



T R A N S P O W E R

Inter-Island HVDC Pole 1 Replacement Investigation

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GIT Consultation Document – Attachment F

MAV Pole 1 - Economic Analysis

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Changes made to this document since its last issue, which affect its scope or sense, are marked in the right margin by a vertical bar (|).

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Executive summary

Following a request from the Electricity Commission on 7 January 2008, Transpower has carried out a high level economic analysis for a hypothetical situation where full service operation of the existing Pole 1 of the HVDC link (Pole 1), or half of Pole 1, is possible beyond the earliest likely commissioning date of a new Pole 1 (i.e. 2012). This represents a period of future operation which would be more than twice as long as the one to two years recommended within the Environmental report⁴.

The purpose of the economic analysis is to determine whether this hypothetical situation could reasonably provide benefit by hypothetically deferring the preferred HVDC Pole 1 replacement option as determined by the GIT. As such, the analysis attempts to identify whether there would be any significant net market cost in complying with the Environmental report's recommendations, without comprehensive regard to all of the practicalities that arise from not carrying out the report's recommendations.

1 Background and purpose

Transpower has been concerned for some time about the continued deterioration in the HVDC Pole 1 assets given the age of the plant and the risks identified in the 2005 GUP¹.

As part of the HVDC Pole 1 Replacement Investigation Project, Transpower needed to quantify the economics of continued Pole 1 operation. To that end, Transpower commissioned assessment from its insurance advisers in mid-2007 on the costs of insuring Pole 1. It was intended that these costs would then form part of the necessary GIT analysis for the replacement project.

Advice from Transpower's insurers was that the Pole 1 assets were uninsurable in their current state because of the potential consequences of failure and the age and condition of the assets². Transpower subsequently commissioned further reports on mitigation costs and timings^{3,4}.

After considering all the reports, Transpower decided on balance that it could not prudently continue to operate the Pole 1 assets other than in a limited mode of operation for a limited time without risking a high impact event. Transpower consequently announced that it intended to decommission one half-pole and look to make the other half-pole available for limited northbound operation during peak demand periods only.

Pole 1 Assets Background

The existing Pole 1 was commissioned in 1965 and uses technology that is now obsolete. Spares are no longer available and Transpower has had to procure 'used' spares when other similar links overseas have been shut down. One other similar link remains in operation – but as a backup supply only.

The existing assets were built to different standards that are considered inadequate by modern standards, and pose consequential environmental risks that are very costly to mitigate and, in the case of mercury, remain intrinsic to the technology and cannot be fully mitigated.

Although robustly constructed at the time, the ageing assets have uncertain future performance, and repairs and refurbishment are very expensive.

¹ HVDC Grid Upgrade Plan, Sep 2005 submitted to the Electricity Commission

² Risk Analysis Pole 1 HVDC Link, Marsh, 19 September 2007

³ Pole 1 Risk Mitigation Evaluation for Continuous Operation, Marsh, 18 December 2007

⁴ Environmental Risk Analysis of Pole 1, Resource and Environmental Management Limited, 18 December 2007



Even if some components are refurbished, many components are aged and expected to have increasing failure rates with failed components difficult to repair or replace. There is a risk that the refurbishment costs could be stranded if performance drops or a catastrophic failure occurs.

The above considerations have been key drivers in Transpower expediting the HVDC Pole 1 Replacement Investigation Project.

HVDC Pole 1 Replacement Investigation Project

At the commencement of the HVDC Pole 1 Replacement Investigation Project into Pole 1 replacement, the economics of the existing Pole 1 continuing in some form in the future were considered. To assist that analysis and determine whether it would be possible to continue operation of Pole 1 beyond 2010, Transpower engaged TransGrid Solutions to provide advice on the condition of the equipment and further engaged insurance advisers Marsh to advise on the cost of insuring against events relating to the aging Pole 1 assets. It was intended to use these costs in the GIT analysis for Pole 1 replacement.

Professional Advice Received

In its initial report⁵, Marsh advised that the Pole 1 assets, because of age and condition, had potential modes of failure with severe consequences. It was Marsh's opinion that these assets were uninsurable in current operating condition.

