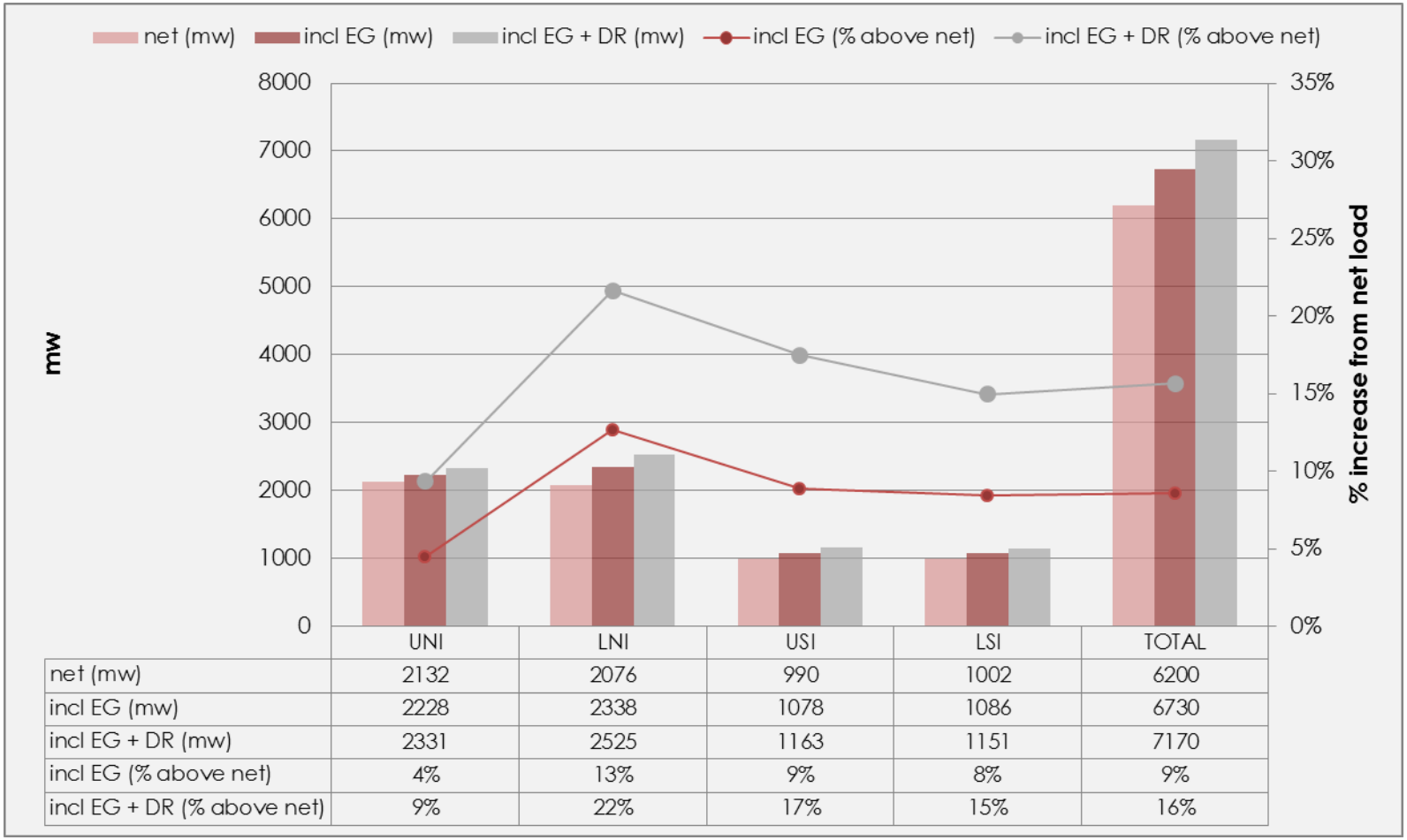
Other non-grid category

Station name	GXP	Type	Capacity (MW)
Kaimai	TGA0331	Hydro	41
Rotokawa	WRK0331	Geothermal	34
Te Huka	WRK0331	Geothermal	23
Highbank	ASB0661	Hydro	25
Ngawha	KOE1101	Geothermal	25
Paerau	NSY0331	Hydro	12
Mangahao*	MHO0331	Hydro	42
Cobb**	STK0661	Hydro	34

- Other includes all non-grid generators that were not included in the wind or co-gen/load gen categories***
- The largest generators classified as "other" are shown above

*Mangahao generation is classified as non-grid from 2011
**Cobb generation is classified as non-grid from 2015
***This could be because their identification as a co-gen/embedded wind could not be guaranteed from the supplied RM data

