TRANSPOWER NEW ZEALAND LIMITED

Submission to the Electricity Commission on the draft report on transmission to enable renewables

May 2008

TRANSPOWER

Contents

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1. Purpose of this document

This is Transpower New Zealand Limited's submission in response to the Electricity Commission's ("the Commission's") *Draft report on transmission to enable renewables* ("draft report") dated April 2008.

This document also comments on information presented by the Electricity Commission at its transmission to enable renewables (TTER) workshop on 2 May 2008 (the May workshop) that was not included in the draft report.

2. Purposes and desired outcomes of the TTER workstream

Transpower welcomes the draft report and resource reports from the Commission. Transpower considers that the Commission has an important role in enabling renewable generation through the identification of renewable resource-rich regions.

2.1 Purpose of the TTER workstream

The draft report notes "it is hoped that this workstream will identify renewable resource-rich regions, and that this identification can be used to define regional generation scenarios for use in the GIT process… ". Transpower agrees with this, and considers that the purpose of the Commission's TTER process should be to develop:

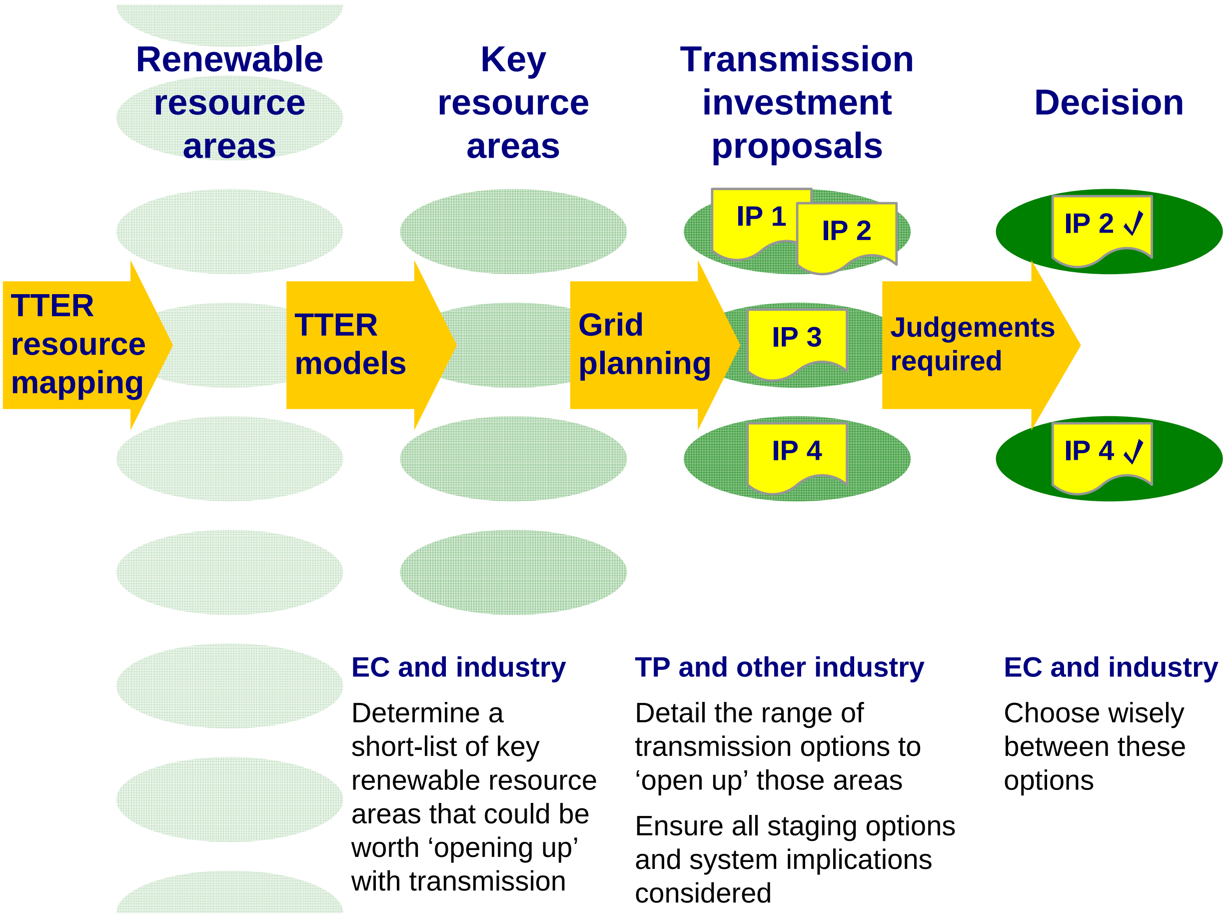
- a full list of resource areas (being progressed through the renewable resource reports); and
- a list of key renewable areas that Transpower should investigate further in terms of the possible commercial generation opportunities and subsequent transmission investments.

That is, the Commission, together with the industry, including Transpower, should identify key resource areas to consider "opening up" with transmission, as the number of renewable areas is too large to contemplate detailed grid planning for all of them. Transpower would then plan any grid upgrades required to "open up" those areas.

This more detailed analysis may indicate that some of the identified key resources areas are not in fact viable from a transmission perspective, and that other transmission options exist for resource areas that were not picked up in the TTER modelling. However, in broad terms, Transpower would develop investment proposals for each identified key resource area.

