Memorandum

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Date: 12 August 201631 August 2016

To: Grant Smith, Jonathan Suggate, Pioneer Energy; Roger Sutton

From: Energy Link

Subject: Impact on Spot Prices from Cessation of Load-shifting

Background

Pioneer has asked Energy Link for an initial opinion, provided quickly, on whether cessation of load-shifting activities in the Orion network, and upper SI as a whole, would increase or reduce total spot purchase costs. We understand this request is motivated by the latest proposal for a new transmission pricing methodology (TPM) which does not feature charges based on regional coincident peak demand (RCPD): instead, the residual charge would be based on installed capacity at each GXP.

Methodology

The question posed is complex and the answer depends on a number of factors, many of which interact, e.g. the amount of load shifted and when, and the shape of the spot market supply curves, which in turn are influenced by a wide of factors including hydrology, fuel costs, contract positions, to mention a few. In addition, the value of load at the margin also depends on possibly rare but significant events in which the gap between supply and demand is squeezed due to outages.

From our point of view, there are three potential approaches to the question:

1. theoretical considerations;
2. taking detailed samples of a range of historical half hours;
3. large-scale models which looks forward using a base case with the existing load profile shape, and comparing this to one or more scenarios with modified load profile shapes.

The third approach is considerably more thorough and would allow us to put a robust estimate on the value of the current load shifting regime in the upper SI (and could include load shifting for all of New Zealand), but this would require extensive modelling with our *EMarket* model and realistically would require at least two and up to five weeks of elapsed time.

As a result, in the interests of answering the question quickly, we have dealt to the theoretical considerations and undertaken a small range of scenarios with our EMO[1] model.

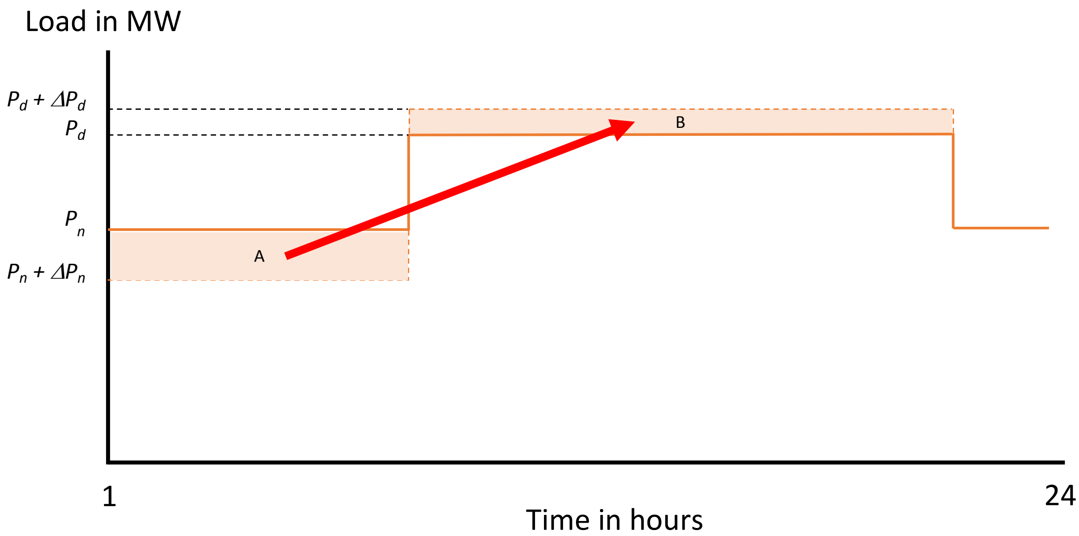
[1] *EMarketOffer*.

Theoretical Considerations

Load-shifting typically takes place across a 24 hour period GXP by GXP. The cost to spot purchasers during any particular 24 hours at a particular GXP is a function of reconciled load (GXP offtake) and spot price, as shown below.

$$Cost = 0.5 \times \sum_{t=1}^{48} P_t S_t$$

where P_t is the average load measured in MW across trading period t and S_t is the spot price in period t. The figure below shows a simplified rectangular load profile across one day[2], where load has traditionally been shifted from the day period (region marked as B) to the night period (region marked as A).



