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# Nodal Price Variation in the New Zealand Electricity Market

PIONEER GENERATION

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**Disclaimer**

# 1 Executive summary

The New Zealand spot market for electricity currently has a large number of pricing nodes given the size of the market.[1] Having a large number of nodes provides better locational price-signalling. However, the complexity of the electricity pricing system increases with more nodes.

This report provides an empirical investigation into the likely materiality of the pricing information that would be lost if the number of pricing nodes was reduced. Our work considers a sample of historical prices and provides an analysis of the extent to which prices have varied between the nodes. Our analysis is preliminary and we test only a representative sample of pricing nodes in the country over a twelve month period.

From our empirical analysis we find that 'inter-regional' price variation was significant, with an obvious distinction between North Island and South Island prices. The data provides a clear indication that a single pricing node for the country would result in too much lost pricing information to be efficient. However, within some parts of the two islands prices were similar enough to consider aggregating some pricing nodes into pricing zones.

Our upper North Island analysis indicates that at least two pricing zones could be created in that area with minimal loss of price information: an 'Auckland pricing zone' and a 'Northland pricing zone'. A more conservative interpretation of materiality may not lead to the same degree of aggregation but it is clear some pricing nodes over the period we considered have virtually indistinguishable prices: Glenbrook, Takanini, Pakuranga, Southdown and Otahuhu is one such grouping in Auckland, as is Marsden and Bream Bay in Northland.

Our upper South Island analysis is less clear as pricing nodes are more dispersed and price variation is more significant. However, in the upper South Island there is also an indication that some node groupings such as a 'Nelson-Blenheim pricing zone' and a 'West Coast pricing zone' also contained immaterial price variation.

Further and more detailed analysis would be required in order to determine the best path forward and different interpretations of 'materiality' will impact the appropriate level of aggregation. However, overall our analysis indicates there is likely to be some scope for reducing the number of pricing nodes in the country without materially impacting locational pricing signals.

[1] The NZ market has 259 pricing nodes. Electricity Authority, "Options to improve retail competition: Findings of the spot market review," Discussion Paper, 12 February 2015, para 3.3.

# 2 Purpose

Pioneer Generation has engaged TDB Advisory (TDB) to undertake an initial empirical investigation of the current nodal pricing system in the New Zealand electricity market. The purpose of this report is to test the amount of price variation between selected nodes at different points around the country. We aim to test the expectation that price differences will be materially[2] different across regions but relatively stable within at least some regions. In order to test this hypothesis we use a representative sample of pricing nodes and trading periods in a two-step process in order to identify whether certain nodes can be aggregated into regional pricing zones without a loss of material pricing information.

In principle, some current pricing nodes could be amalgamated into a single pricing zone without having a material negative impact on the benefits of price signalling if the price variation between the nodes is small enough. We test price variation within two zones in the New Zealand electricity market: the upper North Island and the upper South Island. Our hypothesis is that prices at nodes located within close proximity to one another will be quite similar. Price differences across regions are expected to exhibit far more variability due to transmission constraints and losses. We test these assumptions below using historic price data.

# 3 Methodology

In order to test price variation around the country we have taken a representative sample of half-hourly final prices for a twelve-month period, ending 30 September, 2014. We test the degree of price variation that has occurred across New Zealand's electricity market both 'intra-regionally' and 'inter-regionally'. To do so we run three distinct sets of price comparisons:

- the upper North Island zone: Otahuhu is the initial reference node against which we compare the price of twenty other pricing nodes in the region;
- the upper South Island zone: Stoke is the initial reference node against which we compare the price of seventeen other pricing nodes in the region; and
- inter-regional analysis: Otahuhu is the reference node against which we compare the price of a selection of ten other pricing nodes from around the country.

The price measures we calculate and present for both the inter-regional and intra-regional analysis include:

[2] Our assessment of 'materiality' is discussed in section 3.3 below.

- mean price;
- mean difference;
- mean difference / mean reference price;
- mean absolute difference;
- 90th percentile of the absolute difference;
- percentage of absolute difference observations greater than 10% of the reference node mean (adjusted for location factors)
- maximum absolute difference; and
- maximum price.

We assess the significance of price variation on the basis of mean price difference and the dispersion of price differences (using the mean absolute price difference and 90% percentile of the absolute difference results). We are testing whether prices across nodes in close proximity are similar enough to warrant merging groups of current nodes into a single pricing node. The more similar prices are the less important it is to have distinct pricing nodes because the signalling effect will be weak. If prices at nodes are not materially different on average or if the differences are not sufficiently dispersed to warrant concern, we consider it reasonable to look at grouping nodes into a single price point on a regional basis. Typically we should expect pricing nodes that are very close to one another to be priced similarly: barring major transmission constraints there should be very little difference in the transmission losses because electricity travels a similar distance to arrive at nodes in close proximity.

### 3.1 Node selection

Due to the large number of pricing nodes in New Zealand, we have selected a subset of nodes as a representative sample of the population.

Otahuhu (OTA2201) is a main reference node in the New Zealand electricity market. Otahuhu is also a grid reference node for New Zealand electricity futures listed on the ASX[3] so we use this node as a reference node for the upper North Island region. Originally, TDB was presented with a list of 42 potential nodes for 'intra-regional' analysis. This list contained pricing data for multiple nodes within the same neighborhood, for instance 5 nodes in the Otahuhu area and 4 nodes in the Penrose area. In such cases where the pricing data was very similar, we deemed it appropriate to reduce the sample size and use one node per area. Our analysis of price variation in the Auckland region can therefore be considered fairly conservative: there will be some price differences in the region even less material than the price differences presented in this report.

[3] Australian Stock Exchange website: Energy derivatives, New Zealand Electricity 2014.

Stoke (STK2201) is a pricing node we use in the inter-regional analysis. We have therefore used this node as the reference node in the upper South Island region.

In the situation where there were multiple pricing nodes in an area we have used the following criteria to select one node per area.

- all nodes must have a minimum of 2 years of complete data[4]; and
- when there are multiple nodes for one area, the node with the highest location factor was selected (unless this node is a main reference node).

Below is a table detailing the names of the particular nodes utilised in the 'intra-regional' analysis in the upper North Island region.

**Table 1: 'Intra-regional' pricing nodes – upper North Island**

| **Otahuhu: OTA2201 (Reference node)** | | | | |
|---|---|---|---|---|
| Albany: ALB0331 | Henderson: HEN0331 | Marsden: MDN2201 | Pakuranga: PAK0331 | Southdown: SWN2201 |
| Bombay: BOB0331 | Hepburn Road: HEP0331 | Mangere: MNG0331 | Penrose: PEN0221 | Takanini: TAK0331 |
| Bream Bay: BRB0331 | Kensington: KEN0331 | Maungatapere: MPE1101 | Mount Roskill: ROS0221 | Wellsford: WEL0331 |
| Glenbrook: GLN0331 | Kaikohe: KOE1101 | Maungaturoto: MTO0331 | Silverdale: SVL0331 | Wiri: WIR0331 |

Below is a table detailing the names of the particular nodes utilised in the 'intra-regional' analysis in the upper South Island region.

**Table 2: 'Intra-regional' pricing nodes – upper South Island**

| **Stoke: STK2201 (Reference node)** | | | | |
|---|---|---|---|---|
| Arthur's Pass: APS0111 | Cobb: COB0661 | Kikiwa: KIK0111 | Motupipi: MPI0661 | Westport: WPT0111 |
| Argyle: ARG1101 | Dobson: DOB0331 | Kumara: KUM0661 | Orowaiti: ORO1101 | |
| Atarau: ATU1101 | Greymouth: GYM0661 | Murchison: MCH0111 | Otira: OTI0111 | |
| Blenheim: BLN0331 | Hokitika: HKK0661 | Motueka: MOT0111 | Reefton: RFN1101 | |

The particular nodes used in the 'inter-regional' analysis were selected based on their location: combined they provide a representative sample of pricing nodes across the country. Below is a table detailing the names of the particular nodes utilised in the 'inter-regional' analysis of price variation.

[4] All nodes must have a minimum of 2 years of complete data to be included in either 'intra-regional' or 'inter-regional' analysis.

Table 3: 'Inter-regional' pricing nodes

| Otahuhu: OTA2201 (Reference node) | | | | |
|---|---|---|---|---|
| Benmore: BEN2201 | Haywards: HAY2201 | Invercargill: INV2201 | Stoke: STK2201 | Tuai: TUI2201 |
| Halfway Bush: HWB2201 | Huntly: HLY2201 | Islington: ISL2201 | Stratford: SFD2201 | Whakamaru: WKM2201 |

Maps with the selected nodes highlighted can be found in Appendix 1.

## 3.2 Measures of price variation

We use a number of aggregated measures of price variation. In comparing two nodes we attempt to capture average price difference and also a measure of spread. In considering whether two nodes are similar enough in price to become a single pricing node it is important that prices are not materially different. For example, regular price variation, such as a price difference of -$20 per MWH one trading period and +$20 per MWH the next trading period needs to be considered in conjunction with a mean price calculation to determine the degree of price signalling that would be lost by merging pricing nodes.

### Mean price

The mean price is a simple measure of average price that allows for a quick comparison with other pricing nodes. We use mean prices to calculate the location factors for each node.

### Mean price difference

The mean price difference is the primary measure of the variation in price. This measures the average difference in price between two nodes over the course of a year.

**Mean price difference / mean reference price**

This statistic measures the mean price difference as a percentage of the mean reference node price. It is equivalent to the location factor[5], a term often used in the electricity industry indicating the cost differences between nodes, which we also report. This measure will be a key statistic in making an assessment on the materiality of price differences.

**Mean absolute price difference**

The mean absolute price difference provides us with an indication of how far prices at one node differ from the reference node regardless of the direction: positive or negative. If the market was made up of a static set of customers that regularly purchased a standardised quantity of electricity each trading period our only concern would be mean price differences: price variation would be of little concern in such a market if all the variation washed out over time. However, different market participants may make different generation or purchase decisions depending on the time of day and the time of year and an accurate price signal is important in a fluid market. Although a regular price difference of -$15 per MWH at one time of day or time of the year may be effectively 'cancelled out' by a regular price difference of +$15 per MWH during a separate set of trading periods, these differences may be affecting different customers or generators. The mean absolute price difference is our first measure of dispersion.

**90th percentile of the absolute difference**

This measure provides another indication of the dispersion of observations. It is a simple statistic that indicates the price difference within which 90% of the data falls. It does not provide a complete picture of the dataset but this measure indicates whether the majority of the price difference are clustered together or significantly more spread out. The greater the dispersion observed in the dataset the more important price signalling through distinct pricing nodes becomes.

**Percentage of absolute difference observations greater than 10% of the reference node mean (adjusted for location factors)**

This measure is a test of the 'percentage of outliers' and focuses exclusively on dispersion. We take the price difference between a node and the reference node and then subtract the mean difference to adjust for the location factor. We then take the absolute value and calculate the percentage of observations that are greater than 10% of the mean reference node price. We are testing whether, having taken into account the mean difference,

[5] Location factors for each node are reported in Appendix 3.

price differences are tightly concentrated or dispersed. It is a conservative measure as a difference of 10% of the mean price is relatively small to be considered an ‘outlier’.

**Maximum absolute difference and maximum price**

These two measures provide a quick indication of two extremes: how high market prices can reach and the extent to which prices can vary between two pricing nodes.

**Other statistics**

Appendix 3 contains additional statistical measures.

### 3.3 Materiality

The statistics we provide in the tables below are a positive, factual account of prices and price variation at the various nodes we assess. This analysis can be used to answer whether price variation is more significant across regions than within regions. However, in order to assess whether prices at nodes within close proximity to one another are similar enough to justify merging into a single pricing node we have to make a judgment about the materiality of the price difference.

The price variations we observe need to be considered in two ways:

- average difference; and
- spread.

The first test of price variation is to compare mean prices: over time what is the extent of the price difference we observe across two nodes. Mean prices at nodes around the country range from $60 in the South Island to $75 in the north of the North Island. A mean price difference of a few cents is immaterial while one of $100 is clearly significant.

It is important that we do not dismiss important price signals as unnecessary simply because mean prices over a long period happen to be quite similar. We have included a number of measures of spread because the typical measure, standard deviation, is largely uninformative given the skewed datasets that are typically observed in the New Zealand electricity market with very large outliers. In the New Zealand electricity market it is not uncommon to have large price outliers resulting from constraints and shocks to the system. We therefore consider price variation material if the prices at nodes regularly diverge even if over time mean prices are fairly similar.