The Marsh report was additional to the condition assessments of Pole 1^{6,7} which highlighted the risks of continuing with 40+ year technology that was no longer supported by any manufacturer. Those assessments resulted in Transpower limiting Pole 1 to northward flow only, to limit the stress to transformer windings from 'arc backs' during southward flow.

The initial Marsh report showed that Transpower could not prudently continue to operate the Pole 1 assets with the risks as reported and so Transpower initiated further work to quantify these risks and potential mitigation measures.

The second Marsh report⁸ identified the mitigation works required to make the assets insurable. These works are significant and would take two or more years to complete.

Transpower also commissioned an environmental report⁹ to address issues related to oil and mercury contamination. One of the conclusions of this report was that the assets should only be operated for 'one to two' more years (i.e. less than the period required for mitigation), and only in a limited mode of operation. Given these timeframes, the mitigation works described by Marsh¹⁰ are not reasonably expected to enable the deferment of an investment of a new replacement Pole 1 for a period of 12 months or more. In addition, the probability of any significant benefit arising from the mitigation works is expected to be low.

On the basis of the identified risks, the costs of mitigation and the uncertain operating future of the aging assets and obsolete technology, Transpower has closed one half of Pole 1¹¹. This physically removes half the risk.

In order to mitigate potential supply security risks, Transpower is seeking to make the remaining half pole available until a new pole is operational. Operation would be restricted to periods of shortage and would avoid southward flow.

⁵ Risk Analysis Pole 1 HVDC Link, Marsh, 19 September 2007

⁶ HVDC Grid Upgrade Plan, Sep 2005 submitted to the Electricity Commission

⁷ Pole 1 Condition and Risk Assessment Reports, TransGrid Solutions, 3 October 2007

⁸ Pole 1 Risk Mitigation Evaluation for Continuous Operation, Marsh, 18 December 2007

⁹ Environmental Risk Analysis of Pole 1, Resource and Environmental Management Limited, 18 December 2007

¹⁰ Pole 1 Risk Mitigation Evaluation for Continuous Operation, Marsh, 18 December 2007

¹¹ <http://www.gridnewzealand.co.nz/n960.html>



High Impact Low Probability (HILP) events

Both Transpower and its advisors consider that there is a risk of a catastrophic failure if the existing assets are operated in an unrestricted manner for an indefinite period. This is due to the complexity of the assets, their age (and hence reliability) and technology.

Post-event analysis of a severe failure event would raise questions of prudence in operating aged and obsolete assets with known high impact failure modes.

While it may not be possible to determine whether an HILP event will occur, it is neither prudent nor good electricity industry practice (GEIP) to continue operation when it is known that an HILP event of the identified severity could occur.

Conclusions

To some commentators, Marsh's treatment of individual risks may appear overstated and, conversely, some risks may not appear to be addressed at all. Nevertheless, Transpower has concluded that on balance there are material risks that will be difficult and costly to mitigate and that some risks cannot be mitigated because of the technology used.

The consequences of a catastrophic failure cannot be ignored. Transpower cannot prudently continue to operate the Pole 1 assets other than in a safe mode of operation for a limited time without risking a high impact event.

Should Transpower continue to operate the existing Pole 1 assets and if a high impact were to occur, the knowledge of the risks enumerated in the Marsh and environmental reports would place Transpower in a position where it has not acted prudently and exercised an appropriate level of duty and care.

Operation of a half pole under limited conditions for short periods of time to meet system emergencies may be achievable because of the measures in place to limit the risk, such as the closure of (the other) half pole, the short exposure period and the removal of high risk modes of operation. This represents a balance between the consequences of not having a half pole available and risk of a high impact event.

The proposed restricted operation of the existing assets has the potential to deliver capacity benefits to the North Island for no additional investment. There is a risk that if the assets are run in an unrestricted mode, a failure could lead to the full shut down of Pole 1, potentially foregoing any further benefits of operating in a restricted manner.

