



**ELECTRICITY COMMISSION**

**Wind Generation Investigation Project – Finalised  
Scenarios and Common Assumptions**

**April 2006**

---

## Table of Contents

1. Introduction.....	3
2. Executive Summary .....	3
3. Submissions Summary.....	4
3.1 Aggregate Scenarios.....	4
3.1.1 Submissions.....	4
3.1.2 Commission Response .....	5
3.2 Correlations Analysis.....	5
3.2.1 Submissions.....	5
3.2.2 Commission Response .....	6
3.3 Factors considered in developing regional scenarios.....	6
3.3.1 Submissions.....	6
3.3.2 Commission response.....	6
3.4 Limiting and Causing Factors.....	7
3.4.1 Submissions and Commission Response .....	7
3.5 Common Assumptions .....	7
3.5.1 Submissions.....	7
3.5.2 Commission Response .....	8
3.6 Development of Scenarios .....	10
3.6.1 Submissions.....	10
3.7 Adequacy of the Four Scenarios .....	10
3.7.1 Submissions.....	10
3.7.2 Commission Response .....	12
3.8 General Comments .....	12
3.8.1 Submissions.....	12
3.8.2 Commission Response .....	13
4. Revised Scenarios .....	14
APPENDIX A: Revised Scenarios and Common Assumptions for Wind Generation Investigation Project .....	15

## 1. Introduction

1. In 2005, the Commission established two projects to investigate issues related to the integration of wind generation. This paper relates to the strategic wind generation project, known as the Wind Generation Integration Project (WGIP), which was established to assess and address the wider power system implications of further wind generation over the next 5-10 years.
2. Following approval of the WGIP Scope in September 2005, the Project Team developed a set of scenarios to be used in the Implications modelling stage of the Project. In December 2005, the Commission published a consultation paper '*Scenarios for the Wind Generation Investigation Project*', requesting submissions from interested parties by 9 February 2006. The consultation paper is available on the Commission's website.

## 2. Executive Summary

3. The purpose of the consultation exercise was to seek views as to the quantity and location of wind generation investment that could potentially occur over the next ten years, and where that generation may be located. The scenarios are to be used in the next stage of the project - to examine the impacts on the electricity market and power system of increasing volumes of wind generation.
4. Submissions were received from 13 parties. Broadly the submissions expressed general support for the scenarios and the methodology by which they were developed.
5. The key issues raised by submitters were:
  - (a) Quantity of new wind generation in Low wind scenario;
  - (b) Quantity of new wind generation in South Island in scenarios; and
  - (c) Ambiguity regarding transmission assumptions.
6. The Commission response to these issues is as follows:
  - (a) Low wind scenario quantity increased from an additional 170MW to an additional 200MW;
  - (b) Quantum of South Island wind generation in the scenarios remains unchanged, but (if required) sensitivity analyses will be undertaken to determine the quantities in the South Island at which various issues become binding; and
  - (c) Common Assumptions has been amended to more clearly communicate the intent regarding the modelling of transmission in each of the scenarios.

### 3. Submissions Summary

7. Sections 3.1 to 3.8 provide a summary of the points raised in the submissions relating to each of the eight consultation questions, together with proposed Commission responses to each.

#### 3.1 Aggregate Scenarios

##### 3.1.1 Submissions

8. Question one asked: Do you agree with the approach taken to developing the aggregate wind generation penetration scenarios? Do you consider the aggregate quantities determined for the Very High, High and Low penetration scenarios to be reasonable?
9. Most submitters noted that they were comfortable with the approach taken to developing the aggregate (Low, High, Very High) scenarios. Comalco, Wind Farm Developments (WFD), Mainpower, the Major Electricity Users Group (MEUG), Contact Energy, the New Zealand Wind Energy Association (NZWEA), Transpower, and NEP New Zealand Ltd (NEP) considered the scenarios reasonable. However, some submitters suggested amendments to the aggregate quantities as discussed below.