Our test of materiality is a subjective one that must make a judgment by taking into account mean (average) differences and the relative dispersion (spread) of data. We consider mean price differences of less than around 3% of the reference node mean price to be immaterial. This is equivalent to a location factor of 1.03.

An 'immaterial' degree of price dispersion is more difficult to determine. However, our judgments below are based on a combined consideration of mean absolute price differences, the 90$^{th}$ percentile of absolute price differences, the percentage of outliers (defined as the percentage of observations diverging by more than 10% of the reference node mean once adjusted for mean price difference) and the maximum price difference.

### 3.4 Assessment

We first test the hypothesis that nodes at different points around the country have material price differences. This is our 'inter-regional' test and Otahuhu as the reference node is compared with ten other nodes spread around both the North Island and the South Island.

For the 'intra-regional' tests we group nodes into zones based on the materiality of price variations relative to the reference node. Pricing nodes in the same zone as the reference node will be classed as such because they exhibit limited price variation. Those nodes that exhibit material price variation will be considered 'out of zone'. The first set of tests will provide an indication of how we might group 'out of zone' nodes.

For the second phase of our 'intra-regional' tests we rerun price difference calculations based on new reference nodes in order to test the appropriateness of our initial groupings. We calculate the same measures of price variation against new reference nodes within each new zone.

In those areas where price variation is minimal we suggest indicative pricing zones that could have nodes amalgamated into a single pricing point without a material loss in the benefits of price signalling.

# 4 Findings

In this section we present our findings and group nodes into indicative regional pricing zones.

## 4.1 'Inter-regional' summary

We first test price variation across the country. Table 4 below summarises the price variation of several nodes around the country in relation to Otahuhu. There is a general trend that electricity, on average, becomes more expensive the further north a node is in New Zealand (as you get further from the major source of generation and losses are higher because of this distance).

**Table 4: Summary of 'inter-regional' price variation**

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| HLY-OTA | $70 | -$0.96 | -1.3% | $0.97 | $1.63 | 0.69% | $334 | $9,342 |
| WKM-OTA | $69 | -$2.34 | -3.3% | $2.35 | $4.19 | 1.38% | $807 | $8,870 |
| TUI-OTA | $67 | -$3.72 | -5.2% | $4.31 | $8.22 | 6.11% | $1,760 | $8,526 |
| SFD-OTA | $68 | -$3.07 | -4.3% | $3.53 | $6.66 | 4.29% | $682 | $8,995 |
| HAY-OTA | $67 | -$3.83 | -5.4% | $4.96 | $9.39 | 11.82% | $962 | $8,715 |
| STK-OTA | $66 | -$5.46 | -7.7% | $10.61 | $21.77 | 39.39% | $2,155 | $9,120 |
| ISL-OTA | $64 | -$7.32 | -10.3% | $10.92 | $21.66 | 41.07% | $2,158 | $8,871 |
| BEN-OTA | $60 | -$10.76 | -15.1% | $12.34 | $24.08 | 46.27% | $2,163 | $8,016 |
| HWB-OTA | $61 | -$10.03 | -14.1% | $14.10 | $27.06 | 49.36% | $2,167 | $7,940 |
| INV-OTA | $62 | -$8.99 | -12.6% | $14.50 | $27.95 | 49.09% | $2,169 | $8,062 |
| **Otahuhu** | **$71** | | | | | | | **$9,677** |

Huntly is in relatively close proximity to Otahuhu and there is very little price variation between the two nodes. On average over the twelve months to September 2014, the price at Huntly was a mere 1.3% less than the price at Otahuhu with 90% of price differences less than $1.63/MWh. In contrast, towards the bottom of the South Island mean price differences were as great as -15.1% and -14.1% at Benmore and Halfway Bush respectively.

Even at other nodes in the North Island mean price differences were above $3. Almost 12% of the time prices at Haywards and Otahuhu differed by more than 10% of Otahuhu's mean price once adjusted for the mean price difference. Towards the bottom of the South Island prices diverged from Otahuhu's by at least 10% almost as often as they did not.

The data confirms our expectation that price variation across different regions of the country is material. Individual pricing nodes play an important role in price signalling as different locations around the country often experience divergences in price. At one point the price difference between Otahuhu and the South Island was over $2,000.

### 4.2 'Intra-regional' summary - upper North Island phase 1

Table 5 below summarises the price variation measures for the upper North Island in relation to Otahuhu. We tested the price variation of twenty pricing nodes in the upper North Island against Otahuhu. The region covers a significant area ranging from Glenbrook and Bombay in the south of Auckland to Kaikohe in the upper North Island.

**Table 5: Summary of upper North Island region – phase 1**

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| KOE-OTA | $75 | $3.83 | 5.4% | $3.90 | $6.38 | 2.67% | $746 | $10,423 |
| KEN-OTA | $74 | $3.02 | 4.2% | $3.08 | $5.32 | 1.80% | $716 | $10,393 |
| MPE-OTA | $74 | $2.63 | 3.7% | $2.69 | $4.59 | 1.39% | $588 | $10,265 |
| BRB-OTA | $73 | $1.70 | 2.4% | $1.77 | $2.92 | 0.75% | $378 | $10,055 |
| MDN-OTA | $73 | $1.57 | 2.2% | $1.64 | $2.72 | 0.74% | $362 | $10,039 |
| MTO-OTA | $74 | $3.00 | 4.2% | $3.07 | $5.39 | 2.57% | $713 | $10,389 |
| WEL-OTA | $74 | $2.93 | 4.1% | $3.00 | $5.78 | 2.68% | $759 | $10,436 |
| SVL-OTA | $72 | $0.68 | 1.0% | $0.76 | $1.24 | 0.38% | $206 | $9,883 |
| ALB-OTA | $72 | $0.64 | 0.9% | $0.71 | $1.18 | 0.38% | $223 | $9,899 |
| HEN-OTA | $72 | $0.47 | 0.7% | $0.54 | $0.93 | 0.34% | $212 | $9,889 |
| HEP-OTA | $72 | $0.59 | 0.8% | $0.67 | $1.17 | 0.37% | $288 | $9,965 |
| ROS-OTA | $72 | $0.72 | 1.0% | $0.79 | $1.41 | 0.41% | $308 | $9,985 |
| PEN-OTA | $72 | $0.46 | 0.6% | $0.53 | $0.97 | 0.33% | $93 | $9,770 |
| SWN-OTA | $71 | $0.04 | 0.0% | $0.12 | $0.10 | 0.25% | $28 | $9,682 |
| PAK-OTA | $71 | $0.03 | 0.0% | $0.11 | $0.13 | 0.25% | $28 | $9,677 |
| MNG-OTA | $71 | $0.24 | 0.3% | $0.32 | $0.56 | 0.27% | $98 | $9,775 |
| WIR-OTA | $72 | $0.70 | 1.0% | $0.78 | $1.28 | 0.35% | $820 | $9,807 |
| TAK-OTA | $71 | -$0.05 | -0.1% | $0.10 | $0.10 | 0.25% | $28 | $9,688 |
| GLN-OTA | $71 | $0.12 | 0.2% | $0.21 | $0.37 | 0.24% | $28 | $9,678 |
| BOB-OTA | $72 | $1.19 | 1.7% | $1.27 | $2.17 | 0.59% | $790 | $9,940 |
| **Otahuhu** | **$71** | | | | | | | **$9,677** |

The nodes are ordered geographically in Table 5 above and a clear distinction is evident between Wellsford and Silverdale. Mean differences range from -$0.05 to $1.19 (-0.1% to 1.7% of Otahuhu's mean price) south of Wellsford, while from Wellsford north mean price differences are as high as $3.83 (5.4%) and no lower than $1.57 (2.2%). The analysis indicates that prices between Bombay and Silverdale are relatively stable in comparison to Otahuhu. However, from Wellsford north a clear divergence in prices from Otahuhu emerges.

The measures of spread also support a geographical separation around Wellsford/Silverdale: the 90$^{th}$ percentile and percentage-of-outliers statistics indicate that the Northland pricing nodes exhibit much greater dispersion of price differences than those south of Wellsford. Wellsford, Kaikohe and Maungaturoto are of note with over 2.5% of observations diverging by more than 10% of Otahuhu's mean price once adjusted for mean price difference.

We therefore break the region into two 'zones': an Auckland zone and a Northland zone. A far more conservative assessment of the data may not be comfortable with this level of aggregation: Bombay and Wiri stand out as potential outliers from the rest of the Auckland zone. There has been an occasion where price differences from Otahuhu reached $790 at Bombay and $820 at Wiri. Transpower has also called for demand response from curtailment service providers around these nodes. There may be a case for maintaining Bombay and Wiri as separate nodes until constraint issues around Otahuhu have been improved.

However, even the most conservative interpretation of the data would suggest that some degree of amalgamation could be made without any material loss. Glenbrook, Takanini, Pakuranga and Southdown all have prices virtually indistinguishable from Otahuhu: Glenbrook had the highest mean price difference of $0.12 and at the most extreme point of the year prices did not diverge from Otahuhu by more than $28.

It is worth noting that we excluded pricing nodes that were very closely grouped together, for example, in Penrose and Otahuhu. The scope for aggregating pricing nodes is therefore likely to be understated by our analysis.

### 4.3 Intra-regional' summary - upper North Island phase 2

In the second phase of our analysis we re-test the 'out-of-zone' nodes against a new reference node to confirm whether it is appropriate to group them together. Table 6 below presents price variation statistics for the Northland region tested against a new reference node: Marsden. The 'Auckland zone' presented below remains unchanged from Table 5 above.

Table 6: Summary of upper North Island region – phase 2

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| KOE-MDN | $75 | $2.26 | 3.1% | $2.27 | $3.53 | 1.23% | $524 | $10,423 |
| KEN-MDN | $74 | $1.45 | 2.0% | $1.45 | $2.60 | 0.55% | $354 | $10,393 |
| MPE-MDN | $74 | $1.06 | 1.5% | $1.06 | $1.84 | 0.29% | $226 | $10,265 |
| BRB-MDN | $73 | $0.13 | 0.2% | $0.13 | $0.21 | 0.01% | $16 | $10,055 |
| MTO-MDN | $74 | $1.43 | 2.0% | $1.50 | $2.83 | 1.29% | $351 | $10,389 |
| WEL-MDN | $74 | $1.36 | 1.9% | $1.48 | $3.30 | 1.24% | $397 | $10,436 |
| SVL-OTA | $72 | $0.68 | 1.0% | $0.76 | $1.24 | 0.38% | $206 | $9,883 |
| ALB-OTA | $72 | $0.64 | 0.9% | $0.71 | $1.18 | 0.38% | $223 | $9,899 |
| HEN-OTA | $72 | $0.47 | 0.7% | $0.54 | $0.93 | 0.34% | $212 | $9,889 |
| HEP-OTA | $72 | $0.59 | 0.8% | $0.67 | $1.17 | 0.37% | $288 | $9,965 |
| ROS-OTA | $72 | $0.72 | 1.0% | $0.79 | $1.41 | 0.41% | $308 | $9,985 |
| PEN-OTA | $72 | $0.46 | 0.6% | $0.53 | $0.97 | 0.33% | $93 | $9,770 |
| SWN-OTA | $71 | $0.04 | 0.0% | $0.12 | $0.10 | 0.25% | $28 | $9,682 |
| PAK-OTA | $71 | $0.03 | 0.0% | $0.11 | $0.13 | 0.25% | $28 | $9,677 |
| MNG-OTA | $71 | $0.24 | 0.3% | $0.32 | $0.56 | 0.27% | $98 | $9,775 |
| WIR-OTA | $72 | $0.70 | 1.0% | $0.78 | $1.28 | 0.35% | $820 | $9,807 |
| TAK-OTA | $71 | -$0.05 | -0.1% | $0.10 | $0.10 | 0.25% | $28 | $9,688 |
| GLN-OTA | $71 | $0.12 | 0.2% | $0.21 | $0.37 | 0.24% | $28 | $9,678 |
| BOB-OTA | $72 | $1.19 | 1.7% | $1.27 | $2.17 | 0.59% | $790 | $9,940 |
| Marsden | $73 | | | | | | | $10,039 |
| Otahuhu | $71 | | | | | | | $9,677 |

It appears from Table 6 above that the Northland region could be considered a single pricing zone without a material loss in pricing information. Kaikohe is the one potential outlier with a mean price difference of 3.1%. The nodes south of Kaikohe have small mean price differences ranging from

0.2% to 2.0%. However, although the mean price difference is $2.26 the majority of price differences at Kaikohe are less than $3.53 (the 90th percentile for Kaikohe) which is only marginally higher than Wellsford's 90th percentile price difference, $3.30. In addition, the percentage of outliers at Kaikohe (those price differences greater than 10% of Marsden's mean price adjusted for the mean difference) is 1.27%. This figure is slightly lower than both Wellsford and Maungaturoto. In addition, the analysis above is conservative in that Marsden has the lowest mean price in the Northland region: in using Marsden as the reference node and comparing it to the highest-priced node in the region, Kaikohe, the price difference is somewhat overstated. The price differences between Kaikohe and the rest of the region are less severe than detailed in Table 6 above.