Summary

Given the timeframes required to complete mitigation work on Pole 1 (i.e. two or more years) and the limited future remaining life of Pole 1 (i.e. one or two more years) mitigation works are not reasonably expected to enable the deferment of an investment of a new replacement Pole 1 for a period of 12 months or more. In addition, the probability of any significant benefit arising from the mitigation works is reasonably expected to be low.

Based on the above, implementation of mitigation works required to extend the life of the existing Pole 1 is:

- not reasonably practicable; and
- not considered reasonably likely to proceed.

In addition, Transpower does not consider it prudent nor good electricity industry practice (GEIP) to continue Pole 1 operation in full service when it is known that an HILP event of the identified severity could occur.

The purpose of the analysis is to identify whether complying with the environmental recommendations will impose any significant costs on New Zealand as a whole.



2 Options considered

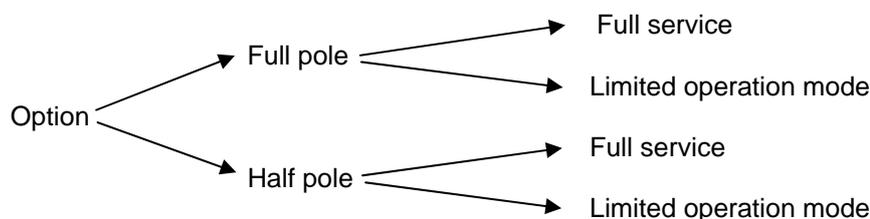
The analysis undertaken involves two phases. The first phase of analysis is a qualitative screening of the options to reinstate a full or half Pole 1. The second phase is a quantitative analysis of the chosen reinstatement option from the first phase screening.

To identify a reinstatement option for further analysis, Transpower considered the following questions:

1. Should a full Pole 1 or a half Pole 1 (if any) be reinstated?
2. If either option (full or half pole) is to be reinstated, will it be for full service or limited operation mode only?

These questions create the following decision tree. The options within this decision tree are evaluated against each other and the option with the highest net benefit is compared with a Reference Case where the existing Pole 1 is not reinstated and a 700 MW Pole 1 replacement is commissioned in 2012. In effect, the Reference Case is the preferred option as identified within the GIT Results (i.e. Attachment A to the GIT Consultation Document).

The comparison is a net benefit test comparing the costs of reinstatement and the benefits of reinstatement against the Reference Case.



3 A qualitative screening of the options

3.1 Should a full Pole 1 or a half Pole 1 (if any) be reinstated?

The Cook Strait cables constrain the potential transmission capacity so that regardless of whether half Pole 1 or a full Pole 1 is re-commissioned, only around 1000 MW can be transferred north.

A full Pole 1 will enable a balanced transfer (each pole will have a maximum transfer capacity around 500 MW) so each pole to some degree can cover the potential loss of the other. This leads to a lesser need for reserves when transfers are high.

As a comparison, just having a half pole re-commissioned will be more unbalanced (approximately a 300 MW maximum for pole 1 versus a 700 MW maximum for pole 2) and reserve requirements will be higher when pole 2 transfers are more than 400 MW, assuming that the reserve requirement is normally set at 400 MW by largest thermal generating plant on the North Island. Disregarding any overloading capability, this allows up to 700 MW to be transferred north without additional reserve requirements while a fully reinstated Pole 1 would be able to transfer about 900 MW in total without increasing the reserve needs.

A proxy for HVDC north transfer levels in the near future are the present levels of transfer. In 2007 up till the end of September, the north transfer levels rarely exceeded 700 MW apart from the beginning of the year, where storage levels were high. The HVDC transfers are shown in the figure below.

