Assessment of the Value of Unserved Energy

Report to Transpower

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Executive Summary

In June 2004 Frontier Economics (Frontier) produced a discussion paper setting out a basis for a Grid Investment Test (GIT). Frontier's paper proposed value of unserved energy of $20,000 per MWh with a range of $10,000 to $30,000 per MWh.

This value of unserved energy was subsequently adopted as part of the GIT and has been used to evaluate transmission upgrade proposals.

There are two problems with the analysis Frontier undertook in estimating value of unserved energy for New Zealand.

Frontier's derivation of the value of unserved energy estimates is inconsistent with the primary studies cited

Frontier's value of unserved energy estimates is inconsistent with the underlying data cited to support its analysis:

- Frontier makes errors in transcribing data from the VENCorp 2002 study
- In respect of the residential value of unserved energy, Frontier selectively ignored the (consistent) estimates of the primary studies, and
- Suggested $10,000 per MWh is a reasonable estimate of residential value of unserved energy based on the Government Policy Statement (GPS) objective of security of supply during a one in sixty dry year. This objective can not be directly translated into a value of unserved energy.

Qualitative assessment of value of unserved energy under estimates value of unserved energy

Frontier then proceeded to bound the value of unserved energy for New Zealand by arguing:

- It must be more than the residential value of $10,000 per MWh, and
- It must be less than $30,000 per MWh because New Zealand has a large residential load.

Castalia's estimates of value of unserved energy

Castalia undertook a quantitative assessment based on the study data presented and with actual end use consumption data. This results of this analysis is presented in Table 1.1

Table 1.1: Comparison of Value of Unserved Energy Estimates

	Low Estimate	High Estimate
New Zealand (Frontier)	$10,000 per MWh	$30,000 per MWh
New Zealand (Castalia)	$22,000 per MWh	$48,000 per MWh
Auckland and North of Auckland (Castalia)	$32,000 per MWh	$50,000 per MWh

Source: Castalia

Furthermore the estimated values of unserved energy are conservative because they include only a part of the total cost arising from power outages.

1 Introduction

In June 2004 Frontier Economics (Frontier) produced a discussion paper setting out a basis for a Grid Investment Test (GIT).[1] Frontier's paper included a proposed value of unserved energy of $20,000 with a range of $10,000 to $30,000 per MWh.

This report

- Sets out the basis of the value of unserved energy estimates made by Frontier and Castalia
- Tests the sensitivity of Castalia's estimates to the value of unserved energy estimates from the underlying studies, and
- Identifies the types of costs that were included by the underlying studies when estimating the value of unserved energy.

2 Basis of Value of Unserved Energy Estimates

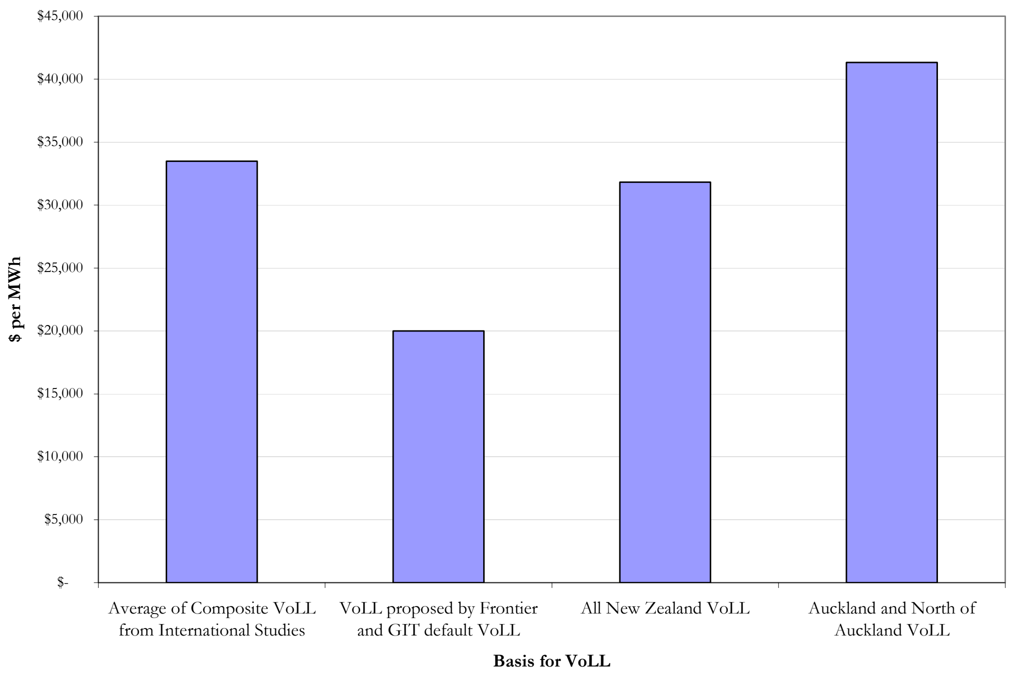
This section:

- Summarizes the studies used in the Frontier paper to estimate value of unserved energy
- Describes Frontier's basis for proposing a $20,000 per MWh value of unserved energy
- Explains why the value of unserved energy for New Zealand as a whole should be $32,000 per MWh, and
- Explains why value of unserved energy for electrical load in Auckland and North of Auckland should be $41,000 per MWh.

[1] Frontier Economics, "Draft grid investment test final draft discussion paper" (2004).

Figure 1 illustrates the difference between values of unserved energy estimates from various sources.

Figure 1. Value of Unserved Energy



Source: Castalia

2.1 Values of Unserved Energy Benchmarks Considered by Frontier Economics

Frontier considered three types of input to devise its estimates of the value of unserved energy:

- The Government Policy Statement (GPS) objective to ensure security of supply during a one in sixty dry year
- A study carried out by the Centre for Advanced Engineering "Reliability of Electricity Supply Project" in 1992, and
- Various international studies.

First, Frontier suggest that (i) the GPS objective of maintaining supply during a one in sixty dry year, and (ii) the $15 to $20 per MWh marginal cost of generation from a reserve unit, together imply a value of unserved energy of at least $9,000 to $12,000 per MWh.

Frontier did not explain this calculation and we note that when the government issued its policy statement on maintaining supply during a one in sixty dry year, the approach was widely criticised by industry commentators as not defining value of unserved energy.

Second, at the time of Frontier's report, the most recent New Zealand Study estimating the cost of electricity non-supply was by the Centre for Advanced Engineering (CAE). This study suggested a value of unserved energy between $1,500 and $5,000 per MWh for residential customers and $10,000 to $70,000 per MWh for non-residential customers.

Frontier noted that the CAE study was not specifically designed to measure the cost of non-supply and suggested that international research, which made a detailed assessment of the cost of non-supply, should be considered in estimating New Zealand's value of unserved energy.

Third, Frontier cited four studies where sector estimates had been developed for the cost of non-supply. These studies are presented in Table 2. Note, the error made by Frontier in transcribing data from the VENCorp 2002 study has been corrected.[2]

Table 2: International Studies to Estimate the Cost of Non-Supply

Study reference	VENCorp	Monash University	Monash University	CEC California
Year	2002	1997	1998	1997
Currency	AUD	AUD	AUD	USD
Sector	**$ per kWh**	**$ per kWh**	**$ per kWh**	**$ per kWh**
Residential	$ 11.88	$ 0.74	$ 0.49	$ 1.30
Commercial	$ 56.67	$ 75.96	$ 52.37	$ 37.20
Agricultural	$ 55.49	$ 96.20	$ 57.59	
Industrial	$ 18.54	$ 11.19	$ 20.46	$ 24.40
Composite VoLL	**$ 29.60**	**$ 28.89**	**$ 20.56**	

Table 2 gives the value of unserved energy for different sectors of the economy. The composite value of unserved energy is the sum of each sector's value of unserved energy multiplied by that sector's percentage of electricity consumption in the relevant jurisdiction.