In judging 'materiality' one must make a judgment call: our indicative assessment of price variation suggests no material loss in price signalling would occur if the region north of Bombay was amalgamated into two regional pricing zones: an 'Auckland zone' and a 'Northland zone'. As mentioned above, a more conservative perspective may be opposed to this degree of aggregation but some clear price similarities emerge:

- prices at Marsden and Bream Bay are virtually indistinguishable;
- a Kaikohe-Kensington-Maungatapere-Maungaturoto-Wellsford zone would have even less price variation than the suggested Northland zone;
- various cuts of the Auckland zone could be made to further minimise the loss of price signalling while still allowing for the amalgamation of some pricing nodes; and
- the nodes most-similarly priced have been excluded from this particular analysis.

Bombay has the highest price differences relative to Otahuhu in the Auckland zone. These are relatively small yet we tested the price differences between Bombay and a couple of nodes to the south: Huntly and Hamilton. Bombay's prices were more similar to other nodes in the Auckland region than those further south, so we consider it appropriate to leave Bombay in the Auckland zone.[6]

## 4.4 Intra-regional' summary - upper South Island phase 1

Table 7 below summarises the price variation measures for the upper South Island in relation to Stoke. We tested the price variation of seventeen pricing nodes in the upper South Island against Stoke. The region covers a significant area ranging from Arthur's Pass, located between Canterbury and the West Coast, to Motupipi and Blenheim in the upper South Island.

[6] Appendix 2 includes further details of this analysis.

Table 7: Summary of upper South Island region – phase 1

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| MPI-STK | $64 | -$1.88 | -2.9% | $2.81 | $4.79 | 3.63% | $409 | $8,711 |
| COB-STK | $62 | -$3.53 | -5.4% | $4.13 | $7.32 | 6.19% | $657 | $8,463 |
| MOT-STK | $66 | -$0.13 | -0.2% | $1.09 | $2.32 | 1.44% | $80 | $9,075 |
| BLN-STK | $67 | $1.24 | 1.9% | $1.24 | $2.24 | 0.46% | $189 | $9,309 |
| ARG-STK | $66 | $0.11 | 0.2% | $0.21 | $0.29 | 0.25% | $14 | $9,134 |
| KIK-STK | $65 | -$0.36 | -0.5% | $0.36 | $0.60 | 0.02% | $64 | $9,055 |
| MCH-STK | $66 | $0.68 | 1.0% | $0.68 | $1.35 | 0.41% | $98 | $9,218 |
| ORO-STK | $67 | $1.50 | 2.3% | $1.50 | $2.68 | 0.73% | $191 | $9,311 |
| WPT-STK | $67 | $1.64 | 2.5% | $2.13 | $3.40 | 1.33% | $248 | $9,367 |
| RFN-STK | $65 | $1.29 | 2.0% | $1.29 | $2.54 | 0.75% | $175 | $9,294 |
| ATU-STK | $67 | $1.63 | 2.5% | $1.72 | $4.15 | 2.03% | $114 | $9,179 |
| DOB-STK | $68 | $1.81 | 2.8% | $2.11 | $5.45 | 2.97% | $133 | $9,100 |
| GYM-STK | $67 | $1.68 | 2.6% | $2.27 | $5.75 | 3.48% | $137 | $9,042 |
| KUM-STK | $65 | -$0.41 | -0.6% | $3.17 | $5.95 | 8.59% | $538 | $8,582 |
| HKK-STK | $66 | -$0.23 | -0.4% | $3.68 | $7.18 | 13.70% | $622 | $8,497 |
| OTI-STK | $64 | -$2.16 | -3.3% | $3.75 | $6.96 | 9.10% | $814 | $8,306 |
| APS-STK | $63 | -$2.77 | -4.2% | $3.83 | $7.07 | 8.18% | $871 | $8,248 |
| Stoke | $66 | | | | | | | $9,120 |

The nodes are ordered geographically in Table 7 above and in the first phase of our testing all price comparisons are with Stoke. The volume of electricity consumed in the region is far lower than the concentrated hub of Auckland. The nodes are more dispersed and price variations follow less of a pattern than in the upper North Island. Notably, mean prices are consistently considerably lower at all South Island pricing nodes compared with North Island pricing nodes.

The first test of the data is to consider which pricing nodes fall within the Stoke zone and which should be considered 'out-of-zone'. A case could be made for amalgamating all the pricing nodes from Motueka down to Hokitika as all mean prices are between -0.6% and 2.8% of Stoke's mean price. However, while mean price differences from Stoke at Kumara and Hokitika are a mere -0.6% and -0.4% respectively, the dispersion of price differences generally increases as the nodes move further away from Stoke. For example, at Hokitika 13.7% of absolute price differences are greater than 10% of Stoke's mean price and Dobson, Greymouth and Kumara all have a 90$^{th}$ percentile price difference above $5.

Within close proximity to Stoke the data indicates a 'Nelson-Blenheim zone' could be formed without materially affecting price signals. This zone would include Motueka, Blenheim, Argyle, Kikiwa, Murchison and Stoke. Mean price differences wihin this zone range from -0.5% to 1.9%. While Motueka has a higer percentage of outliers (1.44%) and Blenheim has a higher maximum price difference ($189) neither of these statistics seem to warrant exclusion from the zone. Blenheim could be maintained as a separate pricing node on the east coast if this was a concern.

Cobb and Motupipi (the 'Golden Bay zone') stand out as a zone distinct from the Nelson-Blenheim region. Both nodes, Cobb in particular, have noticeably lower mean prices and significantly greater price variation than other nodes around Stoke. The similarity of price differences in the region encompassing Orowaiti, Westport, Reefton, Atarau, Dobson and Greymouth indicate a 'West Coast zone' could be created. We test the appropriateness of these two zones in phase 2 below.

The remaining four nodes - Kumura, Hokitika, Otira and Arthur's Pass – will be tested against a few different reference nodes to determine the most appropriate grouping for these four nodes.

## 4.5 Intra-regional' summary - upper South Island phase 2

**Table 8: Summary of upper South Island region – phase 2**

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| MPI-COB | $64 | $1.65 | 2.7% | $1.65 | $2.90 | 0.89% | $248 | $8,711 |
| MOT-STK | $66 | -$0.13 | -0.2% | $1.09 | $2.32 | 1.44% | $80 | $9,075 |
| BLN-STK | $67 | $1.24 | 1.9% | $1.24 | $2.24 | 0.46% | $189 | $9,309 |
| ARG-STK | $66 | $0.11 | 0.2% | $0.21 | $0.29 | 0.25% | $14 | $9,134 |
| KIK-STK | $65 | -$0.36 | -0.5% | $0.36 | $0.60 | 0.02% | $64 | $9,055 |
| MCH-STK | $66 | $0.68 | 1.0% | $0.68 | $1.35 | 0.41% | $98 | $9,218 |
| ORO-DOB | $67 | -$0.30 | -0.4% | $1.59 | $2.93 | 0.96% | $211 | $9,311 |
| WPT-DOB | $67 | -$0.18 | -0.3% | $1.76 | $2.68 | 1.06% | $268 | $9,367 |
| RFN-DOB | $65 | -$0.39 | -0.6% | $1.41 | $2.76 | 0.57% | $194 | $9,294 |
| ATU-DOB | $67 | -$0.18 | -0.3% | $0.67 | $1.38 | 0.17% | $79 | $9,179 |
| GYM-DOB | $67 | -$0.13 | -0.2% | $0.39 | $0.60 | 0.31% | $58 | $9,042 |
| KUM-DOB | $65 | -$2.22 | -3.3% | $2.53 | $4.44 | 4.18% | $518 | $8,582 |
| HKK-DOB | $66 | -$2.05 | -3.0% | $2.80 | $5.12 | 5.01% | $603 | $8,497 |
| OTI-DOB | $64 | -$3.97 | -5.9% | $4.21 | $7.72 | 6.27% | $794 | $8,306 |
| APS-DOB | $63 | -$4.59 | -6.8% | $4.69 | $8.61 | 6.06% | $852 | $8,248 |
| Cobb | $62 | | | | | | | $8,463 |
| Stoke | $66 | | | | | | | $9,120 |
| Dobson | $68 | | | | | | | $9,100 |

The table above presents the results of regrouping the upper South Island nodes into four zones – one at Golden Bay; one around Stoke; one on the West Coast; and one other. The 'West Coast zone' appears to be a natural grouping of nodes: mean price differences are minimal varying from -$0.39

in Reefton to -$0.13 in Greymouth. This variation is generally lower than that observed in both the Auckland and Northland zones analysed above. However, mean absolute price differences are somewhat higher relative to mean price differences in the West Coast region. The price differences tend to fluctuate from positive to negative, unlike the consistency seen in the upper North Island. However, the highest 90$^{th}$ percentile price difference is no greater than $2.93 and Westport is the only node where the percentage of outliers marginally exceeds 1%. This dispersion is relatively minimal and is less than that observed in the Northland zone. In conjunction with the low mean differences we therefore suggest that a 'West Coast zone' would not result in a material loss of price signalling.

Motupipi and Cobb are distinct from the 'Nelson-Blenheim zone'. When compared to one another there is some difference between the two: the mean price difference is $1.65 (2.7%) but it is probably not high enough to require them to be treated as separate pricing nodes. Motupipi is consistently priced above the GIP at Cobb and so the mean absolute price difference is also $1.65 with 90% of observations within $2.90 and only 0.89% of the price differences are outliers. With minimal dispersion in the data and relatively low electricity volumes in the region, we consider a 'Golden Bay pricing zone' reasonable.

We then test the remaining four nodes against the same reference node as the 'West Coast zone' – Dobson – as detailed in Table 8 above. Mean price differences are even greater than when compared against Stoke with all mean price differences in excess of 3%. Our measures of spread stand out as well with the 90$^{th}$ percentile figures, the percentage of outliers and maximum prices all considerably higher than those within the 'West Coast zone'.

The next test in Table 9 below considers whether Hokitika, Kumara, Otira and Arthur's Pass could be grouped as a distinct zone.

**Table 9: Summary of analysis with Kumara as reference node**

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| HKK-KUM | $66 | $0.18 | 0.3% | $0.74 | $1.48 | 0.50% | $85 | $8,497 |
| OTI-KUM | $64 | -$1.76 | -2.7% | $1.87 | $3.11 | 2.48% | $276 | $8,306 |
| APS-KUM | $63 | -$2.37 | -3.6% | $2.51 | $4.00 | 3.37% | $334 | $8,248 |
| Kumara | $65 | | | | | | | $8,582 |

It is clear that Hokitika and Kumara have very similar prices with a mean price difference or 0.3% and minimal variation. Otira and Arthur's Pass still stand out as distinct nodes, however. Table 10 presents a comparison of Otira and Arthur's Pass with Islington to test whether the nodes can be grouped as part of a Christchurch zone.

**Table 10: Comparison of Otira and Arthur's Pass with Islington**

| Summary Statistics | Mean Price | Measure of Average Difference | | Measure of Spread | | | | Maximum Price |
|---|---|---|---|---|---|---|---|---|
| | | Mean Difference | Percentage Difference | Mean Absolute Difference | 90th Percentile | Percentage of Outliers | Maximum Absolute Difference | |
| OTI- ISL | $64 | -$0.29 | -0.5% | $3.39 | $6.87 | 11.90% | $565 | $8,306 |
| APS-ISL | $63 | -$0.91 | -1.4% | $3.25 | $6.38 | 10.51% | $622 | $8,248 |

Although mean differences are relatively low (-$0.29 for Otira and -$0.91 for Arthur's Pass) there is a huge amount of price variation: in excess of 10% of the observations for both nodes are 'outliers'. Grouping these two nodes with Christchurch would not be appropriate as a great deal of pricing information would be lost.