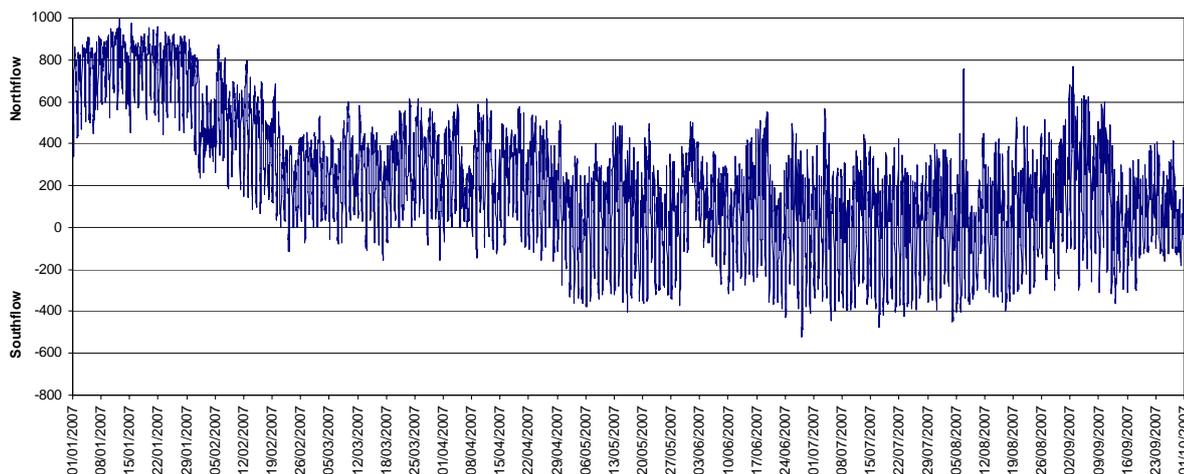


Figure 1: HVDC transfer levels (in MW) for the first 9 months of 2007

Overall, the transfer levels imply that there would be little difference in benefits between having a half Pole 1 available versus a full Pole 1. But as the latter option is twice as expensive, the half Pole 1 option is chosen as the preferred option.

Therefore, it is only relevant to look further at the half Pole 1 options (either as full service or in limited operation mode)

3.2 If either option (full or half pole) is to be reinstated, will it be for full service or limited operation mode only?

The potential costs and benefits of half Pole 1 operation and full Pole 1 operation are listed below in comparison with monopolar operation.

3.2.1 Half Pole 1 limited operation

- Costs: Capital costs of mitigation work
- Benefits: HVDC replacement deferral benefits
Reliability benefits (shorter term)
Dynamic efficiency benefits (longer term)

For the half Pole 1 limited operation option, it is assumed to be used as extra transfer capacity during the coldest winter months. Given the limited use, it will have almost no impact on losses and reserve costs.

The benefits of the half Pole 1 limited operation option would in the shorter term lower the risk associated with capacity shortage on the North Island, which could occur during the coldest winter months. This risk may eventuate if no other capacity can be put in place to meet that peak demand. In the longer term, it may defer or displace the need for such extra capacity.

3.2.2 Half Pole 1 full operation

- Costs: Capital costs of mitigation work
Potentially higher losses
- Benefits: Dispatch costs savings
Lower reserve costs
HVDC replacement deferral benefits
Reliability benefits (shorter term)
Dynamic efficiency benefits (longer term)



Compared with the half Pole 1 limited operation option, the half Pole 1 full operation option will give some additional benefits from lower reserve costs, as the two poles of the HVDC link can, if not fully utilised, cover for some of the risks of losing the other pole.

The larger capacity available to the market may also lead to lower dispatch costs as the system will be less constrained in getting the optimum dispatch. Furthermore, there could be some minor loss savings compared with a 700 MW monopole even if earth return is assumed. However, if the monopole is set up to use the two HVDC line conductors in parallel (which makes it unpractical to use Pole 1 for any kind of emergency service) the losses resulting from having half Pole 1 in full service may actually be higher than no Pole 1 (as the reinstated Pole 1 is running at 270 kV rather than 350 kV as pole 2).

4 A quantitative, model based analysis

Model simulations using the Electricity Commission’s GEM model and the SDDP model are undertaken to identify whether there is a benefit from reinstating a half Pole 1.