Transpower believes that, in some cases, the net benefits of proposals will be clear, both in absolute terms and relative to other proposals. However, it is likely that in other cases, especially for any major strategic transmission investment projects, the values or rankings of net benefits across alternatives will probably not be clear cut, and judgements on how to proceed may need to be made in the face of significant uncertainty.

Transpower's view of the framework for this work, given that the deliverable is approved transmission projects, is illustrated in the following diagram:



Transpower consequently agrees with the comment in the draft report that the TTER workstream should aim to identify renewable resource-rich regions. However, the draft report indicates also that its purpose is to present the transmission augmentations which would be required to accommodate the potential renewable generation identified.

Transpower strongly disagrees that this should be a purpose of the TTER work. Reasonable and prudent grid planning requires detailed analysis of all the different facets involved, and expert judgement. The significant simplifications in the TTER modelling and the uncertainties attached to key parameters, together with the absence of broader considerations, prevent the model from accurately identifying transmission augmentations. This is discussed further below.

Transpower is concerned also that, if the Commission expresses a view on "optimal" transmission investments prior to receiving and reviewing any investment proposals by Transpower, parties may perceive that the Commission has predetermined its approval decision.

Transpower is of the view that the Commission's TTER workstream should be more specifically directed at examining the framework and not the specifics of which generation and transmission investment combination is most "optimal". To this end, Transpower considers that transmission planning to the extent to which the Commission appears to be contemplating it in the TTER workstream may not be an appropriate function of the Commission.

3. Issues

3.1 Identification of future renewable generation resources

Transpower welcomes the Commission's work identifying resources by location and encourages the Commission to continue investigation in this area.

3.1.1 Ranking of resource areas

The ranking of the resource areas cannot be considered as given since the drivers behind generation investment in these areas carry a high degree of uncertainty, both in terms of generation and transmission costs. The impact of cost uncertainty on the ranking should be assessed.

Transpower understands that the Commission is only including "Tranche 1" wind sites as potential key wind resource areas in its modelling; that is, it is assuming that there will be no future generation or transmission investment for "Tranche 2 and 3" sites. This is not consistent with Transpower's understanding that, in some cases, lower average but less turbulent wind sites can be commercially preferable. All tranches that may be commercially viable for generators to invest in should be considered.

3.1.2 Importance of consenting likelihood

It would, in certain cases, be necessary to make some assumptions about the ability to gain consent for certain generation projects, especially the large hydro projects and tidal energy projects, such as in the Kaipara harbour. If a project is considered only 50 per cent likely to occur, should it then occur only in 50 per cent of the scenarios (weighted sum) or carry a 50 per cent probability in each of the scenarios individually. There is a difference, as the renewables projects may only be economic as part of a "renewable" scenario and so modelled as built, in which case they could be assigned an unnecessarily high probability if the first approach were used.

The table below illustrates this. Two scenarios ("thermal" and "renewables") are defined, each given a weighting of 50 per cent. The columns for the two scenarios show the likelihood of consent for a particular renewable project. This project is economic in the renewables scenario, but not in the thermal scenario. The last column shows the likelihood of the project being built when weighed over the two scenarios. It can be seen that the likelihood varies, even though the project is consented only 50 per cent of the time in each of the three cases.

	Assumed likelihood of consent for a particular renewable project		Likelihood of build
	Thermal scenario	Renewable scenario	
Case 1	100%	0%	0%
Case 2	50%	50%	25%
Case 3	0%	100%	50%

In summary, the likelihood of consenting of a particular generation project is an important factor in the analysis of transmission to enable renewables, as automatic consenting cannot be assumed. The consenting likelihood for each generation project needs to be modelled exogenously to the scenarios.

3.2 Seeking information from generators

Each generation project is significantly different and subject to a number of drivers which influence a generator's decision as to when to build.

Transpower is of the view that the parties that are most likely to build new generation are best placed to provide information on generation costs, the commercial drivers for investing at particular locations, and the associated uncertainties around these. For major generation projects, these parties are generally the incumbent generators.

The Commission has expressed the view that it is not appropriate for the Commission to rely on information from generators that is unable to be verified or tested[1]. Transpower accepts the Commission's underlying concern that there may be commercial incentives for generators to understate their costs. However, Transpower believes that these concerns can be substantially mitigated by other means including:

- Obtaining agreement on assumptions by multiple generators. This would substantially mitigate the risk of a distorted outcome, and allow the generators' significant experience to be injected effectively into the process.
- Testing information provided by generators through consultation. This would allow other interested parties to comment on any distortions they perceive in the generators' provision of information.

Transpower believes that it is in the generators' best long-term interests to be open with this information. Transpower suspects also that there is no-one more expert in generation investment issues in New Zealand than the incumbent generators themselves, and hence it is not clear who could provide a useful, independent verification or testing that added value.

For these reasons, Transpower is of the view that the Commission's TTER modelling work, on both resource areas and generation modelling, would be enriched and result in more plausible outcomes if it incorporated more directly generator and proponent information.

As the Commission is aware, Transpower is currently investigating two grid upgrades which may facilitate renewable generation:

- the Wairakei Ring economic upgrade – increasing capacity to the circuits forming the Wairakei transmission ring; and
- the Lower South Island economic upgrade – increasing the export capacity out of the Otago/Southland region.

For these projects, and as a prototype for subsequent projects, Transpower has established an industry working group to advise Transpower on project issues in general and generation assumptions in particular.