##### *Low Wind Scenario*

10. Some submitters noted concern that the Low scenario was too low to enable power system and market implications to be examined.
- Trustpower suggested that 170MW of new wind generation capacity is too low, particularly given that the regionalisation of the Low Wind Scenario (Scenario D) spreads the new capacity across the country. It suggests that there should be 250MW of new capacity in the Low scenario.
  - Meridian suggested that the Low and High wind (aggregate) scenarios are calculated based on a flawed premise: that the Huntly and New Plymouth power stations will continue to operate at the current, high, capacity factors over the period of the study. It suggested that using a lower capacity factor for older thermal plant, with the effect of increasing wind generator capacity by 300-400MW in the two scenarios.
  - Mighty River Power (MRP) suggested that the scenarios should be more strongly linked to projects that have been announced and are likely to proceed. It suggested that a more realistic Low scenario would include 500MW of new wind power capacity, including the Awhitu and West Wind projects. It also suggested renaming the scenarios: Low, Moderate and High.

##### *High and Very High Wind Scenarios*

11. Genesis proposed that the Very High (2,000MW, dispersed) scenario, be increased to 2,500MW, in order to reflect recent announcements of potential projects in the South Island.
12. Trustpower agreed that the Very High scenario should be examined for the purpose of testing limits, but considered it unlikely to occur and suggested that rules should not be developed specifically in response to this scenario.
13. Meridian considered that the 2,000MW of new capacity was appropriate for the Very High scenario, but did not support the assumption that generation investment will be unconstrained by demand growth or that thermal capacity factors would remain at current high levels.

### **3.1.2 Commission Response**

14. The names of the scenarios have been amended to Low, Moderate, and High. The remainder of this paper follows this convention.
15. The new wind generation quantity assumed in the Low scenario has been increased to 200MW over the 10-year study period. The Commission recognises that, in view of the capacity of consented wind generation projects, this figure still appears low, but considers it appropriate for a Low scenario, as it provides a good baseline for comparing the other scenarios against.
16. The Moderate and High scenarios (formerly High and Very High) will remain at 1,000 and 2,000MW respectively. The Commission did not consider it necessary to increase the quantities beyond this, as it expects that most of the identified potential issues will arise prior to 2,000MW being installed. However, sensitivity analysis may be undertaken if any of the specified power system or market implications appear to bind at a higher aggregate quantity.<sup>1</sup>

## **3.2 Correlations Analysis**

### **3.2.1 Submissions**

17. Question two was: Do you have any comments to make with regard to the Correlations analysis and conclusions?
18. Several submitters noted they were pleased that this analysis had been completed, and that it was essential to the work of the WGIP.
19. Meridian, WFD, Genesis and Trustpower noted that the results of the analysis were consistent (or not inconsistent) with their own expectations and observations and/or with current industry thinking and research.
20. MRP expressed agreement with the Commission's conclusions arising from the analysis, but noted concern that the analysis relies on 10-minute averaged data. It suggested that, for examining fast and frequent changes in the power

---

<sup>1</sup> The term "binding" refers to the situation where a particular market or power system issue, if not addressed, will place limitations on wind generation installation.

system, this analysis may be of little use, and that further analysis should be undertaken, ideally including 1-minute averages.

### **3.2.2 Commission Response**

21. The Commission notes that 10-minute averages were used in the study, as this was the highest resolution data available from most monitored sites. All regions for which data was received were considered in the study. It is satisfied that this analysis will be a key input into the implications analysis, and notes that where shorter time frame data is critical for the analysis (e.g. for studies of FRR requirements), real time data will be utilised, where available.

## **3.3 *Factors considered in developing regional scenarios***

### **3.3.1 Submissions**

22. Question three was: Do you agree that the factors outlined [in the consultation paper] are the relevant factors to consider in developing regional wind generation penetration scenarios? Do you agree with the high level regional assessment?
23. In general, submitters agreed with the factors considered in developing the regional scenarios.
24. Genesis agreed that the primary investment driver is the quality of regional wind resource, noting that regions without good quality wind resource would not attract a second phase of investment analysis.
25. A number of submitters, including Trustpower, Meridian, Contact, WFD, and NEP, noted concern that constraints and other transmission issues had not been considered in the development of regional scenarios, as these are a key consideration for developers.<sup>2</sup>
26. Transpower noted that local resistance to wind farms may increase as penetration increases, resulting in more submissions being lodged against wind farms in the RMA consenting process, which may, in turn, limit uptake in any one region.
27. Several parties suggested that the wind speeds shown in the table appeared low in some locations compared to their own monitoring results. Several submitters noted they did not consider regional nodal prices a key driver.