The analysis shows the total system costs when having 300 MW extra north transfer capacity¹² for four different cases:

- 2009-2011 (new 700 MW pole 1 replacement is available from 2012)
- 2009-2013 (new 700 MW pole 1 replacement is available from 2014)
- 2009-2015 (new 700 MW pole 1 replacement is available from 2016)
- 2009-2017 (new 700 MW pole 1 replacement is available from 2018)

The 700 MW Pole 1 has been chosen based on the preferred option identified in the GIT analysis results. For all cases, during 2008 the HVDC is run as a monopole.

4.1 Costs

4.1.1 Generation system costs

The cost results of the model simulations with GEM and SDDP are compared with the costs of the Reference Case, where the HVDC is a monopole connection in 2008-2011 and then a new 700 MW pole is added in 2012.

The models give an assessment of the costs of generation capacity capital costs (GEM) as well as generation fixed (GEM) and variable (SDDP) operating costs only. These costs are to be combined with the costs of mitigation, i.e. reinstatement costs, and deducted from any benefits associated with delaying the investment in the 700 MW Pole 1 replacement option.

4.1.2 Costs of mitigation options

Transpower used the mitigation costs identified in the Marsh reports as the costs of migration in this analysis. The Marsh reports estimates are set out below:

Mitigation options that could return Pole 1 to an insurable condition have been considered in the body of the report and are summarised as follows:

<i>Mitigation options</i>	<i>Pole configuration</i>	<i>Cost estimate (\$NZ millions)</i>	<i>Estimated lead time (Years)</i>
<i>Replace converter transformers and wall bushings</i>	<i>Full pole</i>	<i>200</i>	<i>4.5</i>
	<i>Half pole</i>	<i>115</i>	<i>3.5</i>

¹² The actual capacity is likely to be less than 300 MW, so this value is to be considered optimistic. No increase in South transfer has been assumed as AC grid bottlenecks prevent higher transfers than a monopole can provide.



<i>Mitigation options</i>	<i>Pole configuration</i>	<i>Cost estimate (\$NZ millions)</i>	<i>Estimated lead time (Years)</i>
<i>Fully refurbish converter transformers and replace wall bushings</i>	<i>Full pole</i>	150	3.5
	<i>Half pole</i>	87	2.5

These costs do not include any contingency and do not allow for significant relocation of, or civil works for, converter transformers. If new foundation pads had to be provided, for example, this would increase the costs. These costs also do not include those that are not readily quantified both due to natural fluctuations in market pricing and also simple uncertainty in the scale of additional work (protection, civil works, infrastructure, etc.) involved in replacing or refurbishing the converter transformers.

Accordingly, the costs identified in the Marsh reports are conservative and will fall in the lower end of the expected range. For the purpose of this analysis, the lowest cost option has been selected for the half Pole 1 option, i.e. \$87 million. Transpower has also assumed that Pole 1 could be reinstated by 2009 *and thus far earlier than indicated in the table above*. Overall, the use of low cost estimates and early commissioning will favour reinstatement options and again represents a conservative approach.

Assuming a \$3 million cost per year¹³ of operating the half Pole 1, the total NPV costs of mitigation work and operating Pole 1 is set out below. Operating costs after the replacement of a half Pole 1 are included in the HVDC costs in the following section.

Case	2007 NPV	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Halfpole 2012	\$89	\$87	\$3	\$3	\$3	0	0	0	0	0	0	0
Halfpole 2014	\$93	\$87	\$3	\$3	\$3	3	3	0	0	0	0	0
Halfpole 2016	\$96	\$87	\$3	\$3	\$3	3	3	3	3	0	0	0
Halfpole 2018	\$100	\$87	\$3	\$3	\$3	3	3	3	3	3	3	0

4.2 Benefits

By delaying the investment in replacing a half Pole 1 there will be a benefit equal to the expected expenditure times the discount rate per year of deferral. However, not all elements can be deferred by the same amount. For all cases, it has been assumed that an additional Cook Strait cable is added in 2018. Furthermore, due to lack of spares, the replacement of the control system of HVDC pole 2 operation and HVDC bipole operation is assumed to occur at 2014 at latest.