We are interested in the change in cost when the traditional load shifting ceases, in which case load moves from A to B. The traditional loads in each period are P_n and P_d, and the changes in load are shown as the delta values. We assume the total energy delivered via the GXP is the same with and without load shifting.

During the night with load shifting we shall assume the spot price is a constant value S_n and constant S_d during the day. In very simple terms, the load that shifts from night to day is priced at S_d instead of S_n but in addition the change in load also caused changes in these prices: S_n becomes S_n - ΔS_n and S_d becomes S_d + ΔS_d where both AS's are either zero or positive[3].

We will define α as the ratio of night to day hours, e.g. 8 hours in the night period would give $\alpha = 0.5$, and β as the ratio P_n/P_d. It can then be shown that the change in cost from cessation of load-shifting is

$$\Delta Cost = t_d \left[P_d \left(\Delta S_d - \alpha\beta\Delta S_n \right) + \Delta P_d \left(S_d - S_n + \Delta S_d + \Delta S_n \right) \right]$$

[2] Which can be thought of as representing average load and price during the night and day periods.
[3] As one would expect from basic laws of economics.

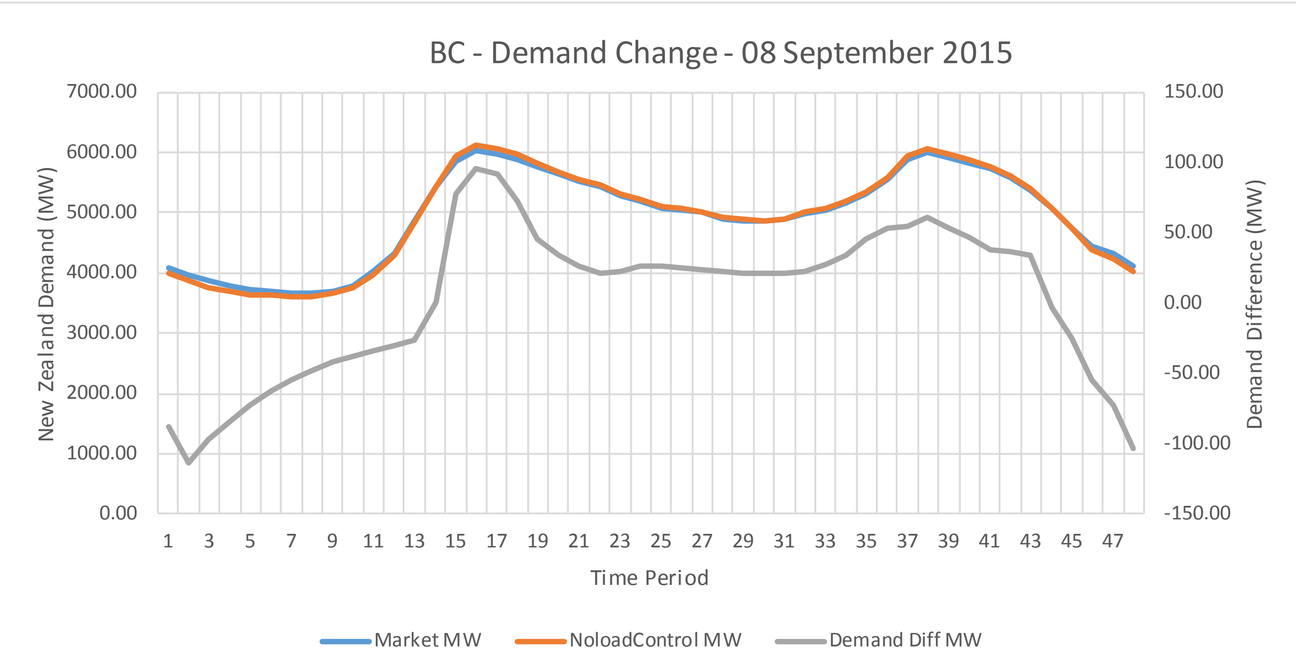
Intuitively, S_d tends on average to be higher than S_n; α and β are less than one, so $\alpha\beta$ is considerably less than one; and in many circumstances ΔS_d will exceed ΔS_n because the higher volatility in daytime prices suggests the supply curve is steeper at the margin during than day then at night. So the formula above strongly suggests that on average $\Delta Cost$ would be positive, although there will be many days on which $\Delta Cost$ could be zero or negative.