Overall in relation to the upper South Island there appears to be two relatively clear zones: a ‘Nelson-Blenheim zone’ and a ‘West Coast zone’. Beyond this we have some small outliers: a ‘Golden Bay zone’ including Cobb and Motupipi; a ‘Southern West Coast zone’ including Hokitika and Kumara and an ‘Arthur’s Pass zone’ including Otira and Arthur’s Pass.

A more liberal interpretation of ‘materiality’ could see further aggregation of nodes, while a more conservative perspective might desire less. However, our indicative analysis suggests that some form of pricing node amalgamation can be made without a material loss in pricing information. Our suggested boundaries are somewhat arbitrary but are intended to be indicative only. Further analysis is required to determine the appropriate regional groupings and we suggest that if a more amalgamated pricing system were adopted it would be necessary to continually review the pricing zones.

# 5 Conclusions

This report considers the current nodal pricing situation in the New Zealand electricity market. Our work provides an initial empirical analysis of historical prices to consider the extent to which prices have in practice varied between the nodes.

Currently there are 259 pricing nodes. The nodes correspond directly to physical points of connection on the transmission grid. This is in fairly stark contrast to the pricing system adopted, for example, in the National Electricity Market in Australia where each state has a single pricing node (with a location factor). New Zealand has a locational marginal pricing system that determines nodal prices by taking into account the relevant energy prices and transmission congestion costs.

In principle, New Zealand could have anywhere from a single pricing node to thousands of nodes. Having more nodes provides a clearer and more accurate picture of the costs of generating and transmitting electricity to different parts of the country. The greater the transparency of the costs of supply in the market the better we would expect generators and electricity purchasers to make decisions based on the cost of supply to different places in the country. An accurate locational pricing signal allows the market to effectively respond to constraints and for Transpower to identify and encourage reduced electricity usage during demand response events.

At some point, however, the locational-based pricing system could become so disaggregated that it is overly complicated and the market becomes highly illiquid at some pricing nodes, making the price at that node irrelevant. With too many pricing nodes, operating in and coordinating the market may become an excessively costly exercise. In addition, the degree of competition in the market may decline as the complexity of the system becomes a barrier to entry and only large incumbents are capable of managing the complexity.

There is therefore a tradeoff when determining the ‘optimal’ number of nodes between price-signalling accuracy and the additional transaction costs that arise with the increasing complexity of the electricity pricing system. Our empirical tests are intended to provide an indication of one aspect of that tradeoff: i.e. how much pricing variation is there in practice in the current system. If, for example, we observe large discrepancies in prices between nodes in relatively close proximity then it may be appropriate to increase the number of pricing nodes. If on the other hand, groups of pricing nodes exhibit only immaterial price variations then it would appear that little price signalling information would be lost if the nodes were amalgamated into a single price point.

Our aim is to determine whether there would be a material loss in pricing information from a reduction in nodes. We test the degree of price variation of a representative sample of pricing nodes from across the country and within the upper North Island and upper South Island regions over the course of the most recent year ending September 2014. We calculate average price differences and measures of price dispersion to inform our materiality tests and indicative regional zones. We test price variation relative to reference nodes within each region to determine whether we can identify zones that exhibit minimal price variation.

We find, firstly, that price variation across the country for the period we reviewed was significant, with a clear distinction between North Island and South Island prices. Although in theory a single pricing node for the country is possible the data suggests that too much pricing information would be lost for this to be efficient. There was also evidence of material price variation between other major nodes across the country, such as between Otahuhu and Haywards. However, within the two regions we tested it appears that some form of pricing node aggregation would not result in a material loss in price signalling.

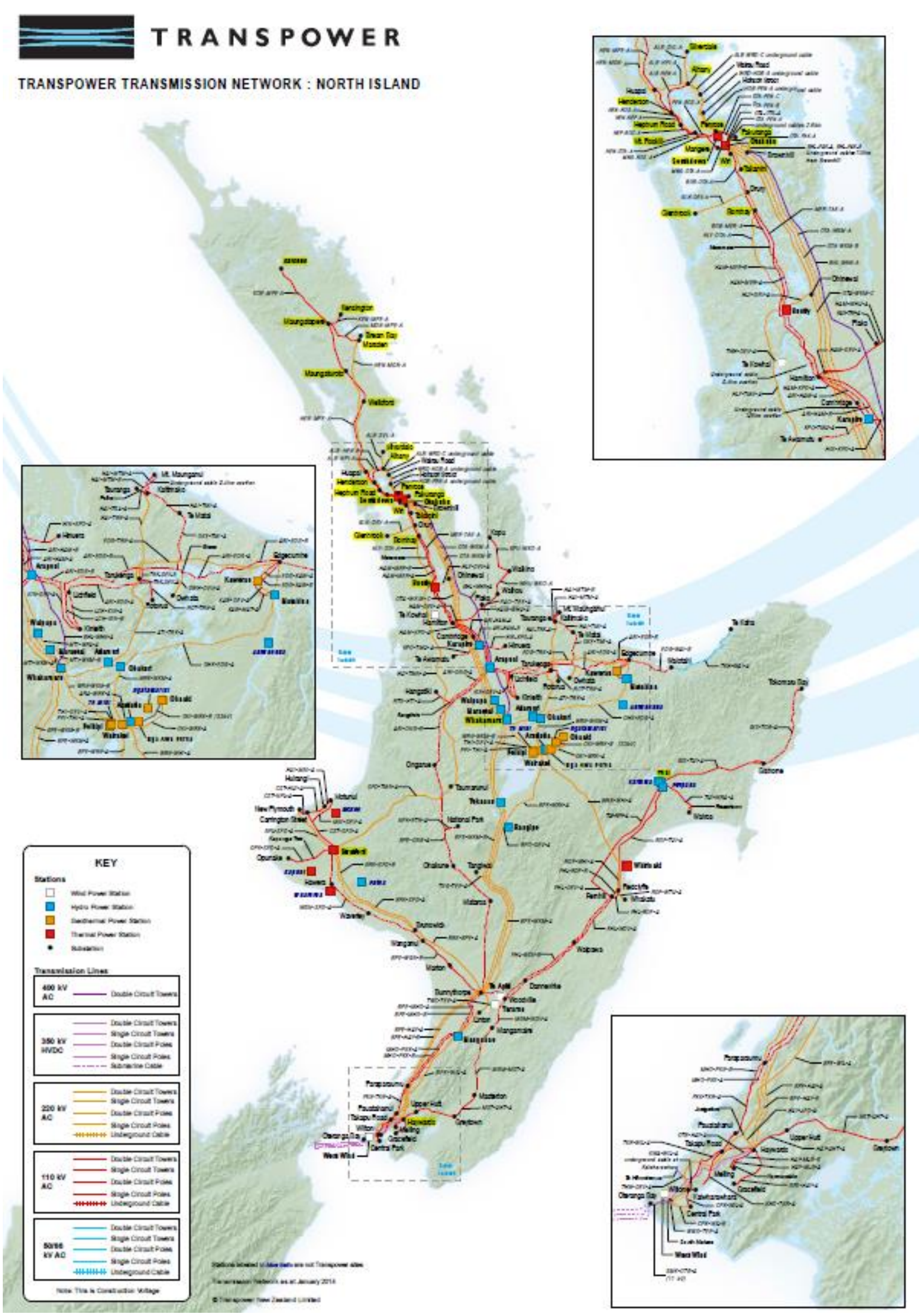
In the upper North Island our findings indicate that an ‘Auckland pricing zone’ and a ‘Northland pricing zone’ may be able to be created with minimal loss of price information. A more conservative interpretation of materiality may not lead to pricing nodes being aggregated to this extent but it is immediately clear that some nodes had virtually indistinguishable prices: Glenbrook, Takanini, Pakuranga, Southdown and Otahuhu is one such grouping in Auckland, as is Marsden and Bream Bay in Northland.

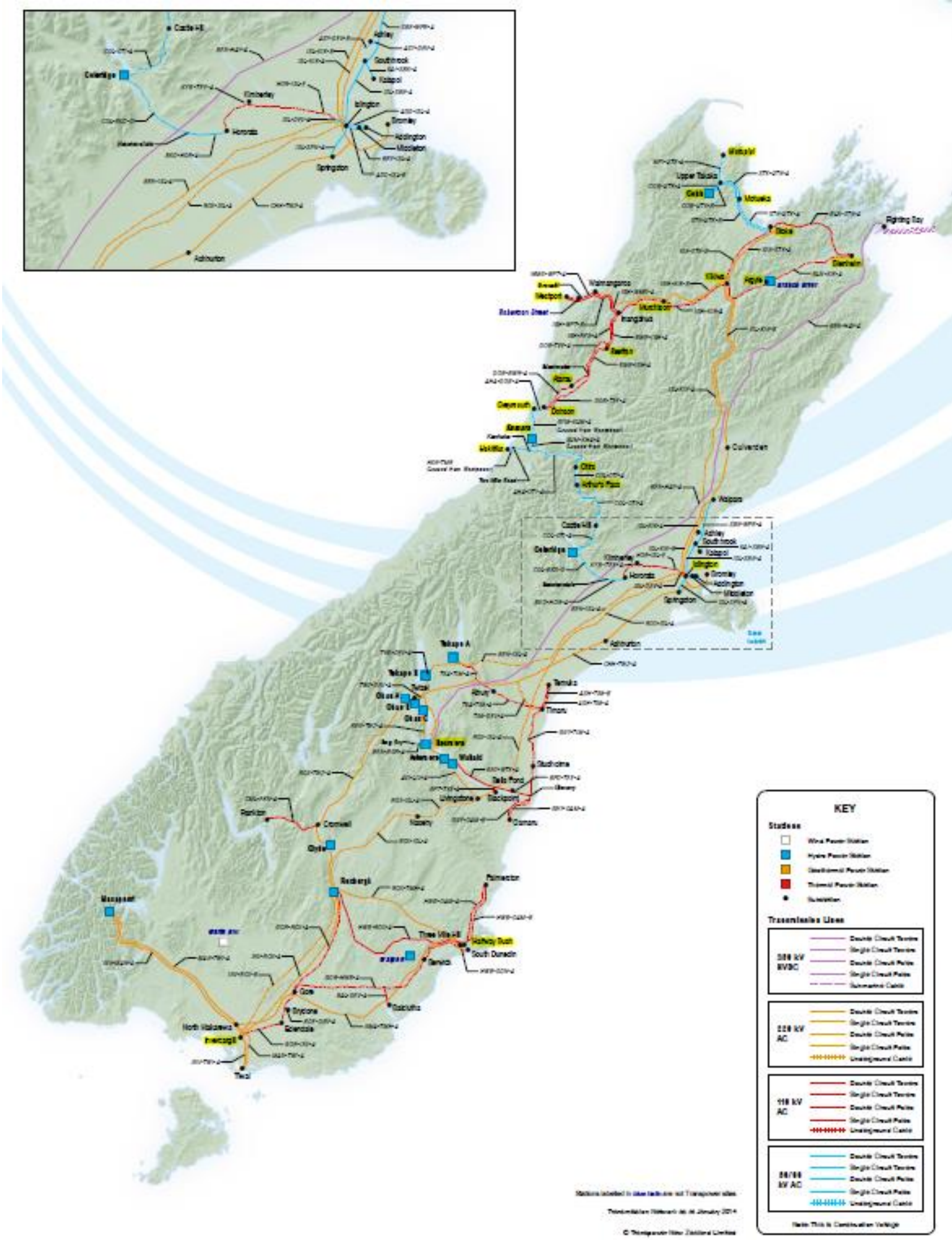
Nodes in the upper South Island are more dispersed but a ‘Nelson-Blenheim pricing zone’ and a ‘West Coast pricing zone’ also appear to be logical candidates for amalgamation based on the immaterial price variation we observed between the nodes. Separately, Kumara and Hokitika, Arthur’s Pass and Otira, and Cobb and Motupipi are groupings that exhibited fairly similar prices.

As stated above, we test only a representative sample of the data and our results are indicative only. Further and more detailed analysis would be required in order to determine the best path forward. A more liberal interpretation of ‘materiality’ than we have adopted could see even further aggregation of pricing nodes than we have suggested here.

Overall, based on our initial analysis, it seems possible that there is scope for a reduction in the number of pricing nodes without materially impacting the accuracy or meaningfulness of the pricing signals. If multiple grid connection points were aggregated into single pricing nodes we suggest regular reviews of the pricing zones should be carried out to account for transmission changes, new generation, changes in demand and supply, the removal of constraints and other factors impacting the electricity industry.