Transpower has used a 7% discount rate in this analysis which is consistent with the approach taken for the discount rate used in applying the GIT to the HVDC Pole 1 Replacement Investigation Project. The deferral benefits for the mandatory 7% discount rate for a half Pole 1 are shown below.

Case	Reference	Deferred	Difference
Halfpole 2012	413.8	413.8	0.0
Halfpole 2014	413.8	375.3	38.6
Halfpole 2016	413.8	341.8	72.0
Halfpole 2018	413.8	311.1	102.7

The last column shows the difference between the Reference Case and the deferred investment. These amounts are in \$2007 million NPV.

¹³ This is less than the budgeted Pole 1 operating costs for 2007, which was ~\$3.5 million for the full pole. It is expected that the cost of having a half pole is not going to be much less and it could increase over time, as equipment gets older.



4.3 Calculating any benefit

The table below sets out the results of combining the generation capital costs and fixed and variable operation and maintenance costs of a half Pole 1 option with the mitigation costs of that half Pole 1 option and deducting any deferral benefits of the half Pole 1 option as identified above.

The results of that calculation show that all the half Pole 1 options have higher costs when compared with the Reference Case. For the half Pole 1 operational till 2012, the cost exceeded the Reference Case by \$88 million dropping to \$74 million for the half Pole 1 operational till 2018.

Year	Item	Reference	Half-pole	Difference
2012	Generation capital costs	9141	9081	61
	Generation fix O&M	1541	1535	6
	Generation var O&M	11051	11117	-66
	HVDC costs*	414	414	0
	Mitigation costs**	0	89	-89
	Total		22147	22235
2014	Generation capital costs	9141	9111	30
	Generation fix O&M	1541	1541	0
	Generation var O&M	11051	11101	-50
	HVDC costs*	414	375	39
	Mitigation costs**	0	93	-93
	Total		22147	22221
2016	Generation capital costs	9141	9123	19
	Generation fix O&M	1541	1533	7
	Generation var O&M	11051	11072	-21
	HVDC costs*	414	342	72
	Mitigation costs**	0	96	-96
	Total		22147	22166
2018	Generation capital costs	9141	9108	34
	Generation fix O&M	1541	1562	-21
	Generation var O&M	11051	11140	-90
	HVDC costs*	414	311	103
	Mitigation costs**	0	100	-100
	Total		22147	22221

*Includes O&M costs for the new HVDC pole

**Includes O&M costs for the life extended HVDC pole

Table 1: Half Pole versus Reference Case Cost differences

The GEM model does not adjust any built decisions pre 2012, so the Reference Case and the half Pole 1 operational till 2012 option are substantially similar in terms of generation system costs (i.e. the sum of first 3 rows in the table above for those two cases). It can be seen that the costs of the Reference Case and the half Pole 1 operational till 2012 option are within \$1 million of each other even though the capital costs and operating costs vary (due to differences in the generation expansion plans after 2012). For future years, it should be assumed that generation system costs increase the longer the capacity is lower (1000 MW max transfer capacity for the half pole options) versus 1200 – 1400 MW capacity for the 700 MW replacement option.

The figure below shows these generation system costs as the differences (in \$million) between the Reference Case and the half Pole 1 options. Negative numbers mean the costs

outweigh the benefits (i.e. there is no expected net market benefit). It can be seen that the modelling uncertainty results in some variation around a linear trend (bold line) that has been added to the graph.

