WELL earthquake resilience

Review of the cost benefit analysis by WELL

NZIER report to MEUG

21 February 2018

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The assistance of Wellington Electricity Lines Limited is gratefully acknowledged.

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Key points

This report is a brief assessment of the business case presented by Wellington Electricity Lines Limited (WELL) in support of its Customised Price Path Application (CPP) for earthquake resilience expenditure to the Commerce Commission. The purpose of the assessment is to:

- highlight the effort made by WELL in analysing the costs and benefits of resilience expenditure
- suggest areas for development of the cost benefit approach that would be appropriate for larger or more complex expenditure on asset renewal regardless of whether the objective of the asset renewal is improved resilience or a change in the service quality trade-off.

WELL based its business case on cost benefit analysis

The WELL business case for its CPP application was based on a cost benefit analysis (CBA) that clearly described the cost of additional resilience projects, the benefit to consumers as the avoidance of lost load and valued that benefit using an estimated price per MWh based on analysis by the Electricity Authority. The cost benefit analysis methodology was used successfully to:

- define the expected cost of outages without investment in resilience
- compare multiple options for improving the resilience of components of the network while avoiding double counting of benefits
- establish a cut-off for resilience investment that did not deliver net benefits to consumers.

Without detracting from the above endorsement of WELL's use of CBA, the business case could have been improved by applying CBA to the expenditure on both 'seismic strengthening of buildings' and 'back-up communications and data access'. (Also, the net present value of the of benefit from network equipment spares was slightly over-estimated by counting benefits when or before the spares were purchased.)

Areas for development in resilience cost benefit analysis

The business case benefits from restoring electricity supply earlier than the 'do nothing' option assumes that demand will resume at pre-earthquake levels and location as soon as supply is restored and that demand cannot shift around the WELL network within or between the 'islands' before supply is restored. This assumption makes the business case assessment tractable but is unlikely to hold in situations where people and businesses are left without electricity for a minimum of several weeks. Also, the assumption does not consider the direct effect on people and businesses of the property damage and transport disruption from the earthquake.

The tight focus of the business case engineering assessment and cost benefit analysis on time to restore supply for the proposed $31 million of expenditure seems to meet the Commerce Commission's proportionality test. However, if this business case method is to be applied to larger scale expenditure to improve resilience a more sophisticated analysis of how total load demand would change or shift between locations after an earthquake will be required.

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1. Improvement in resilience

1.1. Rationale

WELL's rationale for the CPP is to improve the resilience of components of its electricity network to a magnitude 7.5 earthquake. To improve resilience WELL is proposing to:

- locate spare network equipment close to where it is likely to be needed after an earth quake which delivers a net benefit (value of avoided lost load less cost) with a net present value of $26.3 million
- strengthen buildings containing network assets to reduce the cost of rebuilding damaged assets and to increase the likelihood that these assets in these buildings will be accessible after the earthquake with an estimated cost of $10.4 million over three years
- establish back-up data and communication links to ensure that WELL restoration of the electricity supply is not impeded by damage to third party communications infrastructure with an estimated cost of $5.8 million over three years.

WELL has applied specific cost benefit analysis to valuing and comparing options for the spare network equipment but not for the general seismic strengthening of the buildings or the back-up data and communication links. The following table lists the cost and benefits of the network spares.

Table 1 WELL network resilience expenditure proposal

Net present value of costs and benefits of WELL's preferred resilience options ($ million)

Network asset type	Cost	Benefit	Net benefit
33 kV cable faults [1]	2.21	20.68	18.47
11 kV cable and equipment faults[2]	4.32	9.45	5.13
Transformers and switchgear3	8.72	11.41	2.69
Total	**15.25**	**41.54**	**26.29**

Notes:

1. 'Option 2 - carry overhead lines spares for vulnerable routes' see Business Case p33 -34 and '33kV_Cable_Fault_options_CBA_noLinks.xlsx Option2'
2. 'Option 2 – critical emergency spares' see Business Case p47 -48 and '11kV_Cable_Fault_options_CBA_noLinks.xlsx Option2'
3. 'Table 19 –Option 3 and Option 6' see Business Case p454

Source: WELL CPP Earthquake readiness business case and CBA spreadsheets

The business case implies that seismic strengthening and back-up data and communications are general requirements for WELL to restore its network but does not explain how the failure to complete this spending would affect the benefits of the expenditure on spare network equipment.

1.2. Hazard definition and mitigation

The return period of a magnitude 7.5 earthquake is estimated by WELL as once every 300 years restated as an annual probability of 0.33 percent. WELL has assessed that a 7.5 earthquake will affect the network resilience in two ways:

- some network assets will be unusable after an earthquake based on an engineering assessment of its assets
- damage to transport links in Wellington will separate the WELL's network area into '5 islands' for an extended period (up to 12 weeks).