[1] Electricity Commission Board paper on Lower South Island and Central North Island Economic Investments, January 2008 and letter Commission to Transpower on guidance on these investments, 8 February 2008.

Transpower has found that such direct input from generators into its enabling renewables workstream has been hugely beneficial. Generators have been free and frank in talking about and providing information on their investment drivers, expectations and uncertainties. To date, there has been no confidential information provided, and, as such, all information provided will be in the public arena when the first phase of consultation begins in May 2008.

Transpower believes that this approach could provide a useful model of how the Commission could improve the quality of its renewable resource information, and its understanding of costs, drivers and uncertainties around generation investment, and hence the usefulness of the TTER workstream.

3.3 Co-optimisation in GEM

The generation and transmission "co-optimising" version of GEM may be able to provide useful insights into enabling renewables.

However, Transpower questions the value of the proposed use of GEM in co-optimising generation and transmission assuming fixed "building block" costs for both generation and transmission investment. The use of costs which contain little or no information from the proponents of generation is likely to lead to a purely theoretical generation expansion plan. If this plan is then used to determine "optimal" transmission builds, there would be a high risk of proceeding with investment in sub-optimal areas and, as a result of this, sub-optimal outcomes and even stranded assets.

Transpower is concerned that the Commission's modeling implies a level of certainty in the future system that is not appropriate for planning. Transpower strongly encourages the Commission, if it is to continue with this modelling, to start taking account of inherent uncertainties around new generation build, in particular the decision drivers such as cost and ability to consent.

It is important to note that the outcome from the Commission's proposed co-optimisation is still scenario based: it will provide a possible build path for generation and transmission under a given set of input assumptions. These assumptions include fuel and carbon prices, electricity demand and whether certain projects are available or not. Hence, the model answer is only "optimised" for that specific scenario and will not reflect "real life" optimality. As such, it may be more appropriate to describe the model not as a "generation and transmission co-optimisation model", but rather as a "generation and transmission expansion model" or GTEM, to borrow the terminology of GEM.

Other simplifying assumptions in the analysis could significantly affect the results:

- An 18-regional radial model can only ever be a crude approximation to the realities of the full interconnected system. Such models may provide interesting insights, but the impact of the simplifying assumptions needs to be acknowledged.
- The assumption that transmission circuits between modelled regions are all fully loaded at peak transfer is unrealistic. If the system operator dispatched on this basis it would impose significant constraints on the market. This assumption is likely to lead to

significant underestimation of the transmission required to support a healthy generation market.

The Commission, in a presentation at the May workshop, noted that a key finding of its TTER work to date was that, if connection of new plant remote from the grid is “enabled”, then more plant would be installed closer to large load centres; for example, Northland and BOP wind would be preferred over Southland wind. From the discussion at that workshop, it appears that this has been driven by the loss function, given the assumption of certainty in generation and transmission costs. It will be interesting to see how robust this finding is when such uncertainty is taken into account.

3.4 Option analysis

The draft report discussed option value approaches.

3.4.1 The option value of transmission

Transpower generally supports the use of real options analysis when determining the value of transmission investments in the face of uncertainties, and supports the acquisition of transmission corridors as a mechanism that, in some cases, may assist this.

However, the Commission’s outline of the framework is not detailed enough to provide any real clarity with respect to how the approach would be usefully applied. For instance:

- there is a lot more uncertainty around the building of new generation than that outlined in the proposed tree structure, such as demand growth, generation technology costs, individual project costs transmission costs, fuel costs and the ability and length of time required to obtain resource consents;
- the issue at hand is how transmission can facilitate new renewable generation and, in the face of this, waiting for a generation build decision defeats the purpose of this work, since, at that time, we would know that transmission was required;
- the value, from a national perspective, is actually around the generation plant options and not the transmission. This needs to be explicitly taken into account within the framework.
- Independence appears to be assumed between generation and transmission investment decisions (discussed below).

In its current investigation into this issue, Transpower proposes to base its detailed modelling on the Commission’s GEM model. However, in order to consider a wider range of futures that account for real world uncertainty, as outlined in the points above, there are several changes and simplifications required to be made to the model. These are fully detailed in a Transpower consultation document, which is due for release by in May 2008.

It is also important to realise that, whilst our analysis is based on a nationwide generation stack and costs, each generator has its own stack which is a subset of the whole stack. Each generator will make its investment decisions based on costs along with other factors, such as its portfolio cover, so while the analysis may determine that the next cheapest generation is at a given location, the generating company may not consider that option to be optimum in terms of its business objectives.

Hence, to ensure a competitive generation market, the overall approach needs to ensure that sufficient transmission is built to enable new generation to be built in at least two areas, not just one at a time.

All of these considerations lead Transpower to conclude that there is little value in analysing real options for a single investment. Rather, by recognising the considerable uncertainties, indicated above, over a wide range of these uncertainties, an expected outcome can be calculated which captures the options value, without over-emphasising single, indeterminate assumptions.

3.4.2 The option value of generation

It is highly likely that generation investment decisions will depend on the likelihood of transmission being built to facilitate mostly the unconstrained transfer of the projected power generation. Hence, there will almost certainly be an option value to "signalling" the commitment to build by securing designations and easements that can also further reduce the lead time required to build the transmission line. The question is then whether the option value justifies the securing of designations and easements or not.