Historical Half Hours

Theoretical considerations are strongly suggestive that $\Delta Cost$ would be positive if load shifting were to cease. With assistance from Orion[4], we produced load profiles for a number of recent days on the assumption that Orion's load-shifting did not operate, and ran these with our EMO model to produce new spot prices and determine $\Delta Cost$ for each day. We also increased the load shifting, at your request, by a factor of 1.67 on the assumption that the Orion load-shifting is approximately 60% of total upper SI load shifting.

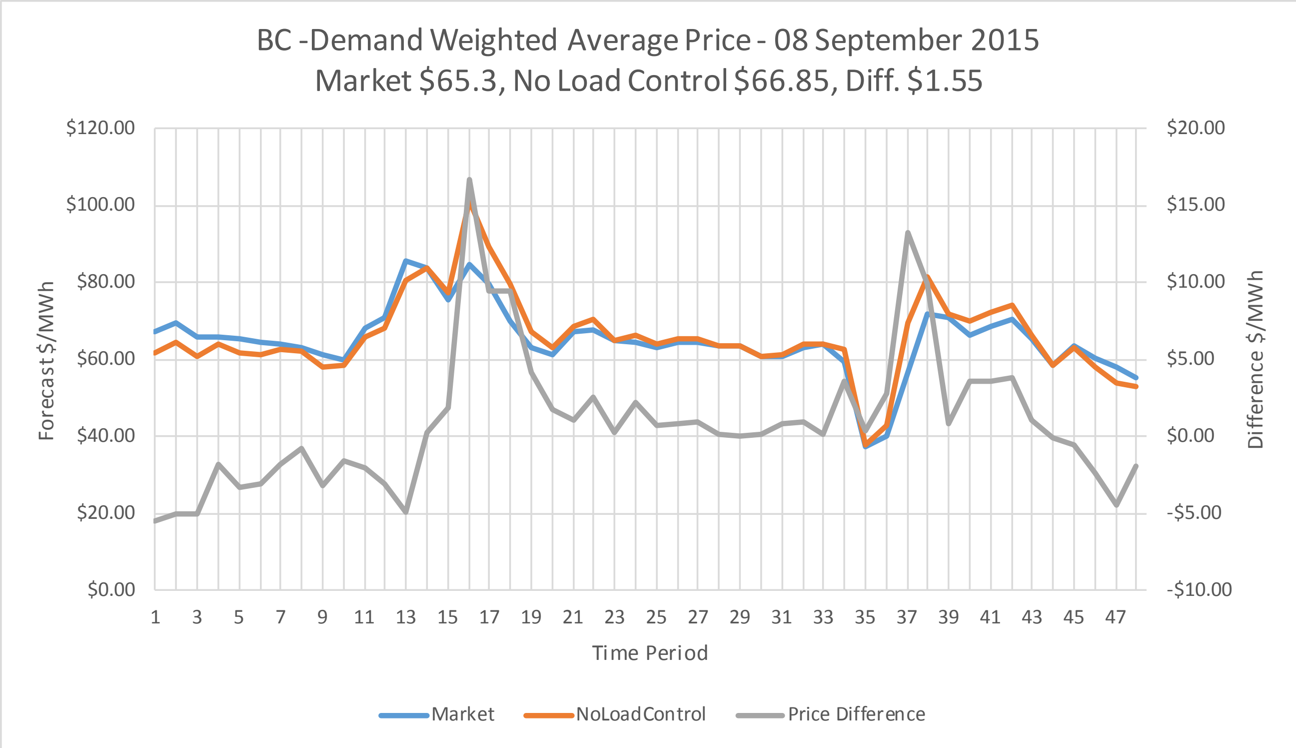
According to Orion, some load shifting is undertaken every day of the week, all year round, and then additional shifting (shown as "load control" in the table of results below) is undertaken in response to regional peak signals. The sample days were suggested by you and include days with a range of load control from none to a large amount.

