Within island basis risk: Characterising the risk

20 November 2012

Market Design

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1 Purpose of this paper

1.1 The New Zealand electricity market will soon have new mechanisms for managing *inter*-island basis risk (IIBR), in the form of inter-island Financial Transmission Rights (FTRs). It remains to be determined whether there is a need for additional mechanisms for managing *within*-island basis risk (WIBR).

1.2 The Authority considers that, in order to determine what mechanisms (if any) are needed to manage WIBR, it will first be necessary to characterise the nature of within-island risk.

1.3 The Authority has previously commissioned Energy Link to investigate the nature of WIBR in New Zealand, and now seeks to build upon the Energy Link work to establish an understanding of key locational risks. The Authority, therefore, proposes to develop a framework for characterising the location and nature of WIBR in a way that takes account of commercial risks.

1.4 The framework will:

(a) describe the nature of locational price risk in New Zealand;

(b) identify where within-island locational price risks may arise;

(c) quantify these risks; and

(d) determine whether they are significant from a commercial perspective.

1.5 This paper sets out the proposed framework (in Sections 2 through 5), demonstrates the application of the framework (in Section 6), and seeks feedback from LPRTG on whether the framework is appropriate.

1.6 Specific questions on the framework are posed to the LPRTG throughout the paper, but the group should feel free to comment on any aspect of the analysis.

1.7 If the LPRTG broadly supports the framework, the Authority will proceed to apply the framework (incorporating any feedback received), and provide the results to the next LPRTG meeting.

2 Describing the nature of locational price risk in New Zealand

2.1 WIBR is the risk associated with unpredictable variations in the difference between spot prices for electricity at two nodes within the same island.

2.2 Note the focus on unpredictability – a constant price difference (in absolute or relative terms) between two nodes does not constitute locational price risk.

2.3 For the purpose of characterising WIBR, the Authority suggests a distinction between two types of locational risk:

(a) *spikes* (the risk that there will be a much higher spot price at one node than another – typically associated with a transmission constraint between the two nodes); and

(b) *tidal flows* (all other locational risk – largely driven by changes in losses caused by changes in the direction and magnitude of power flows, but also resulting from small to moderate price differences across intermittent constraints).

2.4 If it could be shown that one of the two types of risk was dominant, then this might be helpful in terms of identifying:

(a) the locations where material WIBR might arise; and

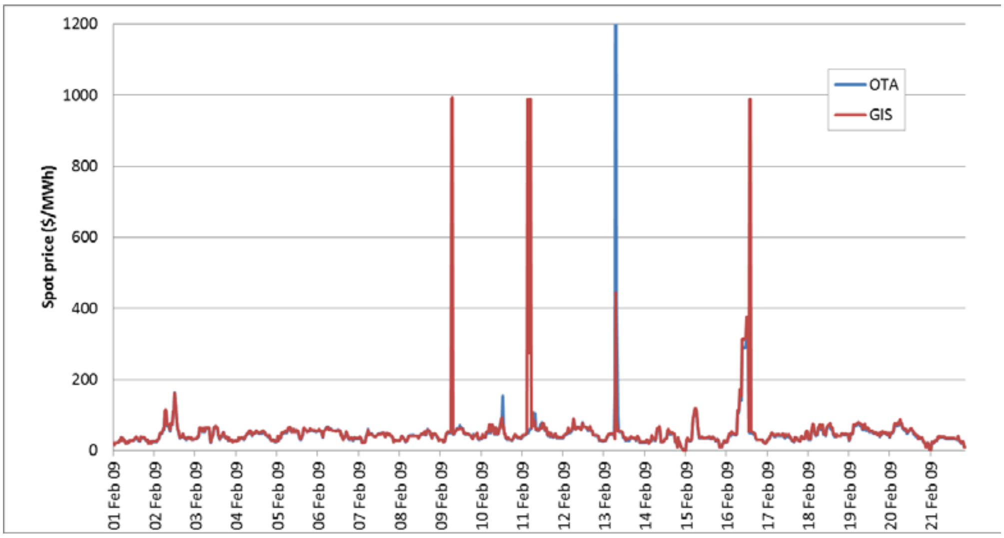
(b) the preferred solution.

2.5 Both *spikes* and *tidal flows* can result in substantial locational price variation – the former through a large price difference in a small number of periods, the latter through a moderate price difference in a large number of periods.

2.6 Both *spikes* and *tidal flows* are potentially unpredictable. *Spikes* are largely driven by transmission and generation outages and generator offer behaviour, and may not be apparent until real time (or even after). *Tidal flows* are largely driven by hydrology, which can be foreseen further in advance but may still not be predictable on hedging time frames.

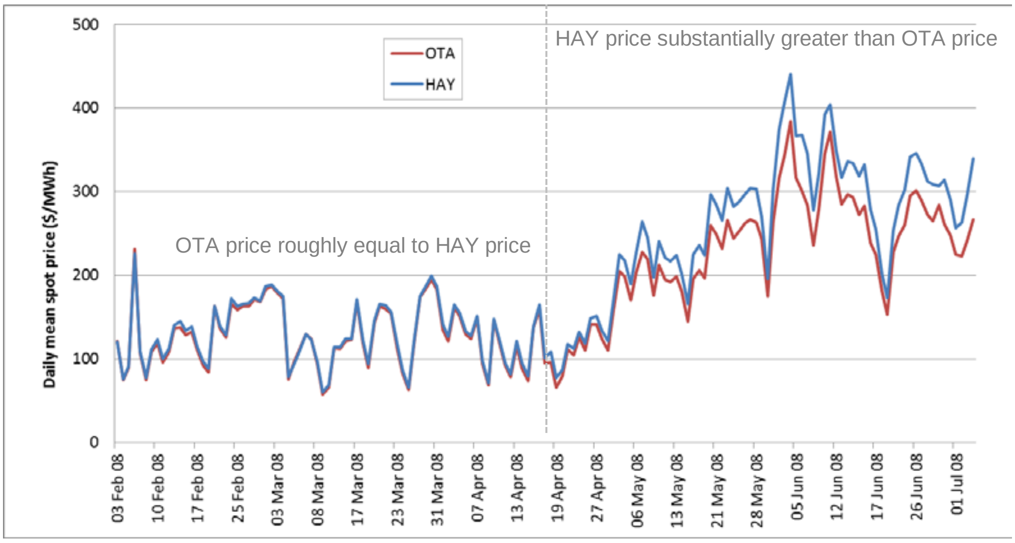
2.7 Some locational price differences driven by *spikes* and *tidal flows* are illustrated in Figure 1 and Figure 2 respectively.

Figure 1 Price differences driven by *spikes*



Source: Centralised Dataset, Electricity Authority

Figure 2 Price differences driven by *tidal flows*



Source: Centralised Dataset, Electricity Authority

2.8 Appendix B *("Spot price spikes since 2000")* briefly reviews price spikes that have occurred in New Zealand since the turn of the millennium, and identifies common themes – for instance, that:

(a) Widespread (affecting many nodes) spikes have been somewhat frequent in the North Island since 2009; but

(b) local spikes have been somewhat frequent in some provincial areas since 2001 at least.

Q1. Based on LPRTG members' experience, do they consider that *spikes* are a more significant source of commercial risk than *tidal flows*, or vice versa?

3 Identifying where within-island locational price risks may arise

3.1 For the purpose of characterising WIBR, the Authority also suggests a distinction between:

(a) *regional* price risk (e.g. between Canterbury and Southland); and

(b) *local* price risk (e.g. between Redclyffe and Gisborne).

3.2 This distinction seems useful, in that the types of mechanisms that could effectively assist at a *regional* level might be different from the types of mechanisms that would be appropriate at a *local* level.

3.3 In order to apply this distinction, the Authority proposes to divide New Zealand into regions. Please note that these regions are only for the purpose of quantifying price risk – there is no expectation that they would be built into any future mechanisms to manage price risk. (They are not, for instance, put forward as a list of potential new FTR nodes!)

3.4 The Authority suggests that a suitable set of regions should have the following properties:

a) *(most importantly)* to the extent possible, the regions should be chosen so that the price risk within each region is smaller than the price risk between regions;

b) each region should include a substantial amount of load, or generation, or both (because otherwise it would have little ability to generate commercial risk);

c) the regions should form a partition (that is to say, each pricing location should fall into exactly one region); and

d) different voltage levels at a single substation should always fall into the same region *(so the regions can be expressed as lists of 3-letter substation codes)*.

3.5 The first two principles can clash, i.e. when significant price variation is associated with a group of nodes including relatively little load and generation. The Authority's view is that in these cases it is appropriate to strike a balance – splitting out small groups of nodes only if their prices are very divergent from other nodes nearby.

3.6 Guided by the above list of properties, the Authority has proceeded to divide New Zealand into regions by:

a) using statistical analysis[1] to find clusters of nodes that have had highly correlated prices in the past; and

b) manually reassigning a relatively small number of nodes (e.g. because the node was relatively new and did not have enough historical data for the cluster analysis to assign it correctly, or because the grid configuration near a node had changed recently).

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[1] To be specific, a *hierarchical cluster analysis* (http://en.wikipedia.org/wiki/Hierarchical_clustering), where the similarity between two nodes is measured by the correlation coefficient of the monthly mean prices at the two nodes in recent years.

3.7 This approach is inspired by Energy Link's earlier analysis,[2] and follows the same theme of clustering nodes based on correlations between prices on monthly timescales.

3.8 The approach is illustrated in Appendix D, and the proposed 18 regions are shown in Figure 3.

Q2. Based on LPRTG members' experience, do they consider that *regional* price risks are more commercially significant than *local* price risks, or vice versa?

Q3. Does the LPRTG agree that the regions set out in Figure 3 are suitable for the purpose of quantifying WIBR?