Similarly, there may be an option value associated with enabling several resource areas. With incomplete (and uncertain) information about the costs of the generation projects, costs that typically are significantly larger than the costs of the transmission required to enable them, enabling more areas than just the ones needed to allow the most cost effective investments to appear may be justified, as generation may be cheaper in some of the otherwise not connected areas, because of hidden information which is commercially sensitive and because of variations in prices of the various technologies (this uncertainty should reduce over time).

The example below illustrates the above. There are two areas, A and B, with a potential generation project in each. The cost is currently unknown and the true value will not be revealed until after the decision to enable a particular region. The cost can take three different values each with a 33.3 per cent likelihood. For the project in area A, the average expected cost is $100 million and, for area B, the average expected cost is $110 million. Furthermore, it costs $10 million to enable area A and just $5 million to enable area B. The table shows that the expected total costs from enabling area A only is $110 million and area B is $115 million. Enabling both results in an expected cost of $109.4 million, a cheaper solution that the other options, as the cheapest option in either A or B can be selected.

Enable areas	Generation costs	Realisation of uncertainty Area A	Area B	Tx cost to enable	Total costs
	80	1	-		
A only	100	2	-		
	120	3	-		
Average	**100.0**			10	110.0
	90	-	1		
B only	110	-	2		
	130	-	3		
	110.0			5	115.0
	80	1	1		
	80	1	2		
	80	1	3		
	90	2	1		
A plus B	100	2	2		
	100	2	3		
	90	3	1		
	110	3	2		
	120	3	3		
Average	**94.4**			15	109.4

This example is to demonstrate the significant option value associated with enabling generation choice in the face of uncertainty.

3.4.3 Option value summary

Real options analysis is a useful tool for considering the economic benefits of strategic transmission investment. The draft report focuses on "one side of the option coin", namely the benefits that could accrue from deferring transmission investment. The other side of the coin comprises the options provided to generation by bringing transmission investment forward, or of opening up a number of renewable resource areas. This can be considerable, because of the uncertainty of future generation costs, and the size and primacy of efficiency in the generation investment market.

3.5 Overview of the TTER modelling work

Because of the importance of a full understanding of the strengths and limitations of possible modelling approaches to the TTER workstream, Transpower engaged ROAM Consulting when reviewing the draft report. In particular, Transpower sought advice from ROAM on:

- reviewing the proposed modelling approach, which includes the co-optimisation approach and possible real options analysis set out in the draft report;
- suggesting alternative modelling approaches that could be considered; and
- considering issues that may arise as a result of the modelling approaches above, particularly in relation to uncertainties with assumptions.

Attached to this submission is the resultant report from ROAM Consulting.

Transpower considers that the ROAM report is valuable and provides both Transpower and the Commission with useful insights with regard to:

- considering and illustrating the effect of uncertainties in the GEM co-optimisation;
- the need to consider further modelling (either with GEM or another model) to test sensitivities and uncertainties;
- the use of real options analysis as a tool that is independent of GEM;
- the benefits of using a mesh rather than a radial model;
- the consideration of greater resolution modelling;
- how modelling resolution affects GEM's ability to capture high impact low probability events;
- issues with market representation in GEM; and
- the use of GEM as a modelling tool, with the qualification that it is only used to inform a final decision.

3.6 Robustness of the modelling results

As described above, Transpower has significant concerns about the implications of the simplifications used in modelling assumptions and the uncertainties attached to key inputs to the Commission's TTER modelling.

Transpower draws attention to section 2.1 of the attached ROAM report, which includes a useful discussion of this issue and a suggested approach in overview to determining when a renewable resource area can be considered robust to the sensitivities, and when it cannot.

3.7 Runbacks and inter-trips

The draft report discusses the potential use of runbacks and intertrips. Runbacks and intertrips have their place in an efficient system, but they can have significant reliability implications and commercial complexities, especially on the interconnected system. Transpower believes that the Commission is overstating their role with regard to enabling renewables.

Nevertheless, Transpower routinely investigates the use of non transmission alternatives, including both supply and demand side alternatives, when developing options for investment proposals. Generation inter-trips and runback schemes are two of the non transmission alternatives that appear in the long-list used for the assessment of transmission investments to relieve generation constraints.

Transpower has recently provided comments on the use of runbacks and intertrips in Attachment B to its revised *Investment Proposal for the Central North Island Thermal Upgrades*, April 2008. Rather than repeat this here, Transpower refers the Commission and other interested parties to those comments. The report is available on Transpower's GridNewZealand website[2].

2 At http://www.gridnewzealand.co.nz/n1470,247.html.

3.8 Wind integration modelling

At the May workshop, the Commission presented on wind integration modelling. The presentation outlined some work to develop a probabilistic view of security margins and forecasting accuracy. While this work remains an academic exercise, Transpower has no concerns. If, however, there is any intention to develop this work to support policy development, then it needs to be open and reviewed.

Transpower is particularity concerned that the models being used to form views on dependency and interdependency themselves may contain significant assumptions on independence. In particular, convolution of probability distributions requires assumption of their independence, and the fundamental assumption of Markov chains is that the future is dependent only on the present and not on the past (i.e. how we got to the present is irrelevant).

If it is intended that such work be developed to contribute to policy decision, the Commission should open this work to review.

3.9 Transmission cost assumptions

The Commission supplied its cost assumptions[3] to Transpower prior to issuing the draft reports and Transpower is currently reviewing the cost assumptions. It would be premature for Transpower to comment on the cost assumptions as part of this submission, as that review in still in progress. Transpower will supply comments and updated costs as soon the review has been completed.

