# Regional load probability curve forecasts from 2007

**Brian Bull**

**Electricity Commission**

**November 2007**

## 1. Introduction

This document presents regional, island and national load probability curve (LPC) forecasts, covering a 40-year period. Both annual and seasonal forecasts are included.

This is an update of the long-term LPC forecast published by the Commission as draft Grid Planning Assumptions (GPAs) in May 2007[1], updated with new data from winter 2007, and with some changes to assumptions in the underlying peak and energy forecasts.

The Initial Statement of Opportunities (SOO) did not include load probability curve forecasts. They are to be included in subsequent SOOs for use in applications of the Grid Investment Test (GIT). They would be used to determine the timing of major investments under the GRS and to calculate expected unserved energy.

The methodological approach described has not been used by the Commission previously. A simpler version of the approach was used to produce load probability curve forecasts for the Auckland/North Isthmus region, for the Commission's consideration of Transpower's Revised Proposal for the Auckland grid upgrade.

Key inputs to the LPC forecasts are the Commission's regional forecasts of energy (annual[2]), and half-hourly peak (annual[3] and seasonal).

The definition of demand used in the LPC forecasts is consistent with that used in the Commission's regional energy and peak demand forecasts. The forecasts predict half-hourly demand (as opposed to instantaneous demand) at grid exit point (at GXP, i.e. inclusive of local lines losses), by transmission region. Embedded generation is netted from demand – i.e. the demand forecast presented is for the expected demand less that which is satisfied by embedded generation.

This forecast is consistent with the GPAs long-term energy and peak demand forecasts cited above, which are also expressed in terms of demand at GXP net of embedded generation, and use the same region definitions.

The forecasts presented are not consistent, however, with the medium-term peak demand forecasts prepared by the Commission for Security of Supply purposes[4]. The medium-term forecast treats embedded generation differently and uses different region definitions. The numbers produced by these two forecasts are therefore not directly comparable.

As per the peak demand forecast, we note that this is a 'business as usual' forecast, and does not explicitly allow for any changes in consumer behaviour or technology. The forecasts also make no explicit allowance for the possibility of increased future demand-side response with the intention of reducing peak loads. In the Commission's modelling work, we prefer to treat increased demand-side response as a potential tool for meeting future peaks, rather than as a reduction applied to the peak forecast.

This document includes plots of the LPC forecasts out to 2020, but not the actual numerical predictions. These can be obtained from the Commission's website, http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/LPC-forecasts.zip .

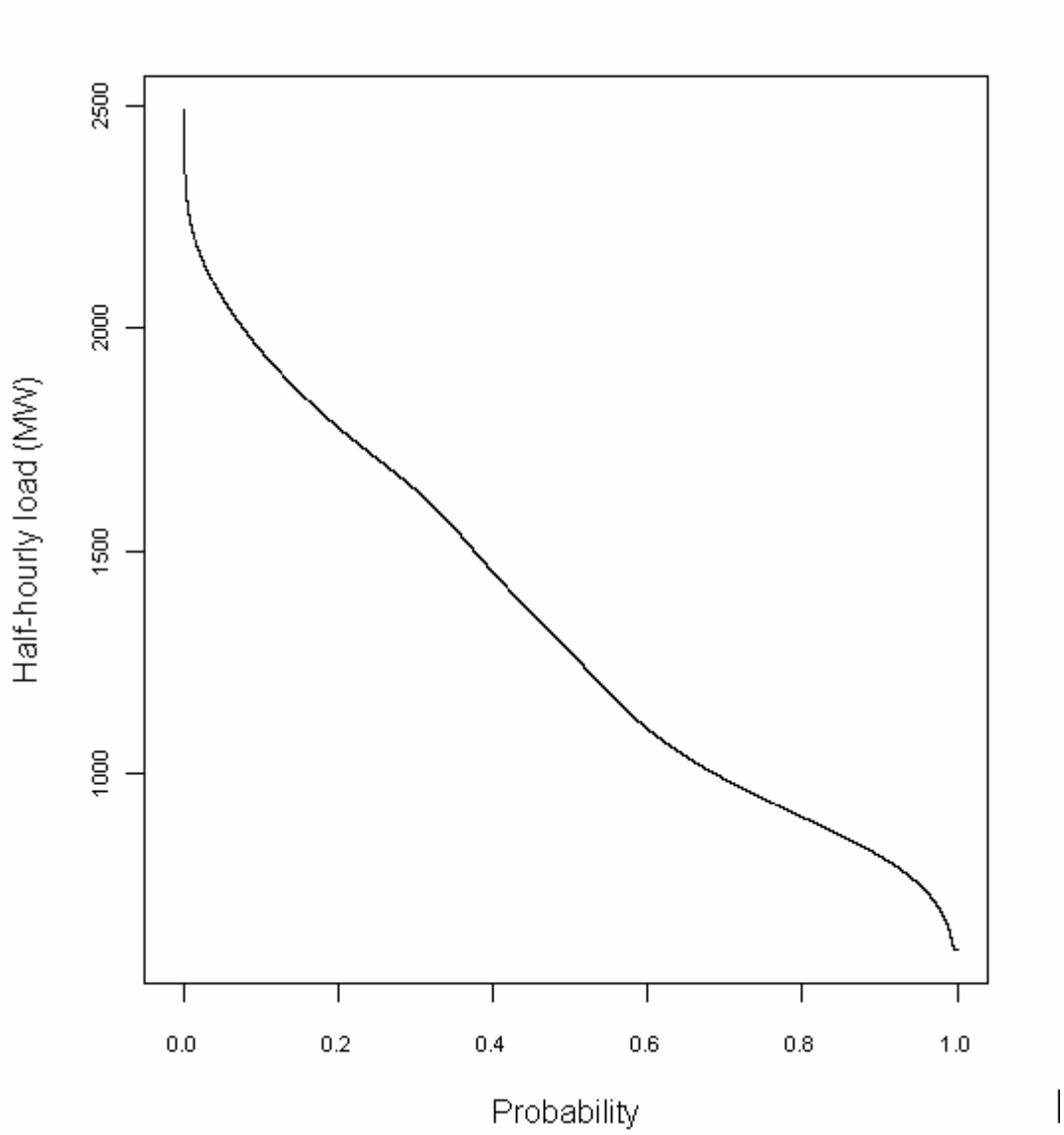
---

[1] http://www.electricitycommission.govt.nz/opdev/modelling/gpas/May2007/Demand/index.html
[2] http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/Demand-Forecast-Review.pdf
[3] http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/Regional-peak-forecast.pdf
[4] http://www.electricitycommission.govt.nz/opdev/modelling/demand/security/index.html

### 1.1 Interpreting the load probability curve forecast

We define a half-hourly LPC as a curve that indicates the probability that any given load level will be exceeded in a trading period drawn randomly from a specified future time period. The LPC is driven by a combination of variation in load within a year and uncertainty in future demand growth.

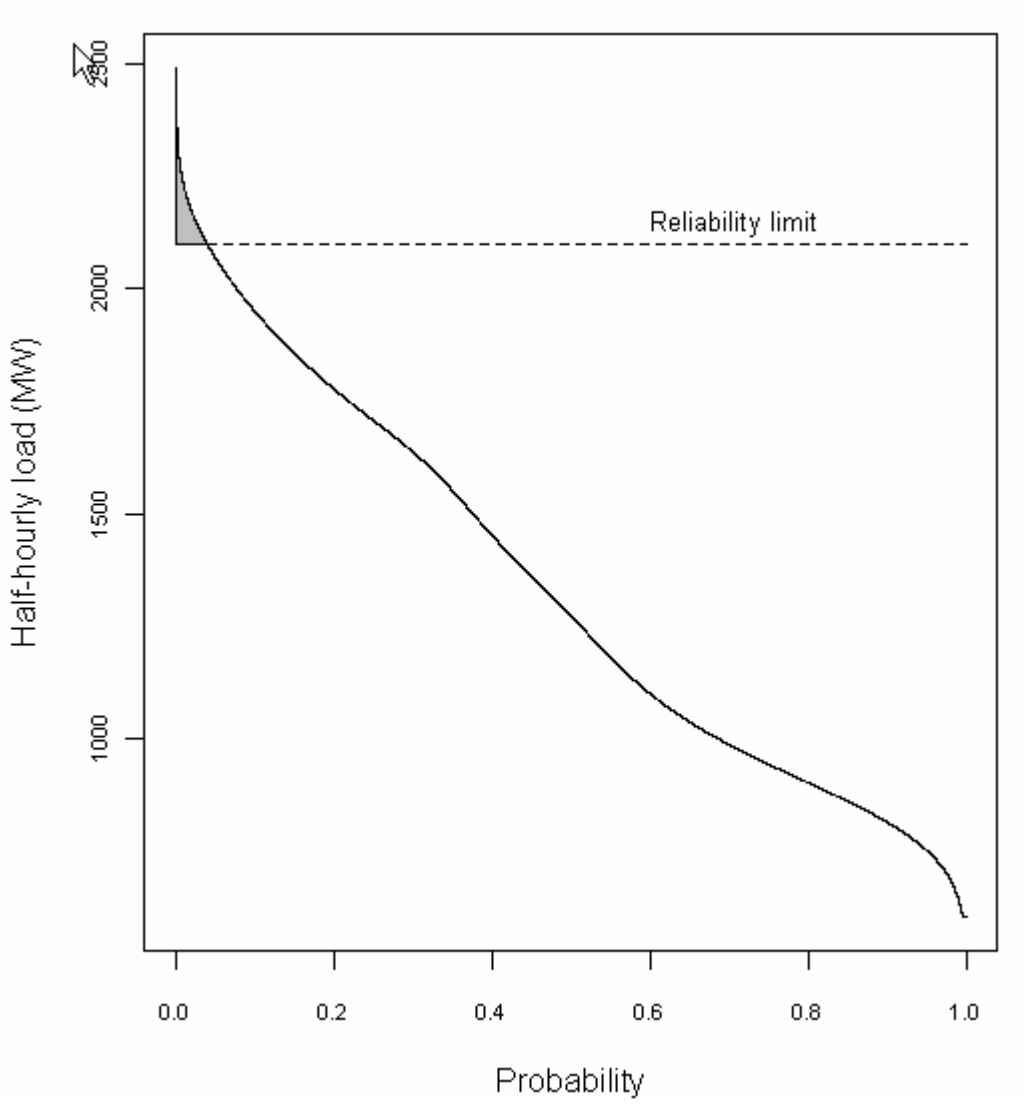
An example load probability curve is shown below:




The LPC should not be confused with the load duration curve (LDC), which is a plot that shows the number of trading periods exceeding each given load level in a time period. The two curves have the same form, but an LPC is a probabilistic forecast which incorporates uncertainty in demand growth, whereas an LDC is deterministic.

It is important to note that these LPCs relate to half-hourly rather than instantaneous demand. If, for example, a given load level of X MW occurs at the 0.1% mark on the curve, then this indicates that there is an 0.1% chance that a randomly chosen half-hour will have an average load of at least X MW - not, for example, that instantaneous load is expected to exceed X 0.1% of the time. Since instantaneous peak is always higher than half-hourly peak, it would not be surprising if the instantaneous peak in a given future year was higher than the top of the half-hourly LPC.

A key use of the load probability curve is in stochastic reliability studies. Here the LPC is used to model variation in demand, including forecast uncertainty. In a simple case, a given load level is defined as the maximum that can be supplied, with all load over this level being unserved. The expected unserved energy over a given time period is then calculated as the area of the portion of the load probability curve over the maximum served load level (shaded area in plot below), multiplied by the duration of the period.




In more complex studies, the load level that can be supplied is also stochastic (depending on generation and transmission availability), and the calculation of expected unserved energy involves convolving the distributions of supply and demand.

## 2. Methodology

This section describes the methodology used to produce the peak demand forecast. Subsections describe:

- the region definitions used;
- the season definitions used;
- the inputs, including peak forecasts, energy forecasts, reference LDC curves, and historical curve steepness data; and
- the statistical methodology used to generate the forecast from these inputs.

All references to 'years' in this document denote calendar years, except where otherwise noted.

'Energy demand' refers to total electricity demand in GWh (as opposed to non-electricity energy demand!).

### 2.1 Region definitions

The analysis has been carried out at the 'transmission region' level, for consistency with the Commission's GPA energy demand forecast. North Island regions are Auckland, Bay of Plenty, Central, Hawkes Bay, North Isthmus, Taranaki, Waikato and Wellington; South Island regions are Canterbury, Nelson/Marlborough, Otago/Southland, South Canterbury, and West Coast.

Forecasts have also been carried out at island and national level. The island and regional forecasts are independently derived from source data – neither is calculated from the other via diversity factors. The national forecast is likewise produced independently of the regional forecasts.

We also include forecasts at the 'half-island' level, again produced independently rather than by a diversity-based approach. These regions include:

- Upper North Island (UNI, defined as Auckland and North Isthmus),
- Lower North Island (LNI, all other North Island regions),
- Upper South Island (USI, defined as Canterbury, Nelson/Marlborough, South Canterbury and West Coast),
- Lower South Island (LSI, Otago/Southland only).

### 2.2 Season definitions

Reliability analysis for transmission planning is commonly carried out separately for the winter and summer seasons, since line thermal ratings and generator capabilities vary between seasons. Accordingly, LPC forecasts have been carried out separately for each season. These seasons have been defined for consistency with those used in transmission:

- Extreme summer: January and February, between 7 am and 9 pm.
- Summer: From 1 March until 9 May inclusive, and from 20 October until 30 December inclusive, between 7 am and 9 pm in both cases.
- Winter: From 10 May until 19 October, all hours. At other times of year, before 7 am and after 9 pm only.

For convenience, the number of trading periods in each season is shown here:

| Season | Trading periods (leap year) | Trading periods (non-leap year) |
|---|---|---|
| Extreme summer | 1680 | 1680 |
| Summer | 4004 | 3976 |
| Winter | 11884 | 11864 |

The same season definitions were used for the Commission's seasonal peak demand forecasts.