As an example, the chart below shows the shifted and controlled load on 8th September 2015, along with the New Zealand load profile. It is interesting to note the magnitude of load shifting which is up to 91 MW during this particular day and 114 MW at night.

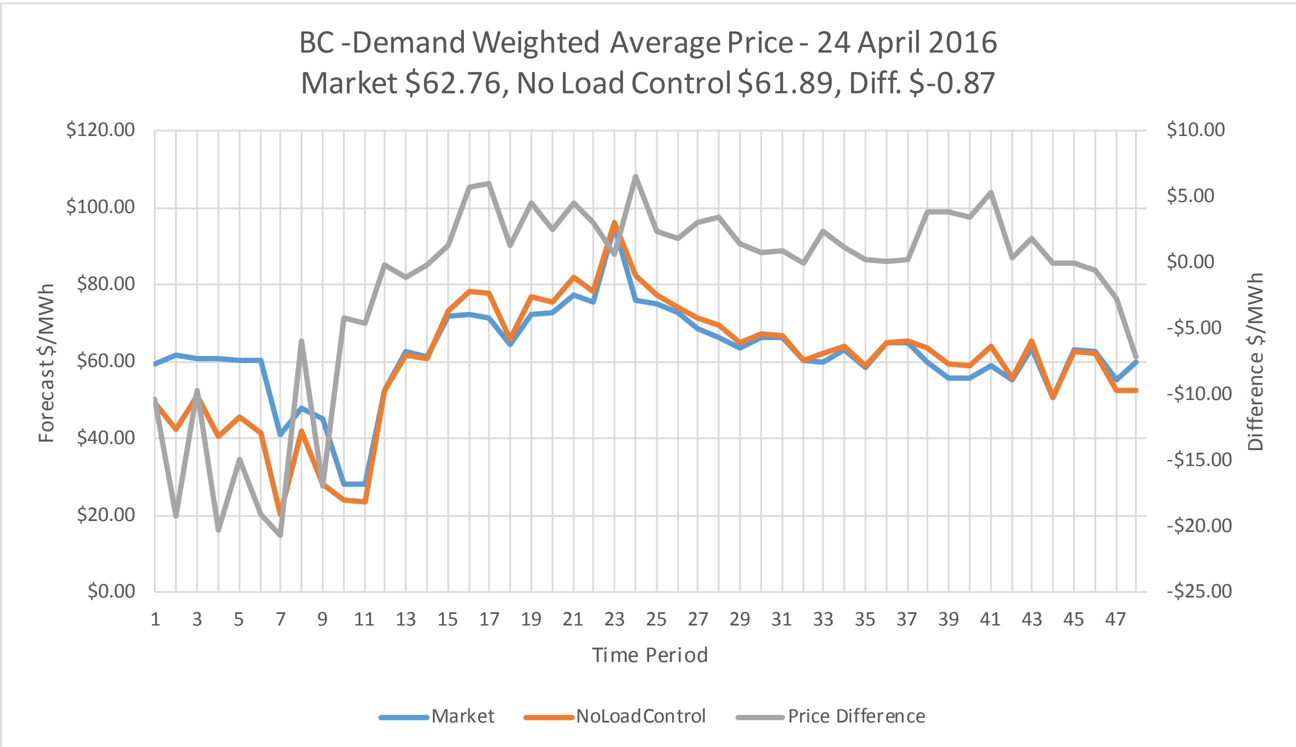


The next chart shows the results of EMO solves with reserves and energy co-optimised to give spot prices with and without load shifting and control. The reduction in price at night is up to $5.50 by during the day the increase spikes to $16.60.

[4] Assistance provided by Alex Nisbet at Orion.