### **3.3.2 Commission response**

28. The Commission agrees that transmission adequacy is likely to be a key driver of wind generation investment.

---

<sup>2</sup> Several submitters acknowledged, in making these comments, the Commission's intent to consider transmission effects later in the Project.

29. The rationale for excluding transmission adequacy from consideration in developing the scenarios was to allow consideration of a broader range of possible futures. The alternative, to assume only existing and committed transmission would result in a much 'narrower' set of scenarios. The Commission has reconsidered this approach and is comfortable that it is appropriate for this type of analysis.
30. The Commission notes that changes have been made to the Common Assumptions regarding transmission, as a result of this consultation. These amendments are intended to clarify assumptions made about transmission for each of the scenarios. This is discussed in more detail in section 3.5.
31. With regard to nodal prices as a driver of investment, the Commission notes that these were reviewed in developing the scenarios and it was determined that the differences between regions were relatively insignificant in terms of driving investment, and that it was not, therefore, considered a key driver.

### **3.4 *Limiting and Causing Factors***

#### **3.4.1 Submissions and Commission Response**

32. Question four was: Do you have any comments to make with regard to the identified limiting and causing factors? Do you believe this list is complete or should other factors also be considered?
33. Causing and limiting factors were defined as a means of ensuring that the regional scenarios (developed based on quality of wind resource and other factors) enabled examination of known and potentially significant power system and market issues. For example, it needed to be ensured that a scenario with high South Island penetration be included in order to test the effect on South Island frequency keeping.
34. A number of submissions commented on the limiting and causing factors. However, there appeared to be some confusion regarding the purpose of these, and the Commission acknowledges that the consultation paper was not sufficiently clear as to the purpose of these factors or how they were used in the scenarios. The Commission believes that the scenarios will address the issues raised by submitters, and it does not therefore intend to consider these submissions further.

### **3.5 *Common Assumptions***

#### **3.5.1 Submissions**

35. Question five was: Do you agree with the Common Assumptions listed and consider the list to be complete? If not, what additions, amendments or deletions would you recommend?
36. Several of the assumptions were challenged, as discussed below. Others were generally accepted by submitters.

***Assumption (k) – transmission capability***

37. Assumption (k) was that transmission constraints into/out of regions do not affect the assumed generation locations and quantities.
38. A number of submitters, while acknowledging the Commission's intention to consider this issue later in the Project, expressed concern regarding this assumption. TrustPower, Transpower, Meridian, WFD, Comalco, NEP, Genesis, and Contact all considered that decisions of developers to invest are likely to be affected by transmission constraints. Several cited examples of how insufficient transmission capacity into or within some regions has already halted wind generation investment.
39. Meridian noted that that it believes transmission constraints may be the cause of some of the problems or impacts on the power system in this study. It requested that any results arising from the study acknowledge this assumption and recognise the limitations of it.
40. Genesis suggested that more emphasis be placed upon transmission capability, and that further work should be undertaken to gain better insights into regional and national limits for wind generation and into the impacts of wind generation variability on non-wind based generation.
41. Transpower noted that the common assumptions do not define the state of the transmission system. Several other submitters appear to have misunderstood the intended treatment of transmission in the scenarios and implications modelling. Genesis recommended the Commission provide clarification of the assumptions regarding transmission.

***Assumption (d) – Technological advances in wind turbine technology***

42. Assumption (d) states that advances in wind generation technology will be incorporated in new wind generation installations.
43. MRP recommended that this assumption be amended to state that the present state of the art technology is implemented as opposed to all future technological advances in wind generation. It suggested that this has the benefit of providing a conservative assumption given the time frame of the study, which in turn would serve to better highlight weak points in the power system.

***Proposed New Assumptions***

44. Some submitters proposed additional Common Assumptions, relating to how HVDC charges will be allocated, and how frequency will be managed in the future (e.g. whether there will be a national frequency market). Others suggested that an assumption about whether wind farms will develop primarily at utility-scale or otherwise should be included.