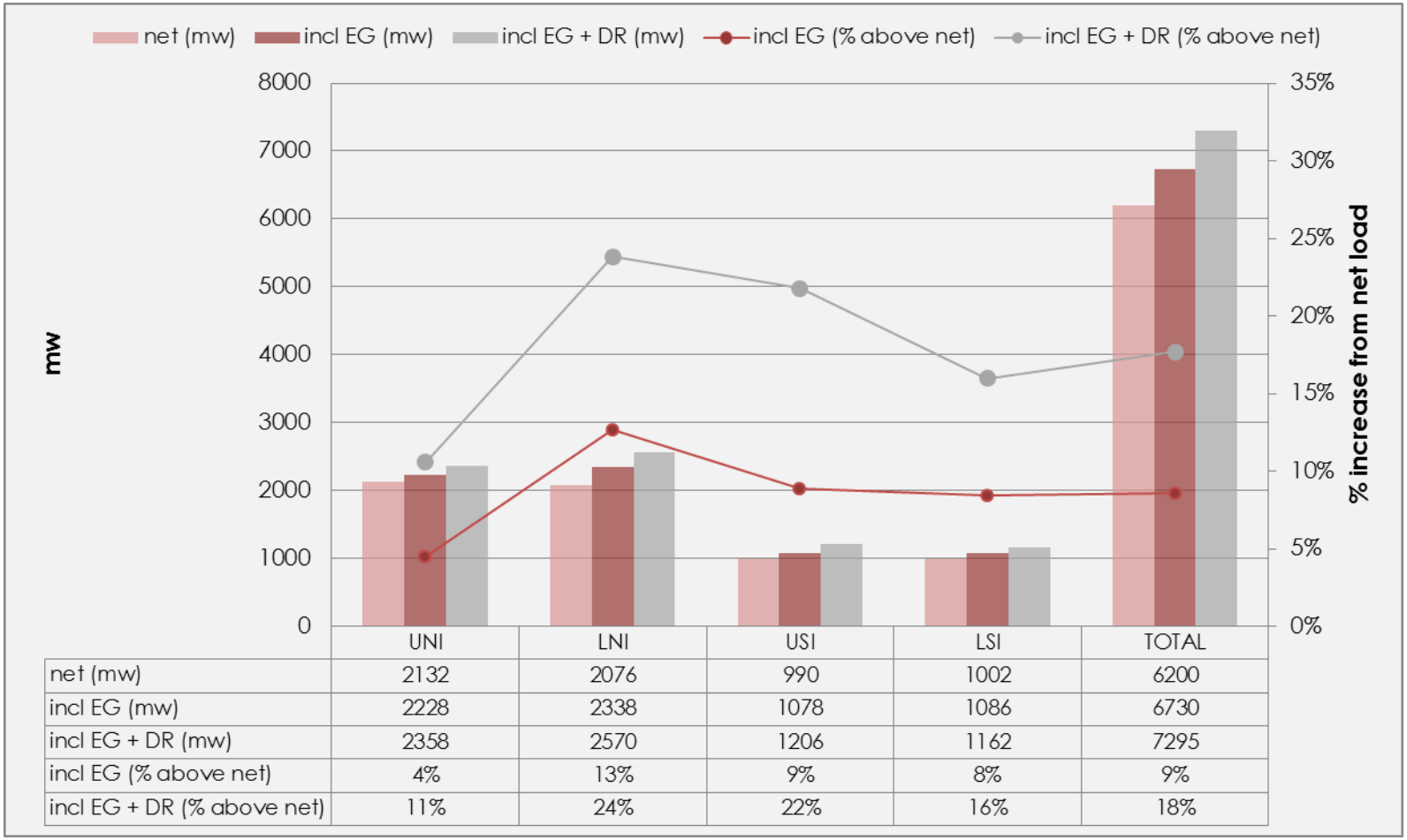
Results - 40% modelled distributor response



	UNI	LNI	USI	LSI	TOTAL
net (mw)	2132	2076	990	1002	6200
incl EG (mw)	2228	2338	1078	1086	6730
incl EG + DR (mw)	2331	2525	1163	1151	7170
incl EG (% above net)	4%	13%	9%	8%	9%
incl EG + DR (% above net)	9%	22%	17%	15%	16%