The studies were conducted in Australia and the United States in different years. In order to compare the studies, we have adjusted the value of unserved energy numbers to make them comparable with the value of unserved energy set out in the GIT, that is, adjusted them to 2004 New Zealand dollars.

Each sector and composite value of unserved energy was adjusted as follows:

- Converted into New Zealand dollars at the average exchange rate in the year of the study
- Inflated for the time between the study and 2004 using the average of New Zealand's consumer price index from 1997 to 2002
- Adjusted from $ per kWh to $ per MWh

Table 3 sets out the process for adjusting the value of unserved energy estimates to 2004 New Zealand dollars and the adjusted value of unserved energy estimates.

2 Frontier list Value of unserved energy estimates from page 6, Table 4 of the VENCorp study and make two errors. The first error is that the values cited are Sector Value of unserved energy × Sector weighting rather than just the sector Value of unserved energy. The second error is the conversion from units of $/kWh to $/MWh where they multiply by 10,000 instead of 1,000 except for the composite Value of unserved energy estimate which is converted correctly.

Table 3: Value of Unserved Energy Estimates Adjusted to 2004 New Zealand Dollars

Basis for adjusting VoLL estimates to 2004 NZ$ per MWh

Adjustment factor	**VENCorp 2002**	**Monash University 1997**	**Monash University 1998**	**CEC California 1997**
Currency conversion	1.17	1.12	1.17	1.51
Average CPI 1997 to 2004	2.0%	2.0%	2.0%	2.0%
Years of inflation	2	7	6	7
Total inflation	104%	115%	113%	115%
kWh to MWh	1000	1000	1000	1000
Net conversion factor	**1,218**	**1,289**	**1,321**	**1,732**

VoLL estimates in 2004 NZ$ per MWh

Sector	**VENCorp 2002**	**Monash University 1997**	**Monash University 1998**	**CEC California 1997**
Residential	$ 14,474	$ 954	$ 647	$ 2,252
Commercial	$ 69,044	$ 97,892	$ 69,163	$ 64,435
Agricultural	$ 67,607	$ 123,975	$ 76,057	
Industrial	$ 22,588	$ 14,421	$ 27,021	$ 42,264
Composite VoLL	**$ 36,063**	**$ 37,231**	**$ 27,153**	

Source: Castalia

Each study has a different value of unserved energy. We do not know if any one study is better than another, so we have initially taken a simple average across the studies for each sector. (We return to the variability of the sector estimates later.)

Table 4: Simple Average of Adjusted Value of Unserved Energy Estimates

Sector	**Average**
Residential	$ 4,582
Commercial	$ 75,134
Agricultural	$ 89,213
Industrial	$ 26,574
Composite	$ 33,483

Source: Castalia

This average suggests a composite cost of non-supply of approximately $33,500 per MWh before considering the proportion of electricity used in by each of New Zealand's end use sectors.

2.2 Frontier's Basis for Proposing a Value of Unserved Energy of $20,000 per MWh

Frontier proposes a value of unserved energy of NZ$20,000 per MWh. The reasoning is:

1. $10,000 per MWh is a reasonable estimate of value of unserved energy for residential customers based on the GPS objective of security of supply during a one in sixty dry year
2. A composite value of unserved energy of greater than $30,000 per MWh would be hard to support in a New Zealand context because New Zealand has a relatively large residential load
3. On the basis of points 1 and 2, Frontier proposed that a value of unserved energy range of $10,000 to $30,000 with a mid point of $20,000 per MWh be used in the GIT.

In respect of point 1:

- We think the GPS security of supply objective cannot be directly translated into a value of unserved energy estimate
- We note that the international studies ($4,582 per MWh) and the range of value of unserved energy from the CAE study ($1,500 to $5,000 per MWh) overlap, and
- We conclude that there is no reason to reject the residential value of unserved energy as suggested by the international studies.