Transpower notes that the simplicity of the analysis in which these costs are intended to be used, and the uncertainty in other critical assumptions, limit the accuracy to which transmission costs are reasonably required.

3.10 Minor errors of fact

3.10.1 HVDC charge

The draft report states that the HVDC charge promotes efficient uptake of renewable generation by signalling the locational cost of connection in the South Island. This is true only to the extent that the charge influences investment in new HVDC capacity and, even then, it cannot be claimed that the charge in any way accurately reflects the long run marginal cost of investment in HVDC capacity.

3.10.2 Capacity rights

The draft report states that "loss and constraint rentals are allocated to those that pay for transmission assets. These are the financial equivalent of capacity rights as whenever a transmission constraint occurs the difference in the value of the electricity that flows through the constraint link is refunded as a constraint rental." This is correct only for radial connection assets, not for the core grid. Radial generation connection assets are rarely constrained. Rentals on

[3] Outlined as Appendix 4 to the draft report: *Transmission network reinforcement – input for GEM* (prepared by System Studies Group).

connection assets amount to under three per cent of total rentals[4]. Connection rentals are also often negative.

3.10.3 Grid connection

Transpower agrees with the Commission that the timely and efficient provision of transmission and connections is important, and that this is important for all parts of the process, including the system investigations, approval process, and implementation.

The Commission's comments on connection assets are generic and do not recognise that there are two distinct types of connections assets, and each type has different performance requirements. The performance requirements for connection assets connected directly to the grid without a circuit breaker are significantly more stringent than those connected via a circuit breaker, because the two have entirely different effects on other grid users.

As noted by the Commission, there are a number of generation proponents who have used non Transpower resources to undertake power system studies.

3.10.4 Transmission pricing methodology and new connection asset investments

The discussion in paragraph 6.2.9 of the consultation paper about the way in which a return on new connection asset investments would be recovered is misleading. If a new transmission line were approved by the Commission pursuant to a GUP in order to enable generation investment in a "green field" renewable generation region, a return on that investment would be recovered in accordance with the transmission pricing methodology (TPM) contained in schedule F5 to section IV of Part F of the rules. Under the TPM, if a line classified as a connection asset were subsequently shared by a new customer connecting to it, each customer would contribute to the connection charge for the line in proportion to their anytime maximum injection (AMI) or anytime maximum demand (AMD), and in proportion to the length of the line that each used. Paragraph 6.2.9 states that if a line were built to connect NL2, NL1 could subsequently connect to that line at no cost – that is not correct. If the line were built pursuant to a new investment agreement (NIA) with a transmission customer, say NL2, the capital component of the investment would be entirely recovered from NL2 pursuant to the terms of the NIA between NL2 and Transpower. If a new customer, say NL1, were subsequently to seek to connect to the new line, Transpower would negotiate new NIAs with NL1 and NL2 to share the capital cost between them.

It is also important to appreciate that, if a return on the capital cost of a new line that is classed as a connection asset were recovered in accordance with the TPM, some of the capital cost of the line, during the early years of its life, would be recovered from other connected customers. In later years, the reverse would be the case, and the parties connected to the line would contribute to the cost of other connected assets. This is because of the way that the asset return rate (ARR) connection assets is calculated for assets in the connection asset "pool". The ARR is calculated using the regulated asset value of all connection assets, some of which are heavily depreciated, and the ARR is then applied to the replacement costs of those assets. What this means, in practice, is that, initially,

4 2.7% of HVAC or 2.2% of total HVAC and HVDC over the two years ending March 2008.

a return on the capital cost of the new line would be shared approximately 60:40 between the first connecting party and all other connected customers with assets in the "pool". This proportion would increase over time as the regulated asset value of the line depreciated and other assets in the connection asset "pool" were replaced or new connection assets added to the "pool".

Another important point in relation to transmission pricing is that, if a transmission customer were able to demonstrate that it could by-pass existing transmission assets at lower commercial cost to itself, it could make a case for a prudent discount in accordance with section 9 of the TPM. If a sound prudent discount case were made, the connection charges would have to be adjusted down and Transpower would be required to "write down" the value of the line.

This clarification is provided to ensure a full understanding of how the current TPM is applied, and/or NIAs used, in such cases. Other allocation methodologies and charging methods are, of course, possible.

4. Recommendations

Transpower recommends that:

- The focus of the EC's work should be on identifying renewable resource areas and identifying a small number of key renewable resource areas for Transpower to consider further. This would assist Transpower when developing investment proposals.
- The Commission's modelling work should be labelled more accurately, i.e. instead of transmission and generation "co-optimisation" describe it as "expansion" or similar.
- Generators are actively involved in developing assumptions relating to generation costs and commercially-viable resources sites.
- The impact of the simplifications inherent in the modelling be acknowledged and allowed for when drawing any conclusions from the analysis.
- Extensive sensitivity analysis be conducted across the range of dependent and independent uncertainties in the assumptions to test the robustness of the results.
- Option values be considered, both for generation and for transmission.
- The wind integration modelling work, if it is to influence policy development, be opened to review.