**3.5.2 Commission Response*****Transmission***

45. Transmission issues (e.g. the proximity of transmission lines with sufficient capacity to accommodate wind generation output) has been cited by submitters as a major factor in limiting wind generation uptake in a region. This generally relates to the capability of connection type assets (e.g. spur lines). It is likely that constraints on the core grid will also affect wind generation investment if wind generation behind the constraint is likely to be constrained back or receive low energy prices (affecting investment economics).
46. Assumptions regarding transmission capacity will clearly have a significant effect on the implications modelling outcomes. The Commission continues to believe, as noted in section 3.3, that it is more appropriate for this type of analysis to assume, at least initially, that transmission capacity will not constrain development of wind farms. At a later stage, transmission capability relative to the requirements of the scenarios will be evaluated.
47. While submitters have reasonably argued that transmission issues may mean future wind generation locates differently than as studied in the scenarios, the Commission's approach ensures that transmission limitations are identified and reported. At the same time, this approach will not limit the ability of the scenarios to test for the onset of causing and limiting factors other than transmission, and will allow modelling of greater concentrations of wind generation in particular areas, which may allow identification of onset of other factors such as frequency keeping impacts that otherwise may not occur.
48. Following consultation, the Commission has considered in more detail how transmission will be treated in each scenario, and it was determined that each scenario should include different assumptions around transmission:
  - All scenarios will assume that transmission capacity issues on connection-type assets are resolved between the grid owner and the wind farm owner;
  - The Low scenario will assume that no further grid investment (other than what is already committed) will proceed during the study period;
  - The one High and two Moderate scenarios will initially assume that sufficient investment in the grid occurs such that lack of transmission capability will not negatively affect the investment economics. Where necessary, the capacity of the core grid will be increased to relieve obvious constraints on regional wind generation. Capacity increases will be assumed to be upgrades on existing equipment (e.g. re-tensioning circuits to have a higher operating temperature or through re-conductoring of circuits) where ever possible, to a level commensurate with the 'need' for transmission in that scenario. The inclusion of new lines to provide necessary capacity increases will be only used where there is no other option;
  - Following the main analysis, a second stage of analysis will be undertaken for the High and Moderate scenarios. This will be based on the existing grid and committed upgrades, and will be used to determine what levels of regional wind generation are possible before constraints on the core transmission grid become significant.

***Wind turbine technology***

49. The Commission notes that this assumption was not clear. A sentence has been added to the relevant assumption to clarify that the implications analysis will assume that the capability and performance of future wind farms will be equivalent to the capability and performance of the current state of the art wind generation technology.

***Other proposed assumptions***

50. The Commission did not consider it necessary to include any of the proposed new assumptions in the Common Assumptions.
51. If the HVDC charging methodology affects investment in wind generation over what would otherwise occur, this would fall within the existing scenarios. Similarly, the Commission considers the assumption of utility-scale investments to be a conservative approach, as a predominance of smaller scale investments would be expected to achieve greater diversity benefits (i.e. a less extreme effect, which would therefore fall within the range of scenarios already defined).
52. Regarding the potential for frequency arrangements to limit wind generation investment, the Commission notes that options to alleviate such limits will be considered in the Options stage of the Project.

**3.6 *Development of Scenarios*****3.6.1 Submissions**

53. Question six was: Do you believe that the scenarios outlined above reflect the information used to develop them? If no, how would you change the Scenarios and why?
54. Submitters either agreed that the scenarios appeared to reflect the information used to develop them, or did not comment on this question.

**3.7 *Adequacy of the Four Scenarios*****3.7.1 Submissions**

55. Question seven was: Do you agree that the four scenarios outlined above are sufficient to enable consideration of all necessary power system and market impacts? If not, what additions, amendments or deletions do you recommend in order to develop a complete set of scenarios for the intended purpose?

***General comments***

56. Meridian agreed that the four scenarios are sufficient to enable consideration of possible impacts on the power system and market. It noted that the regional diversity of new generation, assumed in 3 of the 4 scenarios, is important, particularly given the results of the correlations analysis.

- 
57. In contrast, MRP did not consider that the scenarios were best suited to examining the major expected effects of new wind development. It suggested that the scenarios approach is unlikely to properly analyse localised variability. It suggested using sensitivity analysis to model an increasing volume of wind generation in each region (particularly Manawatu, Hawkes Bay, Wellington) and determine when the system or market 'breaks'.
58. Genesis agreed that it is appropriate that no one scenario is expected to be more likely than the others. In contrast, WFD considered that a *most likely scenario* would be necessary to enable consideration of system and market impacts, but noted that this would require forming a view on factors such as thermal fuel availability and cost.
59. Transpower noted that it does not believe that high levels of wind generation penetration are achievable if grid development follows wind generation investment.