In respect of point 2:

- We agree that it is important to consider the composition of the load
- We note that Frontier has made a qualitative attempt to adjust the international studies to reflect New Zealand end use, and
- We disagree that a composite value of greater than $30,000 would be hard to support (see section 2.3).

We conclude that the value of unserved energy proposed by Frontier ($20,000 per MWh) is inconsistent with the findings of the international studies and other evidence cited.

2.3 A New Zealand Value of Unserved Energy of $32,000 per MWh

In Table 5, we calculate a central estimate of New Zealand's value of unserved energy of $32,000 per MWh (rounded to the nearest thousand dollars). This is based on the average of the international study sector values and New Zealand's sectors' end use loads obtained from the Energy Data File.[3]

[3] Table G13: Electricity End Use for Year End March 2005 provided the total energy consumption by ANZSIC code. Each ANZSIC code was associated with a sector and the ANZSIC consumptions aggregated to provide a sector electricity end use weighting.

Table 5: New Zealand Weighted Average Value of Unserved Energy (NZ$ 2004)

Sector	Sector VoLL	% of MWh	Weighted VoLL
Residential	$ 4,582	35%	$ 1,581
Commercial	$ 75,134	22%	$ 16,239
Agriculture	$ 89,213	4%	$ 3,338
Industrial	$ 26,574	40%	$ 10,666
Composite VoLL		**100%**	**$ 31,823**

Source: Castalia, Energy Data File

2.4 An Auckland and North of Auckland Value of Unserved Energy of $41,000 per MWh

The pattern of energy consumption in the Auckland and North of Auckland areas is different from New Zealand as a whole. Using census data from Statistics New Zealand, we were able to estimate the proportion of load within each sector.[4] Table 6 sets out a summary of this analysis and shows that value of unserved energy for Auckland and North of Auckland should be $41,000 per MWh (rounded to the nearest thousand dollars).

Table 6: Value of Unserved Energy for Load in Auckland plus North of Auckland (NZ$ 2004)

Sector	Sector VoLL	% of MWh	Weighted VoLL
Residential	$ 4,582	29%	$ 1,346
Commercial	$ 75,134	41%	$ 31,164
Agriculture	$ 89,213	2%	$ 1,535
Industrial	$ 26,574	27%	$ 7,288
Composite VoLL		**100%**	**$ 41,333**

Source: Castalia, Energy Data File, Statistics NZ

3 The Sensitivity of the Value of Unserved Energy to Underlying Sector Estimates

In section 2 we used a simple average of sector values of unserved energy from international studies as the basis for estimating New Zealand value of unserved energy because we did not know if any one study was better than another.

This section tests the robustness of our finding that the value of unserved energy adopted in the GIT ($20,000 per MWh) is too low by calculating New Zealand's value of unserved energy for a range of scenarios.

Three scenarios were developed in addition to the simple average of the sectors value of unserved energy estimates:

[4] Geographic units by ANZSIC code and region in 2005 were obtained from Statistics NZ table builder. The number of households for Auckland and North of Auckland was obtained from the Statistics NZ publication "Projected Households by Regional Council Area"

- Low Estimates—the minimum estimate of a sector's value of unserved energy across the studies
- High Estimates—the maximum estimate of a sector's value of unserved energy across the studies, and
- VENCorp—the estimates from VENCorp's study. This scenario was used as it is the most recent study and builds on the work of the Monash Studies.

Table 7 sets out the sector values of unserved energy in each scenario used to calculate the New Zealand value of unserved energy estimates.