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Final Report (Trp00012) to

TRANSPOWER

NEW ZEALAND ELECTRICITY MARKET DEVELOPMENT

Transpower Transmission to Enable Renewables Evaluation

1 May 2008

VERSION HISTORY

Version History					
Revision	**Date Issued**	**Prepared By**	**Approved By**	**Date Approved**	**Revision Type**
0.9	2008-05-01	Richard Bean	Ian Rose	2008-05-01	Draft
1.0	2008-05-08	Richard Bean	Ian Rose	2008-05-08	Final

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1) Background

Transpower has requested ROAM Consulting to evaluate the New Zealand Electricity Commission's TTER (Transmission To Enable Renewables) project. GEM (Generation Expansion Model) was originally developed by Concept Consulting in 2006 and has been refined and expanded by the Electricity Commission since then. GEM was initially developed to assist with the development of the GPAs (Grid Planning Assumptions) and was then used to analyse the various HVDC upgrade options. Most recently, with the launch of the TTER project, the EC intends to use GEM to model the expansion of transmission as well as generation to enable renewable generation to reach 90% of generated electricity by 2025. The optimisation of transmission and generation simultaneously is referred to as "co-optimisation". ROAM has experience in projects involving the optimal development, taking into account transmission and generation costs, of electricity networks in the North Island of New Zealand and also in Australia.

Six key issues with respect to the Electricity Commission's "Draft Report on transmission to enable renewables" have been identified for comment:

- Co-optimisation of transmission and generation
- Real options analysis
- Network representation – radial versus mesh
- Timesteps / granularity
- Duration of outlook / residual
- Market representation

2) Evaluation

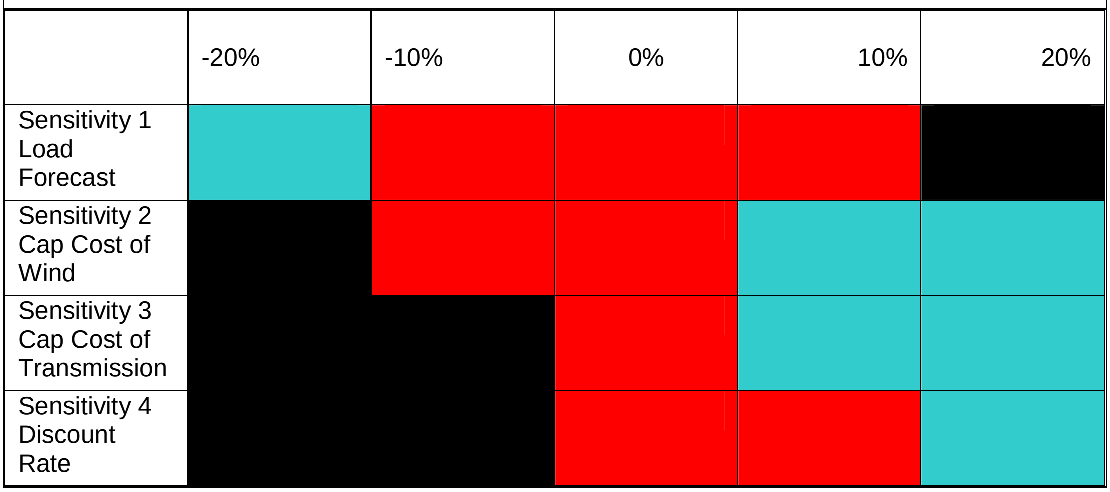
2.1) Uncertainty in Data

TTER para 6.1.1 and 6.1.2 suggests that costs of transmission are estimates only and should not be used for transmission planning. This supports the need for a very wide range of sensitivity analysis in order for the EC to attempt to use GEM to establish generation scenarios for the GPA.

Both the ECNZ and Transpower have noted that transmission costs can vary considerably based on the ease or otherwise of obtaining consents. Also, Appendix 2 to the report notes that the estimates of the cost of future hydro-electric schemes can vary by up to 30%. The GEM model currently includes 55 potential hydro schemes and modelling the sensitivities by re-running the mixed integer program would be infeasible.

A so-called "tornado diagram" can be used to illustrate the effects of adjusting various sensitivities in the study. An example of a tornado diagram is shown in Figure 2.1.

Figure 2.1 – Tornado Diagram Example



In this diagram, for example, red may indicate the outcome of the base case (a combination of North and South Island wind), blue may indicate an outcome with a predominance of North Island wind and geothermal, and black may indicate an outcome with a predominance of South Island wind and South Island hydros. It is emphasised that this is not a simulation outcome but an illustration for instructive purposes only. ROAM has successfully constructed diagrams from IRP (integrated resource planning) studies for other projects. Fewer projects indicate a robust model outcome whereas a larger number of projects indicate a high degree of uncertainty in decision making.

Transpower indicated that a tornado diagram (which is similar in appearance to a Christmas tree) would be useful for studying a short list of options (for example if GEM can produce two or three outcomes to be studied).

2.2) CO-OPTIMISATION OF TRANSMISSION AND GENERATION

The GEM model attempts to simultaneously optimise the cost of transmission and generation using a NPV (net present value approach).

Compared to the version of GEM which was used to evaluate the HVDC transmission upgrade, the number of regions has been increased to 18 and the supply demand balance equation (supply + net imports = demand + pumped generation) accounts for imports into any of these regions. A set of new constraints accounts for the possibilities of transmission upgrades at particular times between regions (for example, BTX is a 0-1 variable indicating whether a particular transmission path exists in a given year; TXPROJVAR and TXUPGRADE indicate whether a project or transmission upgrade goes ahead). Transmission upgrades, like generation upgrades, are assumed to happen on an annual basis in the new GEM model. In the input data spreadsheet, a fixed cost is applied to each upgrade path and capacities with losses are listed for each possible upgrade. Earliest upgrade years are assigned to each possibility with a few of the upgrades having a fixed year (for instance, the HVDC link upgrade will occur in the model in the year 2015 with a capital cost of $686 million).