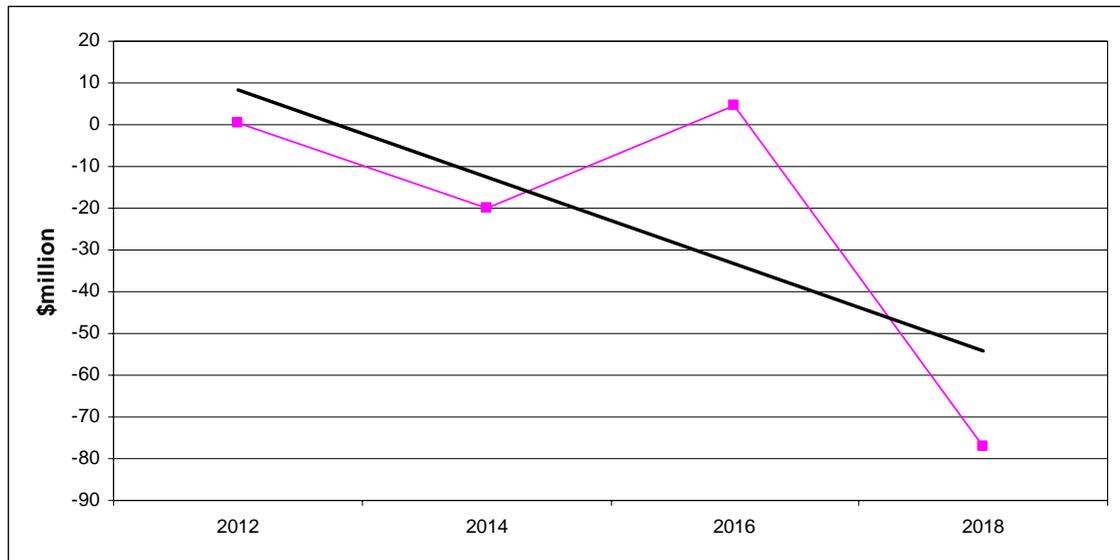


Figure 2: Cost differences between Reference Case and half pole 1 options

In the table below, that linear trend estimate of generation cost differences has been used instead to level out some of the model uncertainty.

Year	Item	Reference	Half-pole	Difference
2012	Generation costs total	21733	21725	8
	HVDC costs*	414	414	0
	Mitigation costs**	0	89	-89
	Total	22147	22227	-81
2014	Generation costs total	21733	21746	-13
	HVDC costs*	414	375	39
	Mitigation costs**	0	93	-93
	Total	22147	22214	-67
2016	Generation costs total	21733	21766	-33
	HVDC costs*	414	342	72
	Mitigation costs**	0	96	-96
	Total	22147	22204	-57
2018	Generation costs total	21733	21787	-54
	HVDC costs*	414	311	103
	Mitigation costs**	0	100	-100
	Total	22147	22198	-51

*Includes O&M costs for the new HVDC pole

**Includes O&M costs for the life extended HVDC pole

Table 2: Cost differences between Reference Case and half pole

The results show that the costs are lowered by between \$7 million (initially) and \$3 million (later on) per year the half Pole 1 is operational and not replaced. Hence, over time keeping the half Pole 1 operational becomes marginally more economic, but not in any material respect. This implies that even if the mitigation costs were zero or negative (indicating unidentified pre 2012 benefits larger than the costs), the benefits of keeping it beyond 2012 would be limited to \$3-\$7 million per year.

The graph below shows the expected utilisation of a 1400 MW link (i.e. a 700 MW pole 1 replacement) for the 90% renewables scenario based on a SDDP model simulation.