The resulting seasonal LPC forecasts have been combined for each year, forming annual LPC forecasts.

These annual LPC forecasts are plotted in Section 3 of this report; plots of seasonal forecasts and actual forecast numbers (both annual and seasonal) are not included in this report but can be downloaded separately from the Commission's website.[5]

### 2.3 Data inputs

The data inputs to the forecasts were:

- Randomisations of peak and energy, for each region in each season of each year. These are produced as part of the regional peak forecasting process. In terms of the LPC process, they are used to align the LPC forecasts with the energy and peak forecasts already produced.
- Reference LDCs. A 'reference' load duration curve from the 2004 year has been extracted from the Centralised Dataset, for each region and season. The forecast LPCs are produced by transforming (scaling and reshaping) these reference curves.
- Historical steepness values. 'Steepness' is defined in this context as the ratio $(max - P_1) / (max - mean)$, where *max* is the maximum value of a half-hourly load duration curve, $P_1$ the first percentile, and *mean* the mean. An LDC has a high steepness value (typically up to 0.3) if the curve slopes downwards steeply from the peak, or a low steepness (as low as 0.05) if the curve slopes downwards very gradually from a broad peak. Steepness values were calculated for each region and season, for each calendar year from 1997 to 2006 inclusive, using half-hourly load data from the Centralised Dataset. See section 2.4 for how these values were used in the analysis.

### 2.4 Statistical methodology

The production of a single forecast (for a specific region, season, and year) uses the following process.

Firstly, 1,000 randomised LDCs, each corresponding to a draw from the set of randomisations of peak and energy, are produced using the following process:

a) A randomisation of peak and energy is drawn from the available set of forecasts for this region, season and year (see Section 2.3 for the derivation of these figures)

[5] http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/LPC-forecasts.zip

b) A random steepness value is drawn from the set of historical steepness values for this region and season (see Section 2.3 for the definition and derivation of these steepness values)

c) The reference LDC for this region and season (again see Section 2.3) is transformed so as to yield a curve with maximum value equal to the peak draw in (a) above, mean equal to the energy draw in (a) above, and steepness equal to the steepness value in (b) above. The transformation used is multiplication by a piecewise linear function with a 'hinge' at the 1$^{st}$ percentile.

d) If necessary, the curve is further adjusted to ensure that the minimum of the transformed LDC is not less than the minimum of the reference LDC, using a transformation that changes the shape of the lower part of the curve without altering the mean or peak.

e) The randomised LDC is the resulting transformation of the reference LDC.

These 1,000 randomised LDCs are then combined into a single 10,000-point LPC by concatenating and sorting them then interpolating at 10,000 points along the X-axis.

The LPC can therefore be considered as an amalgam of 1,000 possible futures, each representing a possible demand growth path. The demand growth paths considered are exactly those used in the Commission's seasonal peak forecasts; as a consequence, the resulting LPC forecasts are fully consistent with the peak and energy forecasts.

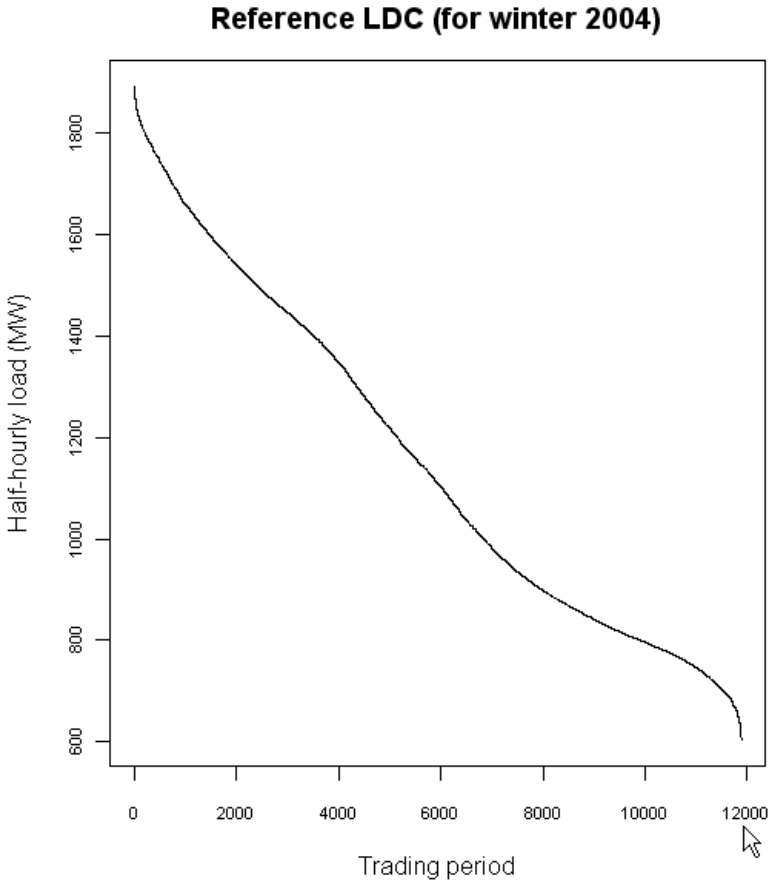
The steepness parameter is used to incorporate the variability in load duration curve shapes into the modelling. Typically, the most important part of the LPC is the top; the speed with which the curve slopes down from the peak has a strong influence on reliability analysis. The use of randomly drawn steepness parameters models the possible variation in this slope from year to year. This also has the effect of removing possible biases stemming from the use of the 2004 reference year. If the steepness parameter had not been explicitly modelled, and the 2004 year had unusually flat peaks for some region, then the resulting LPC forecast for that region would be unrealistically flat.

Seasonal forecasts for a given region and year are combined to produce an annual forecast as follows:

- The forecast curve for each season is interpolated at $N$ points, where $N$ is the number of trading periods in that season (which depends on whether it is a leap year)
- The interpolated seasonal forecast curves are concatenated to produce a single annual forecast curve, with $N_{winter} + N_{summer} + N_{extreme\_summer}$ points
- This curve is interpolated at 10,000 points to produce the annual LPC forecast.

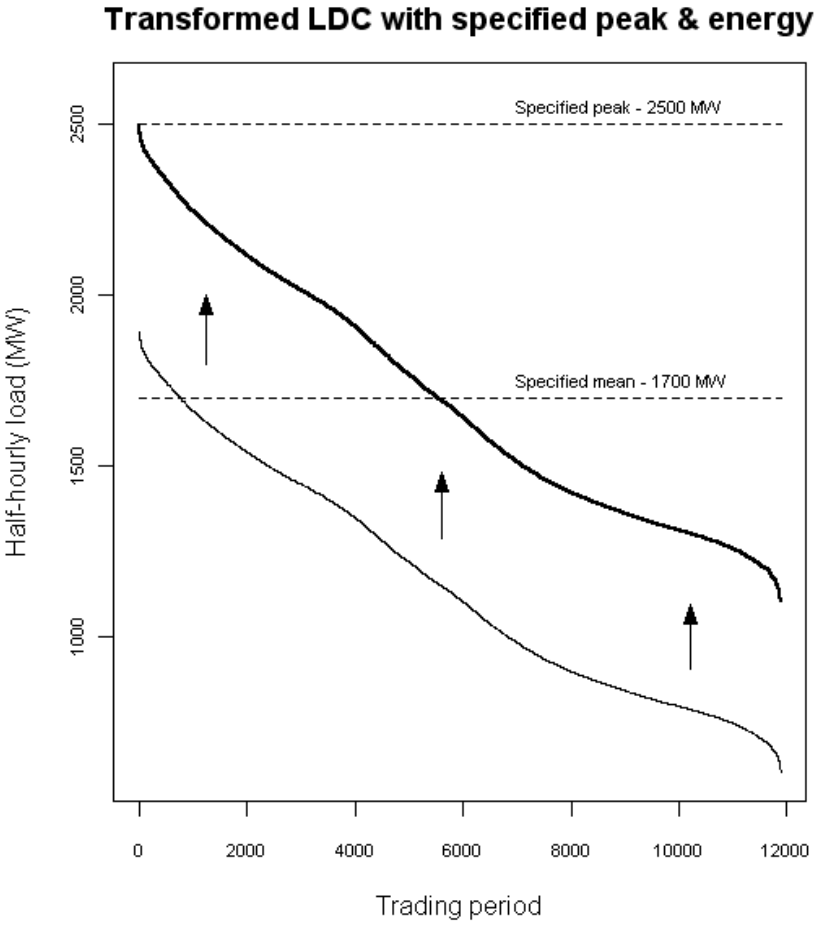
The plots on the following pages illustrate the seasonal forecasting approach.

(a) The reference LDC is based on 2004 load data.



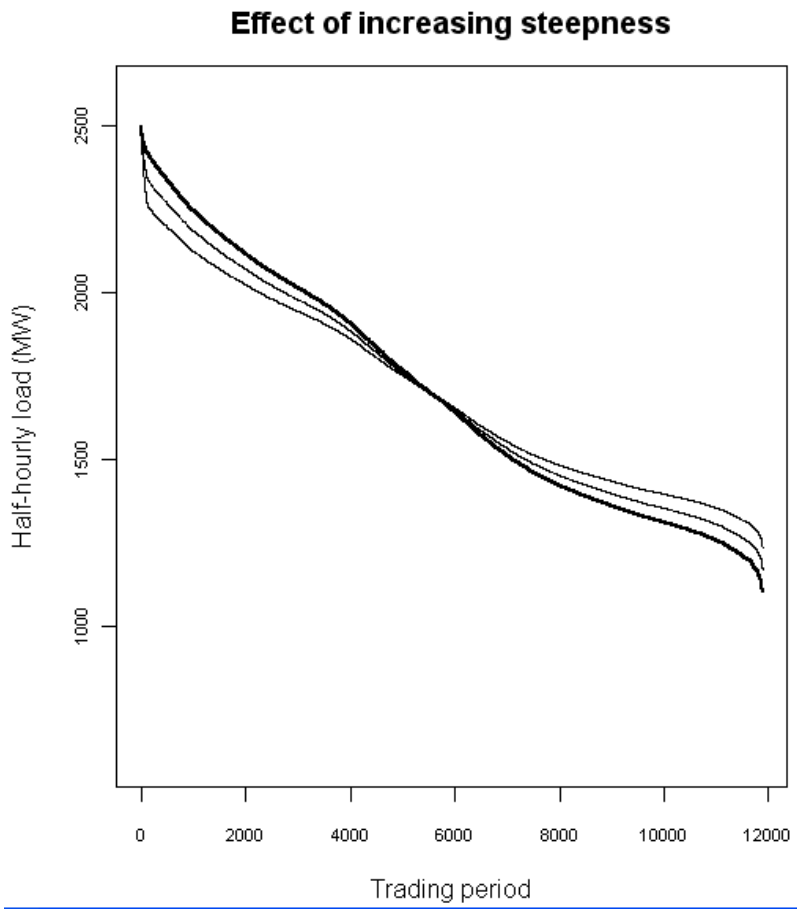

(b) We will start by producing a single randomisation of this LDC. This will be based on a single randomisation of peak (2500 MW) and energy (average of 1700 MW) for the forecast year, which in turn are taken from the peak forecasting process. It will also use a steepness value from a randomly selected historical year.

This is the transformation of the reference LDC which matches the specified peak and energy randomisations and the random steepness:



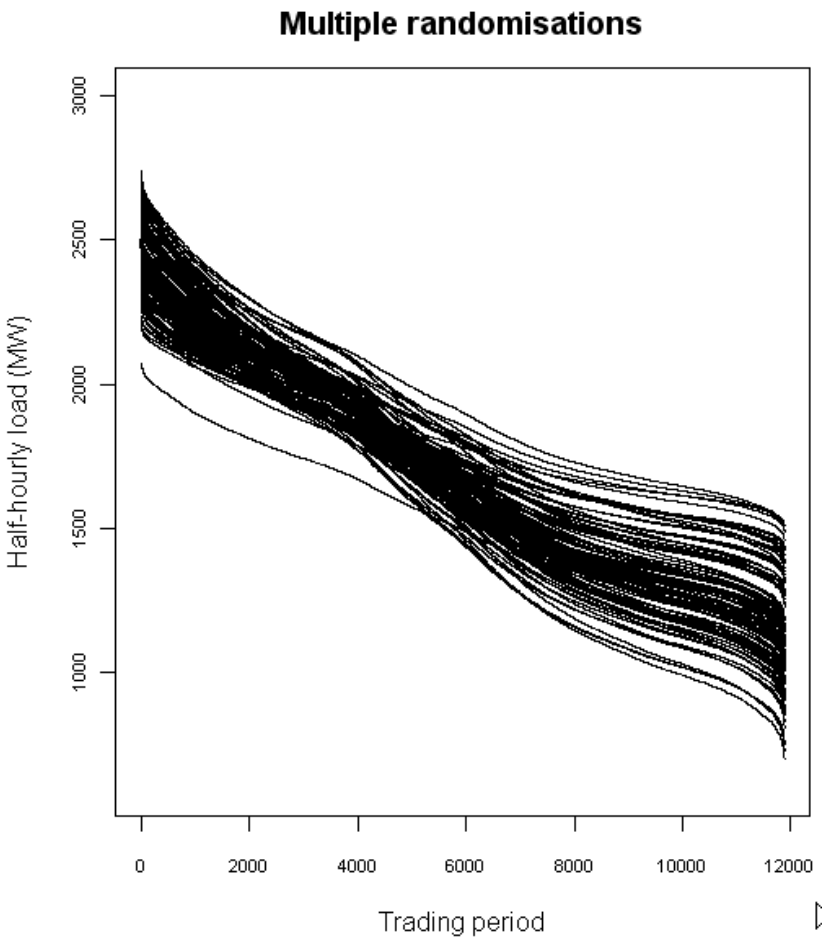
(c) This plot shows the effect of changing the steepness value used.