The main driver of benefit from the location of network spares throughout the region is to mitigate the impact of post-earthquake transport delays on the restoration of damaged network assets.

For each category of spending on network spares (11kV, 33kV and transformer/switchgear) WELL has:

- assessed the potential impact of a magnitude 7.5 earthquake on WELL's ability to supply energy to areas of its network (measured by the proportion of installation control points (ICPs) affected and undelivered energy to those ICPs)
- estimated the potential reduction in the undelivered energy from options to restore some network capacity by avoiding delays caused by severed transport links.

WELL's proposed resilience expenditure allows for partial replacement of the network components that could fail based on what WELL considers to be prudent and usable level of spare equipment. For the three types of network spares WELL's estimates of the potential undelivered energy under a 'do nothing' scenario and under WELL's 'preferred' option are shown in the following table.

Table 2 Potential reduction in undelivered energy

Undelivered energy under 'do nothing' and 'preferred' options (MWh)

Network asset type	'Do nothing' option	'Preferred' option	Reduction in lost due to 'Preferred' option
33 kV cable faults	36,650	21,017	15,633
11 kV cable and equipment faults	96,180	86,573	9,607
Transformers and switchgear	35,430	23,836	11,594

Source: WELL CPP Earthquake readiness business case and CBA spreadsheets

The following tables show the expected reduction in the time to restore electricity supply for '33 kV cable faults' and 'transformers and switchgear' under the 'preferred' options and the number of estimated ICPs affected.

Table 3 Potential reduction in undelivered energy - transformers

Undelivered energy under 'do nothing' and 'preferred option' (MWh)

Location	WELL Area	Impacted ICPS (number)	'Do nothing' option	'Preferred' option	Reduction in lost due to 'Preferred' option
Seaview	Northeast	855	3,406	3,406	
Korokoro/ Petone	Northeast	974	6,766	1,691	5,074
Mana	Northwest	2,423	10,046	10,046	
Evans Bay	Southern	1,140	4,410	2,520	1,890
8 Ira St	Southern	2,660	10,801	6,172	4,629
Total		**8,052**	**35,430**	**23,836**	**11,594**

Source: WELL CPP Earthquake readiness business case and CBA spreadsheets

Table 4 Potential reduction in undelivered energy – 33kV

Undelivered energy under 'do nothing' and 'preferred option' (MWh)

<Heading>		Impacted ICPS (number)	'Do nothing' option	'Preferred' option	Reduction in lost due to 'Preferred' option
Brown Owl	Northeast	5,320	13,278	10,623	2,656
Maidstone	Northeast	1,672	7,599	6,079	1,520
Trentham13	Northeast	5,605	4,449	0	4,449
Korokoro	Northeast	974	0	0	0
Wainuiomata	Northeast	5,776	1,910	0	1,910
Mana	Northwest	3,610	3,139	3,139	0
Titahi Bay	Northwest	2,120	2,940	1,176	1,764
Evans Bay	Southern	1,140	0	0	0
8 Ira St	Southern	2,660	0	0	0
Moore St	Southern	190	3,334	0	3,334
Total		**29,067**	**36,650**	**21,017**	**15,633**

Source: WELL CPP Earthquake readiness business case and CBA spreadsheets

The reduction in lost load attributed to 'transformers and switch gear' is partly dependent on the deployment of spares for the 11 kV and 33 kV networks. (A table is not included for the 11 kV network as the preferred option only provided information on avoided energy loss in the Hutt Valley and the CBD.)

1.3. How much more resilient?

To provide some perspective on the resilience scenarios (the 'do nothing' and the 'preferred' options) compared to the size of the network:

- WELL has approximately 167,000 customer connections: 58,000 in the Southern (most of Wellington City) area, 66,000 in the Northeast (Hutt Valley) and 43,000 in the Northwest (northern suburbs of Wellington City
- Total electricity use and load is spread over three consumer groups:
  - About 150,000 'residential' connections using about 1,060 GWh per year with an average hourly load of about 121 MW
  - About 15,900 'commercial' connections using about 400 GWh per year with an average hourly load of about 46 MW
  - About 1,300 'industrial' connections using about 900 GWh per year with an average hourly load of about 103 MW.