Table 7: Sensitivity of New Zealand's Value of Unserved Energy to Sector Value of Unserved Energy Estimates

	Scenarios			
Sector	**Simple Average**	**Low Estimates**	**High Estimates**	**VENCorp**
Residential	$ 4,582	$ 647	$ 14,474	$ 14,474
Commercial	$ 75,134	$ 64,435	$ 97,892	$ 69,044
Agricultural	$ 89,213	$ 67,607	$ 123,975	$ 67,607
Industrial	$ 26,574	$ 14,421	$ 42,264	$ 22,588

New Zealand VoLL estimates	**Simple Average**	**Low Estimates**	**High Estimates**	**VENCorp**
New Zealand	$ 31,823	$ 22,467	$ 47,754	$ 31,513
Auckland and North of Auckland	$ 41,333	$ 32,035	$ 58,580	$ 40,248

Source: Castalia

The sensitivity analysis shows that under all circumstances the values of unserved energy estimated for New Zealand are greater than the $20,000 per MWh value adopted in the GIT.

4 Costs Included in the Value of Unserved Energy Estimates

This paper has limited its scope to an assessment of an appropriate value of unserved energy for New Zealand based on the studies cited by Frontier. This section takes a brief look at the questions of

- What costs should be included in the value of unserved energy?, and
- What costs were included in by the studies cited?

4.1 What Costs should be included in the Value of Unserved Energy?

The value of unserved energy should include all costs to market participants associated with the interruption of power supply. Such costs can be categorised as follows:

Direct costs

Direct costs are those needed to cope with an interruption to power supply and put things to right afterwards.

For example a residential consumer might use candles as a substitute for lights and might purchase a new tub of ice-cream to replace the tub that melted during a power outage.

Commercial and industrial end users may have to write off the perishable input materials and repair damaged machinery.

Consequential costs

Consequential costs are the lost profits from an interruption to power supply.

Short term consequential costs include the lost profit on sales that didn't happen because the shop lights were out and potential customers didn't enter the shop.

In a residential context these costs are harder to define but include the value of lost leisure or other opportunity costs.

Longer term consequential costs include impacts on growth and profit. Industrial customers frequently work to just-in-time delivery schedules. A power outage may mean they are not able to meet a delivery deadline. The missed deadline may result in losing a customer or future order and the associated profit.

Indirect costs

Indirect costs are direct costs and lost profits to third parties.

For example a manufacturer has to shut down their production because a supplier didn't deliver. Conversely a supplier sells less than they would have because their customer's production process was interrupted.

4.2 The Costs Identified in the International Studies

We undertook a brief review of the international studies cited by Frontier to identify what costs were included in the evaluation of the value of unserved energy estimates. We were able to locate the original VENCorp 2002 and California Electricity Commission June 1997 studies but not the Monash studies. The VENCorp 2002 study claims to use the same method for evaluating value of unserved energy as the Monash Studies so the comments made in respect of VENCorp 2002 are likely to apply to the Monash studies.

This section:

- Explains the method used in each study to estimate and evaluate value of unserved energy
- Identifies which types of costs have been included in the value of unserved energy estimates, and
- Comments on the validity of the study for estimating the value of unserved energy.

We find that all of the studies are likely to have underestimated the value of unserved energy.

4.2.1 VENCorp 2002

VENCorp's study used two methods to estimate value of unserved energy. One method was used for residential value of unserved energy, another method for commercial, industrial and agricultural.

The residential value of unserved energy was estimated by asking users to specify their responses to power supply interruptions of varying durations. The responses ranged from doing nothing, to buying candles, staying in a hotel, and renting a generator. Based on the actions selected, a value of unserved energy was imputed from the cost of acquiring the substitute goods. For example candles cost 50 cents per hour.

The commercial, industrial, and agricultural values of unserved energy were evaluated by asking end users to quantify the direct costs incurred and the sales foregone as a consequence of a power interruption.

Table 8 summarises the types of costs included in VENCorp's value of unserved energy estimate.