Higher steepness values lead to a steeper drop at the start of the curve (compensated for by a slower drop at the other end).

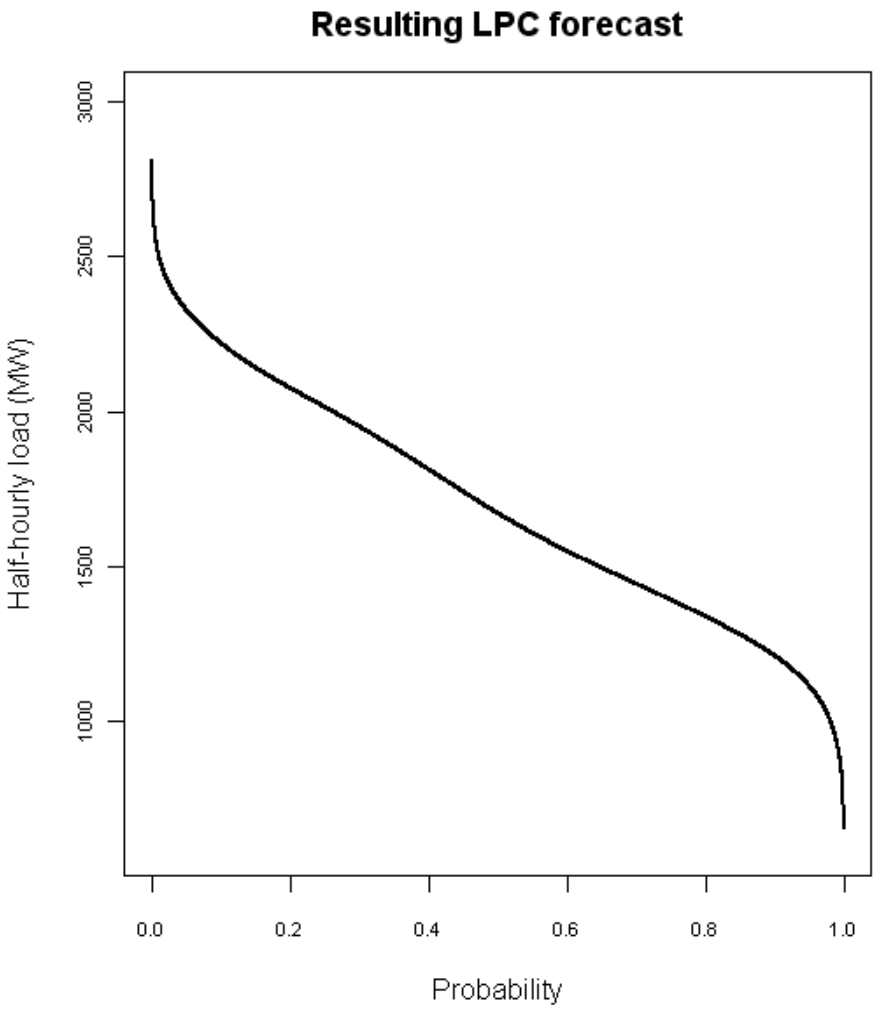



(d) Many more randomisations of the LDC are produced, each based on a different randomisation of peak and energy and a different steepness value.

Some of them are shown here:



(e) These are combined to produce a single LPC, effectively a random mixture of all the LDC randomisations.



## 3. Forecasts

This section presents plots of the annual LPC forecasts. For each region, each island, and all New Zealand, the forecast curves for each year from 2007 to 2020 are graphed. On each page, the plot on the left shows the entire curve and the plot on the right shows only the first 5% (which is the key part for reliability analysis).

Plots of seasonal LPC forecasts are not shown here, but these can be downloaded from the Commission website.[6]

The annual and seasonal forecasts to 2040 are also available in tab-delimited text format at the above website.[7]

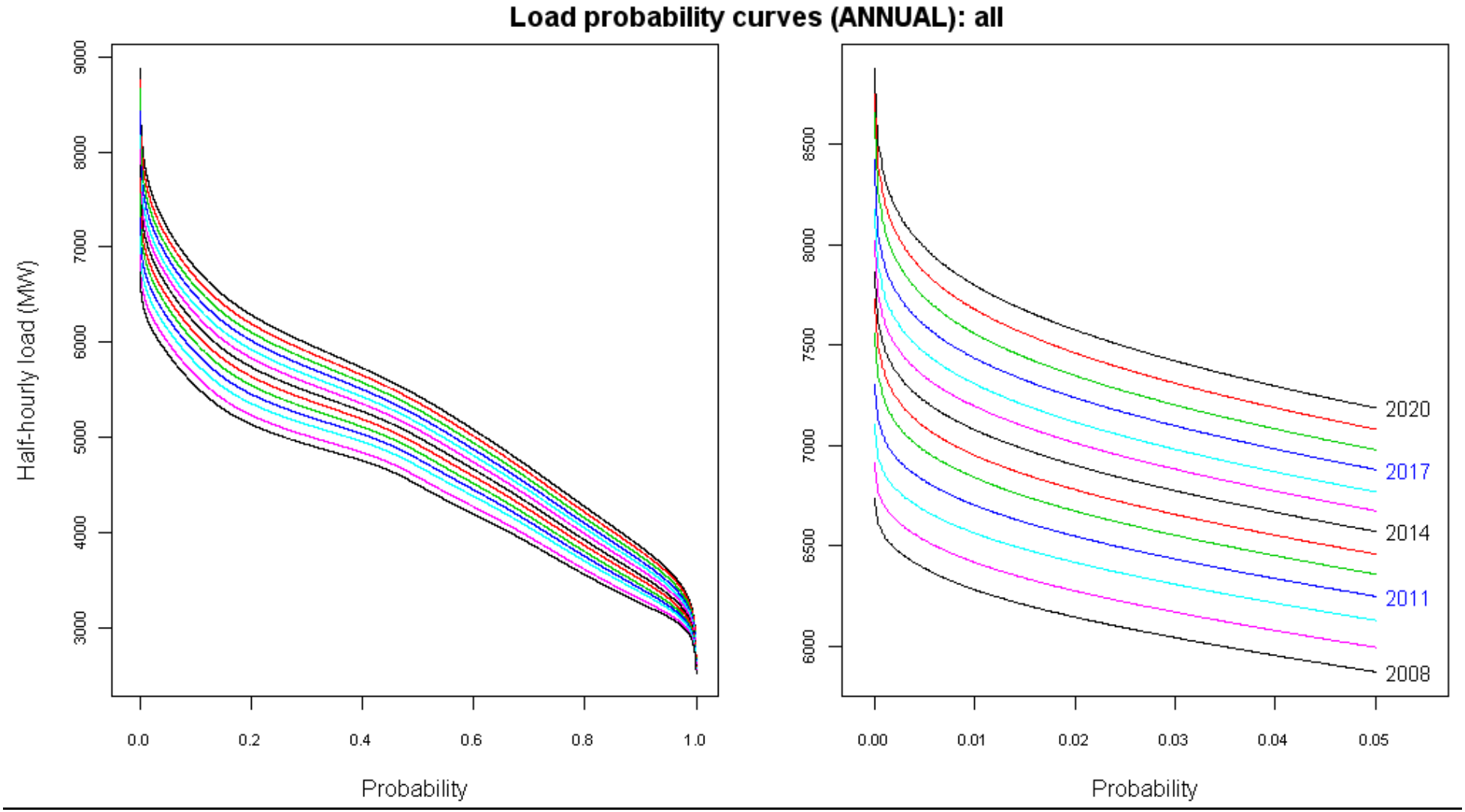
All these forecasts are of seasonal peak electricity demand at GXP, on a half-hourly time frame, including local area losses but net of embedded generation.

For commentary on predicted future growth rates and comparisons with other forecasts, see the energy and peak forecast documents.

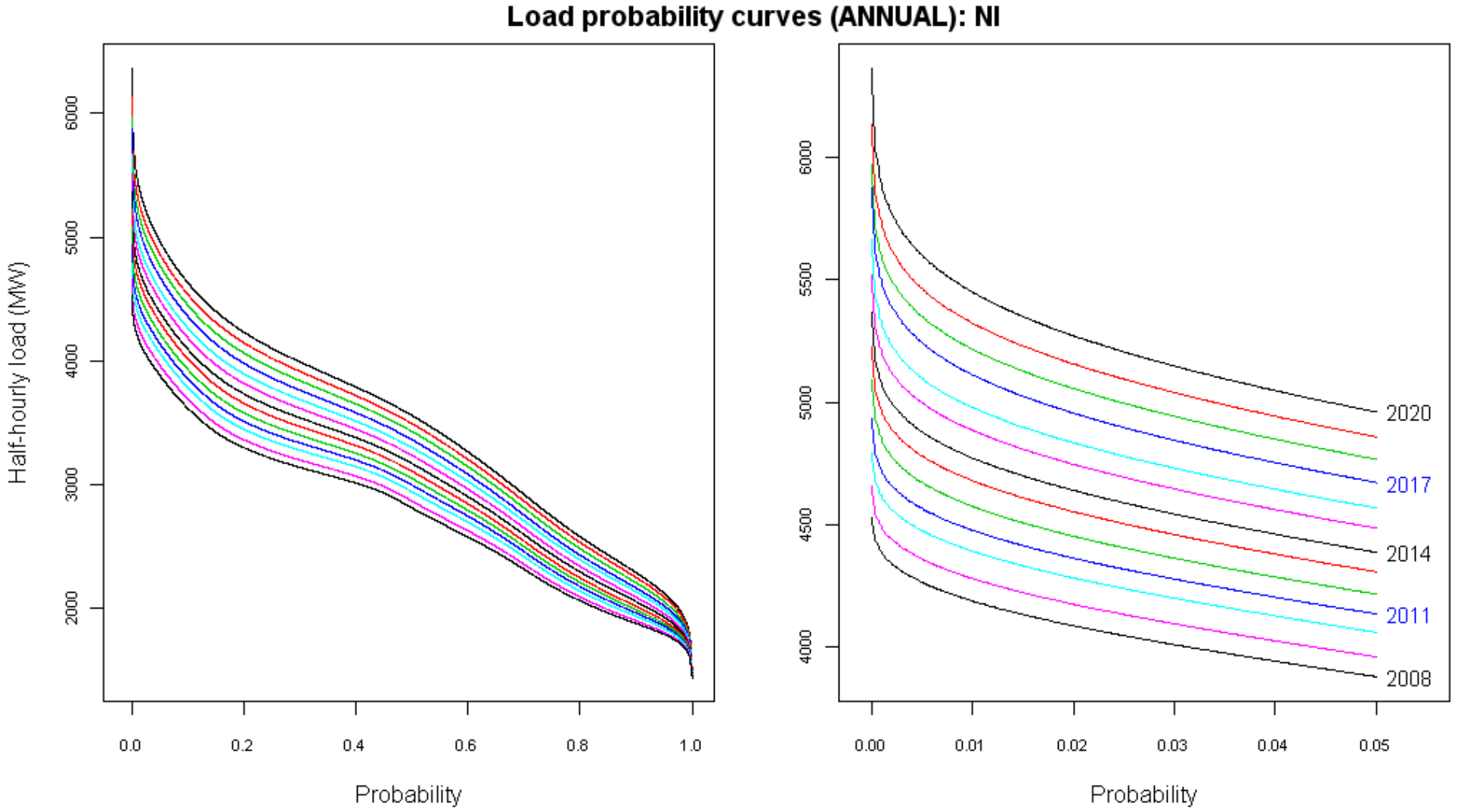
West Coast demand growth over the next few years is expected to be high, driven primarily by new industrial loads from the mining and dairy industries. The effects of these changes on load shape are uncertain, so no LPC forecasts for the West Coast are presented here. An attempt has been made to reflect these changes in the Commission's peak and energy forecasts, though the Commission understands that Transpower will propose a different forecast for their West Coast Grid Upgrade proposal.