# Appendix 1: Pricing node selection




Castle Hill
Coleridge
Kimberley
Hororata
Ashley
Southbrook
Kaiapoi
Islington
Bromley
Addington
Middleton
Springston
Ashburton
Upper Takaka
Cobb
Motueka
Stoke
Fighting Bay
Blenheim
Kikiwa
Argyle
Waimangaroa
Westport
Murchison
Inangahua
Reefton
Greymouth
Dobson
Kumara
Hokitika
Otira
Arthurs Pass
Culverden
Waipara
Tekapo A
Tekapo B
Twizel
Ohau A
Ohau B
Ohau C
Benmore
Aviemore
Waitaki
Albury
Temuka
Timaru
Studholme
Bells Pond
Livingstone
Glenavy
Oamaru
Naseby
Cromwell
Frankton
Clyde
Roxburgh
Manapouri
Palmerston
Three Mile Hill
Halfway Bush
South Dunedin
Berwick
Gore
Brydone
Edendale
Balclutha
North Makarewa
Invercargill
Tiwai
KEY
Stations
Wind Power Station
Hydro Power Station
Geothermal Power Station
Thermal Power Station
Substation
Transmission Lines
350 kV HVDC
220 kV AC
110 kV AC
66/50 kV AC
Double Circuit Towers
Single Circuit Towers
Double Circuit Poles
Single Circuit Poles
Submarine Cable
Underground Cable
Stations labelled in blue italic are not Transpower sites.
Transmission Network as at January 2014
© Transpower New Zealand Limited

# Appendix 2: Bombay analysis

In relation to other nodes located within close proximity to Otahuhu, Bombay's pricing node exhibited larger price differences. We therefore compared the price data of Bombay with price data from Hamilton and Huntly to test whether Bombay would be better suited to a 'Hamilton pricing zone'. The results are presented below:

**Table 11: Summary of Bombay and reference nodes**

| Summary Statistics | Mean Price | Median Price | Highest Price | Locational Factor |
|---|---|---|---|---|
| BOB0331 | $72 | $64 | $9,940 | 1.02 |
| HLY2201 | $70 | $62 | $9,342 | 0.99 |
| HAM0331 | $71 | $62 | $9,363 | 1.00 |
| OTA2201 | $71 | $63 | $9,677 | 1.00 |

**Table 12: Summary of price comparisons to Bombay**

| Summary Statistics | Mean Absolute Difference | Median Absolute Difference | Highest Absolute Difference |
|---|---|---|---|
| BOB-HAM | $1.65 | $1.10 | $783 |
| BOB-HLY | $2.15 | $1.62 | $787 |
| BOB-OTA | $1.27 | $0.95 | $790 |

The mean price difference between Bombay and Otahuhu ($.127) is somewhat lower than the two nodes to the south: Huntly ($2.15) and Hamilton ($1.65). The Bombay pricing node most appropriately fits with the 'Auckland pricing zone'.

# Appendix 3: Other summary measures

Additional summary statistics for the ‘inter-regional’ analysis and the ‘intra-regional’ analysis can be found below. The additional measures provided are:

**2014 Location Factors**

The location factor provides an indication of the extent to which mean prices vary. It is calculated by dividing mean price at one pricing node by the mean price of the reference node. For example, a locational factor of 1.01 indicates that on average prices are 1% higher than prices at the reference node.

**Median price comparisons**

The measures below involving median price are similar to those calculated using mean prices discussed in section 3.2 above. The median price avoids the distortion to the measures of the mean that results from the few trading periods where electricity prices can reach as high as $10,000.

**Standard deviation**

The standard deviation is a typical measure of spread and so we report these calculations in this appendix. However, we do not focus on this measure in the report is the standard deviation is distorted by the skewed datasets and the significant outliers that arise in the New Zealand electricity industry.

**Table 13: Further statistics for the 'inter-regional' zone**

| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| HLY-OTA | 0.99 | $62 | -$0.64 | $0.64 | $17 | -$334 | $3 | $99 |
| WKM-OTA | 0.97 | $61 | -$1.70 | $1.70 | $17 | -$807 | $8 | $95 |
| TUI-OTA | 0.95 | $60 | -$2.09 | $2.15 | $185 | -$1,760 | $24 | $90 |
| SFD-OTA | 0.96 | $60 | -$2.49 | $2.56 | $59 | -$682 | $9 | $95 |
| HAY-OTA | 0.95 | $58 | -$3.43 | $3.80 | $133 | -$962 | $12 | $92 |
| STK-OTA | 0.92 | $57 | -$3.22 | $5.97 | $194 | -$2,155 | $29 | $96 |
| ISL-OTA | 0.90 | $55 | -$4.74 | $6.40 | $184 | -$2,158 | $29 | $93 |
| BEN-OTA | 0.85 | $53 | -$7.58 | $7.85 | $165 | -$2,163 | $32 | $85 |
| HWB-OTA | 0.86 | $52 | -$7.92 | $9.43 | $190 | -$2,167 | $35 | $85 |
| INV-OTA | 0.87 | $52 | -$7.38 | $9.71 | $203 | -$2,169 | $35 | $86 |

**Table 14: Further statistics for the upper North Island – phase 1**

| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| KOE-OTA | 1.05 | $66 | $3.27 | $3.28 | $746 | -$25 | $8.81 | $110 |
| KEN-OTA | 1.04 | $65 | $2.48 | $2.49 | $716 | -$26 | $7.05 | $109 |
| MPE-OTA | 1.04 | $65 | $2.19 | $2.21 | $588 | -$26 | $5.86 | $108 |
| BRB-OTA | 1.02 | $64 | $1.48 | $1.49 | $378 | -$27 | $3.80 | $106 |
| MDN-OTA | 1.02 | $64 | $1.35 | $1.36 | $362 | -$27 | $3.64 | $106 |
| MTO-OTA | 1.04 | $65 | $2.26 | $2.28 | $713 | -$26 | $7.14 | $109 |
| WEL-OTA | 1.04 | $65 | $1.88 | $1.90 | $759 | -$25 | $7.58 | $109 |
| SVL-OTA | 1.01 | $63 | $0.58 | $0.58 | $206 | -$28 | $2.14 | $104 |
| ALB-OTA | 1.01 | $63 | $0.53 | $0.53 | $223 | -$28 | $2.22 | $104 |
| HEN-OTA | 1.01 | $63 | $0.36 | $0.36 | $212 | -$28 | $2.13 | $104 |
| HEP-OTA | 1.01 | $63 | $0.45 | $0.45 | $288 | -$28 | $2.70 | $105 |
| ROS-OTA | 1.01 | $63 | $0.53 | $0.54 | $308 | -$28 | $2.93 | $105 |
| PEN-OTA | 1.01 | $63 | $0.32 | $0.32 | $93 | -$27 | $1.33 | $103 |
| SWN-OTA | 1.00 | $63 | $0.05 | $0.05 | $18 | -$28 | $0.85 | $102 |
| PAK-OTA | 1.00 | $63 | $0.06 | $0.06 | $18 | -$28 | $0.84 | $102 |
| MNG-OTA | 1.00 | $63 | $0.18 | $0.18 | $98 | -$28 | $1.34 | $103 |
| WIR-OTA | 1.01 | $63 | $0.52 | $0.52 | $820 | -$28 | $6.60 | $104 |
| TAK-OTA | 1.00 | $63 | -$0.03 | $0.03 | $18 | -$28 | $0.84 | $102 |
| GLN-OTA | 1.00 | $63 | $0.10 | $0.11 | $18 | -$28 | $0.86 | $102 |
| BOB-OTA | 1.02 | $64 | $0.94 | $0.95 | $790 | -$28 | $6.77 | $105 |

**Table 15: Further statistics for the 'Northland pricing zone'**

| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| KOE-MDN | 1.03 | $66 | $1.86 | $1.86 | $524 | -$0.82 | $5.49 | $110 |
| KEN-MDN | 1.02 | $65 | $1.06 | $1.06 | $354 | $0.00 | $3.51 | $109 |
| MPE-MDN | 1.01 | $65 | $0.79 | $0.79 | $226 | $0.00 | $2.32 | $108 |
| BRB-MDN | 1.00 | $64 | $0.12 | $0.12 | $16 | $0.00 | $0.17 | $106 |
| MTO-MDN | 1.02 | $65 | $0.99 | $1.08 | $351 | -$5.03 | $3.74 | $109 |
| WEL-MDN | 1.02 | $65 | $0.59 | $0.70 | $397 | -$5.67 | $4.17 | $109 |

**Table 16: Further statistics for the upper South Island – phase 2**

| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| MPI-STK | 0.97 | $54 | -$2.27 | $2.45 | $76 | -$409 | $4.93 | $92 |
| COB-STK | 0.95 | $53 | -$3.73 | $3.80 | $75 | -$657 | $7.45 | $89 |
| MOT-STK | 1.00 | $56 | -$0.48 | $0.71 | $80 | -$45 | $2.10 | $96 |
| BLN-STK | 1.02 | $58 | $1.01 | $1.01 | $189 | $0 | $1.99 | $98 |
| ARG-STK | 1.00 | $57 | $0.09 | $0.10 | $14 | -$7 | $0.66 | $96 |
| KIK-STK | 0.99 | $56 | -$0.33 | $0.33 | $0 | -$64 | $0.64 | $95 |
| MCH-STK | 1.01 | $57 | $0.41 | $0.41 | $98 | -$1 | $1.42 | $97 |
| ORO-STK | 1.02 | $58 | $1.18 | $1.18 | $191 | -$1 | $2.37 | $99 |
| WPT-STK | 1.02 | $58 | $1.53 | $1.53 | $248 | -$138 | $5.90 | $99 |
| RFN-STK | 1.02 | $57 | $0.99 | $0.99 | $175 | -$1 | $2.25 | $98 |
| ATU-STK | 1.02 | $58 | $0.68 | $0.73 | $114 | -$2 | $2.67 | $97 |
| DOB-STK | 1.03 | $57 | $0.48 | $0.92 | $133 | -$20 | $3.26 | $97 |
| GYM-STK | 1.03 | $57 | $0.34 | $1.16 | $137 | -$77 | $3.65 | $97 |
| KUM-STK | 0.99 | $55 | -$0.38 | $2.23 | $85 | -$538 | $7.43 | $92 |
| HKK-STK | 1.00 | $55 | -$0.41 | $2.66 | $105 | -$622 | $8.31 | $92 |
| OTI-STK | 0.97 | $53 | -$1.79 | $2.74 | $96 | -$814 | $9.22 | $90 |
| APS-STK | 0.96 | $53 | -$2.25 | $2.96 | $100 | -$871 | $9.51 | $89 |

**Table 17: Further statistics for the upper South Island - phase 2**

| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| MPI-COB | 1.03 | $54 | $1.42 | $1.42 | $248 | $0 | $3.27 | $92 |
| ORO-DOB | 1.00 | $58 | -$0.01 | $1.34 | $211 | -$36 | $2.79 | $99 |
| WPT-DOB | 1.00 | $58 | $0.00 | $1.35 | $268 | -$138 | $6.07 | $99 |
| RFN-DOB | 0.99 | $57 | $0.00 | $1.16 | $194 | -$37 | $2.52 | $98 |
| ATU-DOB | 1.00 | $58 | $0.03 | $0.50 | $79 | -$19 | $1.18 | $97 |
| GYM-DOB | 1.00 | $57 | -$0.17 | $0.30 | $17 | -$58 | $1.10 | $97 |
| KUM-DOB | 0.97 | $55 | -$1.28 | $1.51 | $25 | -$518 | $7.20 | $92 |
| HKK-DOB | 0.97 | $55 | -$1.36 | $1.82 | $45 | -$603 | $7.77 | $92 |
| OTI-DOB | 0.94 | $53 | -$3.19 | $3.27 | $36 | -$794 | $9.12 | $90 |
| APS-DOB | 0.93 | $53 | -$3.69 | $3.71 | $41 | -$852 | $9.70 | $89 |