#### ***Specific Comments relating to North Island Penetration***

60. TrustPower noted that it does not expect that the scenarios will cover *all* necessary system and market impacts, but that it does anticipate some useful learning coming from them. It suggests that the 300MW in the Hawkes Bay in two of the scenarios may be useful for testing limits, but is quite optimistic.
61. NEP suggested that the regions used for analysis may be too simplistic, and notes significant potential (several hundred megawatts) in the area between the Hawkes Bay and Wairarapa regions.

#### ***Specific Comments relating to South Island Penetration***

62. A number of submitters raised the issue of whether one of the scenarios should examine the case of high wind penetration in the South Island. This follows recent announcements of large-scale wind farm proposals for the South Island, made after the publication of the consultation paper.
63. Contact considered the four scenarios reasonable, but suggested that, given recent announcements, an additional scenario with a higher proportion of wind penetration in the South Island should be included.
64. NZWEA noted that the highest penetration of wind in the South Island in any of the scenarios is 600MW (26% of total wind generation capacity) in Scenario C (Very High), and suggested increasing wind capacity in the South Island in one or more of the scenarios.
65. Genesis suggested that the North/South split in the dispersed scenarios be amended from 70/30 to 60/40, but the 90/10 split retained for Scenario A (High, concentrated in North Island).
66. Mainpower suggested that Scenarios B and C (High and Very High, diversified) are limited by lack of consideration of wind farm development in North Canterbury, and recommended inclusion of 50MW and 100MW respectively.

***Other Proposed Scenarios***

67. Transpower noted that grid development will have a significant effect on wind generation investment, and suggested a fifth scenario be developed under which high wind areas are identified, and pre-emptive grid development (thermal capacity and voltage) undertaken in those areas. The scenario would assume that a strategic policy-level decision had been made to develop wind generation in specified areas. It would enable the economic benefits of pre-emptive grid investment, plus the effect of even more highly concentrated wind farm development to be explored.
68. NZWEA noted that there may be value in having many small wind farms, say 20MW each, rather than fewer larger wind farms, as envisaged in scenarios B and C (High and Very High, diversified) where wind farm sizes are 135MW and 250MW respectively. It suggested a new scenario to examine the likely effect on the scheduling and dispatch process of smaller wind farms.

**3.7.2 Commission Response**

69. The Commission is satisfied that the proposed nature and number of scenarios, together with the use of sensitivity analyses will enable the power system and market implications to be evaluated.
70. Regarding the South Island quantities, it agrees with submitters suggestions that 650MW of wind generation in the South Island is unlikely to reveal all potential South Island issues. However, it notes that the South Island issues would be expected to arise first in the North Island, and will be addressed as a result of that (and by default, mitigate the same issues for the South Island). In addition, the Commission will undertake sensitivity analyses to determine the 'breakpoints' for the South Island, i.e. the MW quantities at which the issues become binding.
71. The Commission also considers that 300MW in the Hawkes Bay region is plausible, based on the current activity and consented quantity in the region.
72. With regard to the other proposed new scenarios, the Commission considers that these are implicit in the four scenarios proposed by the Commission. The impacts that might be expected under Transpower's proposed scenario would be expected to arise under the High (2,000MW) scenario. The many small wind farms scenario proposed by NZWEA would produce greater diversity benefits than the proposed scenarios, and is therefore a less extreme variation of the proposed scenarios.

**3.8 General Comments****3.8.1 Submissions**

73. Finally, submitters were asked whether they had any general comments they wished to make regarding the consultation paper.

***Counterfactual***

74. Meridian noted concern that there does not appear to be a counterfactual to the analysis, and questioned whether the study is assessing the impact of different quantities of wind power against each other, against the next best alternative, or the status quo (incl. current transmission grid).