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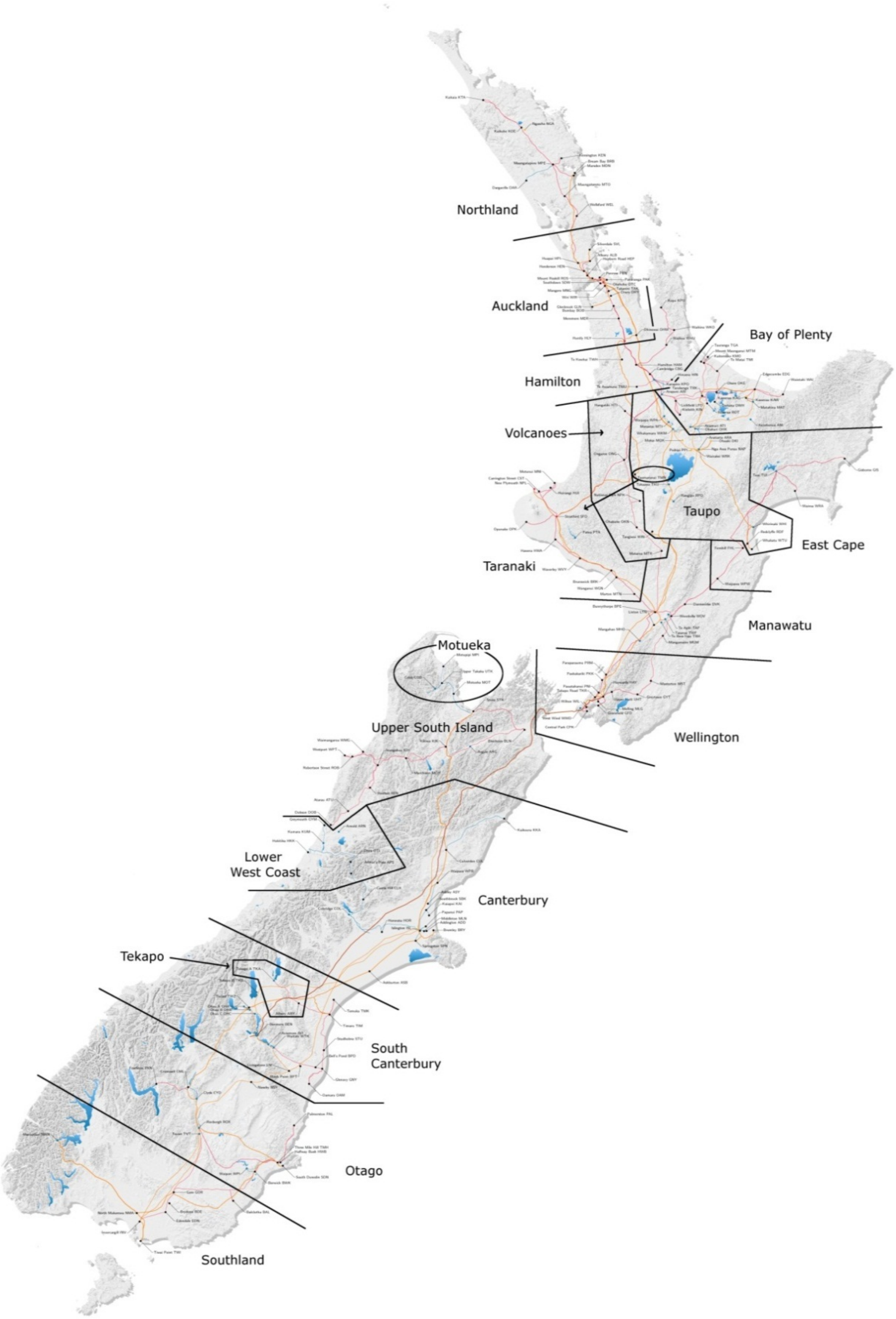
[2] http://www.ea.govt.nz/dmsdocument/13285

Figure 3 Proposed division of New Zealand into 18 regions, for the purpose of distinguishing between *regional* and *local* risk



Source: Electricity Authority

4 Quantifying within-island locational price risks

4.1 This section proposes a methodology for quantifying WIBR.

4.2 The methodology focuses on the *variability* of nodal price differences (because, as previously noted, a constant price difference, in either absolute or relative terms, does not constitute price risk).

4.3 This section:

(a) describes how the methodology would be applied at the *regional* level (based on price differences between the regional reference nodes defined in Section 3 and island reference nodes);

(b) explains how the methodology would quantify the portion of WIBR associated with *tidal flows* (as opposed to the portion associated with *spikes*);

(c) provides a short worked example;

(d) extends the methodology to the *local* level (based on price differences within each of the regions defined in Section 3); and

(e) explains that, although the quantification of risk would be largely based on historical price variation, it should also consider that future risk may differ from what has been observed in the past.

4.4 The application of the proposed methodology is illustrated in Section 6.

Quantifying *regional* risk

4.5 Regional risk exists when prices within a region are variable, relative to prices outside the region.

4.6 In principle, any pair of regions could be compared with each other. However, it may be most useful to quantify regional risk in terms of differences between prices within a region and prices at island reference nodes. Such differences determine the extent to which a participant could manage regional risk using hedging instruments based on prices at the island reference nodes.

4.7 It seems reasonable to assert that the locational price risk associated with a region is minimal if:

(a) prices within the region are always roughly equal to the price at the island reference node (Otahuhu or Benmore); or (more realistically)

(b) prices within the region are always roughly equal to a fixed[3] *scalar multiple* of the price at the island reference node; or

(c) prices within the region are always roughly equal to a fixed[4] *linear combination* of the prices at the two island reference nodes.

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[3] Fixed in the sense that the scalar does not change over time.

[4] Fixed in the sense that the coefficients do not change over time.

4.8 In any of these cases, participants should (at least in principle) be able to manage regional risk through some combination of FTRs and energy contracts at the island reference nodes:[5]

(a) in the first case, by hedging against the island reference node;

(b) in the second case, by hedging against the island reference node, covering a quantity that is a scalar multiple of the party's actual quantity; and

(c) in the third case, by hedging against the two island reference nodes in appropriate proportion.

4.9 Therefore, the Authority suggests it is appropriate to quantify the locational price risk associated with a specific region in terms of the variability of the difference between:

(a) some measure of the prices in the region; and

(b) an appropriate combination of the prices at the island reference nodes.

4.10 The following regional risk measure is therefore suggested:

RR_{reg} = standard deviation over m of $(MM_{ref(reg),\,m} - (alpha\ MM_{BEN,\,m} + beta\ MM_{OTA,\,m} + gamma))$

where: RR_{reg} is a measure of the regional risk associated with region *reg*;

m are months;

$MM_{n,m}$ is the mean price at node n during month m;

ref(reg) is a reference node within region *reg*;

BEN and *OTA* are Benmore and Otahuhu 220 kV respectively; and

alpha, *beta* and *gamma* are chosen so as to minimise squared differences between $MM_{ref(reg),\,m}$ and $(alpha\ MM_{BEN,\,m} + beta\ MM_{OTA,\,m} + gamma)$. The differences that remain represent the locational price risk.

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[5] Here, as elsewhere in the paper, the complexities of hedging are simplified for the purpose of illustrating the point. For one thing, the discussion focuses on price risk and ignores quantity risk. (In practice, the quantity a party must cover may vary along with the price it must pay. If a retailer's quantity increases as the price it pays decreases, then this effectively reduces its locational risk. Conversely, if its quantity increases with price, then the locational risk is increased.) The discussion also largely ignores issues of load shape, of multi-node hedging, and of one-sided hedging (i.e. to manage downside risk only).

4.11 The following table discusses some key design features of the proposed measure.

Design decision	**Discussion**
It is appropriate to use a reference node rather than a weighted average of nodes	The proposed regional risk measure is based on prices at a single reference node within the region, rather than (say) GWAP or LWAP throughout the region. This is considered to be reasonable because if there *is* any intra-region variation relative to the reference node, it should be picked up in the analysis of local risk.
The standard deviation is a useful measure of variability, but other measures are possible	The proposed regional risk measure quantifies price risk in terms of the standard deviation of differences in mean price, on the basis that the standard deviation is an appropriate measure of unpredictable variation. For presentational purposes, it may sometimes be preferable to show a multiple of the standard deviation – e.g. +/- two standard deviations, to indicate the likely range of monthly outcomes. It may be useful (instead, or as well) to use quantile-based measures – e.g. the 5th and 95th percentiles. These may be a more familiar and useful measure for some participants.
The monthly time frame is important for commercial risk, but other time frames may also be relevant	The proposed regional risk measure uses monthly mean prices – because this is the time frame on which the spot market is settled, and can drive cashflow considerations for some parties. For other parties, quarterly or annual time frames may be more relevant because they are aligned with finance and reporting requirements. It would certainly be possible to shift the analysis to these timeframes, or to continue working at the monthly level and extrapolate results to quarterly or annual timeframes based on observed month-to-month serial correlation.
There is no need to use seasonally varying coefficients	It would be possible to allow *alpha*, *beta* and *gamma* (the coefficients of the linear combination of Otahuhu and Benmore prices) to vary seasonally. This would be appropriate if there was a predictable seasonal pattern in the relationship between prices in the region and prices at reference nodes. However, preliminary investigations do not show that there is a significant seasonal pattern. It, therefore, seems appropriate to use the same values of *alpha*, *beta* and *gamma* for all seasons.

Design decision	**Discussion**
The proposal is to use simple averages of prices, but a load profile could alternatively be applied	The proposed regional risk measure uses simple averages of prices, rather than (say) applying some typical load profile. This approach is proposed for simplicity and because it broadly reflects the price risks faced by a baseload or intermittent power plant, or by an inflexible industrial load. LPRTG may feel that it is worth taking a more detailed approach here, i.e. using some form of load profile approach. One way of doing this would be to base a regional risk measure on the difference between: • the cost of purchases in the region in a month (i.e. sum of price x quantity); and • an appropriate linear combination of the costs of purchasing the region's normal quantity at that time of year at Otahuhu and Benmore, using the purchaser's normal load shape at that time of year). Such a measure would capture both LPR and quantity risk (and hence the regional risk would be nonzero even for the reference nodes). The measure could be seen as measuring the regional risk that remains after hedging using a linear combination of flat monthly obligation FTRs (or inter-regional swaps).

Quantifying the portion of WIBR associated with *tidal flows*

4.12 The portion of *regional* risk that is associated with tidal flows can be measured by determining the risk measure based on values of MM that exclude all prices arising from *spikes*.