In comparison the:

- 11 kV 'do nothing' option forecasts the loss of about 48 MW of load (96 GWh) with the resilience investment reducing the lost load by about 10 GWh almost entirely in the Hutt Valley
- 33 kV 'do nothing' option forecasts the loss of about 42 MW of load (37 GWh) with the resilience investment reducing the lost load by about 16 GWh primarily in the Hutt Valley
- transformer and switchgear 'do nothing' option forecasts the loss of about 15 MW of load (35 GWh) with the resilience investment reducing the lost load by about 12 GWh shared between Wellington City and the Hutt Valley

1.4. Conclusion

The resilience expenditure proposed by WELL achieves a modest reduction in the potential undelivered energy compared to the 'do nothing' option estimated by WELL. Most of the benefit is achieved in parts of the Hutt Valley which are expected to be worst affected by the loss of transport links.

2. Cost benefit analysis (CBA)

2.1. Contribution of CBA method

The WELL business case for network spares provides a good example of how a simple application of cost benefit analysis (CBA) can be combined with a detailed risk and engineering assessment to quantify the benefits of resilience expenditure compare options for delivering resilience and make a business case for resilience expenditure. The CBA provides a common framework for consistent comparison of the value to consumers of do-nothing versus other options. However, the CBA method does not either define the 'do-nothing' option or the options for mitigation.

2.2. Role of CBA input assumptions

WELL's risk and engineering assessment defined the key input assumptions for the CBA with respect to:

- the 300-year return period of a 7.5 magnitude earthquake which was used to calculate the annual probability of an earthquake – one of the inputs into calculating the 'expected value' of the benefits[1]
- WELL's engineering assessment of the earthquake damage to individual network assets, the effect of that damage on the capacity of the network to supply electricity and the time required to replace damaged network assets allowing for the disruption of transport links forecast in the 'Wellington Lifelines Group Restoration Times report - November 2012'[2] – the key input to estimating the lost load for the 'do nothing' option
- WELL's engineering assessment of feasible engineering responses (stock of spare equipment and where the stock should be held) to mitigate the delays to restoring supply caused by disruption of transport links – one of the inputs into the options for resilience investment.

The engineering assessment was a key driver of the CBA in that it quantified the both the expected impact of the earthquake on electricity supply and the extent to which the effect of the earthquake could be mitigated. For the '11kV network' and 'transformer and switchgear' options the engineering assessment did not provide any options that could fully avoid the 'do-nothing' outage. The '33 kV network did include one option that almost fully avoided the 'do nothing' option but this option was prohibitively expensive.

[1] A point estimate of the probability of a single large earthquake event understate the benefit of the resilience spending for less destructive more frequent events.

[2] Available at http://www.gw.govt.nz/assets/Emergencies--Hazards/Emergency-Planning/12-11-13-WeLG-report-to-CDEM-Joint-Committee-restoration-times-FINAL.pdf

2.3. Opportunities to improve the CBA

Without detracting from the endorsement of WELL's use of cost benefit analysis as a tool to compare options for resilience investment there a small number of second order observations on how the business case could have been improved:

- net benefits were only estimated for the 11kV, 33kVand mobile substation resilience expenditure of $15 million or just under half of the $32.2 million of the additional proposed expenditure
- estimated benefits of the 11kV, 33kV and mobile substation investments are all slightly overstated because they included benefits while the capital expenditure to create the resilience was still under way. However, the net present value of the net benefit of the preferred options is still positive after this adjustment and is reduced[3] as follows:
  - 11 kV from $5.13 million to $3.32 million
  - 33 kV from $18.47 million to $15.80 million
  - transformer and switchgear from $2.69 million to $2.19 million
- estimated net benefit of avoided rebuilding expenditure of '6 to 8 times' the proposed $10.8 million cost of seismic strengthening (based on the experience of Orion) is unlikely to exceed the cost – based on WELL's modelling approach for the network resilience expenditure which assumes the 'annual probability' of an earthquake is 0.33 percent
- net benefit of expenditure on maintaining data and communications ($5.8 million) was not estimated separately. The rationale for the investment seems to be avoid additional delays caused by telecommunications utilities waiting for WELL to restore their electricity supply while WELL waits for the telecommunications utilities to restore communications links that WELL needs to restore electricity supply.

2.4. Conclusion

Overall the estimated net benefits of the 11kV, 33kVand mobile substation resilience expenditure exceeded the cost of the seismic strengthening and maintaining communication and data links. (WELL's business case implied that the investments in 'seismic strengthening' and 'maintaining data and communication' were part of the resilience investment package.)

[3] For the two or three years in which capex is positive the reduced benefit is calculated as the WELL estimate of the benefit multiplied by the proportion of the total capex that has been completed in previous years. If all the capex must be completed before ant resilience benefit is available the net present value of the net benefit is reduced to about $2.8 million for the 11 kV project, $14.9 million for the 33 kV project and $-0.17 million for the transformers and switchgear project.