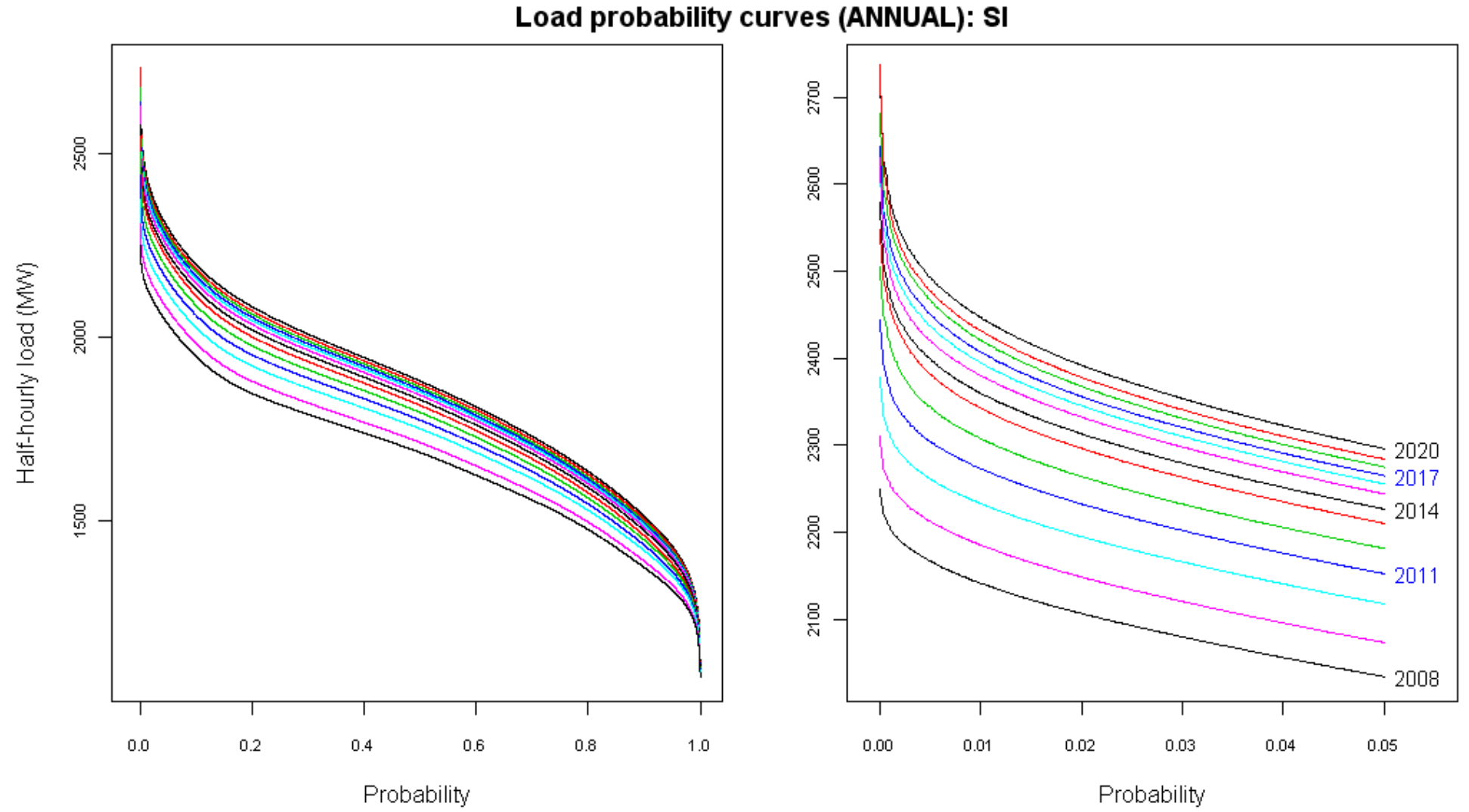
[6] http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/LPC-forecast-plots.zip
[7] http://www.electricitycommission.govt.nz/pdfs/opdev/modelling/pdfconsultation/GPA/LPC-forecasts.zip

The national forecast is as follows:

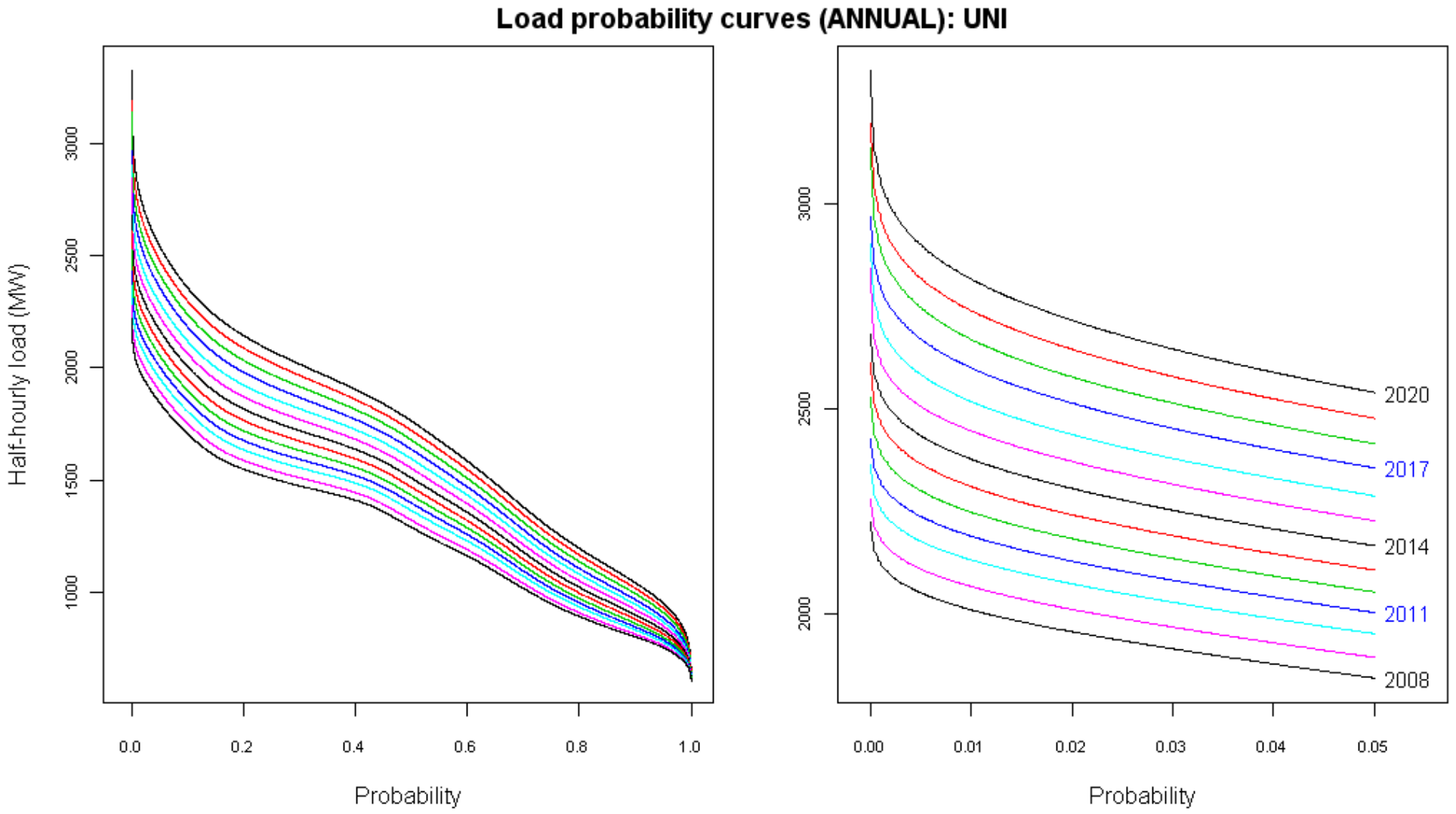


Island forecasts follow:

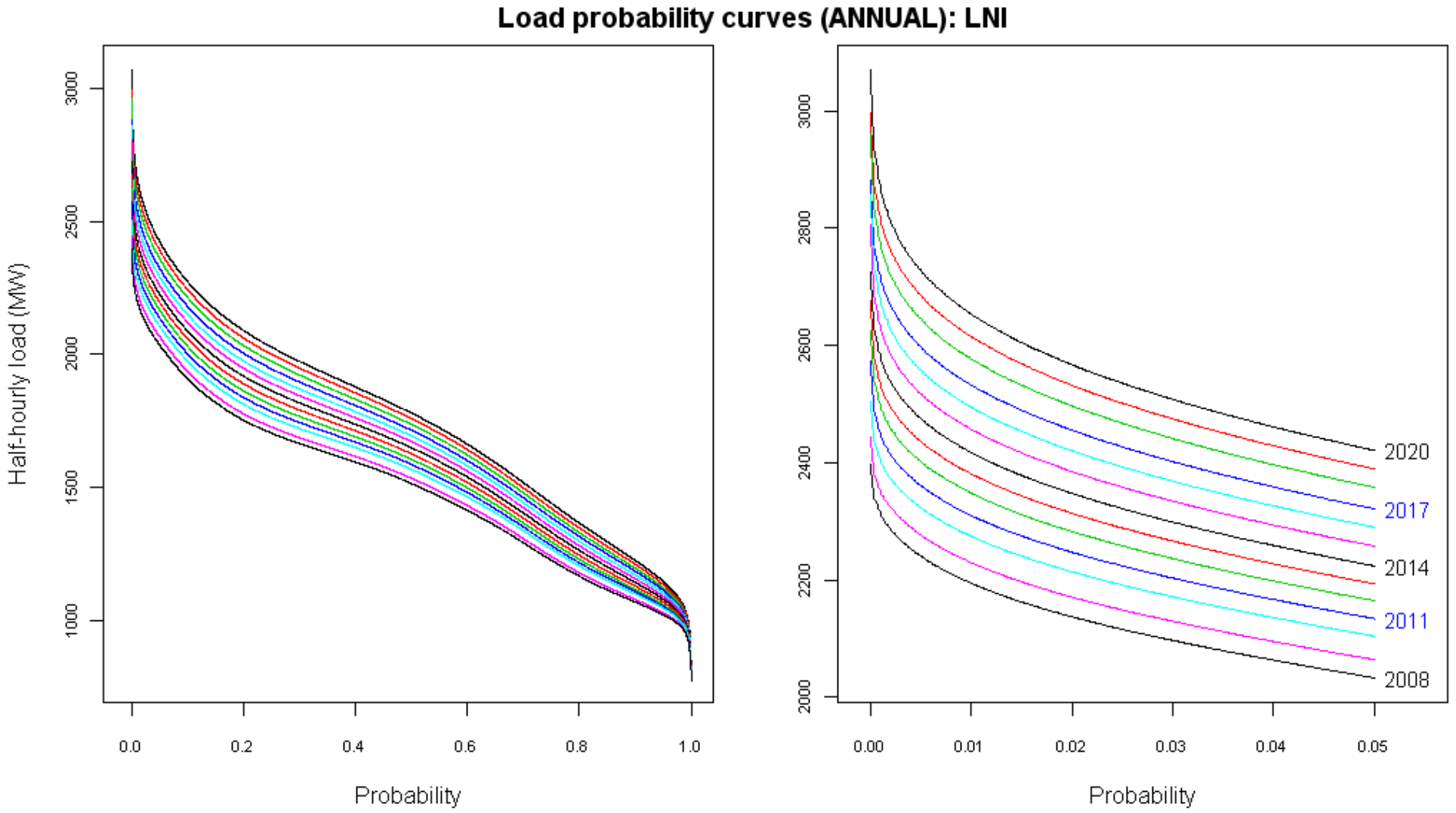



Load probability curves (ANNUAL): SI
Half-hourly load (MW)
1500
2000
2500
0.0
0.2
0.4
0.6
0.8
1.0
Probability
2100
2200
2300
2400
2500
2600
2700
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

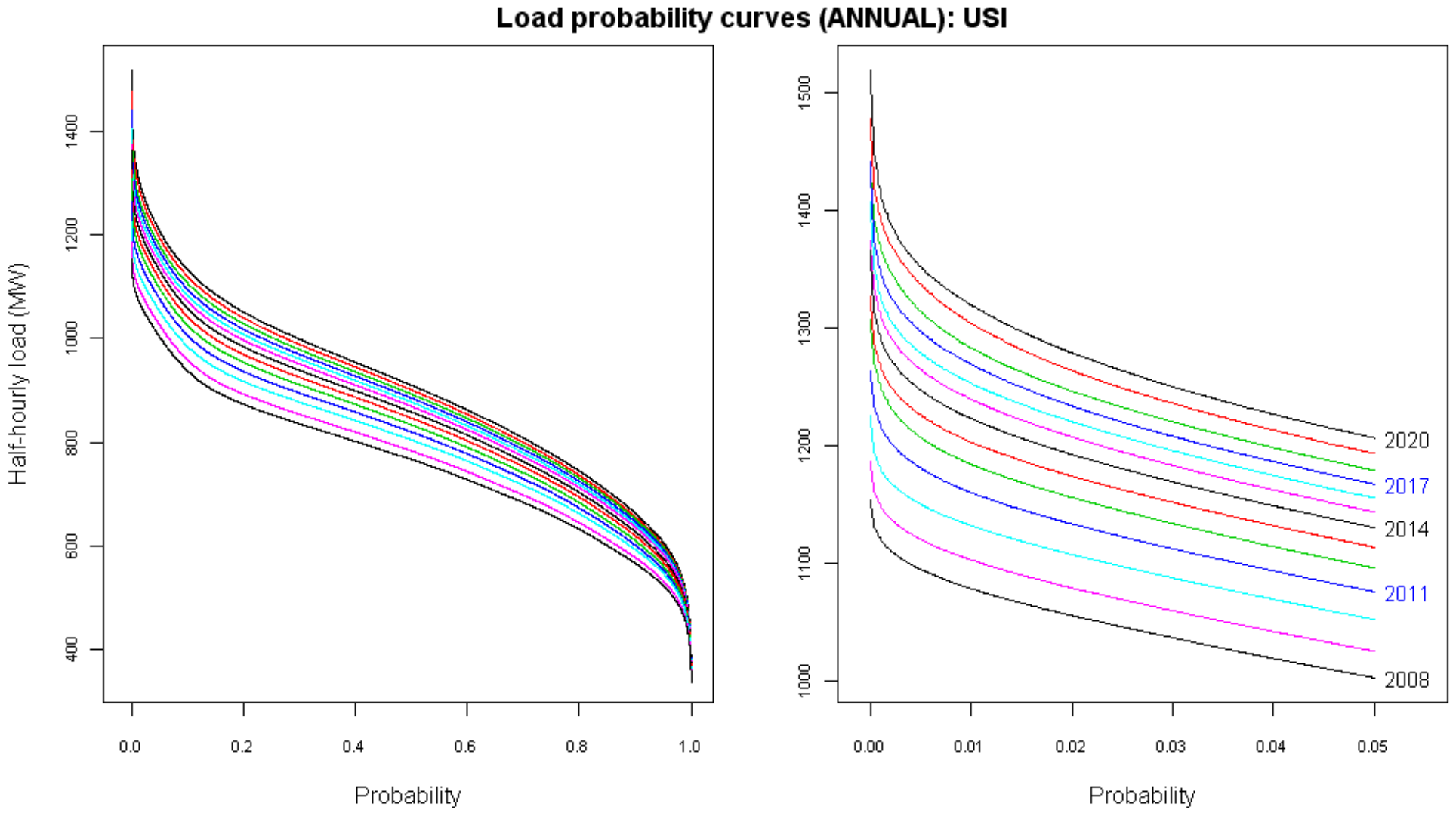
The upper North Island forecast:



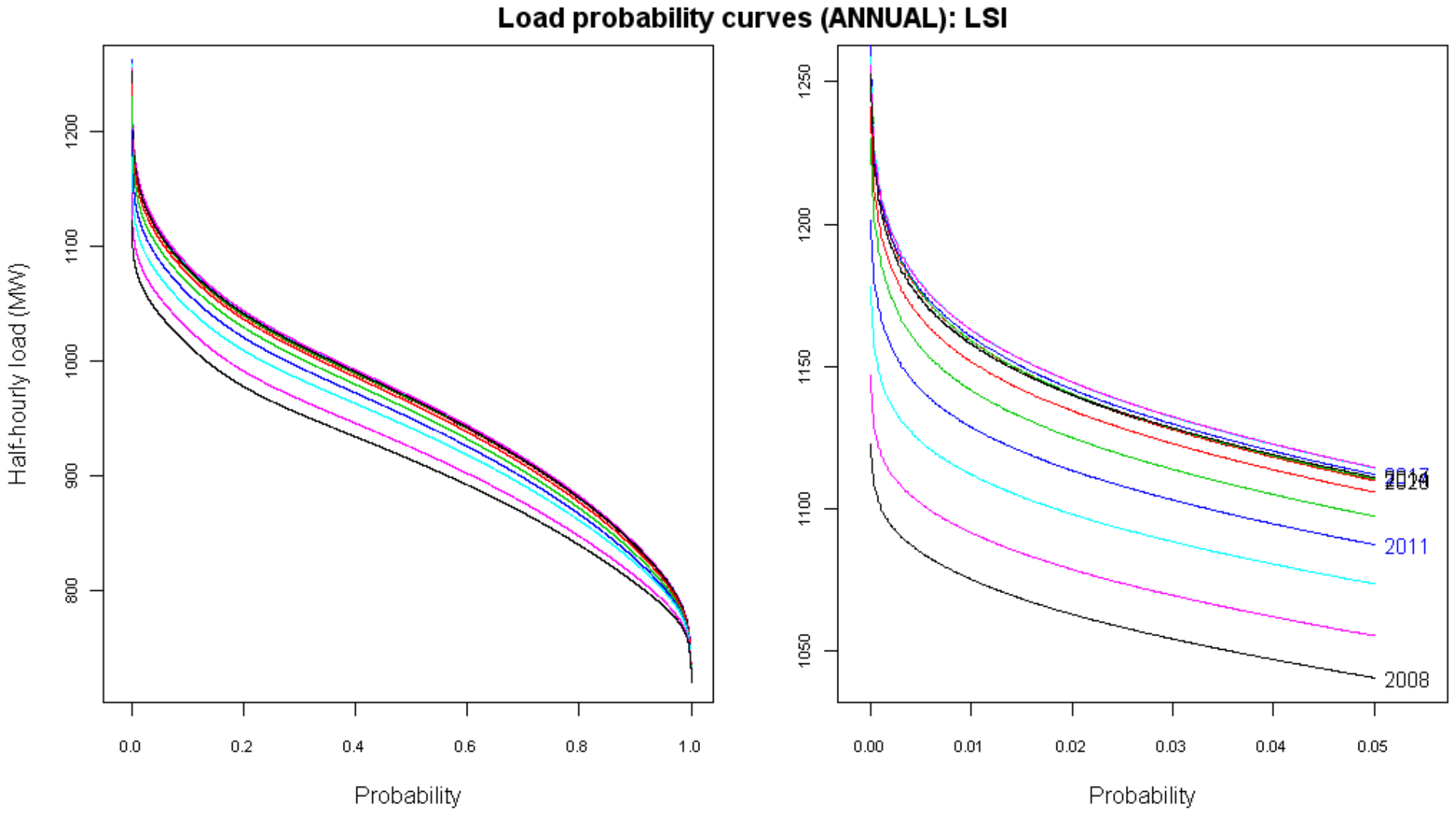
The forecast for the remainder of the North Island:



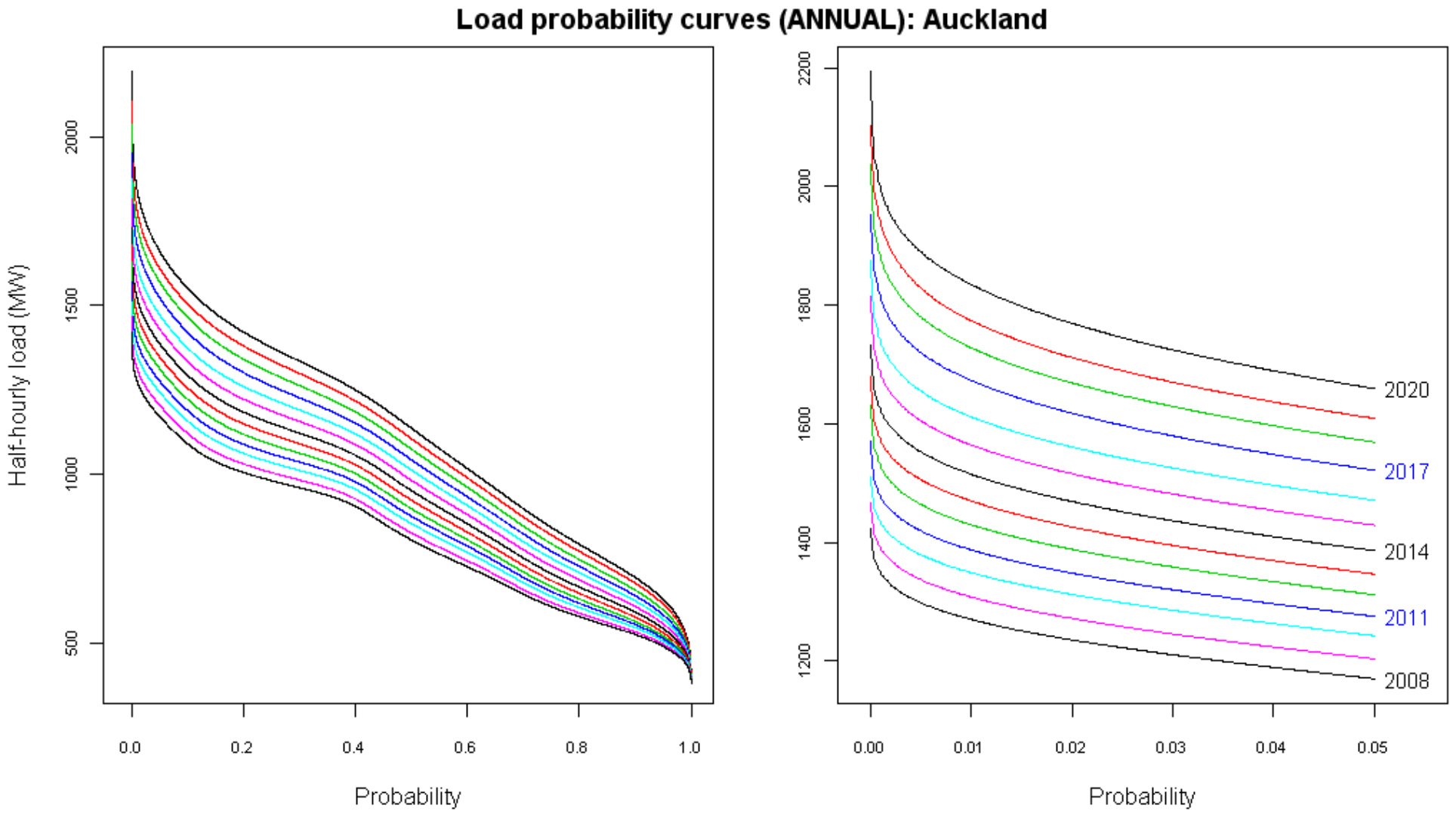
The upper South Island forecast:

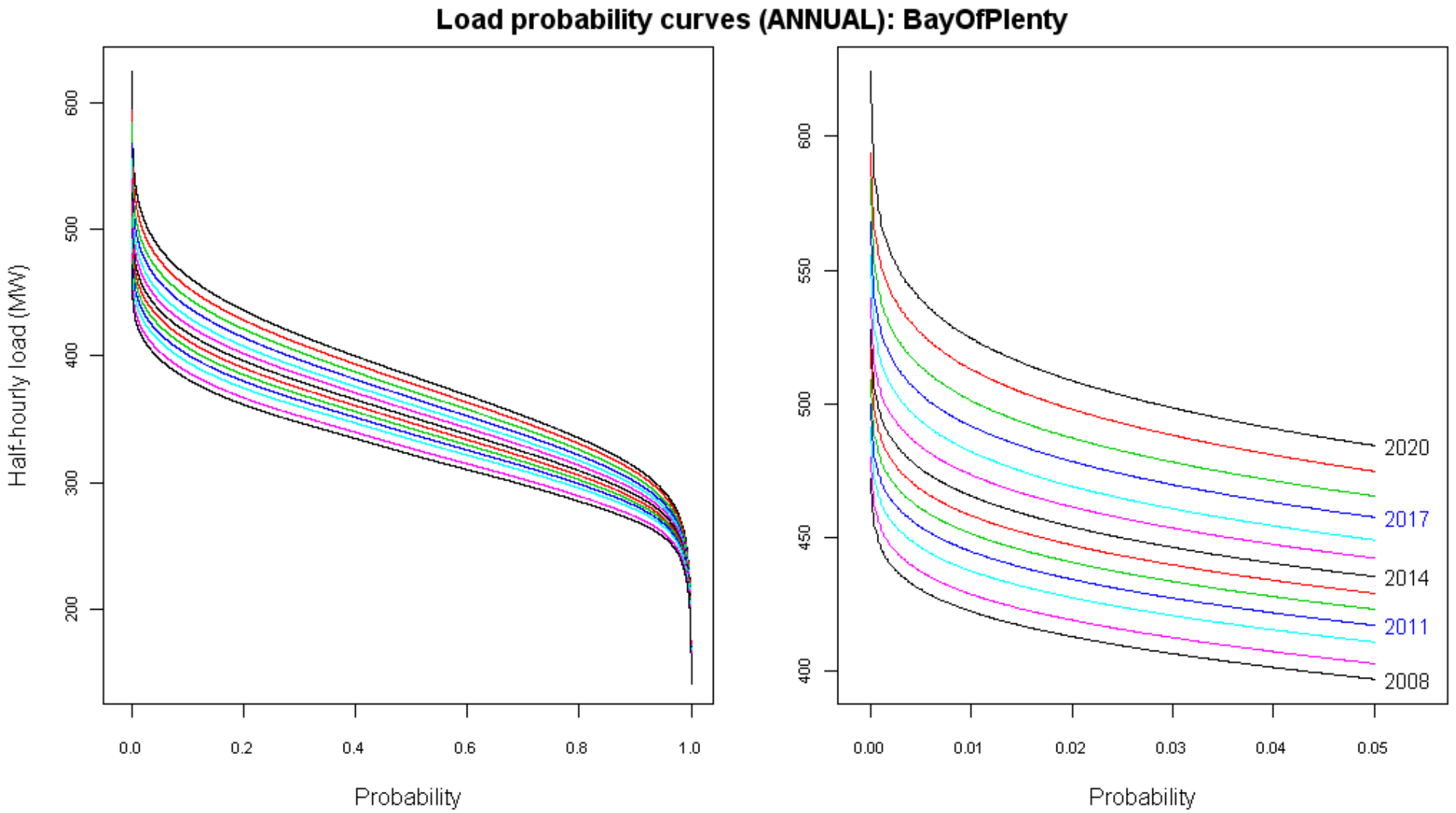


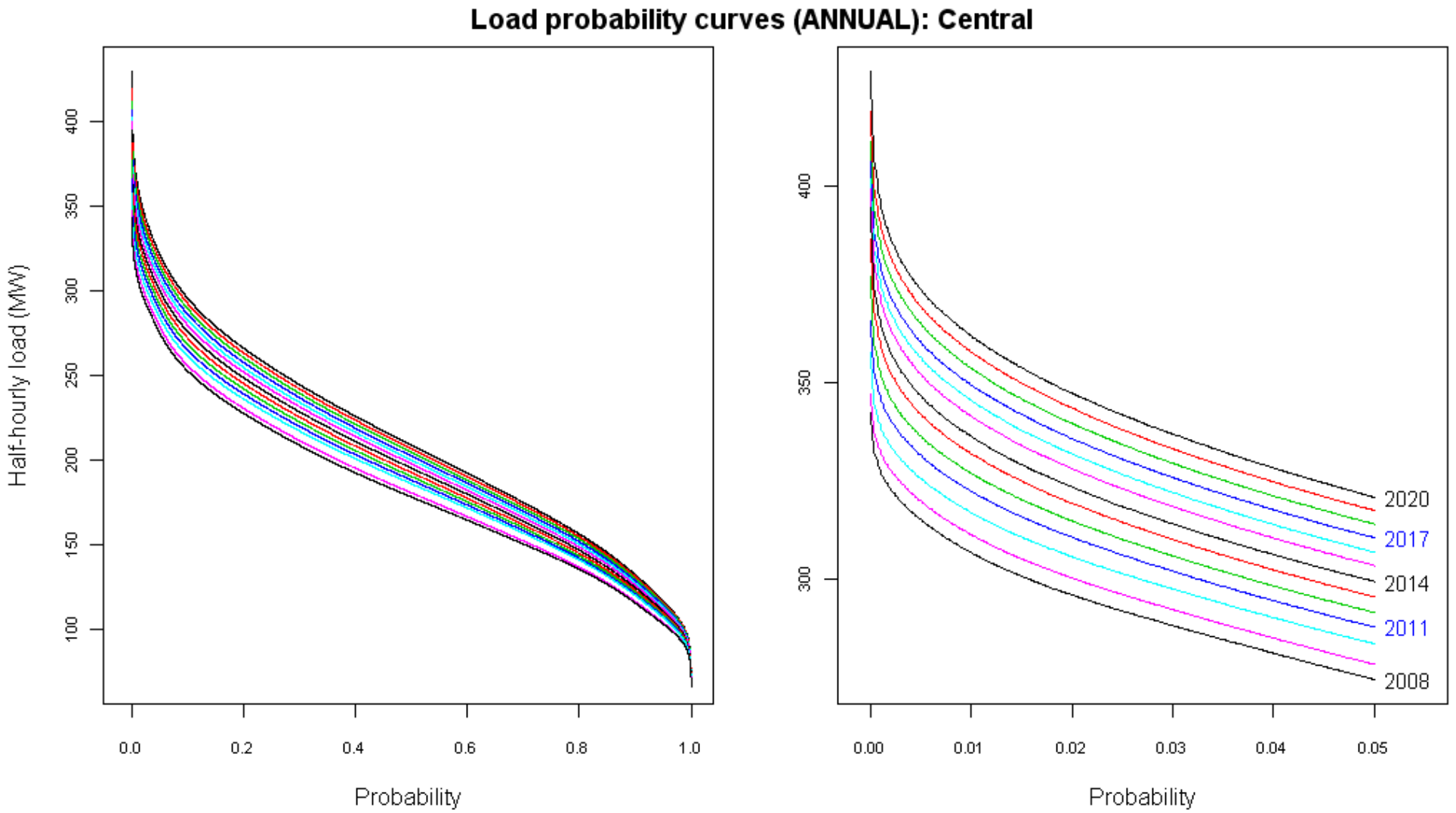
The forecast for the lower South Island:

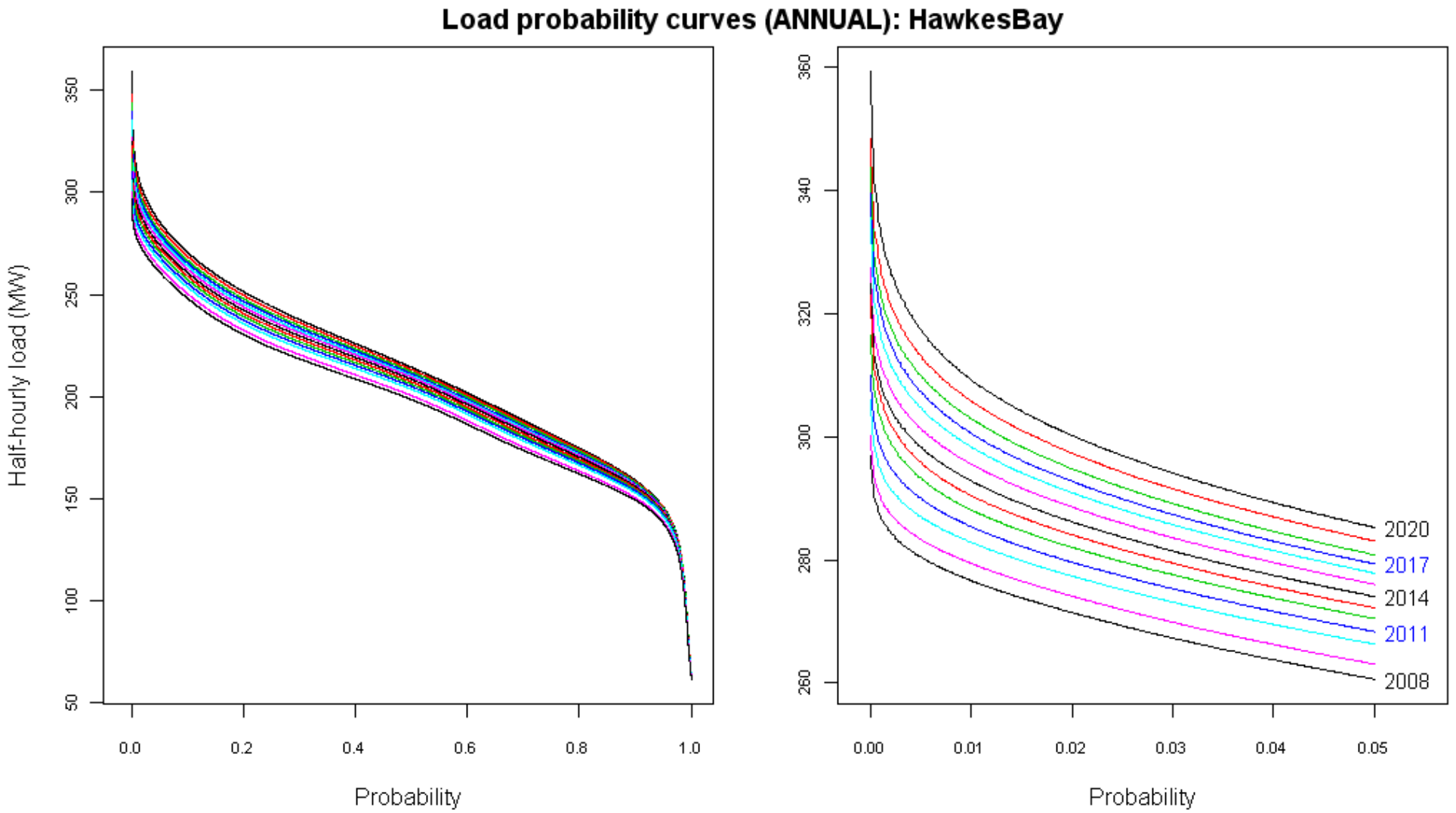


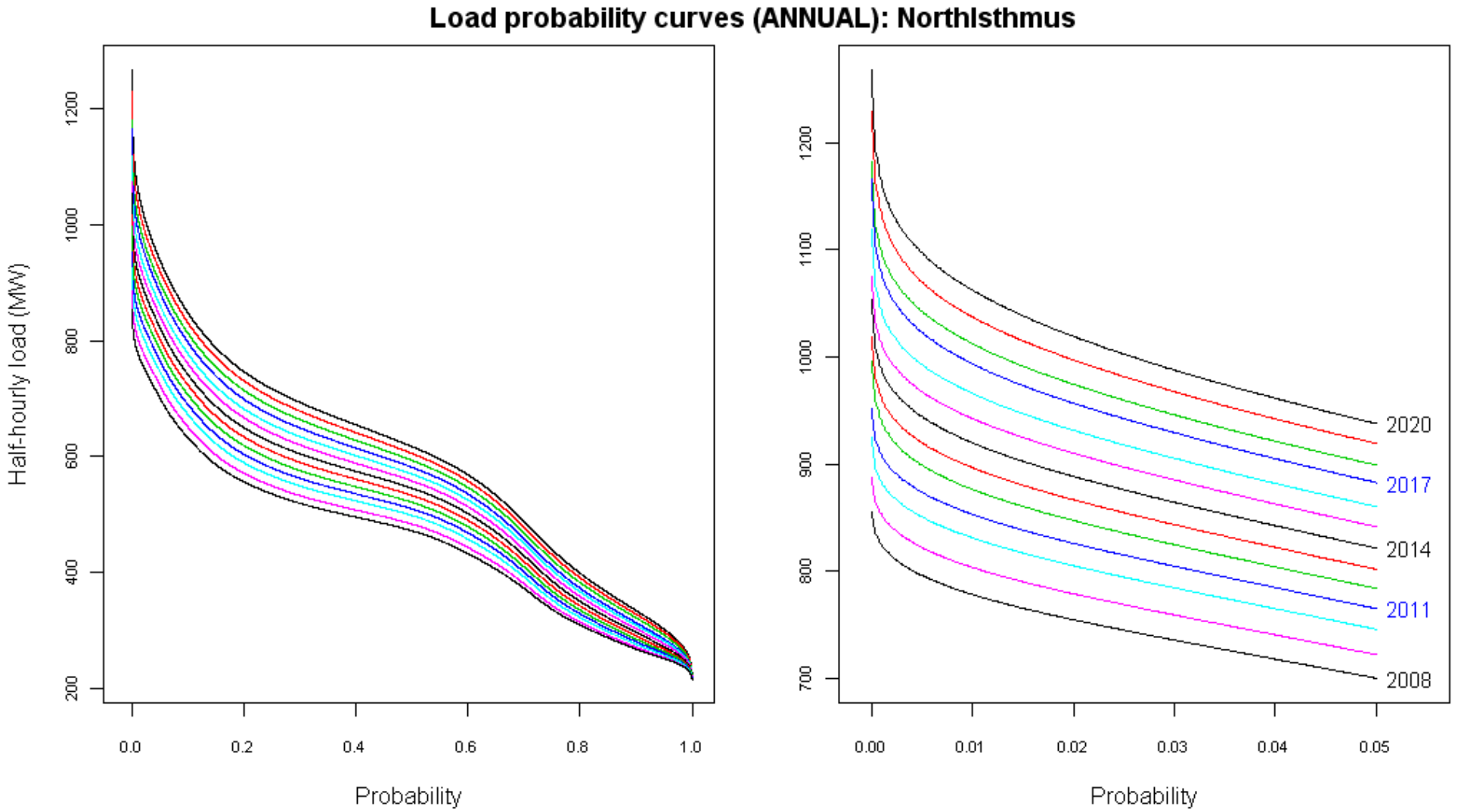
North Island regional forecasts:



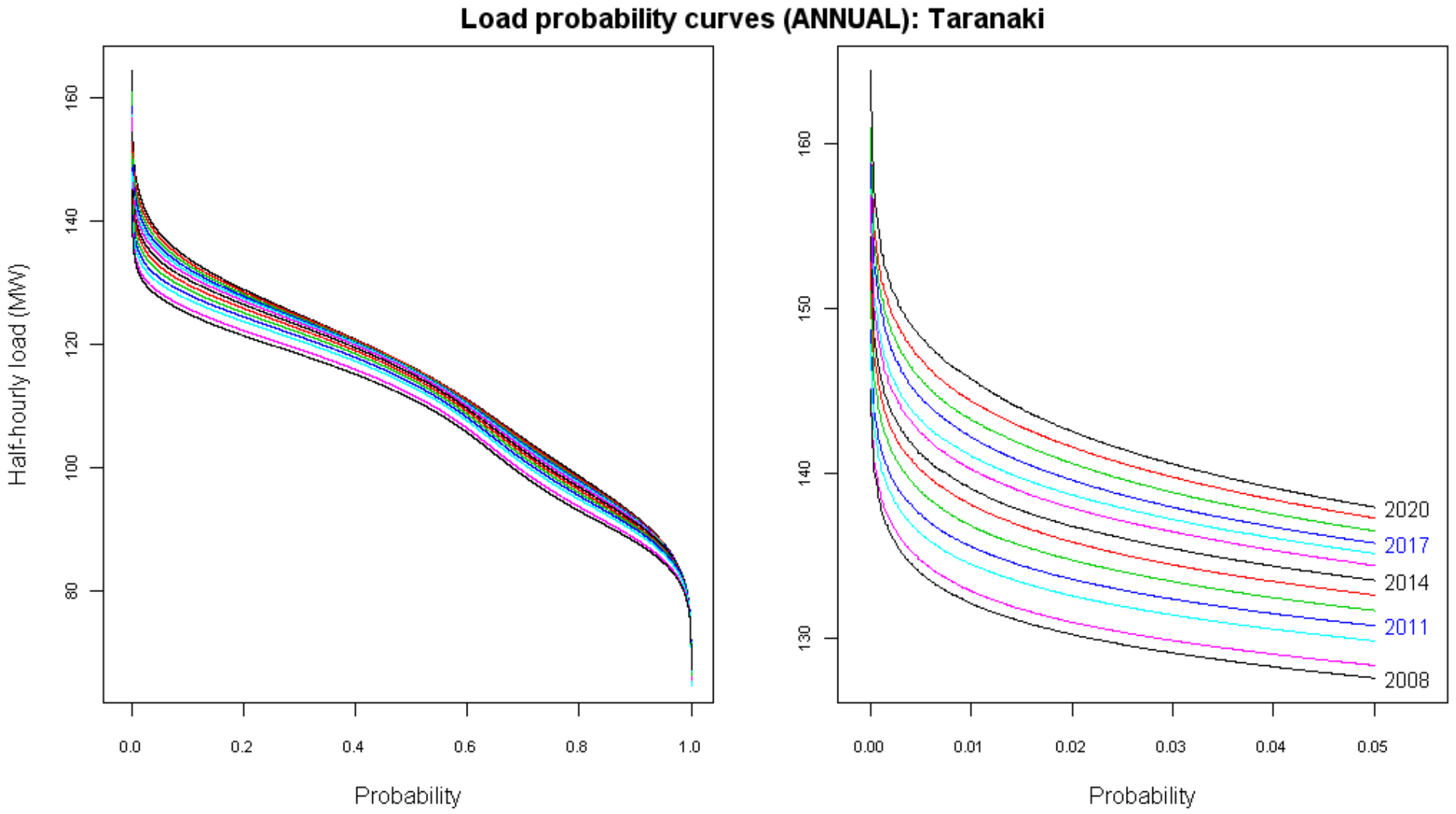

Load probability curves (ANNUAL): BayOfPlenty
Half-hourly load (MW)
600
500
400
300
200
0.0
0.2
0.4
0.6
0.8
1.0
Probability
600
550
500
450
400
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