4.13 The Authority proposes to identify *spikes* as trading periods in which:

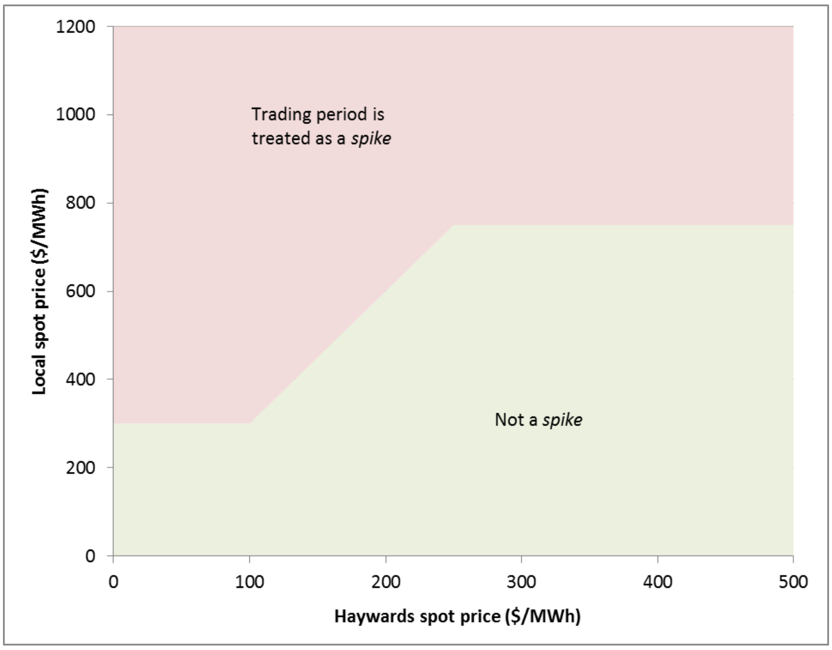
(a) the local price is in excess of $750/MWh; or

(b) the local price is at least triple the Haywards price and the Haywards price is in excess of $100/MWh; or

(c) the local price is in excess of $300/MWh and the Haywards price is less than $100/MWh.

4.14 These criteria are illustrated in Figure 4.

Figure 4 Criteria for identifying prices associated with *spikes*



4.15 Based on these criteria, the number of trading periods that would be classified as *spikes*, between January 2009 and September 2012, was:

(a) 125 (at Otahuhu);

(b) 146 (at Gisborne);

(c) 160 (at Benmore); and

(d) 231 (at Greymouth).

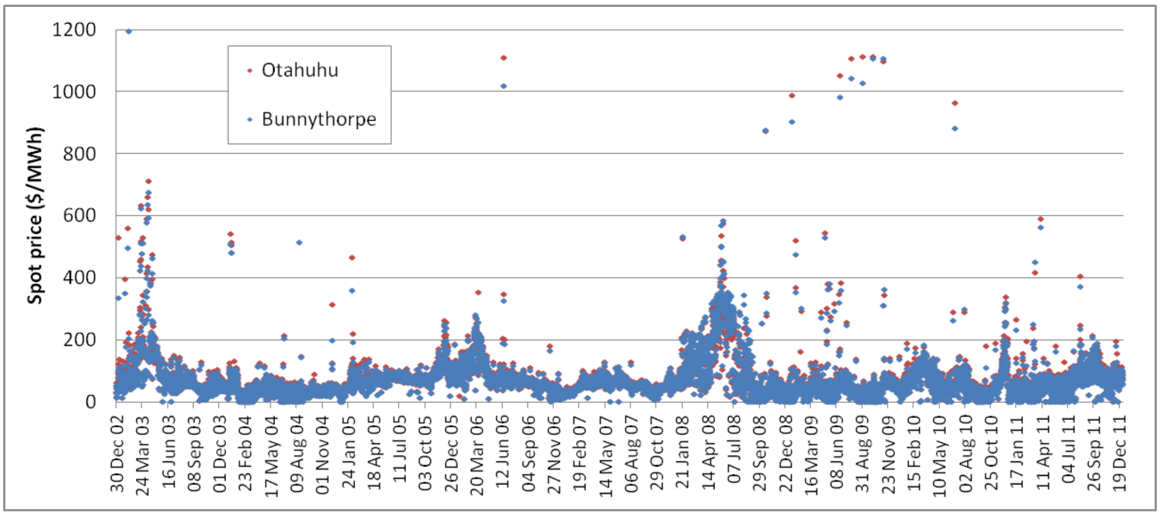
4.16 Note that previous analysis by Energy Link used a broader definition of spikes, encompassing more events. It is appropriate to use a narrower definition of spikes in this paper, because the process of averaging prices over a month means that any single spike would have relatively little impact (unless prices reached a very high level).

A worked example

4.17 Figure 5 to Figure 10 demonstrate how regional risk would be quantified, and how the portion of the risk associated with *tidal flows* would be calculated, based on historical data.

Figure 5 Calculation of the regional risk measure: Step A

Take spot prices at a suitable reference node in the region – in this case, Bunnythorpe.

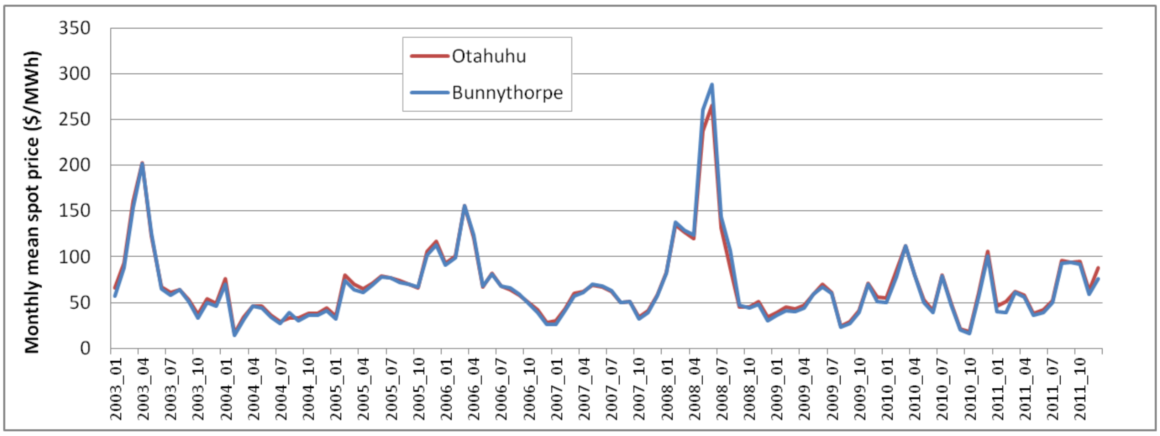


Source: Centralised Dataset, Electricity Authority

Notes:
1. The standard deviation of spot prices at Bunnythorpe was $**86**/MWh.
2. Prices at Otahuhu are shown as a point of reference.
3. Only every 17th trading period is shown (to reduce the size of the plot).

Figure 6 Calculation of the regional risk measure: Step B

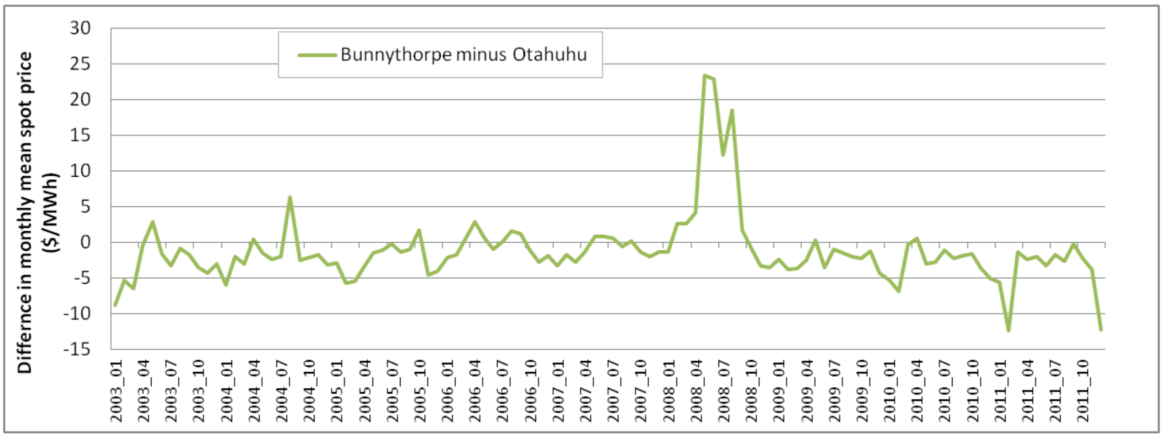
Calculate monthly mean prices



Notes:
1. The standard deviation of monthly mean spot prices at Bunnythorpe was $**43**/MWh.
2. This may indicate the level of basis risk faced by a completely unhedged baseload purchaser at Bunnythorpe.

Figure 7 Calculation of the regional risk measure: Step C

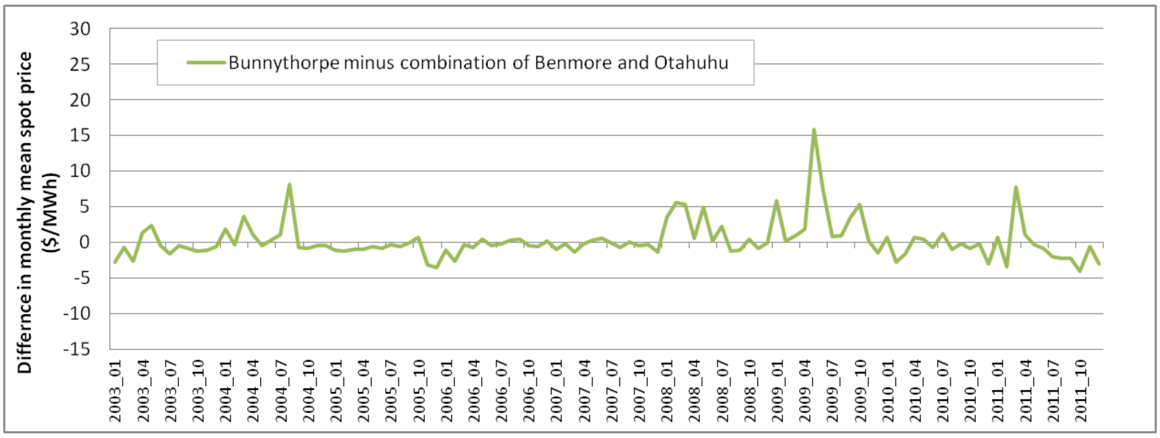
Calculate differences between monthly mean prices at the regional reference node and at an island reference node



Notes:
1. The standard deviation of the difference between Bunnythorpe and Otahuhu was $**4.90**/MWh.
2. This may indicate the level of locational risk faced by a baseload purchaser hedging each 1 MW at Bunnythorpe with 1 MW at Otahuhu.