### ***Options***

75. Meridian suggested that some wind generation may be installed and operated such that variability is managed internally and does not impact on the power system or market (subject to an unconstrained grid between the relevant plant). It also suggested that transmission investment should be considered a means of addressing some of the power system or market issues.
76. Green Zephyr submitted that it is important to consider the benefits of modelled storage, suggesting that failing to do so will render the potentially valuable WGIP initiative a farce, as results will not be achievable in practice.
77. MRP recommended the Commission consider international experience and literature more widely. For example, Germany's experience with wind variability, Spain's experience with clusters of wind farms in different regions, and Ireland's experience as a nation with a grid of similar size to New Zealand, which is relatively isolated and based on a large transmission "backbone" running the length of the country. MRP also provides references to specific reports it believes warrant consideration.

### ***Analytical approach***

78. Meridian submitted that the analysis must consider the impact of other existing factors that cause variability and inaccuracies in forecast prices, and also take diversity benefits into consideration.
79. The Project team considers that an assumption regarding load variability should also be included, stating that load variability is assumed to be of a similar nature in the future as in the present, i.e. rates of change are low during some periods (e.g. early hours of the morning) and very large (sudden switching of large amounts of industrial load) in others. Large changes (e.g. switching of large industrial loads) will be a similar size as that experienced in the present day.

### **3.8.2 Commission Response**

80. The Commission notes that it is intended that the scenarios be compared with one another, with the Low scenario providing a baseline.
81. Options proposed by submitters will be added to the Commission's options register, and considered at the relevant time in the process. The Commission is currently undertaking international research on the subject, which will also assist in the Options phase of the Project.
82. The implications analysis will consider the incremental increase in variability arising from the wind generation in the scenarios. This will take into consideration the diversity benefits noted by the submitter.

## 4. Revised Scenarios

83. Based on the submissions and proposed responses outlined in section 3 of this paper, the scenarios and common assumptions have been revised as shown in appendix A.
84. Key Amendments made to the Scenarios and Common Assumptions are as follows:
- a) Clarification of transmission assumptions for each scenario;
  - b) Quantity of wind generation in Low wind scenario rounded up to 200MW (from 170MW), with corresponding changes in regional allocation;
  - c) Sensitivity analyses to be undertaken on South Island quantities;
  - d) Common assumption regarding wind generation technology evolution clarified;
  - e) Common assumptions added:
    - Load variability will be of a similar nature in the future as in the present;
    - Wind generation installations are assumed to be utility-scale; and
    - Investment in significant amounts of other types of intermittent generation (than wind) does not occur over the study period.



## APPENDIX A: Revised Scenarios and Common Assumptions for Wind Generation Investigation Project

### Scenarios

Table 1: Scenario A

<b>Scenario A: Moderate Penetration, Concentrated in North Island</b>	
Aggregate MW of new wind generation	1,000MW / 3,565GWh of new wind generation between 2006 and 2016.
Regional allocation	<ul style="list-style-type: none"> <li>• 100MW in Waikato</li> <li>• 300MW in Hawkes Bay.</li> <li>• Additional 200MW in Manawatu (for total of 450MW).</li> <li>• 300MW in Wellington.</li> <li>• 100MW in Southland.</li> </ul>
Transmission assumptions specific to scenario	For this scenario, it is assumed that sufficient investment in transmission has occurred to enable the assumed wind farms to be developed and operated without experiencing significant negative effects from constraints (i.e. spill). (Second stage analysis will assume only existing/ committed transmission, in order to examine when constraints will restrict regional wind farm development).
Purpose commentary	<p>Scenario A has most new wind generation concentrated in the central or lower North Island, in only a few areas, and little in the South Island (90%:10%).</p> <p>The purpose of this scenario is to enable:</p> <ul style="list-style-type: none"> <li>▪ Evaluation of the effect on North Island frequency;</li> <li>▪ Consideration of market issues including thermal commitment, and forecast nodal price integrity; and</li> </ul> <p>Evaluation of some of the transmission issues such as the impact of wind generation output variability on power system capability transfer limits (e.g. transfer into Wellington, Hawkes Bay, Central North Island).</p>