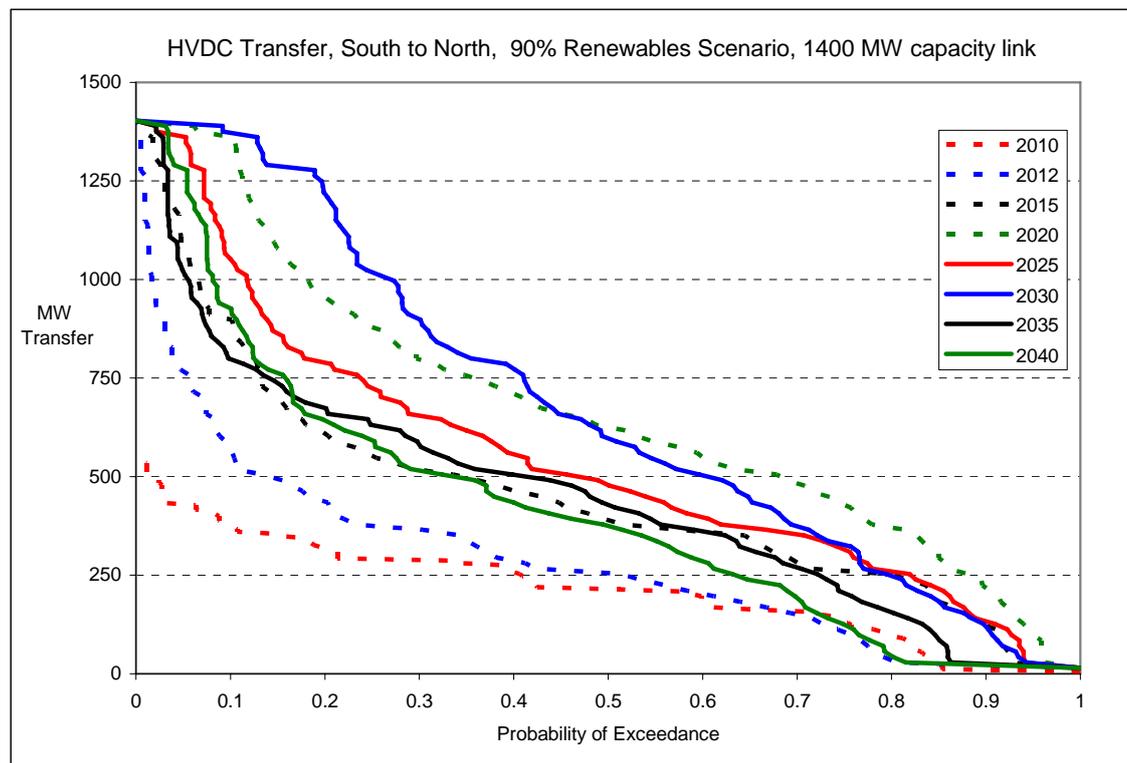


Figure 3: Expected utilisation of 1400 MW link for 90% renewables

It shows an expected increase in the utilisation of the link between 2015 and 2020 and further beyond. The optimal utilisation is expected to exceed 1000 MW in 20% of the time in 2020. Around that time, it must be assumed that having less capacity will become more and more costly.

5 Conclusions

There seems to be no evidence for reinstating a half Pole 1 for full service on an economic basis compared with the Reference Case as defined within this analysis. As previously noted, the benefits would be similar for a full Pole 1 option, but the costs would be higher, so the full Pole 1 options were discarded.

Table 2 further shows that all the reinstatement options have a lower expected net market benefit than the Reference Case even if mitigation costs are almost zero for the half Pole 1 operational till 2012 option.

One issue that the Electricity Commission has raised is quantifying the benefit that would result from either:

- increased reliability; or
- deferred investments in North Island peaking capacity,

that could arise in the shorter term (2008-2012) from having half Pole 1 or full Pole 1 reinstated in those years. Transpower accepts that there could be significant benefits resulting from either increased reliability or deferred investments in North Island peaking capacity (which are not readily identified using the GEM model) when compared against a Reference Case of no Pole 1 operation. However, Transpower is investigating the possibility of making the remaining half of Pole 1 available for limited periods where there is a risk of expected unserved energy. If Transpower is able to achieve limited operation of Pole 1 a substantial proportion of those benefits would be captured by the limited operation of Pole 1.



Therefore, the pre 2012 benefits not captured by the GEM model are substantially less in quantum and the GEM model results are not materially affected by that inability to quantify those benefits.

The purpose of this analysis was to establish whether there would be any significant costs for New Zealand to comply with the recommendations in the Environmental report. It can be seen that even if benefits pre-2012 exceed the cost of reinstating Pole 1, the benefits per year of keeping it beyond 2012 are in the range \$3-7 million as per Table 2. A \$3-7 million benefit needs to be compared to the identified risks and unanalysed benefits a replacement Pole 1 may provide such as increased competition and potentially enabling a national reserve market sharing.

Therefore, in Transpower's view this analysis demonstrates that complying with the environmental recommendations will not impose any significant costs on New Zealand as a whole.