Figure 8 Calculation of the regional risk measure: Step D

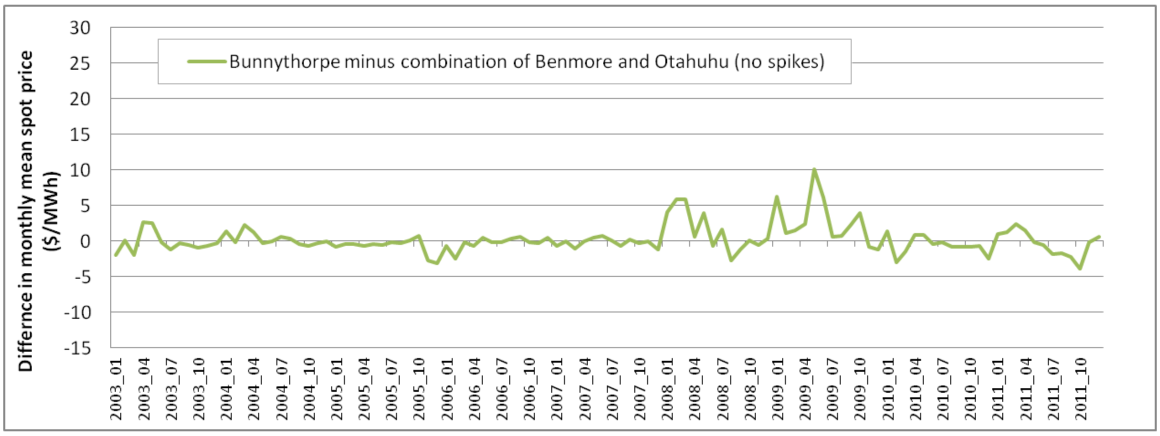
Calculate differences between monthly mean prices at the regional reference node and a fixed linear combination of those at island reference nodes



Notes:
1. The standard deviation of the difference between Bunnythorpe and an appropriate linear combination of Benmore and Otahuhu was just $**2.70**/MWh.
2. This may indicate the level of locational risk faced by a baseload purchaser hedging each 1 MW at Bunnythorpe with 0.72 MW at Otahuhu and 0.28 MW at Benmore.

Figure 9 Calculation of the regional risk measure: Step E

Repeat process with *spikes* removed – all remaining variation is associated with *tidal flows*

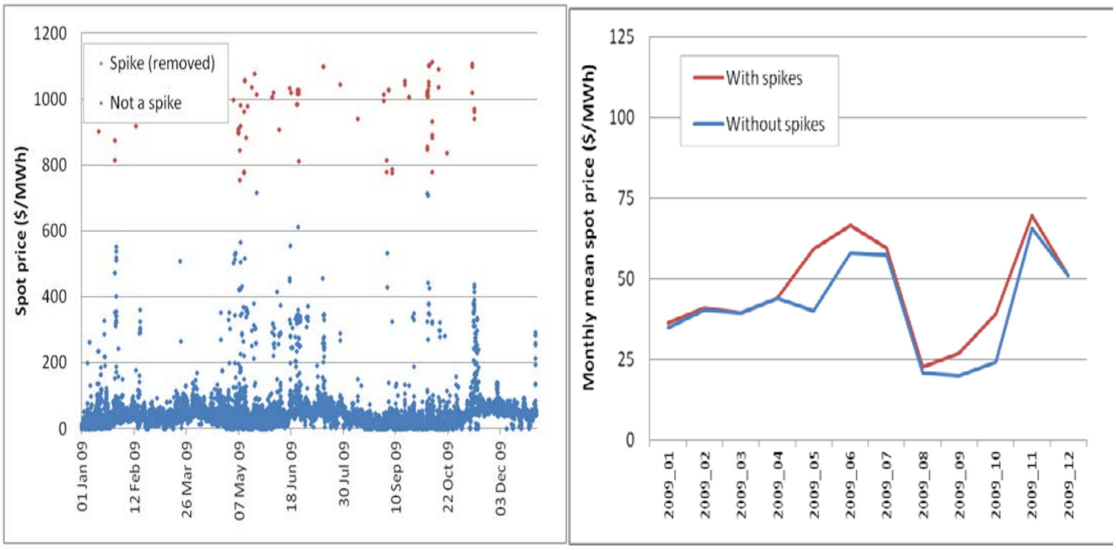


Notes:

1. Removing *spikes* reduces the standard deviation to $**2.0**/MWh – not a big reduction, so in this case, most of the regional price risk appears to relate to *tidal flows*.
2. For any that are interested, the distribution of residuals is shown in Appendix C.

Figure 10 Calculation of the regional risk measure: Further detail on Step E

These plots illustrate the process of identifying and removing *spikes*, for the 2009 year.
The left hand subplot shows the prices at Bunnythorpe that were identified as *spikes* (in red).
The right hand subplot shows the effect of removing these spikes on monthly mean prices.



Notes:

1. Clearly not *all* high price events are filtered out, but removing the ‘spikiest’ events brings down mean prices at Bunnythorpe substantially in some months – particularly May, June, September and October.

Quantifying *local* risk

4.18 Local risk exists when prices within a region are variable, relative to each other.

4.19 The implication is that local risk should be measured through comparisons between prices at the regional reference node and prices at each other node in the region.

4.20 The proposed local risk measure is very similar to the regional risk measure discussed in the previous pages. It is:

LR_n = standard deviation over m of ($MM_{n,\,m} - (alpha\ MM_{ref(reg),\,m} + beta)$)

where: LR_n is a measure of the local risk associated with node n in region reg;

m are months;

$MM_{n,\,m}$ is the mean price at node n during month m;

$ref(reg)$ is the reference node within region reg; and

$alpha$ and $beta$ are chosen to minimise squared differences between MM_n and $(alpha\ MM_{ref(reg)} + beta)$.

4.21 The application of both regional and local risk measures is illustrated in Section 6.

These risk measures can be used both in a backward- and in a forward-looking sense

4.22 It is useful to study the historical record but it is also important to remember that the future may be different from the past.

4.23 The proposed risk measures can be applied to historical prices, to determine the amount of WIBR that has occurred in the past (as in Figure 5 through Figure 10, and in Section 6). However, they can also be used in a forward-looking sense (on the basis of assumptions about future prices).

4.24 The Authority proposes to carry out scenario analysis to demonstrate how price risk could be affected by changes in the level of localised price volatility. This may include:

(a) upweighting historical events that resulted in high spot prices, to indicate how WIBR could be affected if such events were to occur more often;

(b) rerunning historical events using vSPD with different offer prices, to indicate how WIBR could be affected if the structure of offers was to change; and

(c) similarly, rerunning historical events using vSPD with different generation or transmission outages or higher demand.

4.25 The Authority also proposes to carry out scenario analysis to show how WIBR could be affected by the availability of upcoming transmission upgrades (such as the North Island Grid Upgrade). This may involve rerunning SPD for specific trading periods, with modified transmission input assumptions.

4.26 The Authority also notes (but does not propose to quantify) that:

(a) recent announcements of potential load reductions;

(b) the addition of new local generation may have changed the level of WIBR in some regions (such as the Bay of Plenty or Northland) in recent years;

(c) there might be an elevated level of WIBR during the process of constructing and commissioning grid upgrades (i.e. as a result of outages);

(d) WIBR might be affected by various recent, planned or potential regulatory changes (such as scarcity pricing[6] or dispatchable demand); and

(e) the Authority's workplan for 2012/13 includes a project to improve pricing efficiency when suppliers are pivotal in the spot market. It is possible that this project might affect the level of WIBR arising from pivotal supplier situations.

Q4. Does the LPRTG suggest that any changes should be made to the proposed measures of regional and local risk?

Q5. How might the nature and location of LPR change in future?

Q6. What future scenarios should the Authority consider?

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[6] Code amendments providing for scarcity pricing (i.e. setting the spot price to an administered level when the system operator calls for curtailment at an island or national level) will come into force in 2013. It is possible that the introduction of scarcity pricing will affect locational price risk. However, the effect is not expected to be material, because the implementation of scarcity pricing has been designed to preserve node-to-node price ratios within each island.

5 Determining whether within-island locational price risks are significant from a commercial perspective

5.1 The measures of regional and local risk can be used in a *relative* sense, i.e. comparing between regions and nodes to see where the key risks lie – but can also be used in an *absolute* sense, i.e. comparing risks with an appropriate threshold to assess whether they are material or not.

5.2 There is no single “bright line” that demarcates risks that need to be managed from risks that can be safely ignored. However, it may be possible to identify some useful reference points, including:

(a) the level of *inter-island* risk (which can be quantified using a similar measure, i.e. the standard deviation of differences between the monthly price at one island reference node and an appropriate scalar multiple of the monthly price at the other island reference node);[7]

(b) the overall level of basis risk (which can be quantified using a similar measure, i.e. the standard deviation of monthly prices at an island reference node); and

(c) typical retail margins.

5.3 In applying these reference points, it may be necessary to consider that the effect of regional risk and local risk on participants may (in some sense) be *additive*. Even if regional risk and local risk are each individually below a reference point, the combination of the two may still be material.

Q7. What reference points might be useful in assessing whether the observed or forecast level of WIBR is commercially material?

Assessment of materiality may be an iterative process

5.4 It may, at some point, be helpful to carry out the analysis of materiality on an iterative basis, to determine how much WIBR would remain after mechanisms were made available to manage one or more key risks.

5.5 Suppose, for example, it turned out that a key source of WIBR was between the upper North Island and lower North Island. One way to manage this risk might be through adding an additional FTR hub at (say) Bunnythorpe. The question might then arise: how much locational risk would remain after adding this hub? This question could be addressed by recalculating regional risk, assuming that participants could hedge against a linear combination of prices at the *three* hubs.

5.6 However, the Authority has not yet attempted such an iterative analysis.

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[7] Note this measure of inter-island risk is not symmetric – in the sense that the difference between Benmore and (j x Otahuhu) need not be the same as the difference between Otahuhu and (k x Benmore).

6 Examples of the application of the proposed measures

6.1 This section demonstrates how the measures of WIBR proposed in Section 4 might be applied and compared to the materiality thresholds proposed in Section 5. It is not a complete analysis:

(a) the proposed risk measures are only applied to a subset of regions and a subset of nodes; and

(b) the analysis is only carried out on a backward-looking basis, based on historical data – no forward-looking scenario analysis has been attempted at this stage.

6.2 If the LPRTG broadly supports the framework, the Authority will proceed to complete the analysis (incorporating any feedback received), and provide the results to the next LPRTG meeting.

Quantifying regional risk

6.3 This section shows how the Authority would propose to quantify *historical* regional risk.

6.4 Three of the regions defined in the previous section have been chosen for illustrative purposes – Hamilton (or HAM for short), East Cape (GIS), and Otago (HWB).