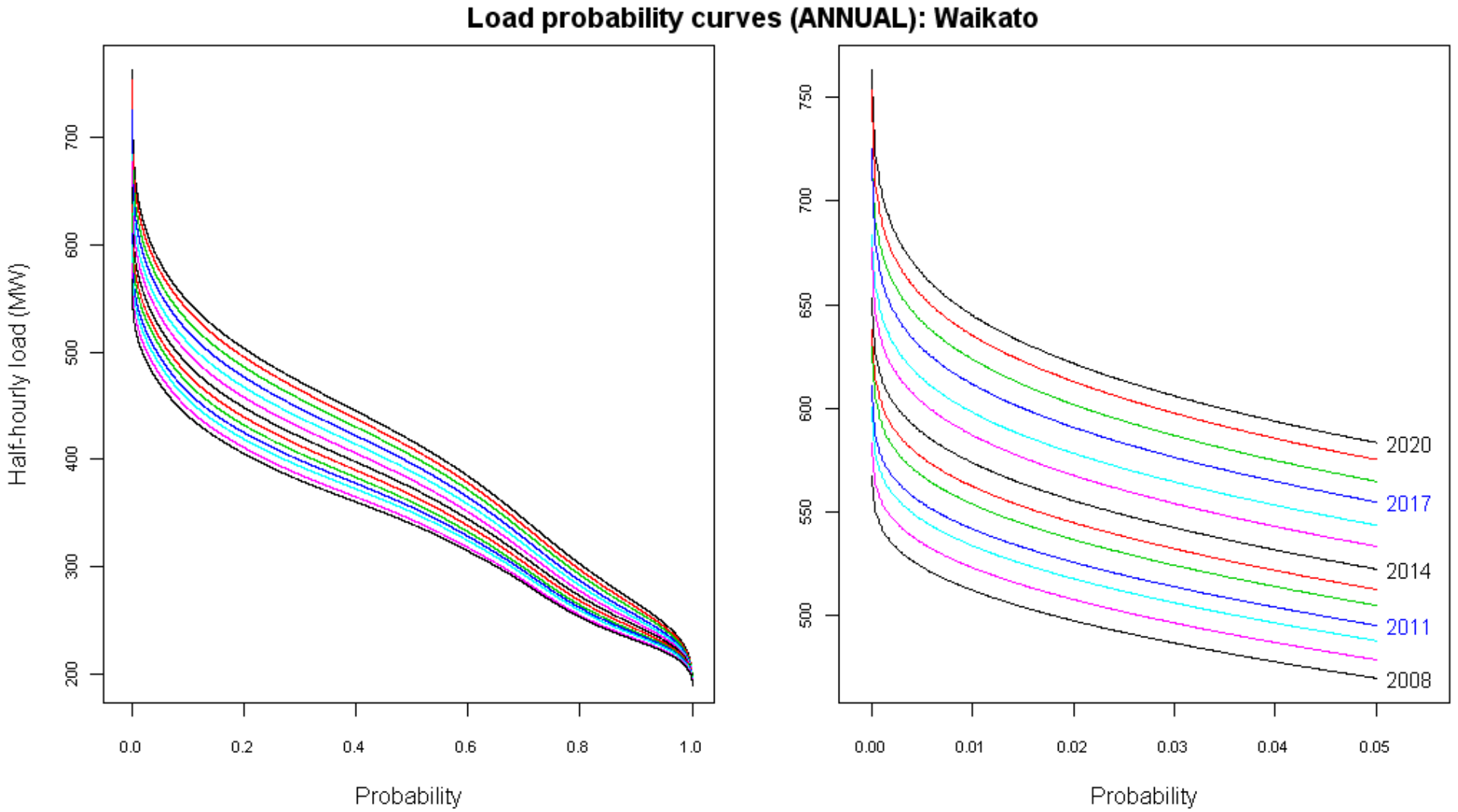

Load probability curves (ANNUAL): Central
Half-hourly load (MW)
100
150
200
250
300
350
400
0.0
0.2
0.4
0.6
0.8
1.0
Probability
300
350
400
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

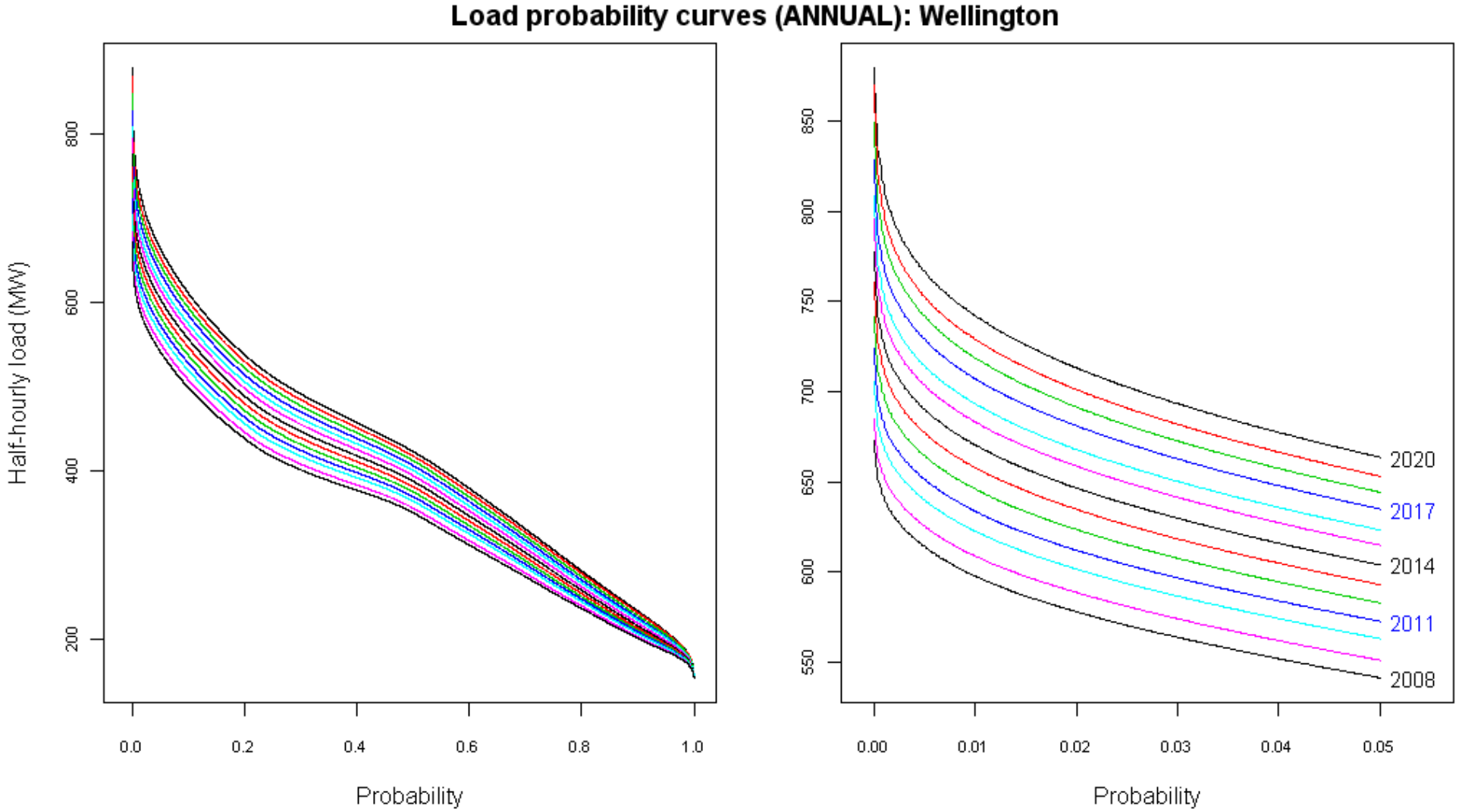

Load probability curves (ANNUAL): HawkesBay
Half-hourly load (MW)
50
100
150
200
250
300
350
0.0
0.2
0.4
0.6
0.8
1.0
Probability
260
280
300
320
340
360
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008


Load probability curves (ANNUAL): NorthIsthmus
Half-hourly load (MW)
200
400
600
800
1000
1200
0.0
0.2
0.4
0.6
0.8
1.0
Probability
700
800
900
1000
1100
1200
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

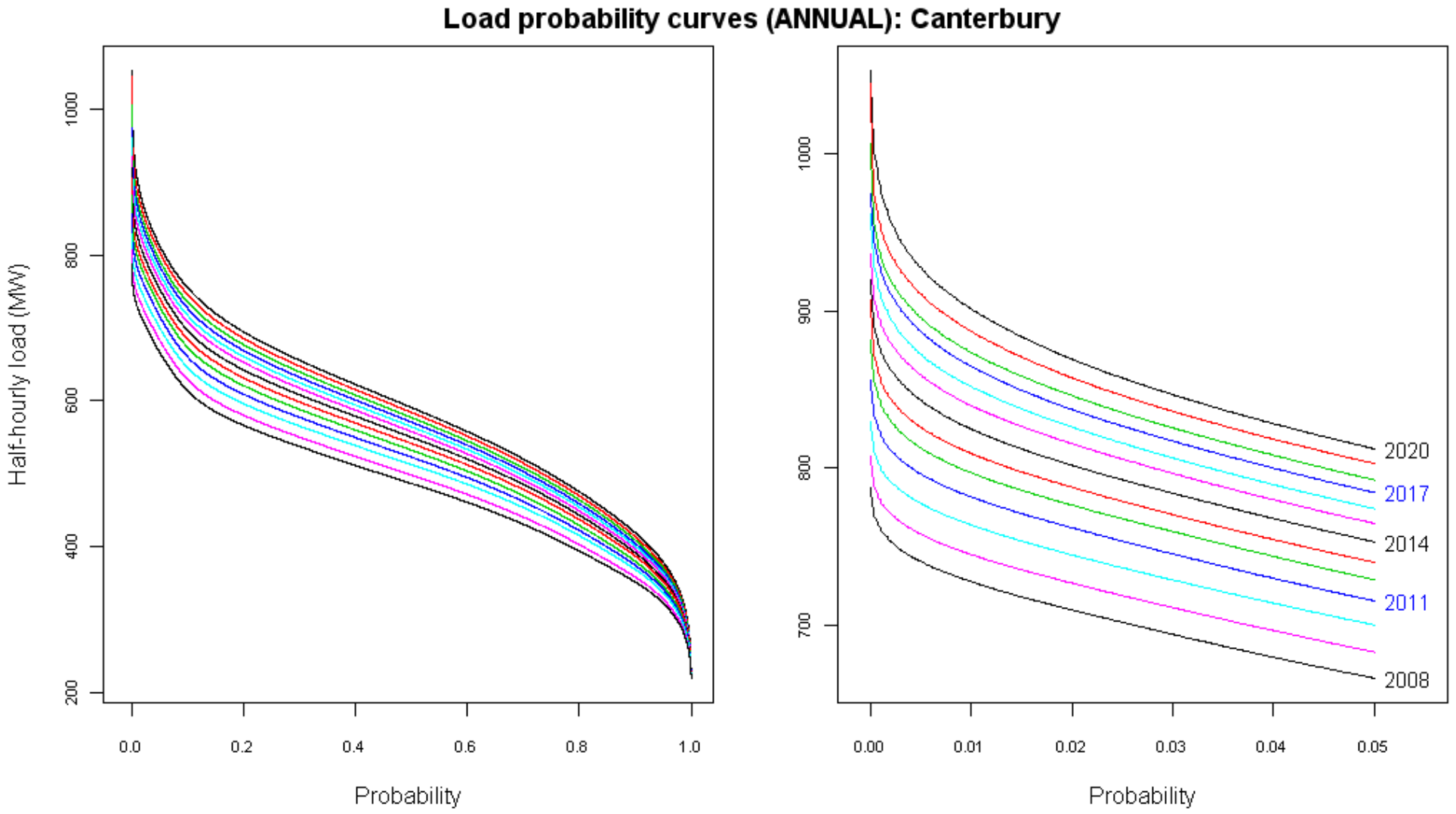
(Note: Taranaki forecast is net of Methanex plant at Motunui)