Table 8: Costs Included in VENCorp's Evaluation of the Value of Unserved Energy

	Costs			
Sector	**Direct**	**Consequential**		**Indirect**
		Short Term	**Long Term**	
Residential	Partial			
Commercial	Yes	Yes		
Agricultural	Yes	Yes		
Industrial	Yes	Yes		

Source: Castalia

In the residential sector no direct cost is recognised for the time taken for each selected action. Survey respondents were not given the opportunity to indicate any additional direct costs not set out in the survey. Also no value was recognised for the consequential costs like lost leisure.

The value of unserved energy evaluations of the commercial, agricultural and industrial sectors asked for all direct costs and the loss of sales without confining the responses to a pre-determined list. Respondents were not asked directly about the longer term consequential costs to their business.

For all sectors, no assessment was made of any indirect costs from an interrupting electricity supply. The VENCorp study recognised and acknowledged this point.[5]

Because data was not collected across all the costs or lost load, or any attempt made to quantify the full spectrum of losses we conclude that the value of unserved energy estimates are likely to be understated.

4.2.2 Monash Studies

We were not able to locate copies of the Monash studies. The VENCorp 2002 study cites the Monash studies and states that it used the same method for evaluating value of unserved energy as was used in the Monash studies.

4.2.3 California Energy Commission June 1997

The California Energy Commission conducted a telephone survey to a sample of California's residential, commercial and industrial electricity consumers to assess the effects of a power outage in the western states on August 10, 1996.

Residential respondents (91 people) were asked if their households had suffered any financial losses caused by the power outage which might have included food spoilage, damage to appliances, computers and air conditioning units. Seven reported losses which ranged from $49 to $5,500.

[5] VENCorp 2002 pg 46

One-third of commercial and half of industrial respondents who experienced the outage incurred losses. This included labour costs, costs of raw materials, costs of products lost, costs of damage to equipment and losses from canceled contracts. The total estimated losses ranged from a low of $40 to a high of $5,000,000.

Table 9 sets out the costs included in the California Energy Commission's survey on the effects of the power outage.

Table 9: Costs Included in the California Energy Commission's Survey of Costs

	Costs			
Sector	**Direct**	**Consequential**		**Indirect**
		Short Term	**Long Term**	
Residential	Partial			
Commercial	Yes	Yes		
Industrial	Yes	Yes		

Source: Castalia

The California Energy Commission's survey was not designed to evaluate the value of unserved energy. It is not clear to us how Frontier derived value of unserved energy estimates from the survey. For example, while we can see tables that show frequency and magnitude of losses from an unplanned power outage, we do not see how dollar per MWh figures were derived.

Furthermore the loss estimates appear likely to understate the value of unserved energy:

- The losses relate to a power outage on a weekend which is likely to understate commercial and industrial loss estimates
- The residential loss estimates do not take into consideration any time dealing with the direct effects of the outage or any consequential costs, and
- For all sectors, no assessment was made of any indirect costs from the power outage.

5 Conclusion

A default value of unserved energy equal to $20,000 per MWh has been adopted in the GIT. This value is the same as the proposed value of unserved energy set out in Frontier's paper of June 2004 titled "Draft Grid Investment Test Discussion Paper."

The value of unserved energy proposed by Frontier, and adopted in the GIT, is inconsistent with the findings of the primary studies and other evidence cited.

A more complete analysis of the data available at the time indicates a central value of $32,000 per MWh (with a maximum range of $22,000 to $48,000) for the whole of New Zealand is more reasonable. A similar analysis shows the area of Auckland and North of Auckland should have a value of unserved energy of $41,000 (with a maximum range of $32,000 to $59,000).

Since the publication of the Frontier report the Electricity Commission has engaged the CAE to update their 1992 study. We are in the process of obtaining this report and the accompanying model for review.

A sensitivity analysis shows that even when the minimum estimates for each sector are used to estimate New Zealand's value of unserved energy the New Zealand composite value is greater than the $20,000 per MWh adopted in the GIT.

All sector value estimates of unserved energy fail to include any indirect costs or long term consequential costs of a power outage. Residential value of unserved energy estimates do not place any value on the opportunity cost of time lost due to power outages.

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