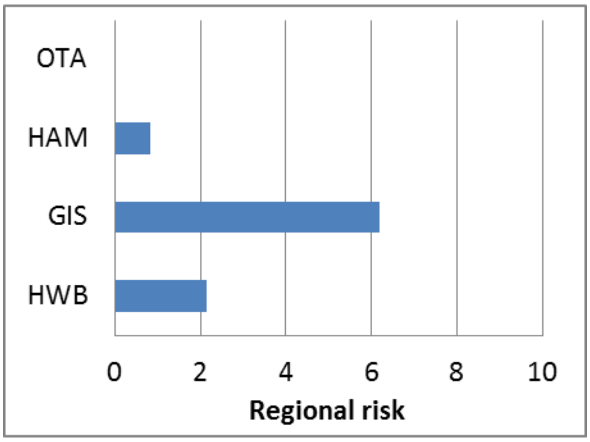
6.5 Some of the plots below also show Otahuhu (OTA), where WIBR (as defined) is nil.

6.6 The analysis here is backward-looking. For the fuller version of the analysis, the Authority would also consider how regional risk might change in future, based on some scenarios.

6.7 The proposed measure of regional risk is based on the standard deviation of the difference between the monthly mean price at the reference node in each region and a suitably chosen linear combination of the monthly mean prices at Otahuhu and Benmore (see paragraph 4.10).

6.8 Figure 11 indicates the level of regional risk, according to this measure.

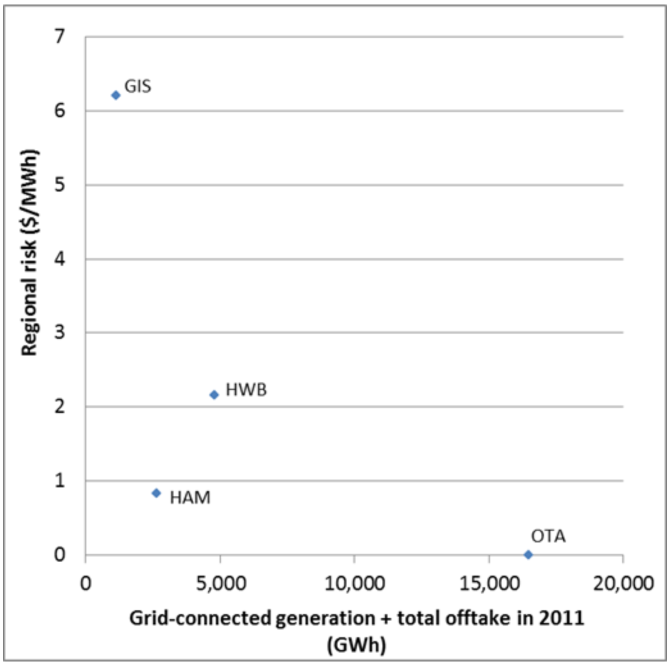
Figure 11 Draft measure of historical regional risk



Source: New analysis based on data from Centralised Dataset, Electricity Authority

6.9 Figure 12 may be a helpful visualisation tool: it compares regions both in terms of the *regional risk measure* and their *materiality* (expressed in terms of the amount of load and generation they contain).

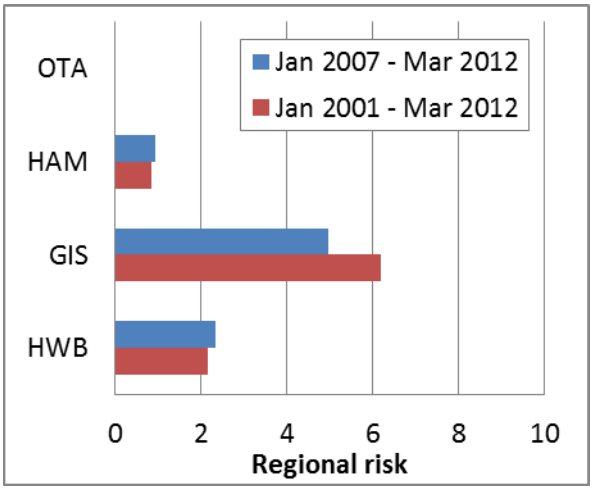
Figure 12 Regional risk vs materiality



Source: New analysis based on data from Centralised Dataset, Electricity Authority

6.10 Figure 13 shows how the risk measure changes if only the historical record from 2007 onwards is considered. In these particular cases it makes very little difference.

Figure 13 Draft measure of historical regional risk (from 2007 onwards)

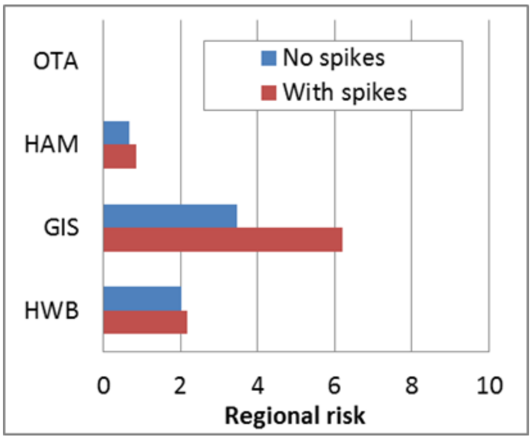


Source: New analysis based on data from Centralised Dataset, Electricity Authority

6.11 Figure 14 shows how the risk measure changes if *spikes* are excluded. In all cases, removing spikes leads to a reduction in the risk measure. The remaining risk is associated with *tidal flows*.

6.12 The reduction is particularly strong in the case of the East Cape region (which has been affected by a relatively small number of localised high price events).

Figure 14 Regional risk excluding *spikes*



Source: New analysis based on data from Centralised Dataset, Electricity Authority

Quantifying local risk

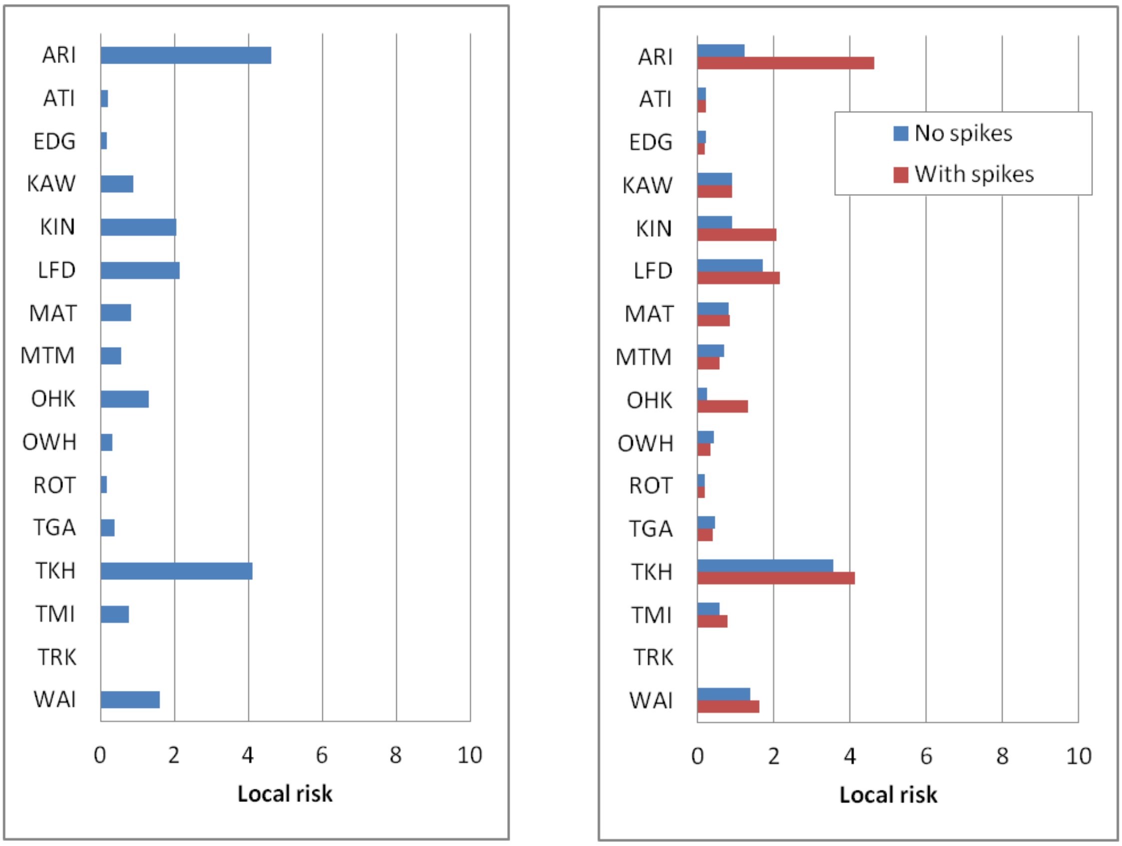
6.13 This section shows how the Authority would propose to quantify *historical* local risk. One region (the Bay of Plenty) has been chosen for illustrative purposes.

6.14 The analysis here is backward-looking. For the full version of the analysis, the Authority would also consider how local risk might change in future.

6.15 The proposed measure of local risk is based on the standard deviation of the difference between the monthly mean price at each node and a suitably chosen multiple of the monthly mean price at the regional reference node (possibly plus a scalar; see paragraph 4.20).

6.16 Figure 15 indicates the level of local risk, according to this measure.

Figure 15 Bay of Plenty – draft measure of historical local risk



Notes:

1. The plot to the right shows how the risk measure changes if *spikes* are excluded.
2. In all cases, removing *spikes* leads to a reduction in the risk measure. The remaining risk is associated with *tidal flows*.
3. The reduction is particularly strong in the case of Arapuni (which has been affected by a relatively small number of localised high price events).

Determining whether risks are significant

6.17 As set out at paragraph 5.2, some useful points of reference may be:

(a) the level of *inter-island* risk;

(b) the overall level of basis risk; and

(c) typical retail margins.

6.18 The level of historical inter-island risk can be quantified using an equivalent risk measure – i.e.:

(a) the standard deviation of the difference between the monthly mean price at Benmore and an appropriate multiple of the monthly mean price at Otahuhu (plus an appropriate scalar). This measure (for historical data from 2001 to 2012) is **$14.0/MWh**; or

(b) vice versa, which (for historical data from 2001 to 2012) is **$10.9/MWh**.[8]

6.19 The overall level of basis risk may be quantifiable in terms of:

(a) the standard deviation of monthly prices at Benmore, which (for historical data from 2001 to 2012) has been **$53/MWh**; or

(b) the same measure for Otahuhu, which (for historical data from 2001 to 2012) has been **$41/MWh**.

6.20 It may be reasonable to estimate typical retail margins as approximately **$10-15/MWh** (once operating costs are taken into account).

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[8] The figure for Otahuhu (relative to Benmore) is lower than the figure for Benmore (relative to Otahuhu) because prices at Benmore have been more variable than those at Otahuhu, on a monthly time frame over 2001-2012.

Appendix A Summary of questions for LPRTG

Q1. Based on LPRTG members' experience, do they consider that *spikes* are a more significant source of commercial risk than *tidal flows*, or vice versa?