Table 2: Scenario B

<b>Scenario B: Moderate Penetration, diversified across the country</b>	
Aggregate MW of new wind generation	1,000MW / 3,565GWh of new wind generation between 2006 and 2016.
Regional allocation	<ul style="list-style-type: none"> <li>• 100MW in Northland.</li> <li>• 100MW in Auckland.</li> <li>• 50MW in Waikato.</li> <li>• 150MW in Hawkes Bay.</li> <li>• Additional 100MW in Manawatu (for total of 350MW).</li> <li>• 50MW in Wairarapa.</li> <li>• 150MW in Wellington.</li> <li>• 50MW in Marlborough.</li> <li>• 150MW in Otago.</li> <li>• 100MW in Southland.</li> </ul>
Transmission assumptions specific to scenario	For this scenario, it is assumed that sufficient investment in transmission has occurred to enable the assumed wind farms to be developed and operated without experiencing significant negative effects from constraints (i.e. spill). (Second stage analysis will assume only existing/ committed transmission, in order to examine when constraints will restrict regional wind farm development).
Purpose commentary	<p>Scenario B has the North Island wind generation more dispersed than in Scenario A, and also there is less wind generation in the North Island / more in the South Island (approximately 70%:30%).</p> <p>Scenario B provides a counterbalance to Scenario A in that it is largely consistent with currently consented wind farms but allows for the possibility of substantial wind generation in the South Island. This makes the effects of wind generation on South Island transmission constraints and frequency keeping more pronounced.</p> <p>The purpose of this scenario is to enable:</p> <ul style="list-style-type: none"> <li>▪ Evaluation of the effect on North Island frequency of a lesser amount of wind generation in the North Island <u>and</u> with more diversity between the output of wind farms; and</li> </ul> <p>Consideration of market issues including thermal commitment, and forecast nodal price integrity. The comparison with Scenario A will be instructive as it will highlight the degree to which diversity will mitigate issues associated with wind variability.</p>

Table 3: Scenario C

<b>Scenario C: High Penetration, diversified across the country</b>	
Aggregate MW of new wind generation	2,000MW / 6,915GWh of new wind generation between 2006 and 2016.
Regional allocation	<ul style="list-style-type: none"> <li>• 150MW in Northland.</li> <li>• 300MW in Auckland.</li> <li>• 100MW in Waikato.</li> <li>• 300MW in Hawkes Bay.</li> <li>• Additional 200MW in Manawatu (for total of 450MW).</li> <li>• 300MW in Wellington.</li> <li>• 50MW in Marlborough.</li> <li>• 300MW in Otago.</li> <li>• 300MW in Southland.</li> </ul>
Transmission assumptions specific to scenario	For this scenario, it is assumed that sufficient investment in transmission has occurred to enable the assumed wind farms to be developed and operated without experiencing significant negative effects from constraints (i.e. spill). (Second stage analysis will assume only existing/ committed transmission, in order to examine when constraints will restrict regional wind farm development).
Purpose commentary	<p>Scenario C has the highest aggregate penetration of new wind generation, with about two-thirds of the total situated in the North Island. The generation is more dispersed throughout both the North and South Islands than is the case in Scenario A.</p> <p>Scenario C allows for the possibility of substantial wind generation in the South Island, which would make the effects of wind generation on South Island transmission constraints and frequency keeping more pronounced. In the event that 650MW of wind generation in the South Island is insufficient to show up the identified power system issues, sensitivity analysis will be undertaken to determine the investment levels at which each issue is expected to become binding under the current arrangements.</p> <p>The purpose of this scenario is to enable:</p> <ul style="list-style-type: none"> <li>▪ Evaluation of a very high level of wind generation penetration on the power system and market in general;</li> <li>▪ Greater focus on the testing the effect of wind generation on South Island frequency keeping requirements; and</li> <li>▪ Consideration of market issues including thermal commitment and operation of thermal plant, and forecast nodal price integrity.</li> </ul>