- 40% EDB response:
  - National gross load ~16% above national net load

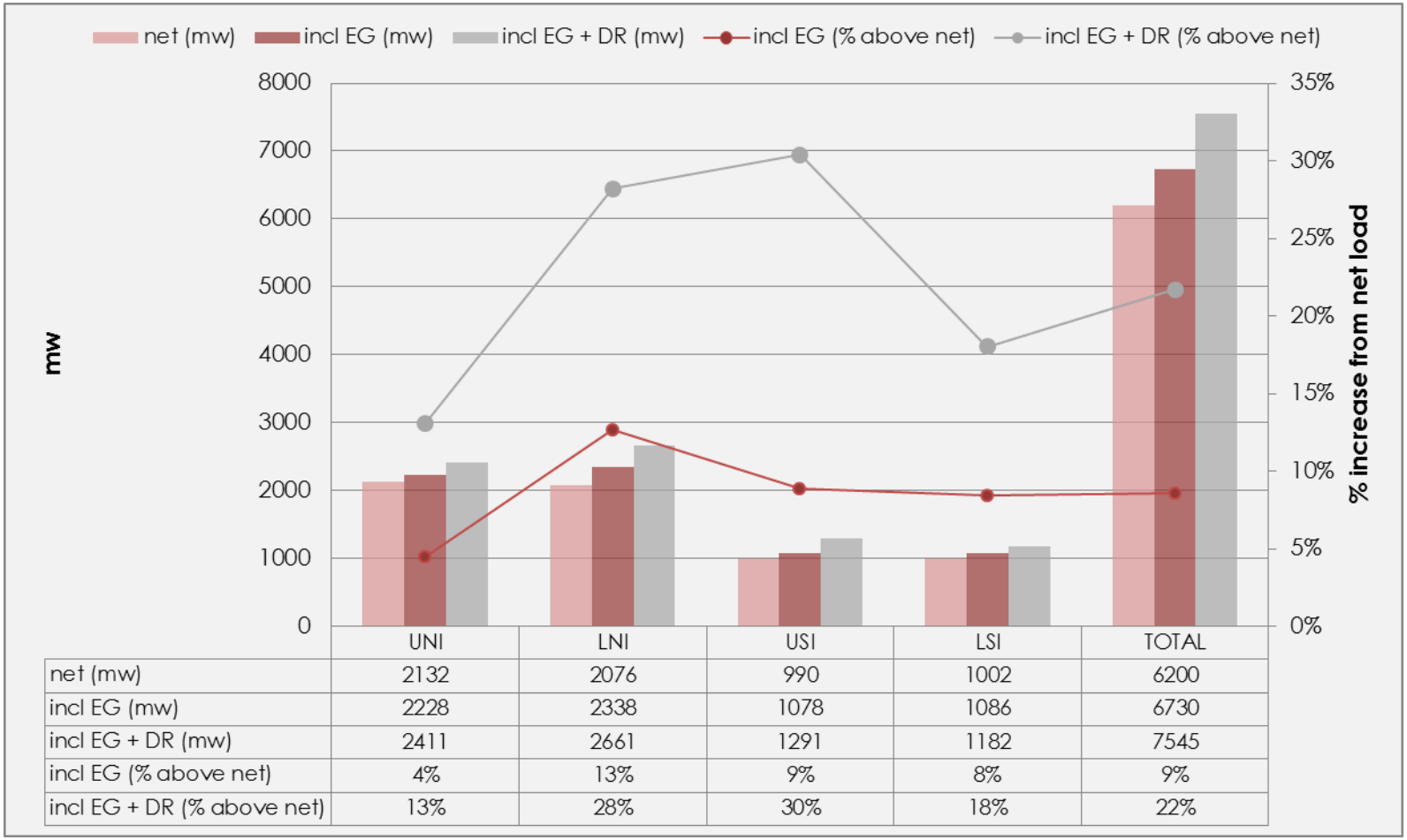
Results - 60% modelled distributor response



	UNI	LNI	USI	LSI	TOTAL
net (mw)	2132	2076	990	1002	6200
incl EG (mw)	2228	2338	1078	1086	6730
incl EG + DR (mw)	2358	2570	1206	1162	7295
incl EG (% above net)	4%	13%	9%	8%	9%
incl EG + DR (% above net)	11%	24%	22%	16%	18%

- 60% EDB response:
  - National gross load ~18% above national net load

Results - 100% modelled distributor response



	UNI	LNI	USI	LSI	TOTAL
net (mw)	2132	2076	990	1002	6200
incl EG (mw)	2228	2338	1078	1086	6730
incl EG + DR (mw)	2411	2661	1291	1182	7545
incl EG (% above net)	4%	13%	9%	8%	9%
incl EG + DR (% above net)	13%	28%	30%	18%	22%

- 100% EDB response:
  - National gross load ~22% above national net load