Q2. Based on LPRTG members' experience, do they consider that *regional* price risks are more commercially significant than *local* price risks, or vice versa?

Q3. Does the LPRTG agree that the regions set out in Figure 3 are suitable for the purpose of quantifying WIBR?

Q4. Does the LPRTG suggest that any changes should be made to the proposed measures of regional and local risk?

Q5. How might the nature and location of LPR change in future?

Q6. What future scenarios should the Authority consider?

Q7. What reference points might be useful in assessing whether the observed or forecast level of WIBR is commercially material?

Appendix B Spot price spikes since 2000

B.1 This Appendix briefly reviews spot price spikes that have occurred in New Zealand since the turn of the millennium, and attempts to identify common themes.

B.2 The analysis focuses on incidents where the final price of electricity[9] was in excess of $1000/MWh. (Note this is a narrower definition of *spikes* than that used in the main body of the paper.)

B.3 For the purpose of this Appendix, spikes are divided into two categories:

(a) *widespread*, affecting at least 40 grid exit points (GXPs); and

(b) *local*, affecting less than 40 GXPs.

Widespread spikes have been somewhat frequent in the North Island since 2009

B.4 There have been 85 widespread spikes since 2000 (if spikes spanning multiple consecutive trading periods are counted as a single event).

B.5 The 20 "most important" spikes are listed in Table 1, in roughly descending 'order of importance'. Here 'importance' is defined as (maximum price reached x duration x number of GXPs affected).[10]

Table 1 The 20 most important widespread spot price spikes since 2000

Date	Maximum price reached ($/MWh)	Region affected (approx.)	Comments
19 Jun 06	13,063	New Zealand	The only national event in the top 20 list. Capacity shortfall associated with cold snap.
4 Jul 10	6,059	North Island	Capacity shortfall associated with unplanned bipole HVDC outage.
17 Mar 11 (am)	5,540	North Island	Capacity shortfall associated with bipole HVDC outage.
17 Mar 11 (pm)	4,759	North Island	"
17 Mar 11 (TP 33)	3,319	North Island	"
13 Dec 11 (TPs 31-35)	6,094	North Island	Capacity shortfall associated with AUFLS event.
13 Dec 11 (TP 27)	18,734	Upper North Island	"

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[9] As opposed to the settlement price, which may differ from the final price as a result of resolving an undesirable trading situation. Also note that spikes in the price of instantaneous reserves are not considered here.

[10] The spike of 26 March 2011 is omitted.

Date	Maximum price reached ($/MWh)	Region affected (approx.)	Comments
21 Feb 11	6,181	North Island (primarily UNI)	Capacity shortfall associated with HVDC Pole 1 outage.
22 Feb 11	6,202	“	“
21 May 09	5,480	North Island	Capacity shortfall associated with unit commitment issues.
3 Nov 10	6,606	North Island	
6 Sep 10	6,297	North Island	
19 May 09	6,264	North Island (primarily LNI)	
13 Feb 09	7,540	North Island (primarily BoP)	Capacity shortfall associated with Otahuhu B unavailability.
12 Jan 04	1,236	North Island	
18 Feb 10	1,610	North Island	
4 Sep 09	1,300	North Island	
5 Oct 09	1,236	North Island	Capacity shortfall associated with unit commitment issues.

B.6 Some points to note are that:

(a) most (but not all) of the top 20 events were national or island-wide and would not have significantly contributed to WIBR;

(b) 19 out of the top 20 events were confined to the North Island;

(c) 18 of the 19 North Island events occurred between 2009 and 2011, during which time HVDC Pole 1 was in limited operation only;

(d) none of the top 20 events occurred in 2012 (to date); and

(e) the highest spikes were typically associated with HVDC and/or generation outages.

Local spikes have been somewhat frequent in some provincial areas since 2001 at least

B.7 There have been 177 local spikes since 2000 (if spikes spanning multiple consecutive trading periods are counted as a single event).

B.8 These events are too numerous to list here. However, the seven events in which the spot price exceeded $5,000/MWh are listed in Table 2.

Table 2 The seven highest local spot price spikes since 2000

Date	Maximum price reached ($/MWh)	GXPs affected	Comments
14 Aug 11	8,569	Dannevirke, Mangamaire, Waipawa, Woodville	Potential spring washer?
11 Sep 12	8,263	Balclutha, Berwick, Brydone, Edendale, Gore	Potential spring washer?
27 Apr 09	8,140	Fernhill, and to a lesser extent Gisborne, Tuai, Wairoa	Transmission outage leading to local pivotal supplier
25 Mar 06	7,153	West Coast, upper South Island north of Kikiwa	
27 Apr 04	5,935	Balclutha, Berwick, Brydone, Edendale, Gore	Potential spring washer?
26 Oct 00	5,618	Western Road	Confirm this price was actually settled on?
4 May 10	5,433	Fernhill, Gisborne, Redclyffe, Tuai, Wairoa	Transmission outage leading to local pivotal supplier

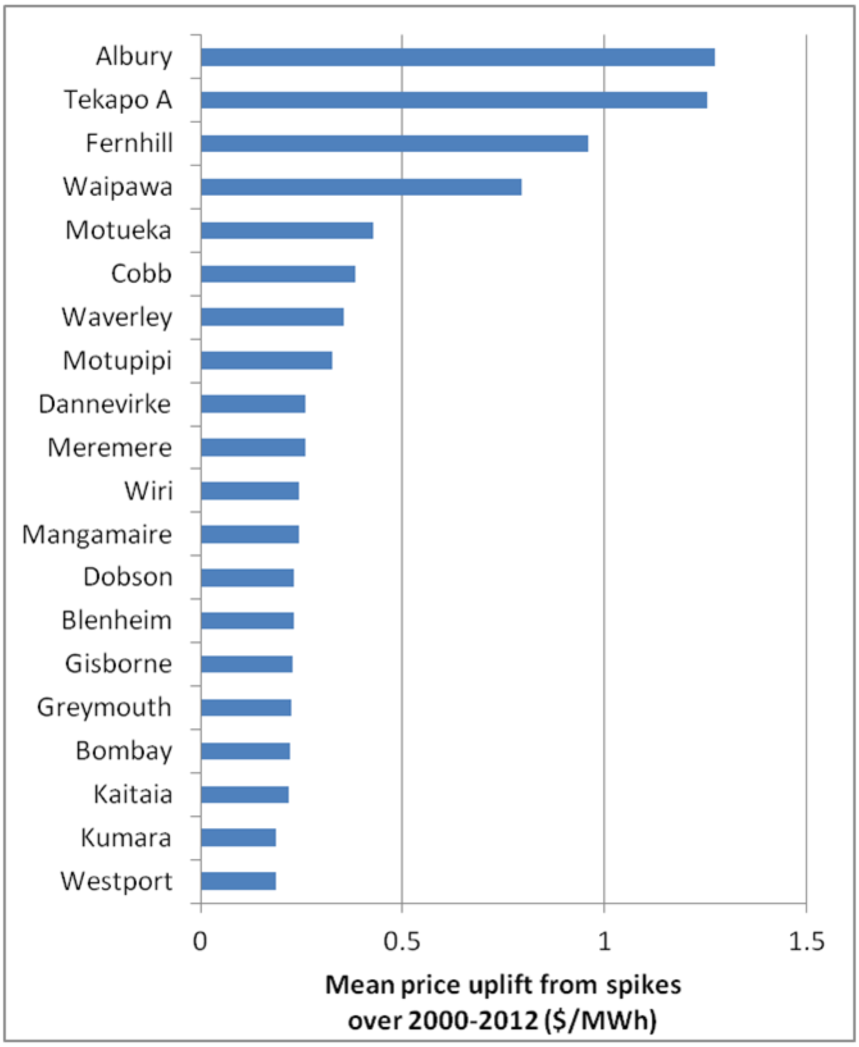
---

B.9 For the purpose of this Appendix, the effect of local spikes will be quantified in terms of the impact on local average prices.

B.10 We define the *mean price uplift* (at a specific GXP, over a specific interval) as the sum of prices during all identified spikes (at the GXP, during the interval) divided by the number of trading periods. (For instance, a single spike of $2000/MWh would lead to a *mean price uplift* of 2000 / 17520 = $0.11/MWh, for the relevant year.) This is a rough measure of the effect of spikes on time-weighted mean prices; it does not take variations in *quantity* into account.

B.11 The 20 GXPs that were most affected by local spikes (i.e. those with highest *mean price uplift* over the entire period from January 2000 to September 2012) are shown in Figure 16. Where there are multiple prices for different voltage levels at a given substation, only one voltage level has been chosen to represent the substation.

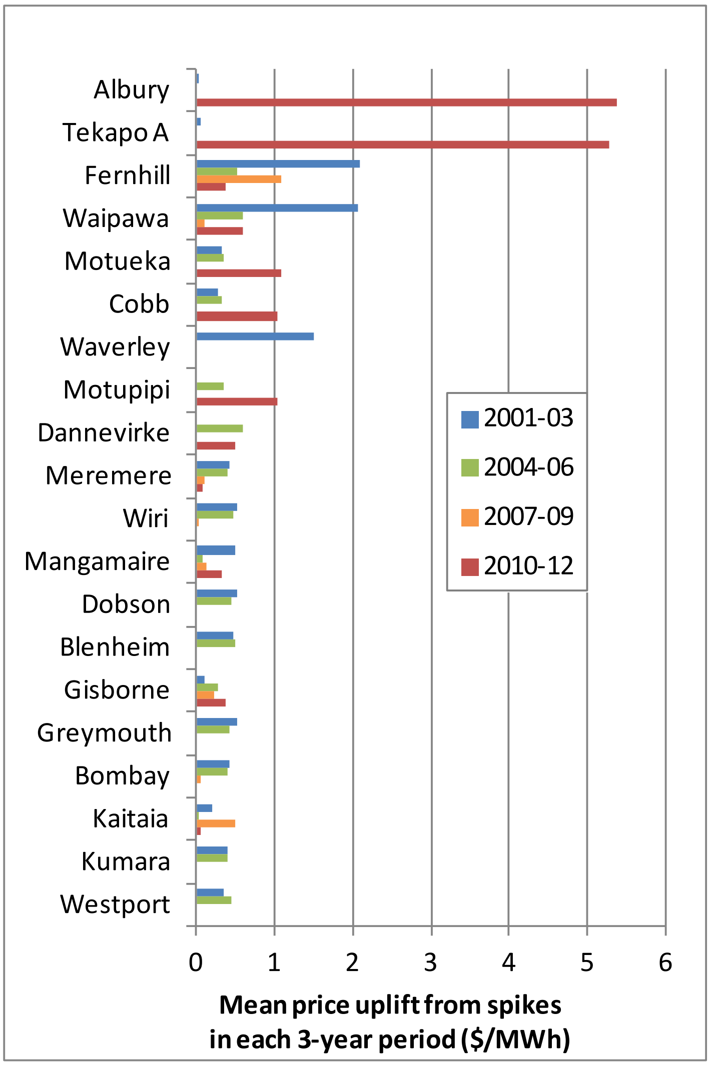
Figure 16 Mean price uplift at the 20 GXPs most affected by local price spikes



Source: New analysis based on data from Centralised Dataset, Electricity Authority

B.12 For each of these 20 GXPs, the *mean price uplift* is broken down by three-year periods in Figure 17.