3. Potential for improvement

3.1. Introduction

The WELL CPP business case relies on simplifying assumptions that demand for electricity continues unabated after a major earthquake disrupts supply and the value of lost load used for short term unplanned outages can be applied to protracted outages.

3.2. What counts for resilience

The key driver of benefits from the proposed WELL resilience expenditure is the value of avoiding lost load. This has two components the '$ price' per MWh of lost load and the estimation of the quantity of electricity that is demanded but not served following a major earthquake.

Both the price per MWh of lost load and the level of unserved load will vary with the consumer group that is affected, the length of the outage and how other consequences from the earthquake affect consumers' demand for electricity.

The WELL business case estimates the value of lost load using:

- the Electricity Authority estimate of the average price for lost load (adjusted for inflation)
- the estimated length of the outage with and without resilience investment at selected major assets multiplied by the average demand at each major asset for a set proportion of customers[4] at each of those assets.

The WELL business case has partly addressed the issue of the variation in the price for lost load with sensitivity analysis but has not commented on the variation in unserved demand.

WELL's lost load estimation approach assumes that demand for load for each asset will recover to average levels as soon as WELL can restore capacity and that consumers will not move their load to other operational ICPs within areas of the WELL to gain access to supply. These assumptions are valid for brief outages, say after a storm but are less likely to hold for the longer outages and more severe property damage after a major earthquake.

For example, the expenditure on the 33kV resilience under Option 2 contributes about $18.5 million of the approximately $25 million of net benefits from network resilience[5] expenditure. Most (about 80 percent) of the net benefit from Option 2 arises from shortening an outage that affects 7,000 ICPs from 15 weeks to 3 weeks. For one of the zones 'Brown Owl' 76 percent of ICPs are affected but for the other 'Maidstone' only 38 percent of ICPs are affected[6]. The WELL estimate of the avoidance of unserved load does not seem to consider the potential for people to move to other ICPs in nearby

[4] WELL's estimate of the share of affected customers supplied by each major asset seems to be based on an engineering assessment of how the capacity to supply the network is affected by the earth quake.

[5] Resilience expenditure on the 11kV, 33kVand mobile substation resilience expenditure

[6] "Brown Owl' and 'Maidstone' are close to each other.

areas or that 3 weeks will be considered too long for some people and they will be evacuated to another part of the city.

3.3. Conclusion

Overall WELL's business case analysis seems to be proportionate to the modest scale of the proposed resilience expenditure. However, for larger scale resilience expenditure the analysis of the benefit of the restoration of supply will need to specifically model how the level and location of demand for electricity alters as people and businesses respond immediately and then adjust to the direct property damage and transport disruption from the same event that damaged the electricity network.

Scenarios for graduated responses by different groups of consumers to earthquake damage in general less reliable supply of electricity could easily be added into the CBA framework already applied by WELL and used as the basis for sensitivity analysis before an event.

Appendix A WELL data

A.1 Introduction

This section lists the data that supports the observations on WELL residential, commercial and industrial consumers in section 1.3. The data is based on the analysis of 'Schedule 8: Report on Billed Quantities and Line Charge Revenues' of the 'Electricity-distributors-information-disclosures' available from the Commerce Commission.

Energy delivered and number of ICPs is reported in Schedule 8 by price plan. We have used these price plans to classify groups of consumers as 'residential', 'commercial' or 'industrial'.

Table 5 Total Energy delivered

GWh per year

Year	Residential	Commercial	Industrial	Total
2013	1,094.4	422.0	891.2	2,407.7
2014	1,051.7	411.6	904.7	2,368.1
2015	1,044.6	392.6	902.0	2,339.2
2016	1,061.5	388.3	904.0	2,353.8
2017	1,035.8	391.6	897.5	2,324.9

Source: NZIER

The WELL estimates of lost load are based on average load per hour for the affected part of the network multiplied by the duration of the outage.

Table 6 Average load per hour

MW

Year	Residential	Commercial	Industrial	Total
2013	124.9	48.2	891.2	101.7
2014	120.1	47.0	904.7	103.3
2015	119.2	44.8	902.0	103.0
2016	121.1	44.3	904.0	103.1
2017	118.2	44.7	897.5	102.4

Source: NZIER

Table 7 ICP

Number

Year	Residential	Commercial	Industrial	Total
2013	147,498	15,991	1,316	164,804
2014	147,526	15,938	1,333	164,797
2015	148,483	15,867	1,340	165,690
2016	149,383	15,865	1,342	166,591
2017	149,358	15,697	1,289	166,344

Source: NZIER