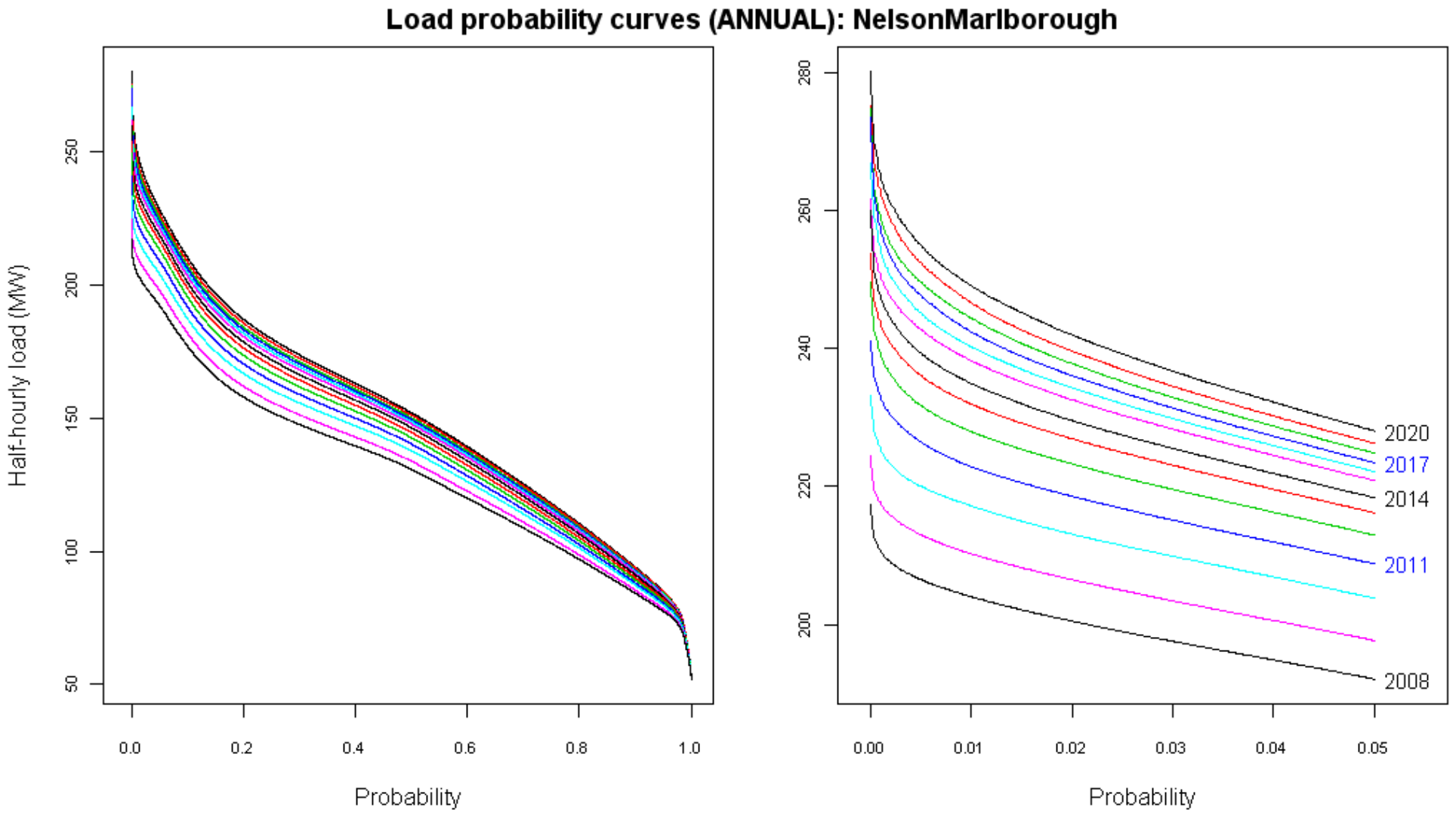


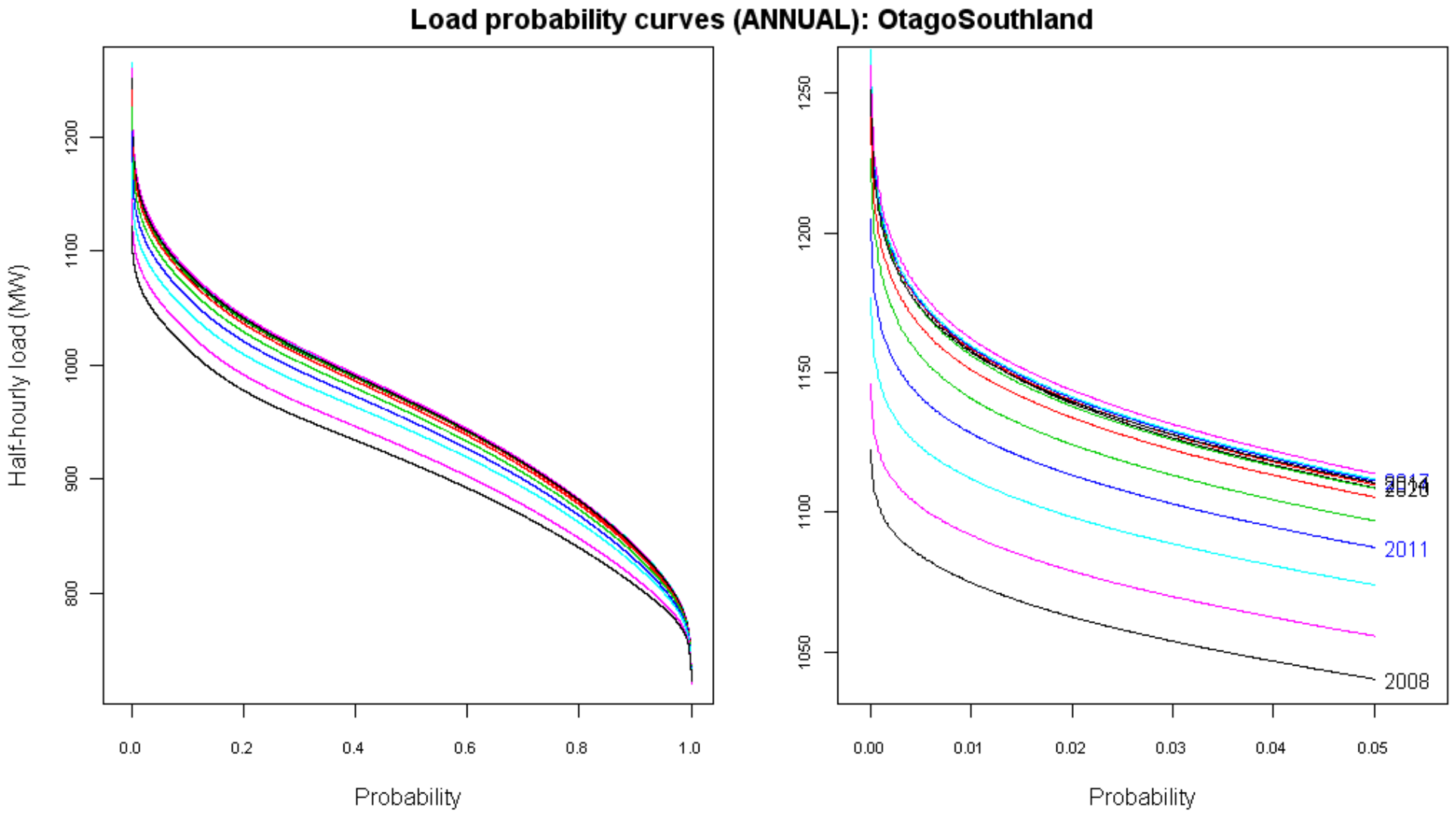

Load probability curves (ANNUAL): Waikato
Half-hourly load (MW)
200
300
400
500
600
700
0.0
0.2
0.4
0.6
0.8
1.0
Probability
500
550
600
650
700
750
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

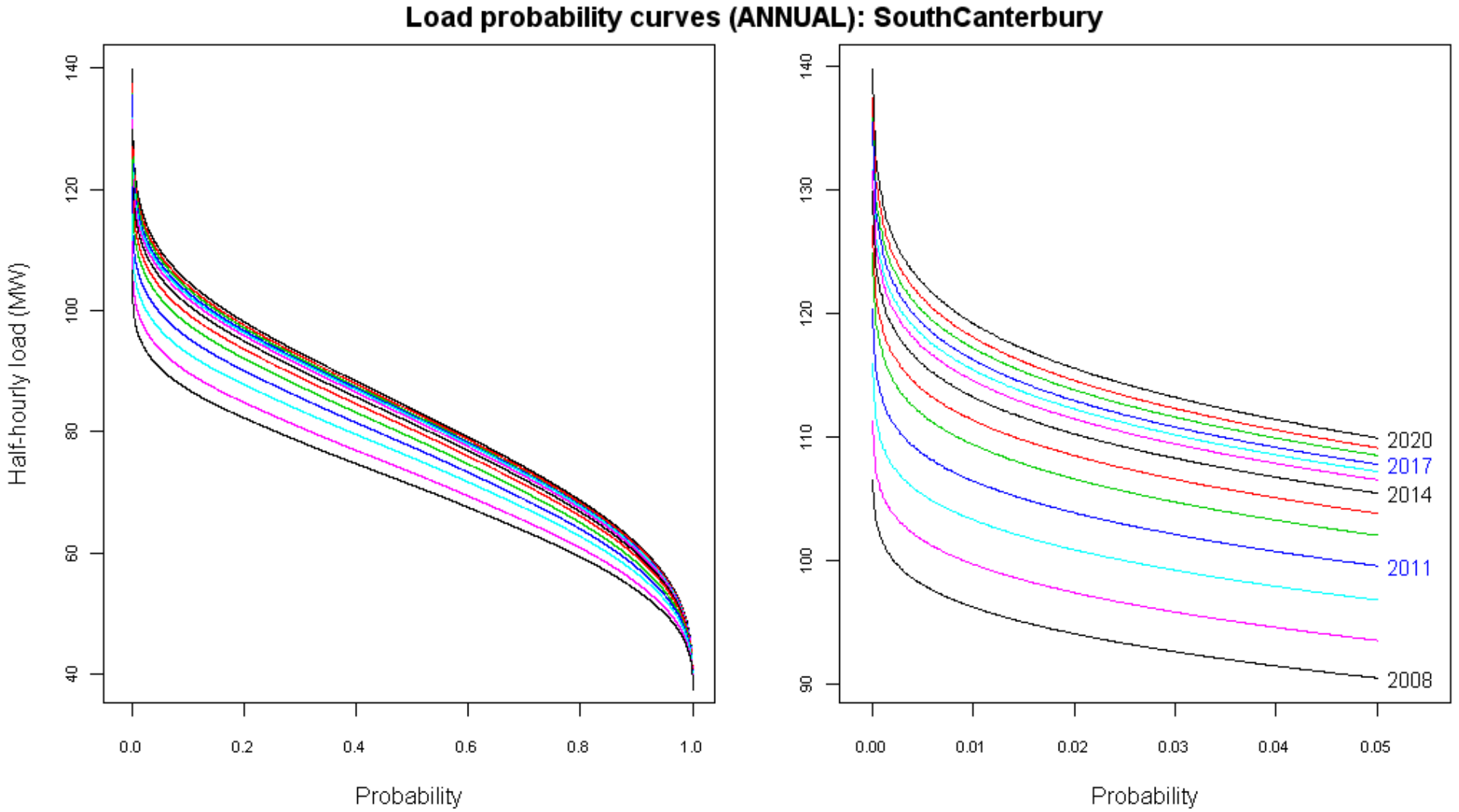

Load probability curves (ANNUAL): Wellington
Half-hourly load (MW)
200
400
600
800
0.0
0.2
0.4
0.6
0.8
1.0
Probability
550
600
650
700
750
800
850
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008

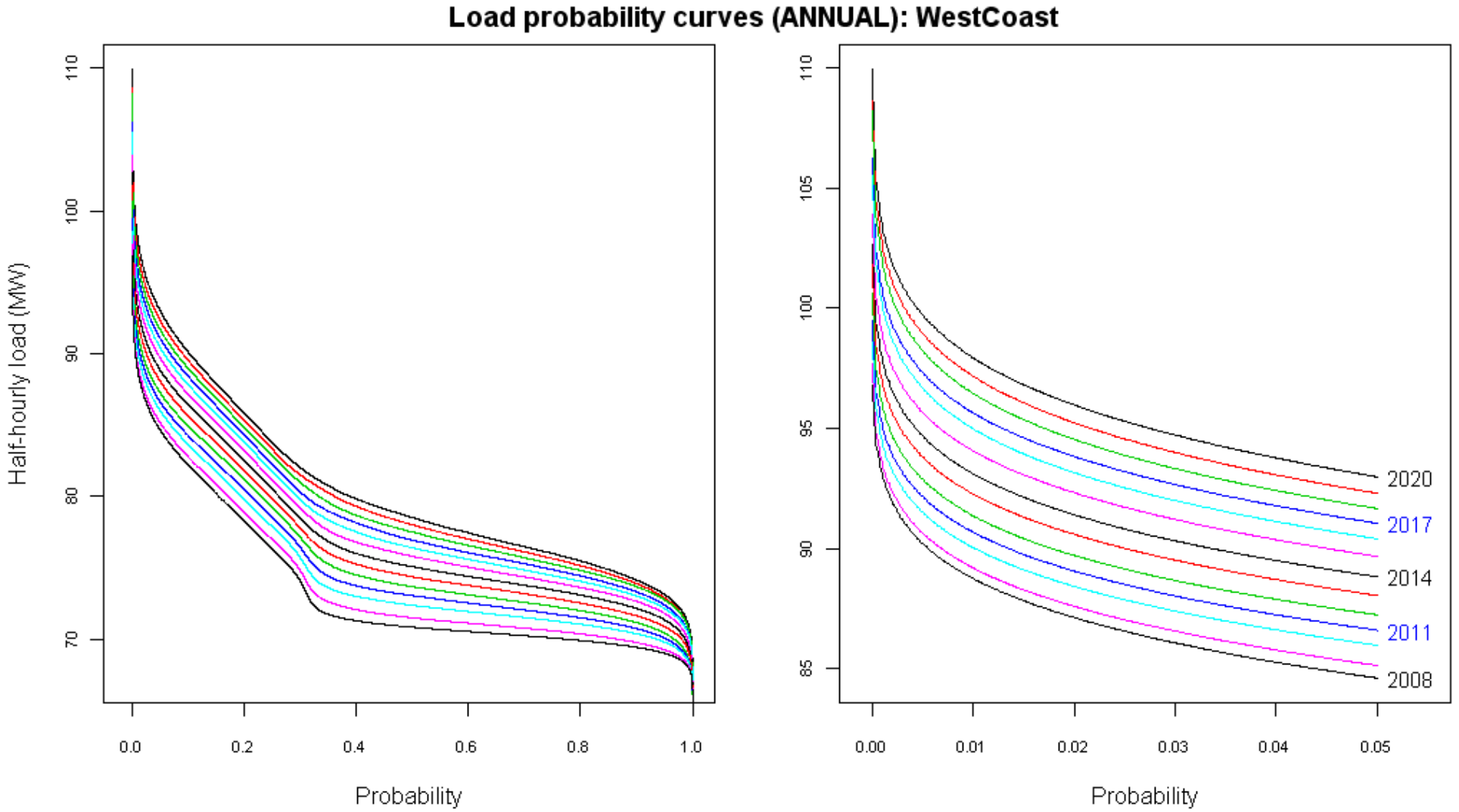
South Island regional forecasts:




Load probability curves (ANNUAL): NelsonMarlborough
Half-hourly load (MW)
50
100
150
200
250
0.0
0.2
0.4
0.6
0.8
1.0
Probability
200
220
240
260
280
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008


Load probability curves (ANNUAL): OtagoSouthland
Half-hourly load (MW)
800
900
1000
1100
1200
0.0
0.2
0.4
0.6
0.8
1.0
Probability
1050
1100
1150
1200
1250
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2011
2008


Load probability curves (ANNUAL): SouthCanterbury
Half-hourly load (MW)
140
120
100
80
60
40
0.0
0.2
0.4
0.6
0.8
1.0
Probability
140
130
120
110
100
90
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008


Load probability curves (ANNUAL): WestCoast
Half-hourly load (MW)
110
100
90
80
70
0.0
0.2
0.4
0.6
0.8
1.0
Probability
110
105
100
95
90
85
0.00
0.01
0.02
0.03
0.04
0.05
Probability
2020
2017
2014
2011
2008