Figure 17 Mean price uplift at the 20 GXPs most affected by local price spikes – in three-year bands



Notes:

1. The final bar, for 2010-12, is based on data to September 2012 – on the assumption of no further spikes in October-December 2012.
2. Price spikes in the Cobb and Tekapo areas in 2012 are particularly notable (shown as red bars for Albury, Tekapo A, Motueka, Cobb and Motupipi).

B.13 Some points to note are that local price spikes:

(a) can arise from pivotal pricing situations;

(b) can arise from spring washer situations;

(c) have been occurring since 2001 at least; and

(d) have often been associated with remote provincial areas rather than major cities.

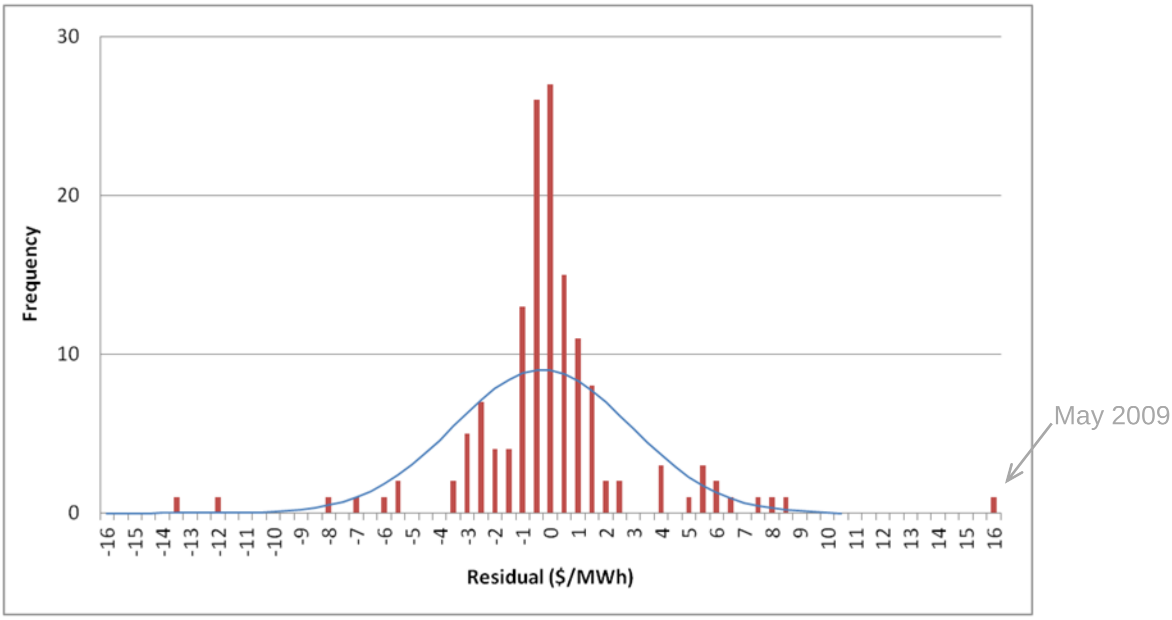
Appendix C Distribution of residuals

C.1 In case any LPRTG members are interested, this Appendix shows the distribution of residuals at Steps D and E of the worked example (shown in Figure 8 and Figure 9).

C.2 The residuals represent the price differences between the regional reference node (Bunnythorpe) and a suitable linear combination of prices at Otahuhu and Benmore. These are the residual locational risks that remain even after applying a suitable hedging strategy.

C.3 The residuals at Step D are inclusive of *spikes* (Figure 18).

Figure 18 Distribution of residuals in the worked example, inclusive of *spikes*

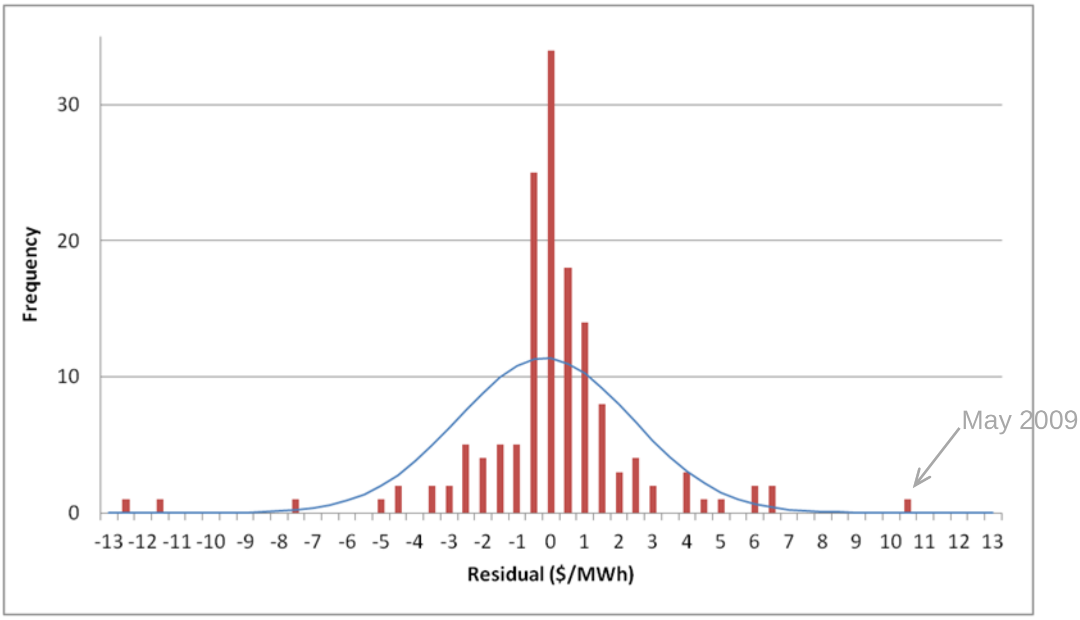


Source: New analysis based on data from Centralised Dataset, Electricity Authority

6.21 The distribution is fat-tailed. The rightmost point *(representing greatest downside risk to purchasers at Bunnythorpe)* is May 2009, a month notable for North Island price spikes.

6.22 The residuals at Step E are exclusive of spikes (Figure 19).

Figure 19 Distribution of residuals in the worked example, exclusive of *spikes*



Source: New analysis based on data from Centralised Dataset, Electricity Authority

6.23 Even without spikes, the distribution is fat-tailed – with the right-hand tail *(representing downside risk to purchasers at Bunnythorpe)* including February and March 2008, January 2009, May and June 2009.

6.24 In the latter three cases, the mean price at Benmore had largely collapsed (to $10/MWh, $4/MWh and $33/MWh respectively), but the Otahuhu price was higher (at $37/MWh, $42/MWh and $61/MWh respectively), and the Bunnythorpe price was only slightly less than Otahuhu. The Bunnythorpe price was therefore substantially higher than a linear combination of Benmore and Otahuhu prices. This pattern of prices was associated with inter-island transmission constraints and would probably be less likely with Pole 3 in service.

Appendix D Division of New Zealand into regions

D.1 This Appendix shows how the Authority has divided the grid into 18 regions, for the purpose of distinguishing between *regional* and *local* WIBR.

D.2 The first step was to obtain a record of historical spot prices for each pricing node. (In this case, the period from January 2001 to March 2012 has been used.) Where prices are set at multiple voltage levels at a particular substation, one voltage level has been chosen to represent the substation.

D.3 The next step was to carry out a statistical analysis for each island, identifying groups of nodes where spot prices have typically been similar (down to a scaling factor). The technique chosen is a divisive hierarchical cluster analysis,[11] using correlation in monthly mean prices as the similarity metric. The output of this technique is a *dendrogram* or tree diagram – somewhat akin to a family tree or evolutionary tree. In the dendrogram, nodes that have had similar prices are connected closely (by horizontal bars near the bottom of the tree) and nodes that have had differing prices are connected loosely (by horizontal bars near the top of the tree). Note that the order of nodes along the x-axis (left to right) is of no significance.

D.4 Dendrograms for the North Island and South Island are shown in Figure 20.

D.5 The dendrograms have been used to derive clusters – i.e. groups of nodes that are connected closely (because they have had similar prices). This is a subjective process, in that it involves a judgement on how many clusters to form.

D.6 Each region has been defined as a single cluster, except that:

(a) some clusters contain many nodes and have been manually split up on a fairly arbitrary basis (just for presentational purposes, not because there has been substantial locational price variation within the cluster).

(b) some clusters contain very little load or generation – most of these have been merged into an adjacent region (except where their prices are very divergent from other nodes nearby).

D.7 Some nodes (e.g. Te Kowhai) were not classified appropriately by the cluster analysis because they do not have a long historical record. They have been manually reassigned to a region based on their electrical location.

D.8 Some nodes (e.g. Mangamaire) were not classified appropriately by the cluster analysis because the configuration of the grid has changed. They have been manually reassigned to a region based on the current configuration of the grid.

D.9 Other nodes (e.g. Bell's Pond) were not included in the cluster analysis (typically because they are quite new and do not have an extended record of price data). They have been manually assigned to a region.

D.10 The resulting regions are set out in Table 3. They are shown on a map of the grid in Figure 3 (which is in the main text of this paper).