Table 4: Scenario D

<b>Scenario D: Low Penetration, diversified across the country</b>	
Aggregate MW of new wind generation	200MW / 700GWh of new wind generation between 2006 and 2016.
Regional allocation	<ul style="list-style-type: none"> <li>• 40MW of new wind generation in each of Auckland and Hawkes Bay, 35MW in each of Waikato, and Wairarapa (in addition to an additional 93MW at Tararua 3).</li> <li>• 50MW installed in Southland.</li> </ul>
Transmission assumptions specific to scenario	No further grid investment, other than that which is already committed, will be progressed within the study period.
Purpose commentary /	<p>Scenario D assumes that most of the future increases in energy demand are met by other forms of generation than wind generation.</p> <p>The wind generation in this scenario is relatively dispersed, allowing the effects of diversity to be seen.</p> <p>The impacts of wind generation in this scenario on the operation of the power system and electricity market will be less than the other scenarios.</p> <p>The purpose of this scenario is to:</p> <ul style="list-style-type: none"> <li>▪ Consider whether a low penetration scenario will result in a need for any changes to market Rules or processes, or whether the effect of it can be addressed using current tools;</li> <li>▪ Provide information regarding how much time is available (in terms of capacity installed) before identified issues will become significant / binding, i.e. the level of urgency to progress alternative arrangements.</li> </ul>

## Common Assumptions

1. A number of assumptions have been made that are common to all scenarios. These are presented below, together with rationale where necessary.

## Demand and Supply

2. Existing/committed wind generation includes the following:
  - Te Apiti: 90MW, connected at Woodville;
  - Tararua I, II, and III: 67.7MW existing, plus a further 93MW from 2008, embedded behind Bunnythorpe and Linton substations;
  - Hau Nui: 8.65MW, embedded behind the Greytown substation; and
  - Tararua III: 93MW (committed but not yet installed).
3. Demand growth of 1.8% per annum over the study period. Committed generation as per the Commission's 2005 Initial SOO.
4. Variability of load is assumed to be of a similar nature in the future as in the present, i.e. rates of change are low during some periods (e.g. early hours of the morning) and very large (sudden switching of large amounts of industrial load) in others. Large changes (e.g. switching of large industrial loads) will be a similar size as that experienced in the present day.
5. Some consented wind generation sites may not be developed.
6. No existing wind generation capacity is decommissioned or re-powered.
7. Investment in significant amounts of forms of intermittent generation other than wind has not occurred.
8. Wind generation installations will be utility scale. This is a conservative assumption, as smaller installations would be expected to provide greater diversity benefits than larger scale developments.

## Market Rules and Connection Requirements

9. Any necessary market or rule changes to accommodate the amount of wind generation in the scenario have been carried out (i.e. Rules are not an impediment to uptake). This assumption is necessary to enable consideration of any increase in wind generation beyond what is currently in place, all of which would be prevented within the current rules without dispensations.
10. Wind generation connected to the power system will meet many of the current Asset Owner Performance Obligations (AOPO's) and Technical Codes (e.g. fault ride through capability, voltage). Additional reactive plant needed to support wind farms is assumed to be installed.

11. Power quality issues (e.g. harmonics) caused by wind generation will be fixed at source.

### **Technology**

12. Advances in wind generation technology will be incorporated in new wind generation installations. We believe this assumption is reasonable, as it recognises that future rules are likely to be based around meeting a higher standard technically than is currently the case, and installation of new technology is likely to be more cost effective than using old technology and paying allocable costs related to dispensations. Analysis of the effects of wind generation penetration on the operation of the power system will assume that the capability and performance of future wind farms will be equivalent to the capability and performance of the current state of the art wind generation technology.

### **Transmission**

13. Wind generation will be located close to existing transmission or load. This is based on the prohibitive costs of constructing major transmission solely for a wind farm. A smaller interconnection may be required, and could be constructed within the study period.
14. Each scenario includes different assumptions around transmission (as noted in the definition of each scenario). For the moderate and high scenarios, two areas of analysis will include different assumptions around transmission.
  - The first area of analysis will be based on an assumption that sufficient investment in transmission has occurred to enable the assumed wind farms to be developed and operated without experiencing significant negative effects from constraints (i.e. spill). Where necessary, the capacity of the core grid will be increased to relieve obvious constraints on regional wind generation. Capacity increases will be assumed to be upgrades on existing equipment (e.g. re-tensioning circuits to have a higher operating temperature or through re-conductoring of circuits) where possible. The inclusion of new lines to provide necessary capacity increases will be only used where there is no other option.
  - The second area of analysis will be based on the existing grid and committed upgrades. This analysis will be used to determine what levels of regional wind generation are possible before constraints on the core transmission grid become significant.
15. In all scenarios, it is assumed that transmission capacity issues on connection type assets are resolved between the grid owner and the wind farm owner.