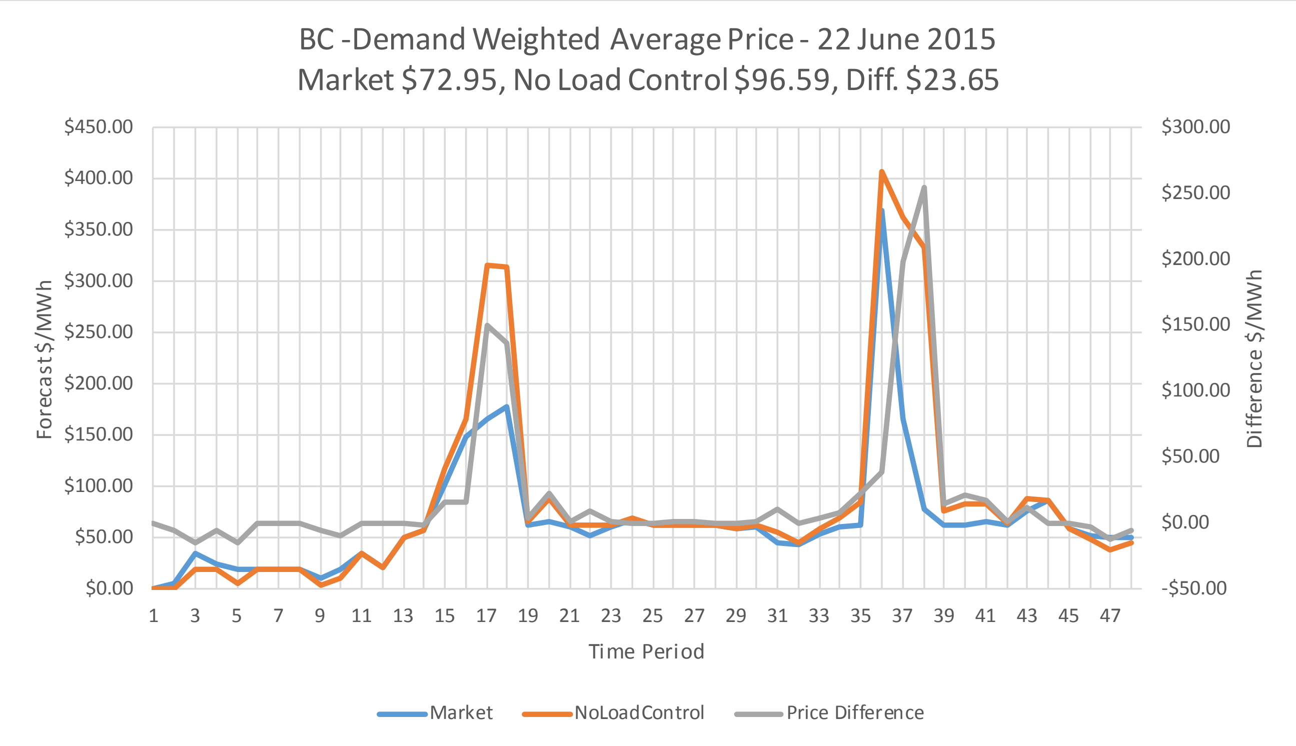


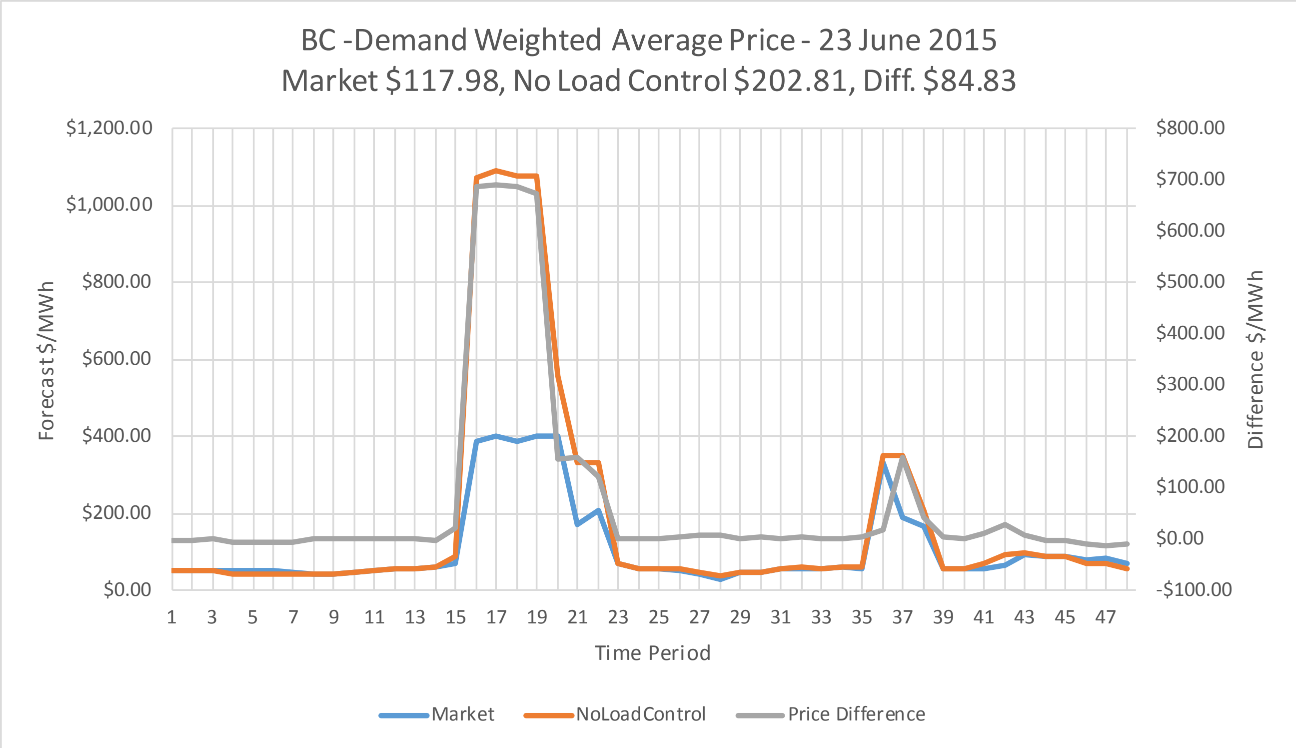
The tables in the Appendix show the results of the modelling using our EMO model on all 11 days selected. The cost during the day increases on all but one day (24th April 2016) due to large prices reductions overnight (up to $20.70), as shown below, with much smaller price increases during the day (up to $6.50).



The tables also show the demand with and without load shifting and control, which is approximately the same in all cases.

Based on the total change in cost over the 11 days, the average increase was 1.6%, but with a range from -1.4% to +72.1% for Orion only when looking at individual days, and -2.4% to 87.2% when all of the upper SI load shifting is included. On the two days with double digit increases the change in the load profile, the increases in price during the day was in the hundreds of dollars for a small number of periods.





Discussion

Theoretical considerations suggest that if load shifting were to cease then *ΔCost* would be positive on average, and a small sample of recent half hours resolved with EMO, using synthesised load profiles with load shifting taken out, tends to back this up. The EMO solves suggest that the distribution of half hourly *ΔCost* values could be highly skewed with a "longer tail" on the positive side, but with a minor portion in the tail below zero.

There will be some random half hour periods in which supply is tightly squeezed, especially during the day, where even small increases in load will cause large increases in price, as is evident on 22nd and 23rd of June 2015. During prolonged periods of system stress, for example during dry periods or periods of significant plant or grid outage, this effect might be seen for days, weeks or even months at a time, suggesting that the value of load shifting could be substantial. This also suggests that more peaking capacity might be required in future without load shifting, possibly with higher fuel usage, than is currently anticipated.

Further comprehensive modelling would *EMarket* would allow these issues to be investigated in much greater depth, possibly including the impact of load shifting across New Zealand if data is available.