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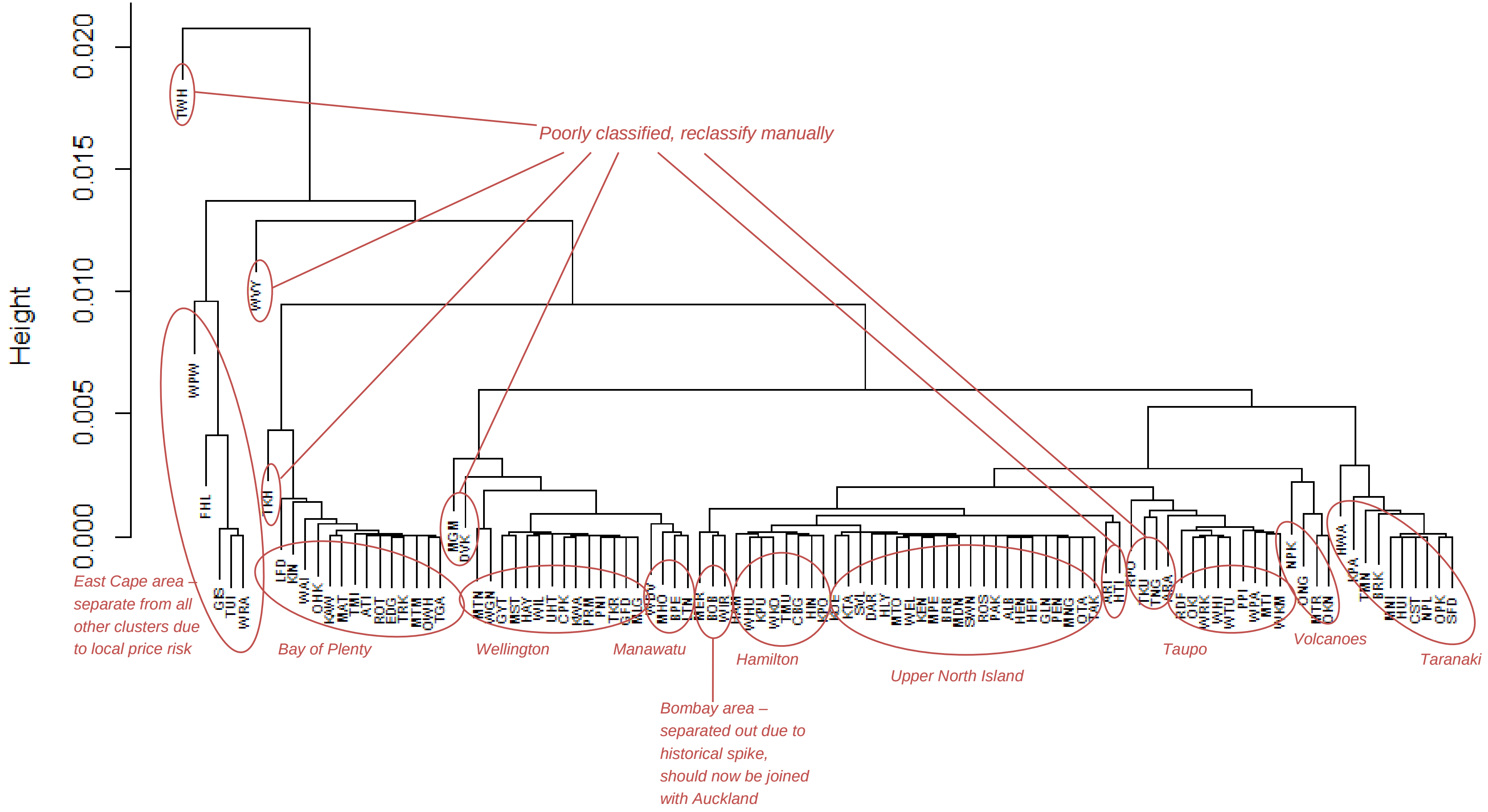
[11] This is a very standard statistical approach – see http://en.wikipedia.org/wiki/Hierarchical_clustering for some background

D.11 A reference node has been identified for each region, on an arbitrary basis (preferring, when possible, to use nodes that are commonly used as points of reference, such as Whakamaru, Bunnythorpe or Stratford)

Figure 20 Dendrograms

North Island



Poorly classified, reclassify manually

East Cape area – separate from all other clusters due to local price risk

Bay of Plenty

Wellington

Manawatu

Hamilton

Upper North Island

Taupo

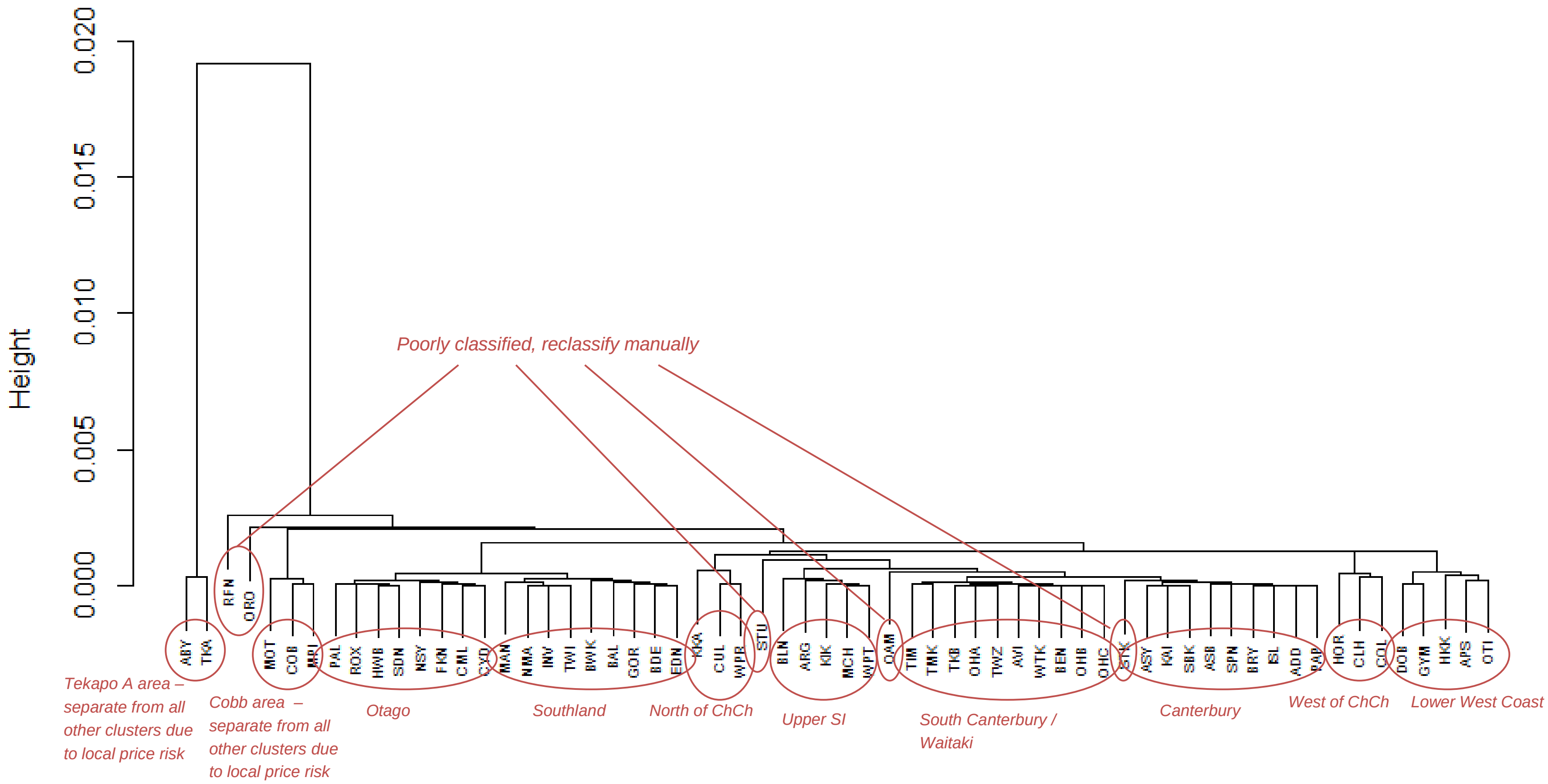
Volcanoes

Taranaki

Bombay area – separated out due to historical spike, should now be joined with Auckland

Source: New analysis based on data from Centralised Dataset, Electricity Authority

South Island



Poorly classified, reclassify manually

Tekapo A area – separate from all other clusters due to local price risk

Cobb area – separate from all other clusters due to local price risk

Source: New analysis based on data from Centralised Dataset, Electricity Authority

Table 3 Proposed regions (for the purpose of characterising WIBR)

Name	Members	Total grid-connected generation in 2011 (GWh)	Total offtake in 2011 (GWh)
Northland	**MDN**, KOE, KTA, DAR, MTO, WEL, KEN, MPE, BRB	0	1,309
Auckland	**OTA**, SVL, HLY, SWN, ROS, GLN, PAK, PEN, MNG, ALB, HEN, HEP, MER, BOB, WIR, TAK	6,853	9,627
Bay of Plenty	**TRK**, LFD, KIN, WAI, OHK, KAW, MAT, TMI, ATI, ROT, EDG, MTM, OWH, TGA, KMO, *ARI, TKH*	3,280	3,359
Hamilton	**HAM**, WHU, KPU, WKO, TMU, CBG, HIN, KPO, TWH	546	2,087
Taupo	**WKM**, ARA, OKI, WRK, WTU, PPI, WPA, MTI, RDF, WHI, NAP, *TKU, RPO, TNG*	7,806	1,590
Volcanoes	**NPK**, ONG, MTR, OKN, *HTI*	0	215
Manawatu	**BPE**, WDV, MHO, LTN, TWC, *DVK, MGM*	726	833
East Cape	**GIS**, FHL, TUI, WRA, *WPW*	505	651
Taranaki	**SFD**, HWA, KPA, TMN, BRK, OPK, NPL, MNI, CST, HUI	1,857	950
Wellington	**HAY**, MTN, WGN, GYT, MST, WIL, UHT, CPK, KWA, PRM, PNI, TKR, GFD, MLG, WWD, *WVY*	496	3,349
Motueka	**MOT**, COB, MPI	195	127
Upper South Island	**MCH**, BLN, STK, ARG, KIK, WPT, RFN, ORO, *ATU, DOB*	50	1,225
Lower West Coast	**GYM**, HKK, APS, OTI, KUM	0	133
Canterbury	**ISL**, ASY, KAI, SBK, ASB, SPN, BRY, ADD, PAP, MLN, *HOR, CLH, COL, KKA, CUL, WPR*	252	3,986
South Canterbury	**BEN**, TIM, TMK, TKB, OHA, TWZ, AVI, WTK, OHB, OHC, OAM, STU, BPD, BPT	7,418	895
Tekapo	**TKA**, ABY	157	26
Otago	**HWB**, PAL, ROX, SDN, NSY, FKN, CML, CYD	3,555	1,254
Southland	**INV**, MAN, NMA, TWI, BWK, BAL, GOR, BDE, EDN	4,865	6,477

Notes:

1. The reference node for each region is shown in **bold**.
2. Nodes tentatively assigned to regions are shown in *italics*.