There is a path state variable TRNTXPS (transition of transmission path states) to ensure that upgrades are defined correctly – that is, that two upgrades do not occur on a particular path during any given year and that upgrades do not occur "out of order". This helps solve the "cost of connection" problems mentioned in paragraph 6.2.9 of the draft TTER report.

An alternative approach would be a dynamic programming approach such as the IAEA's WASP model, which is used in many countries and exemplified by ROAM's IRP (Integrated Resource Planning) program, as noted in a report prepared for Transpower "Capacity Expansion Planning for the New Zealand Electricity Market". Application of dynamic programming effectively enumerates all possible future system 'states' in a sequential manner from the present system state to some horizon year in the future. Each state consists of the transmission network arrangement, the set of operating generators and the system load (demand and energy). Since the enumeration is completed sequentially, time varying parameters and pre-conditions can be included in the determination of reasonable future states.

The TTER draft report para 6.2.9 provides an example of two potential nodes at Northland (NL1 and NL2) north of the current MDN (Northland) node. There is some discussion of the possibilities of ordering the transmission building. This is a situation where dynamic programming would be of assistance.

In the example provided in TTER para 6.2.9 the dynamic program could in any future year transition from:

- Neither NL1 nor NL2 to NL1 in with:
    1. suitable transmission to MDN for NL1 only;
    2. suitable transmission to MDN for NL1 and NL2;
- Neither NL1 nor NL2 to NL2 in with:
    3. suitable transmission to MDN for NL2 only;
    4. suitable transmission to MDN for NL1 and NL2;
- Neither NL1 nor NL2 to both NL1 and NL2 in with:
    5. suitable transmission to MDN for NL1 and NL2

The five new states available in the subsequent years also contain the history of the state which it came from, the parent state. There will then be only certain unique states that are reasonable to transition to, from this new state 1, and so on. In this way multiple possibilities can be catered for in time sequence. The capital costs associated with each path in the sequential tree are then well understood.

The variable cost of energy supply may then be evaluated to any desired level of accuracy. Synonymous with GEM, the annual cost of supply for the system state would be costed in four time steps (quarterly). The benefit of dynamic programming is that each state may be evaluated to a high level of accuracy to take account of market behaviours and the many dynamic relationships between generation dispatch and transmission network capability.

Having evaluated the variable cost component of each state, the dynamic program tree is then spanned again, accumulating the net present value of the capital cost component and the variable cost component from the start year to the horizon year for all possible future paths. In this way the variable operating costs are traded off against capital costs along each pathway. The pathway which results in the lowest total NPV of supply over the term of the outlook then provides both the timing of investments along the path as well as the investments themselves. Without a suitable level of accuracy in the evaluation of the variable cost component it is not clear how the benefits in operational cost reductions would be captured and adequately traded off against the high capital costs of transmission investment.

2.3) REAL OPTIONS ANALYSIS

Real Options Analysis is used in financial modelling to model the situation where a company has a portfolio of put and call options, as well as in other situations where investment decisions must be made in the presence of uncertainty. A decision tree is built and at each node in the tree, a cost is incurred and a decision is made to exercise, or not exercise an option, which in the case of financial modelling may be a put or call option and in the case of energy investment may be building or deferring a generation or transmission project. Probabilities are assigned to each option at each step and the path with the least ROV (Real Options Value) is chosen; the approach adopted by real options analysis is a probability-weighted NPV calculation.

A paper by Graham, Vincent, Coombes and Duffy ("Real Options Analysis – A Case Study" published by the Co-operative Research Centre for Sustainable Development in Australia) describes real options analysis in more detail with respect to decision making in the Australian power generation sector in the presence of uncertainty about future carbon taxes. More detail can be found in Dixit and Pindyck's book "Investment under uncertainty" (Princeton University Press, 1994).

TTER paragraph 3.4.8 suggests that following GEM that Real Options be run, then following Real Options that Monte Carlo be run. IRP with a low level dispatch engine performs Monte Carlo modelling as part of the IRP and may enable this multi-step process to be shortened and made less error prone by incorporating more accuracy in the first stage of the modelling.

Real Options Analysis, as noted at the Electricity Commission seminar, is a process completely separate from GEM. It may be used to justify decisions after GEM produces a set of possible outcomes. GEM, along with all other long-range planning programs, contains no facility for making investment decisions in the face of uncertainty.

2.4) *RADIAL VERSUS MESH REPRESENTATIONS*

The current GEM model chooses to represent the New Zealand network as a radial model, with the present system represented with 18 nodes. However, many loops exist in the physical network which are not being accurately characterised by the current GEM representation. Simple examples include the Wairakei ring and several loops between Othahuhu and Te Apiti. In previous work completed for transmission augmentation assessment in the New Zealand system[1], it has been determined that a radial network would not provide a sufficiently accurate representation of the network.

Meshed transmission networks provide inherently more reliability in delivering energy supply.

Loss factors are linear in GEM which will undervalue losses at high utilization of transmission assets.

Transpower noted at the meeting on 2 May that a GEM version with a 12 node mesh representation and DC load flow is being developed for internal use.