**Table 18: Further statistics for Hokitika, Otira and Arthur's Pass**

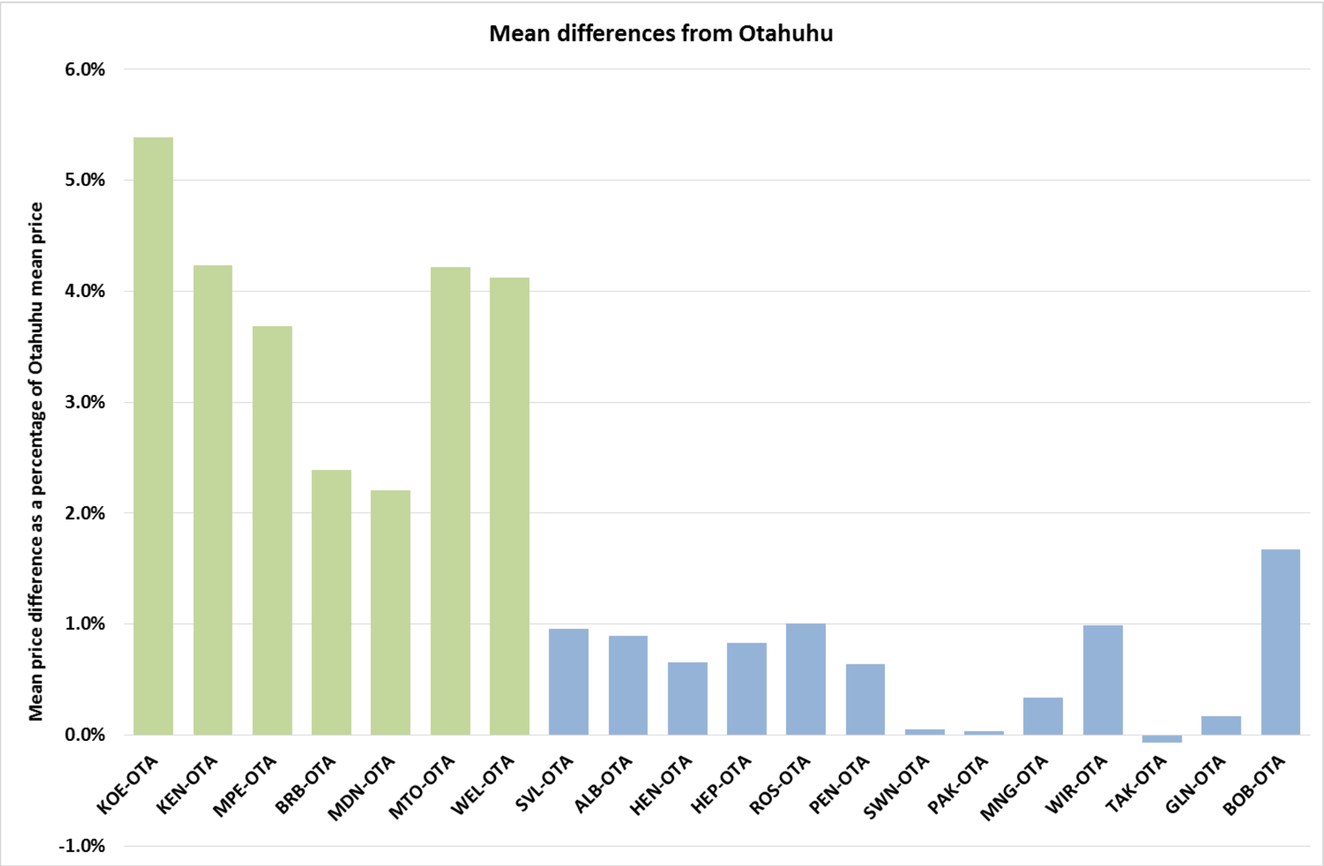
| Summary Statistics | Location Factor | Median Price | Median Difference | Median Absolute Difference | Highest +ve Difference | Highest -ve Difference | Standard Deviation of Mean Difference | Standard Deviation of Price |
|---|---|---|---|---|---|---|---|---|
| HKK-KUM | 1.00 | $55 | -$0.10 | $0.53 | $20 | -$85 | $1.35 | $92 |
| OTI-KUM | 0.97 | $53 | -$1.47 | $1.51 | $46 | -$276 | $3.61 | $90 |
| APS-KUM | 0.96 | $53 | -$1.85 | $1.88 | $52 | -$334 | $4.82 | $89 |

# Appendix 4: A graphical presentation

In order to inform the analysis presented in the tables in the report we present some of the data in graphical form below.

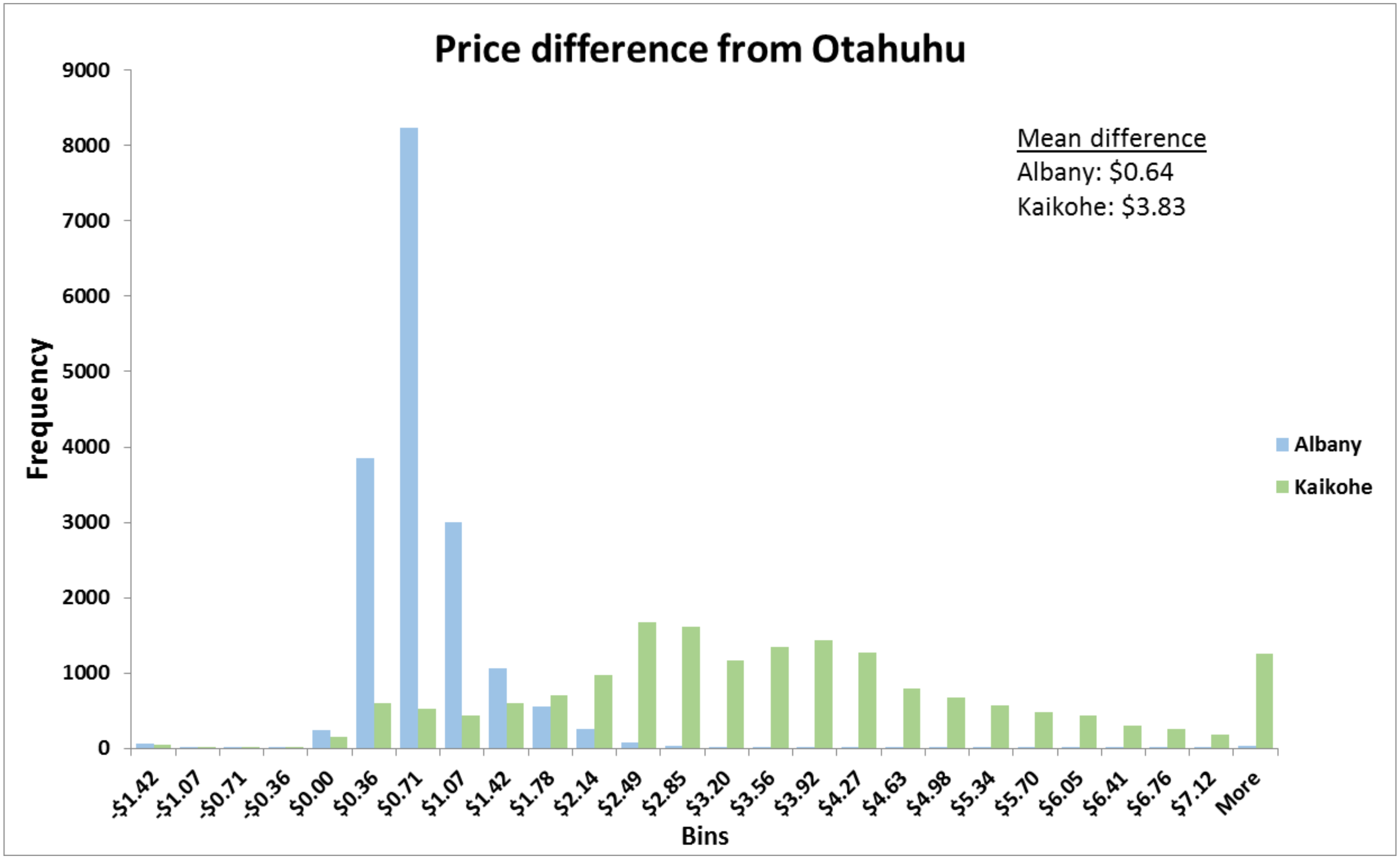
**Example of price variation measures**

Figure 1: Mean price differences – upper North Island



Our first test of price variation is to consider mean price differences. In the upper North Island there appears to be a clear distinction between the Northland region from Wellsford north, and the Auckland region from Bombay to Silverdale. In Figure 1 above the mean differences north of Silverdale stands out as a distinctly different grouping than the Auckland area. Below we consider the mean difference and dispersion tests for two nodes in detail: Kaikohe and Albany. Figure 2 provides an indication of how differently the data is shaped for Kaikohe and Albany.

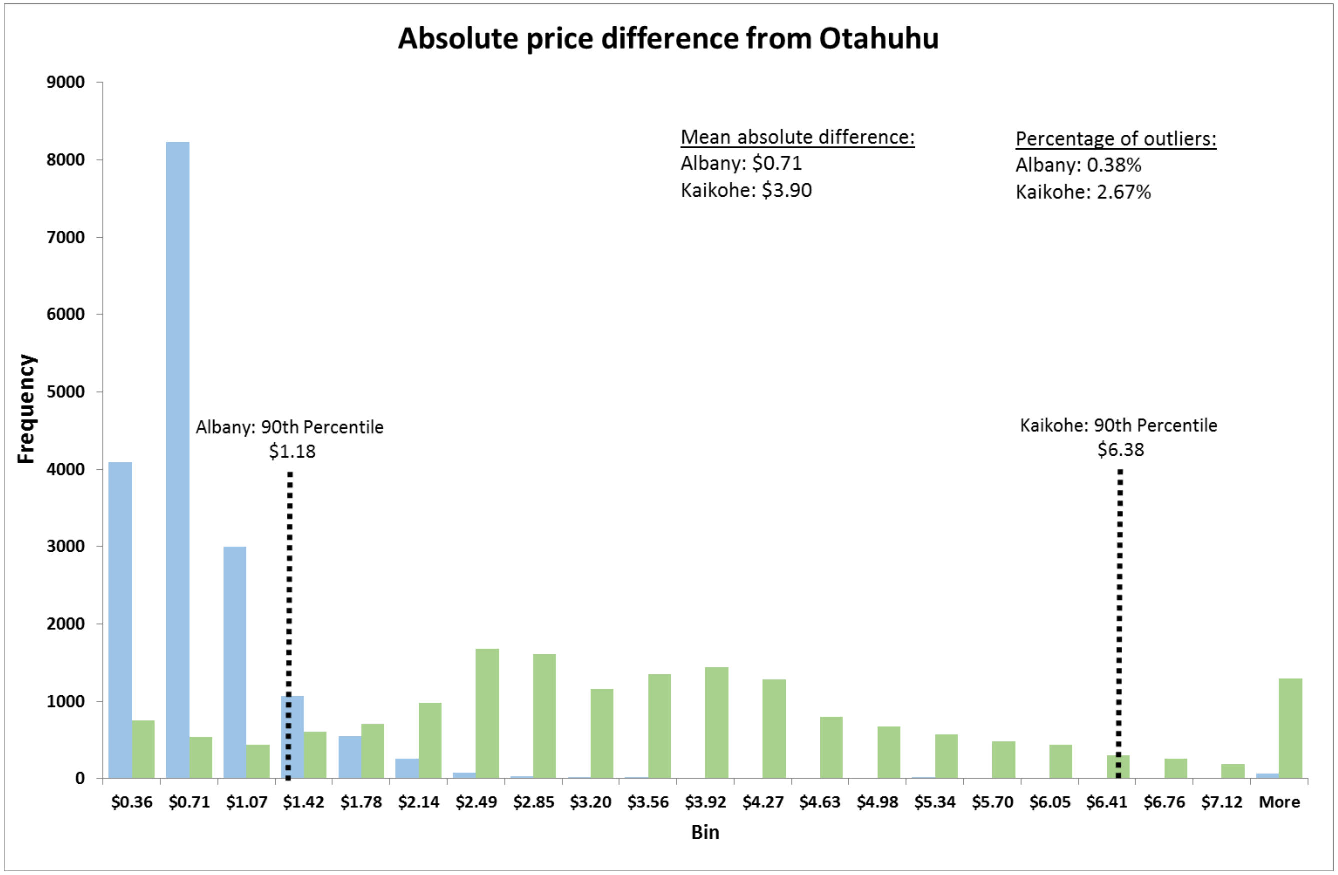
**Figure 2: Price differences from Otahuhu for two sample nodes (Albany and Kaikohe)**



The mean price difference between Albany and Otahuhu is $0.64 while Kaikohe's mean difference is significantly higher at $3.83. However, Figure 2 above also provides a good indication of dispersion: not only does Kaikohe have a significantly higher mean difference, its differences are not centred around the mean difference as they are at Albany. The case for treating Albany as 'in-zone' and Kaikohe as 'out-of-zone' becomes stronger as we consider the degree of price-difference fluctuation in addition to the overall mean difference.