Appendix – Results Tables

Orion-only results

Base Case results

Date	Day	Type Comments	Total Demand (MWh) Market	NoloadCont	Diff	Total NZ Energy Cost Market	NoloadControl BC	Diff		Weighted Average Price ($MWh) Market	NoloadCont	Diff
22/06/2015	Monday	Large net load control	122,120	122,317	197	$ 8,909,848	$ 11,815,406	$ 2,905,558	32.6%	$ 72.95	$ 96.59	$ 23.65
23/06/2015	Tuesday	Large net load control	128,434	128,615	180	$ 15,153,620	$ 26,079,298	$ 10,925,678	72.1%	$ 117.98	$ 202.81	$ 84.83
26/08/2015	Wednesday	Small net load control	117,859	117,882	23	$ 6,242,911	$ 6,334,238	$ 91,327	1.5%	$ 52.99	$ 53.75	$ 0.76
8/09/2015	Tuesday	Large net load control	118,422	118,488	66	$ 7,730,543	$ 7,918,190	$ 187,647	2.4%	$ 65.30	$ 66.85	$ 1.55
22/09/2015	Tuesday	Small net load control	116,971	116,988	17	$ 5,755,509	$ 5,916,283	$ 160,774	2.8%	$ 49.23	$ 50.60	$ 1.37
23/03/2016	Wednesday	No load control	109,713	109,712	-1	$ 7,348,444	$ 7,367,032	$ 18,587	0.3%	$ 66.98	$ 67.15	$ 0.17
24/04/2016	Sunday	No load control	91,385	91,385	0	$ 5,735,172	$ 5,655,580	-$ 79,593	-1.4%	$ 62.76	$ 61.89	-$ 0.87
12/07/2016	Tuesday	Small net load control	121,918	121,946	28	$ 7,179,806	$ 7,414,575	$ 234,769	3.3%	$ 58.89	$ 60.80	$ 1.91
23/07/2016	Saturday	No load control	102,668	102,668	0	$ 4,600,055	$ 4,620,036	$ 19,981	0.4%	$ 44.81	$ 45.00	$ 0.19
25/07/2016	Monday	Large net load control	114,496	114,552	56	$ 5,350,045	$ 5,451,476	$ 101,431	1.9%	$ 46.73	$ 47.59	$ 0.86
4/08/2016	Thursday	Small net load control	122,497	122,514	17	$ 5,746,255	$ 5,877,705	$ 131,451	2.3%	$ 46.91	$ 47.98	$ 1.07
						$ 55,688,742	*$ 56,555,115*	*$ 866,373*	1.6%			

Upper South Island Results

Date	Total Demand (MWh) Market	NoloadCont	Diff	Total NZ Energy Cost Market	NoloadControl BC	Diff		Weighted Average Price ($MWh) Market	NoloadCont	Diff
22/06/2015	122,120	122,449	329	$ 8,909,848	$ 14,662,317	$ 5,752,469	64.6%	$ 72.95	$ 119.74	$ 46.80
23/06/2015	128,434	128,735	301	$ 15,153,620	$ 28,368,290	$ 13,214,670	87.2%	$ 117.98	$ 220.41	$ 102.44
26/08/2015	117,859	117,898	39	$ 6,242,911	$ 6,281,378	$ 38,467	0.6%	$ 52.99	$ 53.29	$ 0.31
8/09/2015	118,422	118,533	111	$ 7,730,543	$ 7,996,747	$ 266,204	3.4%	$ 65.30	$ 67.49	$ 2.19
22/09/2015	116,971	117,000	29	$ 5,755,509	$ 5,925,077	$ 169,568	2.9%	$ 49.23	$ 50.67	$ 1.44
23/03/2016	109,713	109,712	-1	$ 7,348,444	$ 7,366,748	$ 18,304	0.2%	$ 66.98	$ 67.15	$ 0.17
24/04/2016	91,385	91,385	0	$ 5,735,172	$ 5,598,919	-$ 136,253	-2.4%	$ 62.76	$ 61.27	-$ 1.49
12/07/2016	121,918	121,965	47	$ 7,179,806	$ 7,447,931	$ 268,125	3.7%	$ 58.89	$ 61.07	$ 2.18
23/07/2016	102,668	102,668	0	$ 4,600,055	$ 4,621,229	$ 21,174	0.5%	$ 44.81	$ 45.01	$ 0.21
25/07/2016	114,496	114,589	93	$ 5,350,045	$ 5,460,846	$ 110,801	2.1%	$ 46.73	$ 47.66	$ 0.93
4/08/2016	122,497	122,526	28	$ 5,746,255	$ 5,903,755	$ 157,500	2.7%	$ 46.91	$ 48.18	$ 1.27
				$ 55,688,742	*$ 56,602,631*	*$ 913,889*	1.6%			