2.5) *TIMESTEPS, GRANULARITY AND RELIABILITY*

It is understood that the GEM model has been developed to provide an indication of long range generation expansion options that may be expected under a range of market development scenarios. The GEM model provides a high level analysis of the capability for new generation options primarily to meet the energy forecast. Assumed capacity availability factors are applied to estimate the capability of the generation expansion plan to meet forecast demand. On this basis the underlying reliability of supply becomes less certain into the future. Reliability of supply modelling must capture very low probability events and therefore requires much more in depth analysis of the reliability of both transmission and generation supply components at a high resolution in both temporal and special terms.

The recent extension of the GEM model to incorporate transmission flow paths compounds the uncertainty of the likely reliability of supply in relation to both generation availability and transmission availability and capability. In relation to wind generation particularly, coincidence of production from wind generators is known with very little certainty. Should transmission development then proceed to meet the maximum capability of wind power injection? If transmission development provides less than 100% of the capacity of wind power injection then what is the economic level of congestion and how will this be measured? Careful consideration must be employed to ensure that both the generation and transmission development

[1] Transmission Line between Whakamaru and South Auckland, 400kV project.
Reinforce supply to North Auckland and Northland. ROAM Consulting

plans will continue to meet the extremely high levels of reliability that are expected in the energy supply system.

GEM applies energy and demand constraints on a quarterly basis. The next level of detail to improve estimates of generation and transmission utilization involves application of load duration curve analysis. For reliability assessment in large, complex meshed transmission systems, time sequential Monte Carlo simulation with at least hourly (ideally half-hourly) resolution is the generally accepted method for providing reliable modelling outcomes. As opposed to this, load blocks for hydro or wind blocks are at best an approximation as assumptions have to be made as to the equivalent capacity for reliability purposes. Load or wind blocks require benchmarking against a pre-existing half hourly tool.

2.6) DURATION OF OUTLOOK AND RESIDUALS

The last modelled year in the default run is 2040. By then, it is very difficult to predict what kind of generation technologies will be available. For example, marine power generation technology is represented in GEM by six generic wave power projects which can come in (at the earliest) between 2025 and 2035. Companies such as Neptune Power are quite positive about the prospects for wave power in the Cook Strait, though this remains a speculative prospect.

The TOTALCOST function in GEM seems to no longer account for residuals (plant value remaining at the end of the study) – that is, retirements do not incur a negative cost. This may be an issue in modelling accuracy.

Residuals are accurately accounted for in dynamic programming through two alternative methodologies. In the dynamic programming pathway capital costs may be annualized and accumulated as the tree is spanned. At the end of the study the residual value has simply not been 'spent'. Alternatively capital may be spent at the time of commissioning and the residual value refunded based on the duration that each project has been operational.

2.7) MARKET REPRESENTATION

Wind is scaled to 20% of its capacity in the GEM model; that is, the contribution of a wind farm at its peak is only 20% of its maximum capacity. This may tend to underutilise the transmission grid but is better than the approach of choosing the peak contribution factor to be 100%, which would overutilise the grid. Bruce Smith gave a brief talk at the seminar on how a model was developed to calculate this peak contribution factor.

Commercial arrangements between generators, fuel suppliers, customers and transmission service providers (Transpower) are a significant determining factor for project advancement to committed status. The market does not always deliver the apparent 'economically sensible' outcome. This uncertainty is very difficult to capture in any modelling pursuit but must be considered in any outcomes produced.

It should be noted that GEM is one tool that informs an overall decision, rather than producing generation and transmission schedules which must be followed. With the uncertainty about commercial arrangements possibly producing unusual outcomes, attempting to model market participants' behaviour would be a futile exercise.

3) CONCLUSIONS AND RECOMMENDATIONS

Planning is absolutely critical to developing sound development plans under a wide range of uncertainties. Modelling provides a significant input in developing the trade-offs that are required when assessing highly capital intensive investments with very long operational lifetimes. Great care however must be taken to ensure that modelling does in fact provide a good reflection of the present and likely future state of the system being modeled. If it does not, then modelling outcomes may be misleading. Misleading information may be more detrimental than no information at all.

GEM provides a valuable alternative model for understanding future generation development plans. In a similar manner to most NPV evaluation models it provides a single outcome for a defined set of inputs. In order to evaluate uncertainty the model can be re-run with input parameters changed. As mentioned previously this may require a very large number of GEM 'runs'. Despite the computational difficulties that this may impose, strong consideration should be given to completing a wide range of sensitivity analysis to help develop an understanding of the sensitivity to key cost (and benefit) parameters in the GEM model. As discussed in the TTER Real Options Analysis can be used to compliment the GEM analysis and gain an understanding of the key parameters to focus on. However each individual model should be widely tested to ensure robust development planning outcomes are achieved.

It is recommended that GEM's results be treated with caution as the model is quite coarse in some respects. It would be advantageous for Transpower to supplement and check results produced by GEM with results produced by a model more suited to the wide range of cost sensitivities which arise in long-term planning problems.

In summary, GEM is good at modelling the development of generation and transmission when costs are known and technologies for scenarios can be predicted well into the future. However, its key drawbacks are the difficulty of sensitivity analyses and the current lack of a mesh representation of the New Zealand network. Transpower has noted that GEM is an acceptable tool for long-range planning but it is preferable that it remains a tool which informs of possible options as opposed to giving a ranking of projects.