Figure 3 below clarifies the measures of dispersion we report in the tables of statistics. In terms of dispersion we care about how far prices vary from the reference node, not whether they are above or below. In practice, prices are consistently higher at Albany and Kaikohe than at Otahuhu so the mean absolute price difference is only marginally higher than the mean price difference.

**Figure 3: Absolute price differences and measures of dispersion for two sample nodes (Albany and Kaikohe)**



The 90th percentile indicates the price within which the majority of the price differences fall: for Albany this is relatively small at $1.18; for Kaikohe we see that 10% of price differences from Otahuhu are greater than $6.38. Our 'percentage of outliers' calculation adjusts for the mean difference from Otahuhu and calculates the spread around the mean difference: 2.67% of price differences at Kaikohe are greater than 10% of Otahuhu's mean price compared with only 0.38% at Albany.  Although this dispersion is clearly observable graphically this is what we are trying to capture by our measures of spread. If Kaikohe had price differences tightly grouped around its $3.83 mean difference there could be a case for including it in a wider 'upper North Island' zone. However, the spread of price differences in addition to the mean difference itself clearly indicate price signalling through distinct pricing nodes has an important role in these two sections of the market.

## Additional graphs

The following graph is an example of price variation in the North and South Islands. It compares price differences between Wellsford and Otahuhu against the price differences between Hokitika and Stoke. As you can see, the price differences between Wellsford and Otahuhu are almost always positive, reflecting a consistently higher cost of electricity at Wellsford when compared to Otahuhu. In contrast, price differences between Hokitika and Stoke are to varying degrees, positive and negative.

**Figure 4: Price variation across the North and South Island regions**

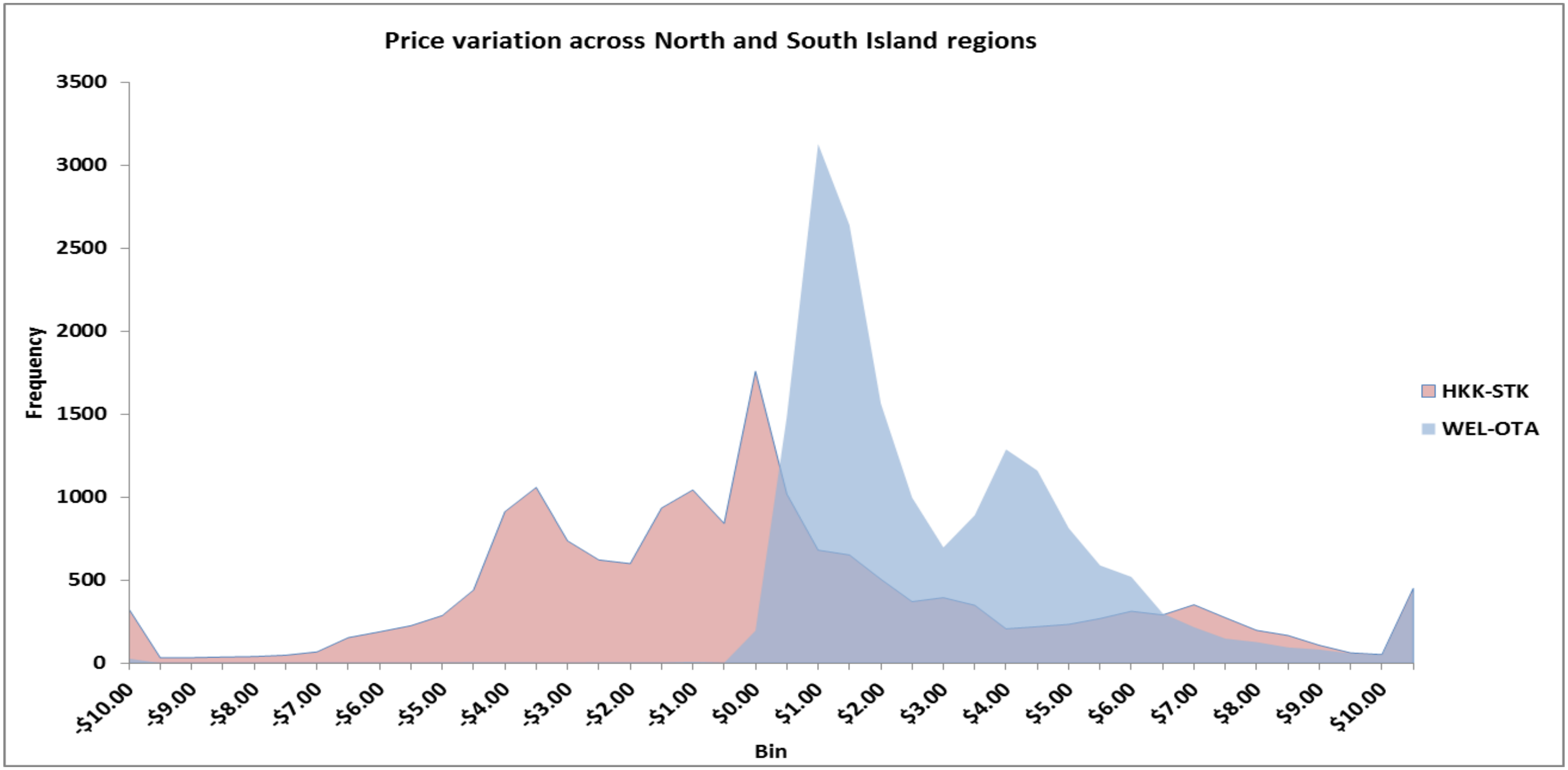


Figure 5: Comparison between 'Intra-regional' and 'Inter-regional' price differences

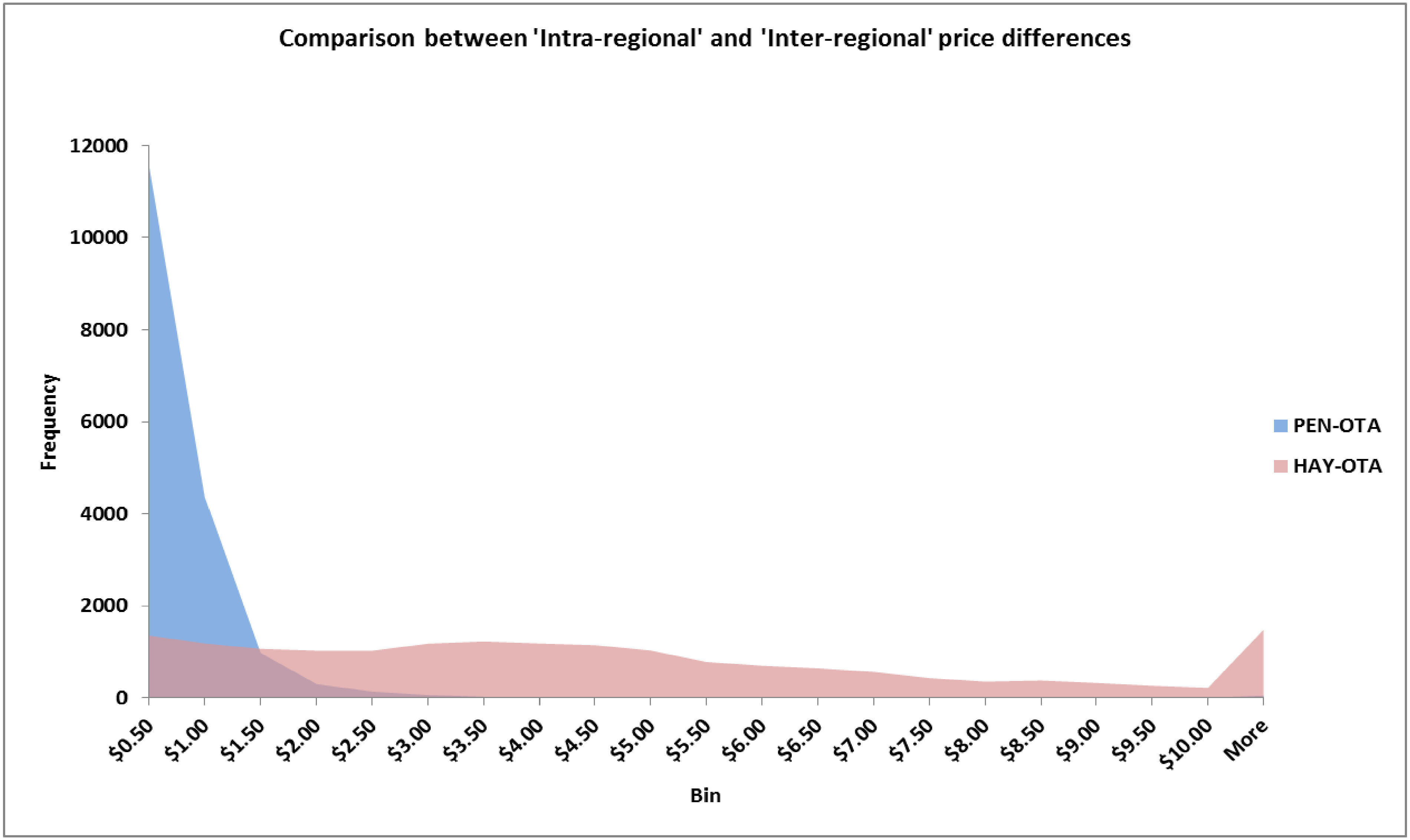


**Figure 6: Comparison between 'Intra-regional' and 'Inter-regional' price variation**

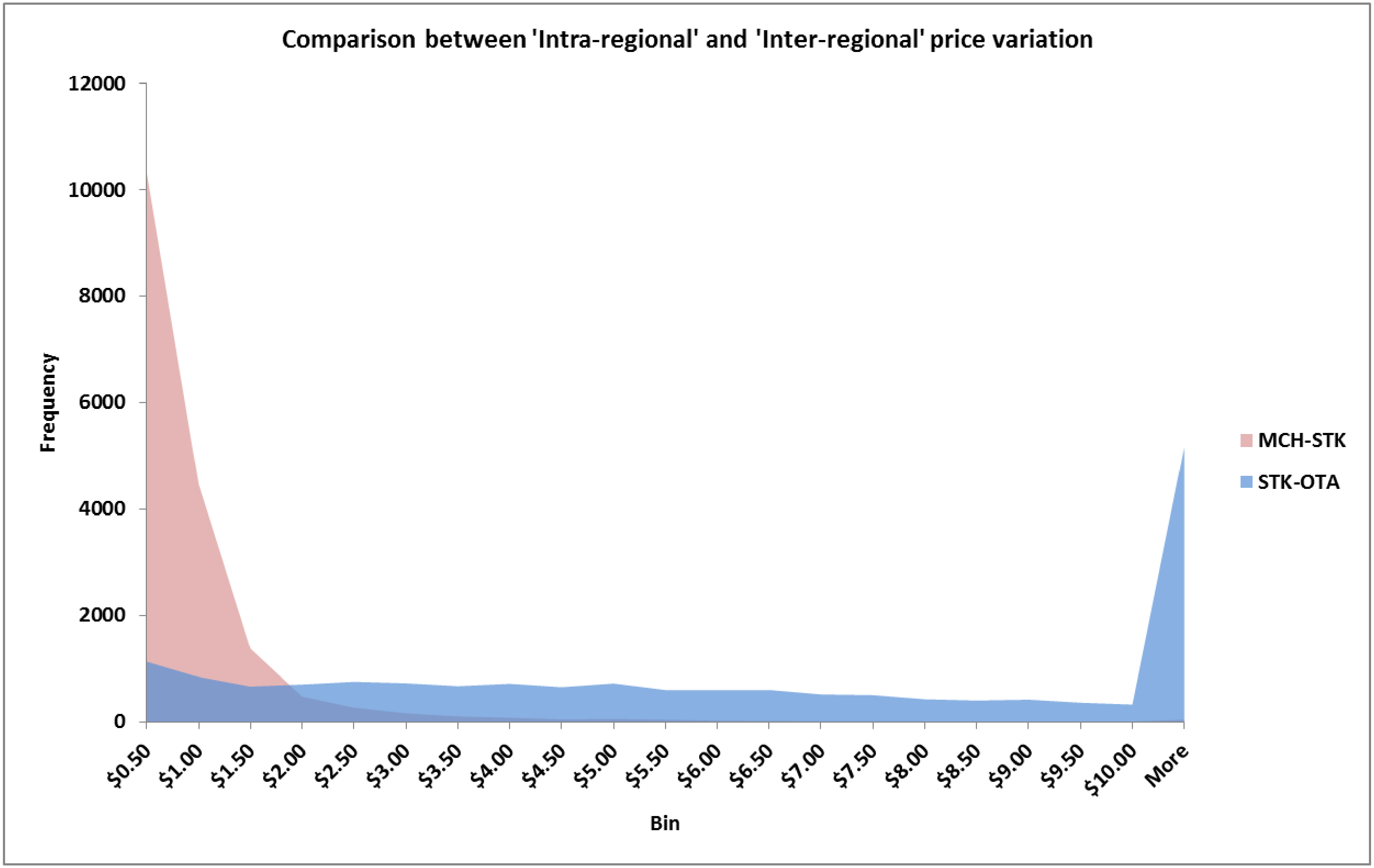


**Figure 7: Absolute differences between Bream Bay and the regional reference nodes**

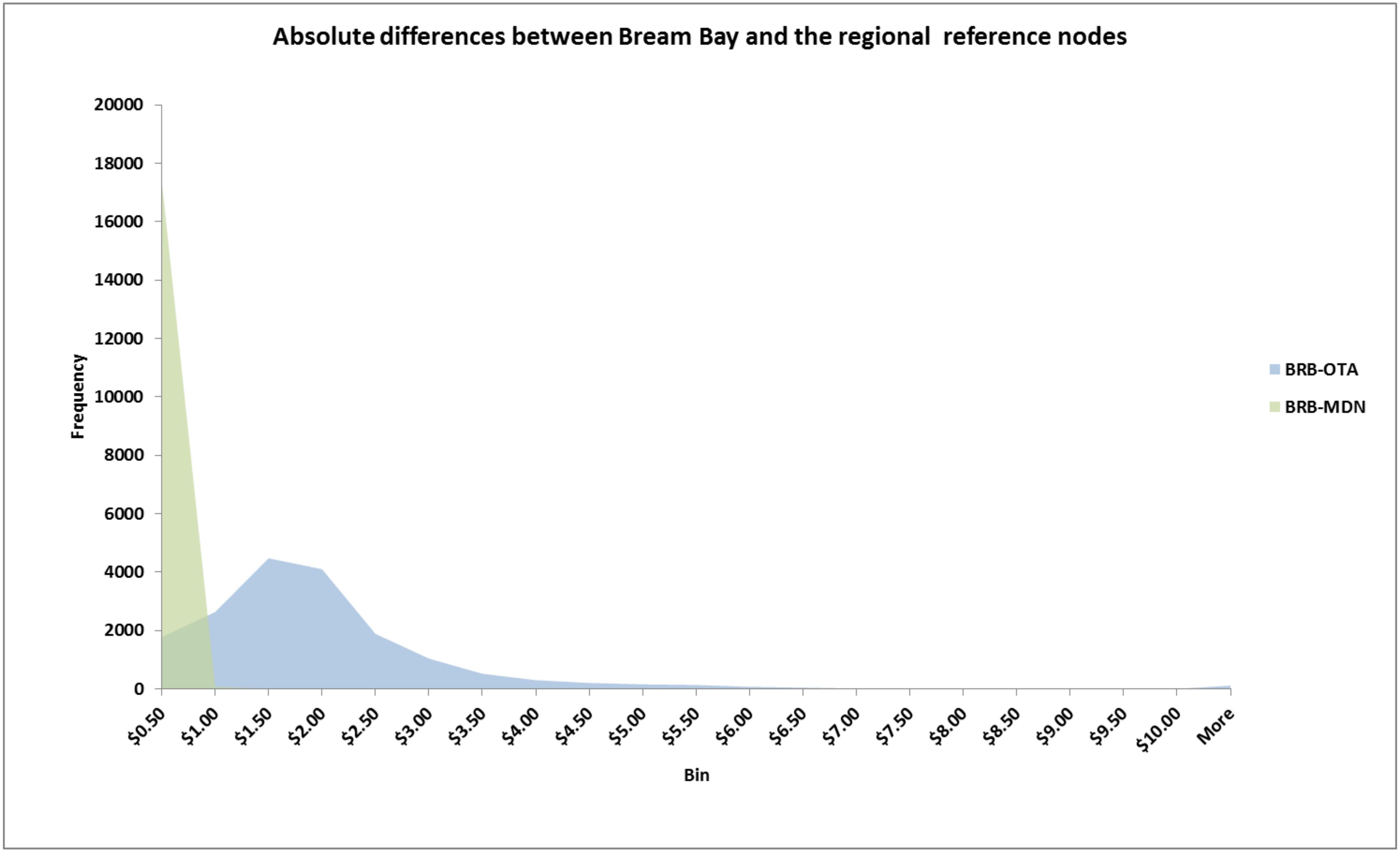


**Figure 8: Absolute differences between Kensington and the regional reference nodes**

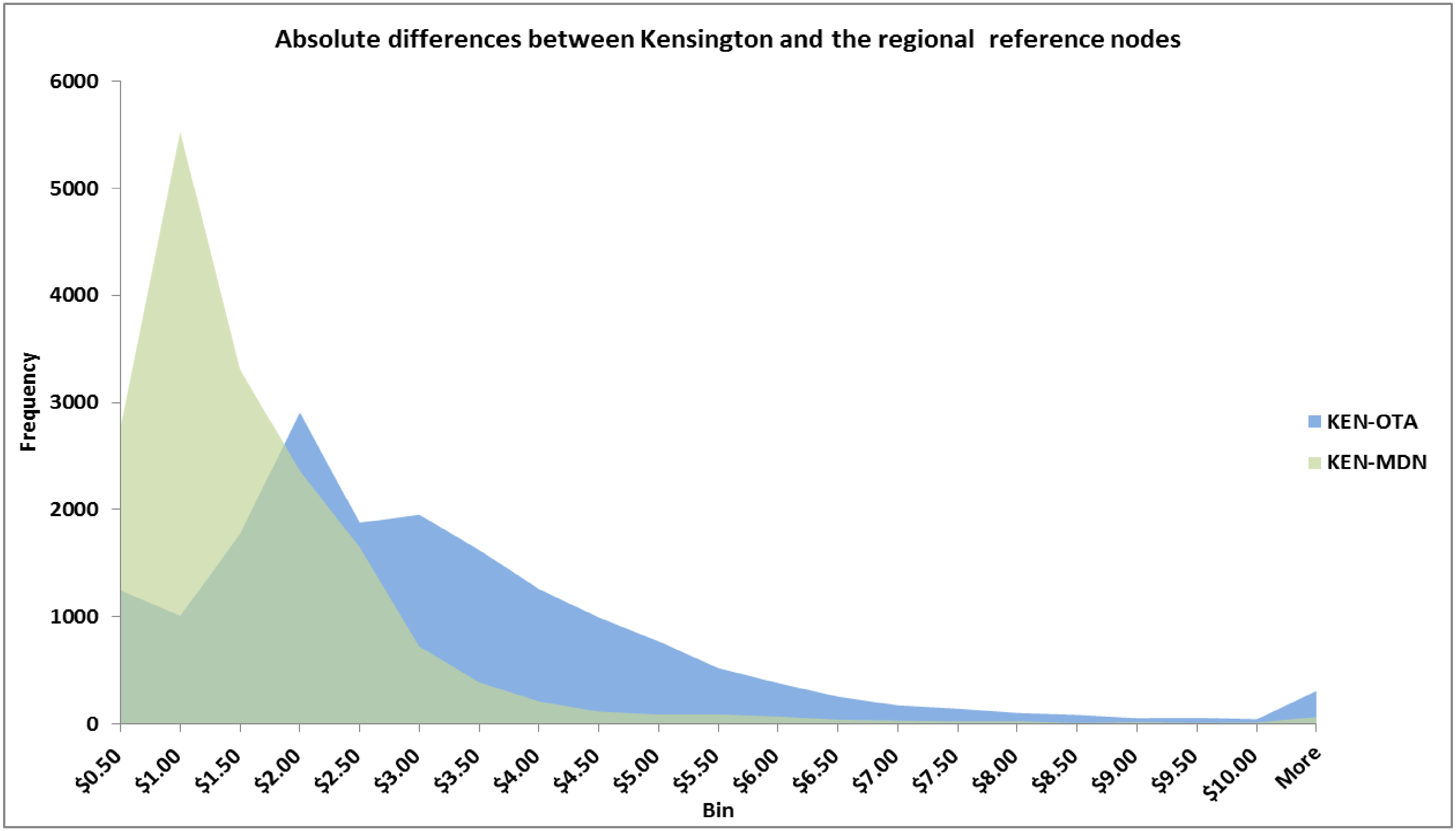


**Figure 9: Absolute differences between Atarau and the regional reference nodes**

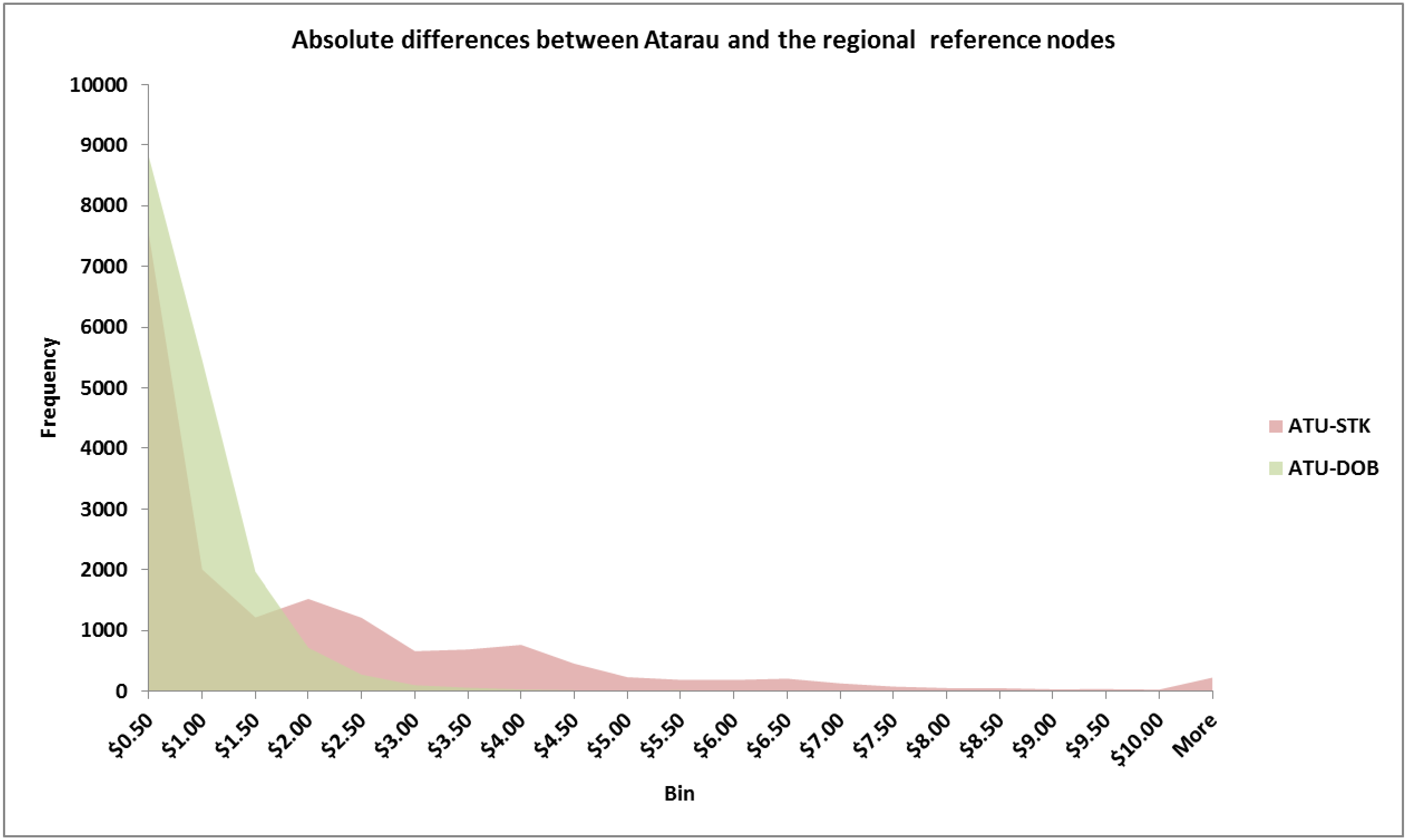


**Figure 10: Absolute differences between Hokitika and the regional reference nodes**